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Economic Impacts of Transportation Investment on Regional Growth: Evidence from a Computable General Equilibrium Model on Japan's Cross-Prefectural-Border Region*

Thi Thu Trang HA[1], Hiroyuki SHIBUSAWA[2]

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Abstract

This paper proposes and examines the economic impact of infrastructure improvement on the San-En-Nanshin region in the Chubu area of Japan. We develop a single transportation computable general equilibrium (CGE) model for each subregion within the San-En-Nanshin region. The explicit modeling of the transportation infrastructure is defined based on interregional commuting flows and business trips, considering the spatial structure of the San-En-Nanshin economy. A CGE model is integrated with an interregional transportation network model to enhance the framework's potential for understanding the infrastructure's role in regional development. To evaluate the economic impact of transportation improvement, we analyze the interrelationship between travel time savings and regional output and income. The economic impact analysis under the CGE framework reveals how transportation facilities and systems affect firm and household behavior and therefore induce changes in the production and consumption of commodities and transportation services. The proposed theoretical model was tested by using data from the 2005 IO tables of each subregion and the 2006 transport flow dataset issued by the Ministry of Land, Infrastructure, Transport, and Tourism in Japan. As a result, the paper confirms the positive effect of transportation investment on the total output and income of the studied region. Specifically, we found that while economic benefits typically appear in urban areas, rural areas can still potentially benefit from transportation improvement projects.

Keywords: CGE Model, Input-Output Analysis, Regional Economics, Infrastructure Investment, Commuting Flows

JEL Classification Code: R11, R12, R13, R15, R41

1. Introduction

The crucial role of the transportation infrastructure in economic growth has been recognized and confirmed in the existing literature. It is a well-known fact that the growth and concentration of economic activity at any given location depends on market access and the locational economies enabled by that access. Historical examples illustrate the variety of ways in which changes in transportation influence economic growth. In ancient times, caravan routes such as the Silk Road and the Gold and Salt route were firmly established as the distribution backbones for importing products from distant areas to European markets. Transportation should therefore be considered a primary means of promoting international trade. In the modern world, highway investment which improves travel times, reliability, and capacity—has been continuously implemented to enable the freer movement and exchange of activities between isolated regions. In addition, road transport infrastructure and freight mobility simultaneously significantly and positively affect the economy (Rahman et al, 2020; Tarigan et al., 2021). Research estimations suggest that if all other driving factors underlying growth were to increase by 10% and the transportation infrastructure remained the same, the income growth realized would be

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[1]First Author and Corresponding Author. School of Economics and Management, Hanoi University of Science and Technology, Vietnam. [Postal Address: No 1 Dai Co Viet Street, Hai Ba Trung District, Hanoi, Vietnam] Email: trang.hathithu@hust.edu.vn
[2]Department of Architecture and Civil Engineering, Toyohashi University of Technology, Japan. Email: shibusawa.hiroyuki.dc@tut.jp

only 9%, meaning that it would be 1% less than it would have been. And the loss would be greater than 4% if the growth were to increase more than 10% when the transportation factor was kept constant (Laird & Venables, 2017).

Transportation is an integral part of the economy, so changes in the transportation infrastructure are likely to impact the economy in various ways. Many researchers, ranging from regional scientists to transportation planners, have attempted to evaluate or predict the economic impact of transportation investment. Among the many modeling methods available, two recently dominant streams in the literature are the spatial interaction model, which takes a spatial econometrics approach, and the computable general equilibrium (CGE model). These approaches attempt to trace the relationships between economic outcomes and transportation investment both directly and indirectly and are thus natural frameworks for assessing externalities in conjunction with conventional-cost–benefit analyses of transportation projects.

The application of spatial econometrics in evaluating the impact of a transportation network requires an investigation of the spatial interaction between units across geographic locations (Celik & Guldmann, 2007; LeSage & Wolfgang, 2008). This method is based on the observation that a transportation network may have spillover effects on regional economic development since the impact of infrastructure is not confined to one specific region. The CGE model considers changes in production, consumption, and labor supply because of a change in transportation investment under an equilibrium framework. CGE enables transportation impact analysis by allowing a transport network to function as a markup industry to production or as a reduction in the value of goods in proportion to transportation costs. Unlike the spatial econometrics approach that relies on a single linear regression equation (Griffith, 2009; Ha et al, 2016), CGE models describe the behavior of economic agents operating in the market through a system of simultaneous equations. Whereas all spatial econometrics models represent abstractions of reality, the CGE model is a mathematical tool for understanding behavior and anticipating future outcomes. Transportation in a CGE model is defined as a subset of commodities produced by one or a subset of industries, consumed by households, and used as input by firms. CGE transport models usually introduce a household's demand for transportation as dependent not only on monetary cost but also on the time needed for travel. Thus, a household can choose between the consumption of travel services and the consumption of other goods. A firm's demand for transportation is treated as a production input. Firms incur costs in money and time. The monetary cost of transportation can be observed in an input–output table, whereas time-related costs must be imputed using travel time data and estimates of the time value in monetary units.

So how do CGE modellers define the transport factor in terms of firm and household behavior to analyze the economic impact of a transportation project on a regional economy? Researchers have developed CGE models in a single-region model, paying special attention to the demand for transportation services; however, they focus mainly on congestion. Conrad and Heng (2002) developed a standard CGE model to incorporate the impact of congestion, infrastructure provision, and the stock of transportation equipment on transportation demand, transportation costs, and congestion costs. In their paper, the congestion cost is measured as the cost of transport service substitutes for firm-owned trucks blocked by the congestion externality. Trucks of each industry and private cars contribute to congestion, and the resulting inefficiency of firms' transportation capital compelled them to spend extra money to transport their output. They compared the cost of the addition to the infrastructure with the savings in congestion costs to determine whether this policy measure was self-financing. Mayers and Proost (2004) introduced a highly detailed transport market structure for passengers that distinguished between private and business transport and different modes of transportation. Berg (2007) focused on households' consumption of transport services and added a spatial dimension by introducing household groups according to their residence. Their model was also extended by incorporating trip purposes, introducing leisure and work journeys, thus enabling the connection between work journeys and the labor supply to be considered.

Under the assumption that most transportation infrastructure achieves economic benefit by increasing accessibility and reducing transportation costs, CGE transportation analysis is constructed using a multiregional structure. In multiregional models, firms' transport demand is explicitly related to the interregional flows of commodities and services. Since spatial effect can be captured using a multiregional model, it is also called a spatial CGE (SCGE) model. An SCGE model aims at quantifying the interregional effect of cross-border transportation projects. Miyagi (2006) evaluated economic impact in relation to changes in accessibility using a spatial CGE (SCGE) model in which economic impact was measured according to the reduction in congestion attributable to specialized infrastructure investment. The rate of return on transportation investment to reduce congestion was estimated by traditional production function analysis and the so-called "free approach" using neural network analysis. Haddad and Hewings (2005) developed an interregional CGE model in which transportation costs were based on origin–destination flows. The model was calibrated considering the cost of moving products in origin–destination pairs, providing spatial price differentiation. Kim et al. (2004) integrated the transport network model with a multiregional CGE model. Whereas the transportation network model is used to forecast travel demand between zones, calculating the highway accessibility of each transportation zone based on the minimum distance and population size, the multiregional CGE model introduces an accessibility index variable into production behavior to estimate the economy-wide impact of highway development on spatial economies.

In capturing the spatial effect of cross-border transportation projects, multiregional models are a more direct means of enhancing the impact based on interregional flows of inputs or commodities. However, multiregional CGE models usually require an interregional input–output table to serve as a database describing the linkages of economic activities between regions. Such an interregional input–output table is not easily available, which leads to a constraint on applying the multiregional CGE model. This paper investigates the regional economic impact of transport network improvement in the San-En-Nanshin region in the Chubu area of Japan. We propose a single-region CGE model for each subarea or zone within the San-En-Nanshin region. Each zone is modeled separately as an individual economy with its own specific transport prices, firms, and consumers. The model reflects economic linkages and interactions between regions via interregional trips for business purposes and commuting flows. The interregional impact can be assessed based on the description of these linkages. The purpose of this study is twofold. (1) First, we develop a transportation CGE model in which transportation costs are explicitly determined as firm expenditures for business travel and household costs of private passenger travel. (2) The impact of cost-reducing transportation investment on firm output and household income in each subregion of the San-En-Nanshin region is then investigated. We estimate the effects of changes in interregional traveling time.

2. A Single-Region CGE Transportation Model

2.1. Overview of the Model

The modeling structure in this paper adopts an edited version of a single-region CGE model developed by Miyata and Ha (2013). Figure 1 provides a graphical overview of the model. According to the illustration, the model considers the equilibrium conditions between the supply and demand for commodities, labor, capital, and the land market. The activities of firms, households, transportation, and landlord sectors are graphically displayed in Figure 1.

The model is a closed economy including two explicit sectors (firms and households) and two implicit sectors (transportation and landlords). Firms produce commodities for consumption by households, the transportation sector, and landlords for use within the production process as input. The production process relies on production capacity and intermediate inputs. The production capacity factor is defined as a composite of the value-add and input of passenger business trips by a firm, whereas the value-add is conventionally composed of labor, capital, and land use. Output is sold in perfectly competitive markets where firms

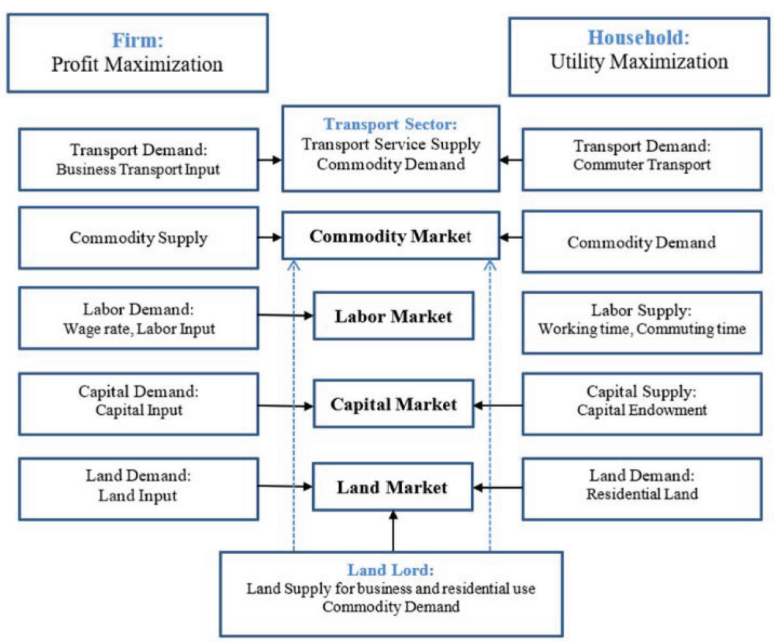

Figure 1: Overview of a CGE Transportation Model

and households maximize profits and utility, respectively. Household primarily provides labor services to the firm and consumes the goods made firm produces. The labor supply is endogenous, arising from a decision to split the household's time endowment between working and total commuting time. Household also owns the capital stock and therefore receive rental income from the firm as part of their total income. The latent transportation sector provides passenger transport services to firms and households. It also consumes the commodities produced by the firm. An absentee landlord provides differential land for business and residential use obtains its income from the land rent earned in the entire region and consumes the goods produced there. In this model, an analysis of the transport cost associated with passenger transport service between regions is enabled to introduce a spatial dimension to the regional CGE model. The firm considers the business trips transport service as a markup to its production capacity and accommodates transport costs in the final commodity purchase price. Household maximizes their consumption of commodity and transport demand for commuting purposes. The spatial dimension is added in terms of business trip flows, and commuting flows between subregions. The main model structures for the various agent blocks are discussed in detail in the following section.

2.2. The Structure of the Model

2.2.1. Firms' Profit Maximization Behavior

There are n zones in the study area, and the number of populations is denoted by N. This model considers an aggregated single industry for simplicity. A representative firm located in zone s is defined as one worker and aims at profit maximization.

$$\max \pi^s \equiv py^s - tc^s \tag{1}$$

subject to

$$y^s \equiv \min\left[\frac{pc^s}{a_0}, \frac{z^s}{a_1}\right] \tag{2}$$

$$tc^s \equiv p_c^s pc^s + p_z^s Z^s \tag{3}$$

$$p_c^s \equiv \left[p_{va}^s va^s + \left(p_{TP} + w_0 \sum_{r=1}^{n} t^{sr} \delta^{sr}\right) Z_{TP}^s\right] / pc^s \tag{4}$$

$$p_{va}^s \equiv \left[w \cdot ld^s + r \cdot kd^s + h_F^s \cdot ad_F^s\right] / va^s \tag{5}$$

$$pc^s \equiv \eta_2 (va^s)^{\alpha} (z_{TP}^s)^{1-\alpha} \tag{6}$$

$$va^s \equiv \eta_3 (ld^s)^{\beta_1} (kd^s)^{\beta_k} (ad^s)^{\beta_a} \tag{7}$$

where,

π^s: firm profit in zone s; p: the price of the commodity; y^s: firm output in zone s; tc^s: firm production cost in zone s; pc^s: firm production capacity in zone s; a_0: firm production capacity rate; z^s: intermediate input in zone s; p_z^s: the price of intermediate input; a_1: intermediate input coefficient; p_c^s: the price of production capacity; t^{rs}: travel time between zone r and zone s; p^s_{va}: the price of value added in zone s; va^s: value added in zone s; p_{TP}: the price of passenger transport service; w_0: wage rate in minutes; δ^{sr}: number of business trips from zone s to other zones; Z^s_{TP}: input of passenger transport service in zone s; PTPB: the choice probability of passenger transport to destination r by a firm in zone s. η_2, η_3: parameters; ld^s: labor input in zone s; kd^s: capital input in zone s; ad^s_F: land input in zone s; and β_l, β_k, β_a: elasticity parameter ($\beta_l + \beta_k + \beta_a = 1$).

We hierarchically solve the cost function and the conditional factor demand function to solve the aforementioned profit maximization problem.

Gross output y^s by region s is determined as a three-level production function of composite production capacity and intermediate inputs. The firm chooses the quantity of the intermediate input and the production capacity using a fixed proportion of output according to a Leontief-type production function (Leontief, 1966) as in the first stage. In the second stage, production capacity is defined as a composite of the value added and the input of passenger business trips in a region. The price of production capacity is a composite price comprising wage rate, capital rental, land rental, and the price of passenger trips.

(1) The First Stage

Since the production function is a Leontief type, the production capacity, and intermediate inputs are obtained according to the following:

$$pc^s = a_0 y^s \tag{8}$$

$$z^s = a_1 y^s \tag{9}$$

(2) The Second Stage

Given the production capacity, pc^s, we solve the following cost minimization problem as follows:

$$\min c^s \equiv p_{va}^s va^s + \left[p_{TP} + w_0 \sum_{r=1}^{n} t^{sr} PTPB \delta^{sr}\right] z_{TP}^s \tag{10}$$

subject to $pc^s \equiv \eta_2 (va^s)^{\alpha} (z_{TP}^s)^{1-\alpha}$ (11)

The value-added input and passenger transport input associated with the production capacity pc^s can also be obtained.

$$va^s = \frac{1}{\eta_2}\frac{\alpha}{p_{va}^s}\left[\frac{p_{va}^s}{\alpha}\right]^{\alpha}\left[\frac{\theta^s}{1-\alpha}\right]^{1-\alpha} pc^s \tag{12}$$

$$z_{TP}^s = \frac{1}{\eta_2}\frac{1-\alpha}{\theta^s}\left[\frac{p_{va}^s}{\alpha}\right]^{\alpha}\left[\frac{\theta^s}{1-\alpha}\right]^{1-\alpha} pc^s \tag{13}$$

$$\theta^s \equiv p_{TP} + w_0\sum_{r=1}^{n} t^{sr} PTPB\delta^{sr} \tag{14}$$

Specifically, the price of passenger trips plus the price of business trips is based on travel distance in time between the firm's located region s and other remaining subregions in the study area and the number of business trips from zone s to other subregions as described in Equation (14). Since all of the values in the CGE model are monetary values, the travel time is converted into a monetary value according to the wage rate per minute.

(3) The Third Stage

In the third stage, the producer requires an optimal set of labor, capital, and land inputs to produce a given value added. Given the value added va^s, the following cost minimization problem is solved.

$$\min C_{va}^s \equiv w\cdot ld^s + r\cdot kd^s + h_F^s \cdot ad_F^s \tag{15}$$

$$\text{subject to } va^s = \eta_3(\text{ld}^s)^{\beta 1}(\text{kd}^s)^{\beta k}(\text{ad}_F^s)^{\beta a} \tag{16}$$

From this, the conditional inputs of labor, capital, and land associated with the value-added va^s can be obtained from the following:

$$ld^s = \frac{1}{\eta_3}\frac{\beta_1}{w}\left[\frac{w}{\beta_1}\right]^{\beta_1}\left[\frac{r}{\beta_k}\right]^{\beta_k}\left[\frac{h_F^s}{\beta_a}\right] va^s \tag{17}$$

$$kd^s = \frac{1}{\eta_3}\frac{\beta_k}{r_1}\left[\frac{w}{\beta_1}\right]^{\beta_1}\left[\frac{r}{\beta_k}\right]^{\beta_k}\left[\frac{h_F^s}{\beta_a}\right]^{\beta_a} va^s \tag{18}$$

$$ad_F^s = \frac{1}{\eta_3}\frac{\beta_a}{h_F^s r}\left[\frac{w}{\beta_1}\right]^{\beta_1}\left[\frac{r}{\beta_k}\right]^{\beta_k}\left[\frac{h_F^s}{\beta_a}\right]^{\beta_a} va^s \tag{19}$$

From the above, we can obtain the minimized cost tc^s associated with the firm's output in y^s and determine its profitability.

2.2.2. Household Utility Maximization Behavior

Each household maximizes its utility function. Household utility maximization behavior can also be hierarchically obtained. Household is assumed to be homogeneous in the study area, so we consider a representative household that resides in zone s and works in zone r. Each household aims to maximize the utility function of its current consumption, future consumption, and land under budget conditions. Current consumption consists of the production commodity and passenger transport service, whereas future consumption is derived from savings.

(1) The First Stage

The household's utility maximization is then obtained as follows:

$$\max u(G^s, H^s, a_H^s) \equiv \text{G}^{s\alpha_G}\, H^{s\alpha_G} ad_H^{s\alpha_a} \tag{20}$$

$$\text{subject to } p_G^r G^{sr} + p_H^r H^s + h_H ad_H^s = w\cdot ls^s + r\cdot ks^s \tag{21}$$

$$w = w_0(\text{T} - \sum_{r=1}^{n} n^{sr} t^{sr})\cdot \text{ls}^s \tag{22}$$

where

u: household utility function; G^{rs}: current consumption in zone r; H^{rs}: future consumption in zone r; ad^s_H: land consumption in zone r; α_G, α_H, α_a: elasticity parameters ($\alpha_G + \alpha_H + \alpha_a = 1$); p_G^r: the price of current consumption; p_H^r: the price of future consumption; h_H^r: residential land rent in zone r; w: wage rate; T: total available time endowed to a household; n^{rs}: number of commuting trips from zone r to zone s; t^{rs}: travel time between zone r and zone s; PTPF: the choice probability of working in zone r by a household residing in zone s; r: capital return rate; and ks^{rs}: capital stock endowed to a household in zone r.

As described in Equation (22), the labor wage is paid based on the real working time of employees. The real working time is calculated by subtracting the total commuting time from residential to working place from the total time endowed to a household. The wage rate, w_0, is given in minutes.

By solving Equations (20), (21), and (22) hierarchically, we obtain the following demand functions:

$$G^s = \frac{\alpha_G}{p_G^r}\left[w\cdot ls^s + r\cdot ks^s\right] \tag{23}$$

$$H^s = \frac{\alpha_H}{p_H^r}\left[w\cdot ls^s + r\cdot ks^{rs}\right] \tag{24}$$

$$ad_H^s = \frac{\alpha_a}{h_H^r}\left[w\cdot ls^s + r\cdot ks^{rs}\right] \tag{25}$$

(2) The Second Stage

Given future consumption and land input, each household maximizes its current consumption.

$$\max G^s \equiv (\text{C}^s)^{\alpha_c}(\text{x}_{TP}^s)^{\alpha_x} \tag{26}$$

subject to

$$P_c^s C^s + q_{TP}^r x_{TP}^s = w_0 \left(T - \sum_{r=1}^{n} n^{sr} t^{sr} \right) \cdot ls^s + r \cdot ks^s - p_H^s H^s - h_H^s ad_H^s (\equiv \Omega_2^s) \tag{27}$$

$$q_{TP}^s \equiv p_{TP} + w_0 \sum_{r=1}^{n} n^{sr} PTPFt^{sr} \tag{28}$$

where

C^s: composite consumption commodity; x^s_{Tp}: total consumption of passenger transport services; p^s_c: the price of composite consumption commodity; and q^s_{Tp}: the generalized price of passenger transport service.

We can obtain the demands for composite consumption commodities and the total passenger transport services by solving this optimization problem.

$$C^s = \frac{\alpha_C}{p_C^s} \Omega_2^s \tag{29}$$

$$x_{TP}^s = \frac{\alpha_x}{q_{TP}^s} \Omega_2^s \tag{30}$$

In the second stage, the generalized price of passenger transport service is composed of transport price and the cost of commuting time quantified in terms of the wage rate. The travel time between each origin–destination pair for commuting purposes is considered the sole transport cost component and is applied to Equation (28).

2.2.3. Behavior of the Absentee Landlord and the Transportation Sector

The absentee landlord in zone *s* provides differentially the land for business use (including the land it uses itself), AS_F^s, and residential use, AS_H^s. The amount of land the absentee landlord services is assumed to be expressed as $h_F^s \cdot AS_F^s + h_H^s \cdot AS_H^s$ using the initial land rents by zone. The landowner obtains its income by providing land to firms and households and consuming the study region's goods. Just like the absentee landlord, the absentee transportation agent provides transport service to firms (for business purposes) and households (for commuting trips) and consumes the goods produced by firms.

2.2.4. Market Equilibrium Conditions

Market equilibrium conditions are denoted as follows:

Commodity market

The production of commodities in region *s* = The demand for commodities consumption of households, landowners, transportation agents, and demand for intermediate input of firms (31)

Labor market

$$ls^s E^s = ld^s N^s \tag{32}$$

Capital market

$$ks^s E^s = kd^s N^s \tag{33}$$

Land market for business use

$$AS_F^s = ad_F^s E^s \tag{34}$$

Land market for residential use

$$AS_H^s = ad_H^s N^s \tag{35}$$

where

E^s: the number of firms in zone *s* or the number of employees; and

N^s: the number of households in zone *s*.

3. Evaluating the Economic Impact of Transportation Improvement in the San-En-Nanshin Region

In this section, we adopt the above-described regional CGE model to investigate the economic-wide impact of road network improvement on the San-En-Nanshin region in Chubu, Japan. We divided the San-En-Nanshin region into 18 subregions to analyze the transport network between regions and measure how travel time savings could affect the regional economy by simulations.

3.1. Database, SAM, and Calibration

Miyagi (1994) mentioned that unlike econometrics models requiring a large amount of data, CGE models could serve regions divided into arbitrary sizes. If an input–output table accounting data of a single collection of regions is available, it could be divided into several subregions. This paper employs each subregion's input–output table as a database. The base year is 2005. The construction of a social accounting matrix (SAM) is implemented based on the input–output table, which is consistent with the overall economic activity of the model. This constructed SAM includes five accounts—manufacturing (production activity); primary factors (labor, capital, and land use); household; transportation; and the external sector.

Two types of datasets for parameter estimation, as described in Table 1. First, the share parameters used in the optimization equations are calibrated endogenously by employing the initial values from the SAM under the assumption that each subregion in the San-En-Nanshin region

Table 1: Parameter Definitions and Calibration

	Parameters	Value	Source	Calibration
β_1	Cobb-Douglas power of Labor in value add function	0.588	2005 IO Table	$\beta_l = \dfrac{ld_0^s}{ld_0^s + kd_0^s + ad_0^s}$
β_k	Cobb-Douglas power of Capital in value add function	0.392	2005 IO Table	$\beta_k = \dfrac{kd_0^s}{ld_0^s + kd_0^s + ad_0^s}$
β_{ad}	Cobb-Douglas power of Land Use in value added function	0.019	2005 IO Table	$\beta_a = \dfrac{ad_0^s}{ld_0^s + kd_0^s + ad_0^s}$
η_3	Efficiency parameter	2.129	2005 IO Table	$\eta_3 = \left(\dfrac{1}{\beta_l}\right)^{\beta_1} \left(\dfrac{1}{\beta_k}\right)^{\beta_k} \left(\dfrac{1}{\beta_a}\right)^{\beta_a}$
α	Cobb-Douglas power of value add in production capacity function	0.983	2005 IO Table	$\alpha = \dfrac{\eta_3 (ld_0^s)^{\beta_l} (kd_0^s)^{\beta_k} (ad_0^s)^{\beta_a}}{\eta_3 (ld_0^s)^{\beta_l} (kd_0^s)^{\beta_k} (ad_0^s)^{\beta_a} + ztp_0^s}$
η_2	Efficiency parameter	1.091	2005 IO Table	$\eta_2 = \left(\dfrac{1}{\alpha}\right)^{\alpha} \left(\dfrac{1}{1-\alpha}\right)^{1-\alpha}$
a_1	Intermediate Input Leontief type coefficient	0.573	2005 IO Table	$a_1 = \dfrac{z_0^s}{y_0^s}$
a_0	Production capacity Leontief type coefficient	0.427	2005 IO Table	$a_0 = 1 - a_1$
α_x	Cobb-Douglas power of Transport Consumption in Current Consumption function	0.006	2005 IO Table	$\alpha_x = \dfrac{xtp_0^s}{xtp_0^s + C_0^s}$
α_c	Cobb-Douglas power of Commodity Consumption in Current Consumption function	0.994	2005 IO Table	$\alpha_c = \dfrac{C_0^s}{xtp_0^s + C_0^s}$
α_G	Cobb-Douglas power of Current Consumption in Utility function	0.629	2005 IO Table	$\alpha_G = \dfrac{(C_0^s)^{\alpha_c} (xtp_0^s)^{\alpha_x}}{(C_0^s)^{\alpha_c} (xtp_0^s)^{\alpha_x} + H_0^s + ah_0^s}$
α_H	Cobb-Douglas power of Future Consumption in Utility function	0.242	2005 IO Table	$\alpha_H = \dfrac{H_0^s}{(C_0^s)^{\alpha_c} (xtp_0^s)^{\alpha_x} + H_0^s + ah_0^s}$
α_a	Cobb-Douglas power of Residential Land Consumption in Utility function	0.130	2005 IO Table	$\alpha_a = \dfrac{ah_0^s}{(C_0^s)^{\alpha_c} (xtp_0^s)^{\alpha_x} + H_0^s + ah_0^s}$
w_0	Wage rate in time unit		Cost-Benefit Manual (2006) *	
t^{sr}	Travel time between zone s to zone r		2007 Japan Google Navigation System	
δf^{sr}	Commuting trips from zone s to zone r		Japan Population Census (2005)**	
δb^{sr}	Business trips from zone s to zone r		Japan Transportation Censor Surveys (2005)*	

**Cost–Benefit Manual* (2006) and Japan Transportation Censor Survey (2005) issued by the Japan Ministry of Land, Infrastructure, Transport, and Tourism. **2005 Japan Population Census issued by the Japan Statistics Bureau and the Ministry of Internal Affairs and Communications.

has the same production technology and the household has the same consumption preferences. This assumption confirms the spillover effect of knowledge (production technologies) and the similarity in the consumption behaviors of nearby regions. The second is the 2006 transport flow censor survey issued by the Ministry of Land, Infrastructure, Transport, and Tourism. A dataset of each pair of origin–destination vehicle business trips and commuting trips were obtained using the current study area's road network. The valuation of the wage rate for non-working time is extracted from the cost–benefit manual of 2006.

The model is coded using the generalized algebraic modeling system (GAMS) language, and a non-linear processing (NLP) path was used to solve the simultaneous system of 20 non-linear equations and 27 variables. The model closure sets the price variables to the numeraire, and the total land supply for business use and residential use is given as benchmark data. GAMS solves the model as previously discussed using the benchmark equilibrium as the starting point for the algorithm. A shock is applied to each price variable to express a change or a percentage change in all the variables from its benchmark equilibrium value. The simulation is implemented to perform the following tasks. (1) Determine the relative changes in passenger transportation cost in response to a change in travel time. Because the spatial economic effect of an investment in the transport network has a direct impact on transportation costs by reducing travel time, the transportation cost is marked up based on the travel distance between each origin–destination pair and the business-related commuting flows between subregions as described in Equations (14) and (28). By the formulation, the travel time savings decrease the price of passenger transport services according to the degree of the non-working time wage rate. (2) To capture the regional economic impact of transportation improvement, the variations in regional output and household income are estimated and compared across the 18 subregions. The result enables us to identify how sensitive the output is relative to the values for passenger transport input.

In this study, we conduct the simulation to shock with different percentage changes in the exogenous travel distance between each origin–destination pair. There are four levels of travel time savings corresponding to four scenarios - 10% (Scenario 1), 20% (Scenario 2), 30% (Scenario 3), and 40% (Scenario 4) - in comparison to the current travel time. 72 simulations are implemented for 18 subregions during the CGE experiments. The functioning mechanism that drives the causal relationship in the simulation results could be expected as follows. The travel time savings cause a reduction in transport costs, reducing the composite commodity price since inputs are less costly. Then, firms become more competitive, and capital investors (households) foresee potential higher returns. Households increase their real income and have higher consumption possibilities. A higher income generates greater domestic demand. This creates room for increasing firm output, which requires additional inputs and primary factors such as labor and capital.

3.2. Simulation Results

Figure 2 illustrates the relative changes in passenger transport costs because of time savings. The calibration is applied for transport expenditures for firm purposes (on the left) and household transport costs for commuting purposes (on the right side). As expected, transport costs decrease to the same degree as the travel time between the 18 subregions. Because the response of transport costs to travel time savings is magnified by the business trips and commuting flows of each interregional-origin–destination pair, the change level of each region differs slightly. Nagoya, Shitara, and Tenryu perform better in response to transport network improvement than the others. This is quite reasonable for a city with a high industry concentration, such as Nagoya, but it is questionable for rural areas, such as Shitara and Tenryu. In an in-depth examination of the business trip data for these two regions, we discovered that the interregional business flows rely primarily on interactions with distant rather than nearby areas. Similar results have been found in some studies by applying econometric models (Ha et al., 2016; Rahman et al., 2020)

So, if the transport network is improved, the impact on regions with more distant journeys would be enlarged. Regarding commuting transportation costs, the same interpretation can also be applied to the rural Nanshin region.

Figure 3 reflects the network effect on regional output for the four scenarios. The change in regional output is converted to monetary value in billions of Japanese currencies per year. We found increasing returns to scale for large-scale economic regions such as Nagoya, West Nagoya, Chita Peninsula, and Heikinan for Scenarios 1, 2, and 3. For Scenario 4, when the travel time is reduced by 40%, West Nagoya and Heikinan showed diminishing returns, which could be interpreted as the marginal effect of transport network improvement in these two regions. Specifically, the simulation of the Toyohashi region - representative of a medium economic scale - illustrates a rapid increase in total output for Scenarios 3 and 4.

However, the output gap between the urban and rural areas is explicit in the simulation results. Figure 4 focuses on the response of the rural areas in the study region. Despite their small manufacturing scale, we found the network effect expanding to rural areas such as Toyokawa, Shinshiro, and the Nanshin region. In addition, having a closer look at the influence of travel time savings on regional output, we observe that the increase in output from Scenario 1 to Scenario 2 and from Scenario 2 to Scenario 3 is much greater

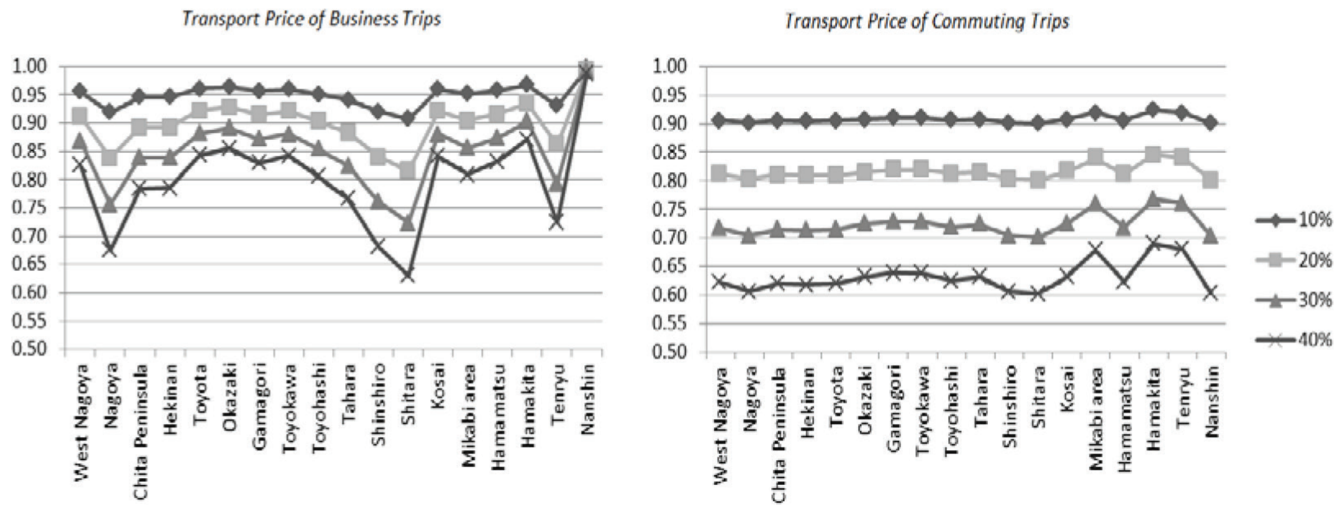

Figure 2: Relative Change in Transport Price in Response to Travel Time Savings for Each Scenario

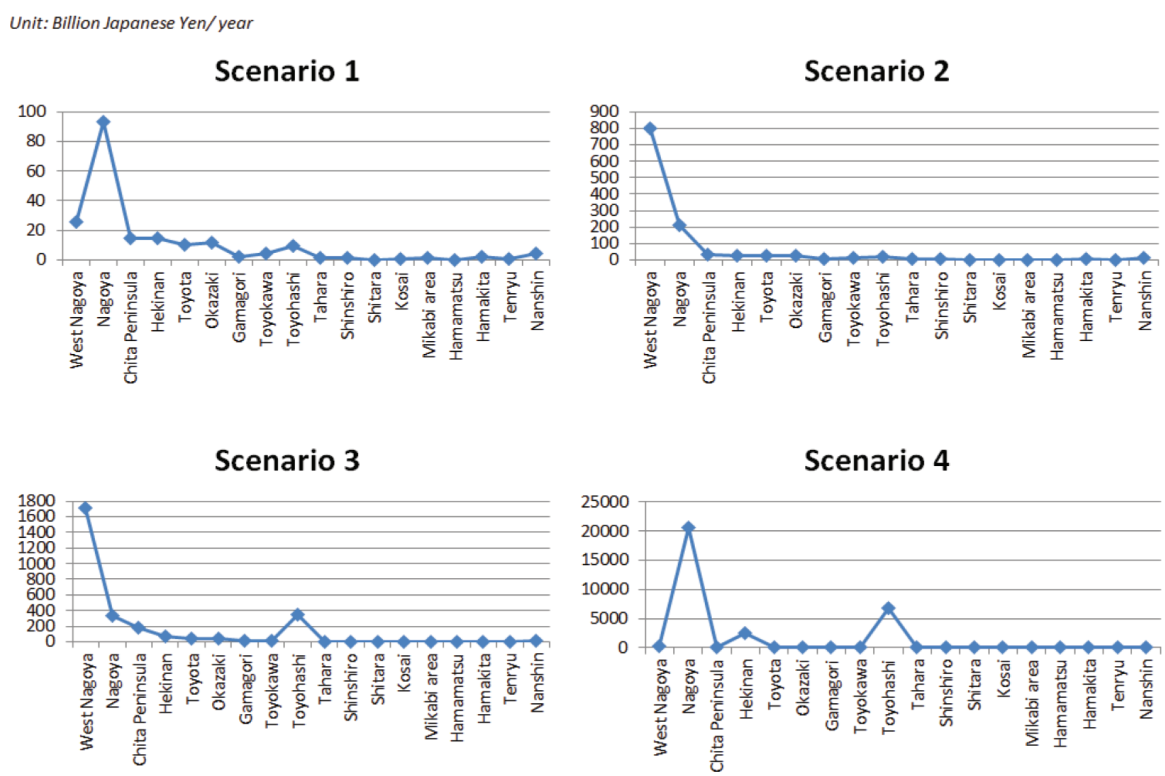

Figure 3: The Change in Total Regional Output for Each Scenario

in magnitude than the increase in output from Scenario 3 to Scenario 4. This observation implies the need for insightful consideration of the marginal effect of transportation investment on the regional economic scale of rural areas. The model's specification of household demand enables the change in household income with respect to travel time savings through reduced commuting costs to be computed under the assumption that households consider splitting total available time into working time and commuting time. The wage is paid for the real working time; the commuting time

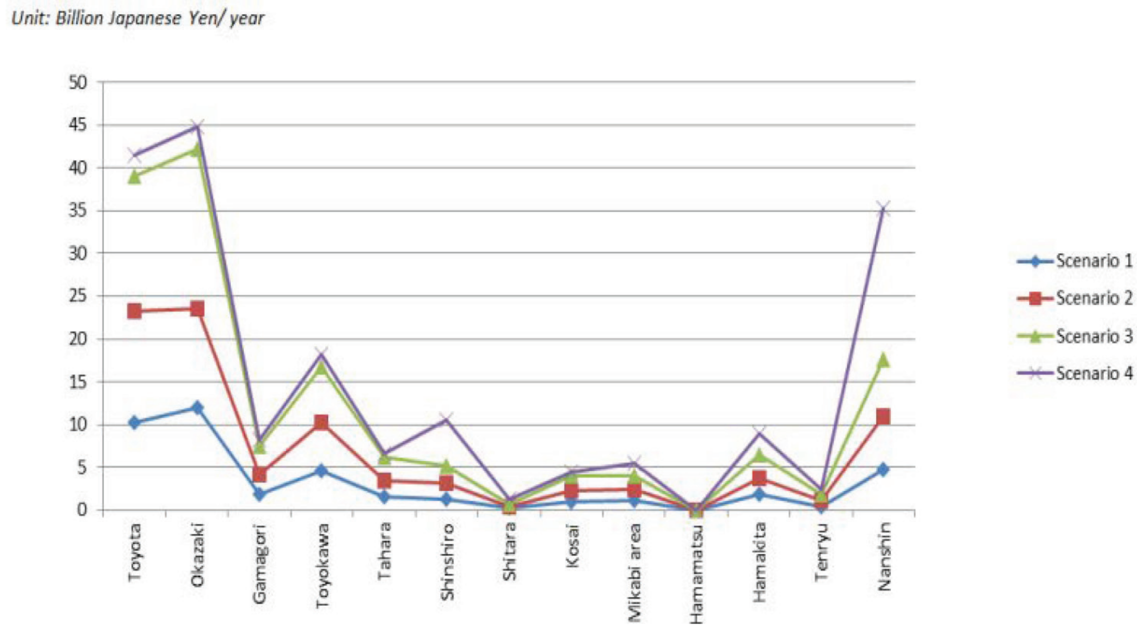

Figure 4: A Focus on the Total Change in Output of the Rural Regions for Each Scenario

is subtracted from the total endowment time. The household income is derived from the labor supply and capital rents.

4. Conclusion

In this paper, we developed a regional CGE model to estimate the economic impact of transportation investment. The explicit modeling of the transportation infrastructure was defined based on interregional flows of passenger transportation and the travel distance between each interregional-origin–destination pair. This formulation considered the spatial structure of the study region, enabling the CGE model to be integrated with an interregional transportation network model to enhance the framework's potential in understanding the crucial role of infrastructure in regional development (Nanan et al., 2013)

The major conclusions are as follows. (1) The model was constructed to combine travel times, one of the measures representing improvements in interregional transport costs, with interregional passenger transport services and enable the relative changes in generalized transport costs due to travel time savings to be calculated, which are magnified in terms of the degree of the wage rate of non-working time savings. (2) The indirect effects of providing improved transportation could be very large compared to the direct effects used to measure consumer benefits in a previous study by Miyata and Ha Thi Thu (2013). (3) The regional CGE model proposed herein theoretically applies to a region of any subregional size if single-region-input–output table data and interregional flows are available. (4) The positive effect of transportation investment on the San-En-Nanshin region has been confirmed. Each 10% decrease in interregional travel time induces an increase of 0.0002% in total regional output and increases rapidly in response to greater reductions in travel time. In Scenario 4, regional output increases to 0.036% when travel time decreases to 40% of the base level. Although the economic benefit usually appears in urban areas, rural areas such as Shinshiro, Shitara, and Kosai are still potential beneficiaries of the transportation improvement project. This finding is the same as the regional output increase conducted by Miyata and Ha Thi Thu (2013), but it differs in magnitude.

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