Spatial economic impacts of highway network completion in Greater Tokyo Area *

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Abstract

Ring road sections of the highway network system in Greater Tokyo area are still missing and planed to complete in near future.. The completion will cause big changes in economic activities in a wide range of the area. In order to estimate the spatial economic impacts of the highway project, this paper builds a spatial computable general equilibrium model, TMUSE, which features agglomeration effects explicitly based on Dixit-Stiglitz type monopolistic competition general equilibrium framework. The model classifies the area into municipality level, namely 376 subregions with three industrial sector.

We apply the model to the highway network development project in Greater Tokyo area. The analysis explores which regions would gain more from the highway project, and estimates changes in sectoral outputs for each region.

JEL classification: C63, R18, O18

Key words: Spatial CGE model, Economy of agglomeration, Highway investment

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1 Introduction

Fundamental plan of the highway network in Greater Tokyo area has launched in 1963. The huge road network project in highly urbanized area takes a long investment period. After a half century, the construction project is still ongoing work. The whole highway network does not open simultaneously. The completed sections open earlier even if the neighbor sections are still under construction. Although the radial system of the highway network, roads from central Tokyo to suburban or peripheral regions, were almost completed earlier, the ring roads are under construction. Completion of the missing links will cause big changes in economic activities in a wide range of the area.

Changes in local economic conditions near the newly opened roads were monitored when a part of the road section completed, actually relocation of firms and logistics center were observed(Yagame (2016)). However comprehensive appraisal of the full network completion is not implemented. This paper aims to evaluate the economic impacts of the rest highway network, in particular featuring spatial distribution of the effects.

Spatial computable general equilibrium (SCGE) model is a convenient tool for comprehensive appraisal of such transport projects. Evaluation of the investment to specific section of highway network requires to describe the improvement of transport condition explicitly in the model. An earlier contribution by Buckley (1992) introduced explicit transport service sector and wholesale sector in the SCGE model. Transport service should be demanded for interregional trade in Buckley's model, the cost is specific to each origin-destination pair. Miyagi et al. (1996) developed a conceptual trade estimation method based on SCGE framework like Buckley's approach. PINGO, Norwegian SCGE model (Ivanova et al. (2002)), assuming explicit transport sector was utilized to estimate freight transport demand.

Haddad et al. (2005) developed a methodology integrating interregional CGE model with transport network, B-MARIA. Haddad et al. (2010) extended the framework of B-MARIA by incorporating nodal transport cost for assessing port capacity investment policy. Alternative technique to represent development of transport system in SCGE model was used by Kim et al. (2003) and Kim et al. (2004). They estimated reduction of generalized travel cost by using transport network module and then converted to regional productivity improvement in SCGE model to assess the trunk transport investment in Korea.

Among variety of the methodologies to describe the role of transport system in the CGE model, modeling based on iceberg transport cost concept, or similar way, has a merit of reflecting the improvement of specific parts of transport network. Bröcker (1998b) firstly established the standard way of transport policy appraisal by SCGE model using iceberg transport cost concept. A remarkable contribution of Bröcker (1998b) is building a clear procedure of calibration from the easily available data.

There exists some criticisms with regard to unrealistic assumption of iceberg transport cost concept (Knaap et al. (2011) and Tavasszy et al. (2011)). Iceberg type transport cost assumes same technology, namely cost structure, between transport service production and the commodity traded. Moreover Knaap et al. (2011)

pointed out the interesting mechanism that "reduction of iceberg transport cost implies the suppliers need to produce less to satisfy the same level of demand on the part of their customers".

Nonetheless iceberg type model is popular in SCGE-transport integrated analysis because of the usefulness. The assumption that a certain percentage of value of the traded goods itself is consumed for transportation allows iceberg transport concept to skip the necessity of knowledge of technology of transport service. Level of data requirement of iceberg transport cost concept keeps lower than the methodology treating explicit transport sector. Information regarding demand and supply for inter-regional transport service can be hardly captured from available data.

Furthermore, investment to some sections of road network for example contributes to reduction of generalized transport cost of the links of the transport network. If the improved sections belong to the shortest path between some regions, the investment can reduce the transport cost of the region-pair and cannot directly reduce the transport cost of other pairs.

A number of SCGE models for policy appraisal of specific transport system improvement actually adopted iceberg type, or 'iceberg like type' modeling. Bröcker (1998a) built a SCGE model with almost similar concept to iceberg type model and analyzed the spatial economic effects of economic integration, assuming reduction of trade barrier, of Eastern and Central European countries. Bröcker's model was expanded to more practical and sophisticated system for the IASON project, CGEurope (Bröcker et al. (2004)). CGEurope was designed for the integrated appraisal of impacts of transport policies on spatial development in the EU. Bröcker et al. (2010) applied the similar model to investigate the spatial distribution of welfare effects generated by series of transport infrastructure development program in EU (TEN-T project). RAEM, SCGE model system for transport policy appraisal in Netherlands, adopted iceberg type transport cost concept (Knaap et al. (2011)). Early RAEM model was applied to assess the Dutch railway proposals and it was developed several versions including additional features such as job search (matching) mechanism (Thissen et al. (2010)) and dynamics (Ivanova et al. (2007)). Koike et al. (2009) discussed the impacts of spatial equity caused by Japanese expressway investment projects using a SCGE model, RAEM-Light. The share of the origin for the goods purchased by regional production sector or households is formulated by logit type model.

The Greater Tokyo Area has more than 35 million population, about 30% of the country, and is also highly urbanized. The big catchment area of goods market extends the diversity of products and it also attracts consumers, thus 'economy of agglomeration' is working. Introducing monopolistic competition, increasing return and firm level scale economy gives microeconomic foundation of economy of agglomeration (Krugman (1991), Helpman et al. (1985), Fujita et al. (2001)). The essence is used in the SCGE models such as Bröcker (1998b), Knaap et al. (2011) and Ishikura et al. (2017). Regional gains arise from increase in product diversity in these models.

The improvement of highway network connecting a lot of municipalities influences to their economic activities and the effects are heterogenous. Therefore road transport policy discussion has a big interest in economic impact analysis of 'spatial resolution of municipality level'. Building a SCGE model dividing an economic system to detailed classified regions may tackle with the lack of consistent available data. Koike et al. (2014), the first SCGE model classifying Japanese economy to municipality level, assess the nation-wide spatial economic impacts of Great East Japan Earthquake. They estimated the inter-municipality trade matrix as a benchmark data by means of doubly-constrained gravity model using road transport generalized cost. Ishikura et al. (2017) also built a SCGE for the transport investment project appraisal for huge urbanized area handling municipality level multi-regional economy. Ishikura et al. (2017) firstly estimated the distance (actually generalized transport cost) decay parameters from rough classified inter-regional trade matrix and then down-scaled to the model with municipality level. No SCGE models classifying municipality level in Japan are built other than these two works.

We build a spatial computable general equilibrium (SCGE) model reflecting the above three aspects, iceberg transport cost concept, economy of agglomeration and spatial resolution of municipality level to explore spatial economic effects of new highway network project in the Greater Tokyo area. The current model named TMUSE (TMU Spatial Economic) model is an extension of Ishikura et al. (2017). We improve several problems remaining in Ishikura et al. (2017); ad-hoc assumption of the elasticity parameters; omitting the difference of commodity sectoral component between consumption and investment in final demand; ambiguous description of regional accounts.

Section 2 provides the description and derivation of the model. Compilation of benchmark data and calibration process are explained in section 3. Section 4 presents the results and discussion of the application. Final section summarizes the contribution, limitation and future prospects of this model.

2 Model

2.1 Basic assumptions

The model illustrates a static multiregional-multisectoral economy. Each region has one representative household and three sectors; primary sector, manufacturing sector and service sector. Household expenditure is identified by consumption and regional savings. The allocation share of the two types of expenditure is given exogenously, namely we do not handle dynamic aspects of capital accumulation in the model. The purpose of the classification of the final demand is to reflect the difference of component of goods between consumption and investment. Consumption demand is determined by utility maximization of the household. Investment is financed fully by regional savings.

We assume iceberg transport cost concept for inter-regional trade, which is familiar in New Economic Geography. Hence, certain amount of the commodity, denoted τ_{rs}^i, needs to be shipped from $r\,(\in \mathcal{R})$ to $s\,(\in \mathcal{R})$ in order to accommodate the unit demand of goods of sector $i\,(\in \mathcal{I})$ at region s. It means that $\tau_{rs}^i - 1$ of the tradable commodity itself should be consumed as the cost of transport.

The economy is assumed to be an open economy system. Since the Greater Tokyo area to which we plan to apply the model is a big consumption area but not a big production area of, in particular, primary industry, trade imbalance to rest of the world (including rest of Japan) is remarkable. Therefore the amount of net export is not negligible, then balance of payment for each region should be explicitly taken into account. Our analysis highlights the regional effects of domestic inter-regional transport policy, and the policy may not affect to trade with the rest of the economy drastically. We assumed that real amounts of the net export of every goods in each region are predetermined and fixed at the level of benchmark equilibrium status.

2.2 Final demand

Representative household living in each region has Cobb-Douglas preference over CES aggregate of commodities labeled by each sector. Indirect utility function for representative household in region s is represented by

$$V_s = \prod_i \left\{ \left(g_s^i\right)^{-\mu_s^i} \right\} (1 - \xi_s)\, I_s \tag{1}$$

where g_s^i, I_s, μ_i and ξ_s denoting price index of the aggregate of commodity i, expenditure for final demand, preference share parameter and regional saving rate respectively. The composite consumption commodity of each sector aggregates the commodity produced in each region. Taking into account of the assumption that each commodity in sector i produced in s is differentiated by individual firm label κ, g_s^j is defined as

$$g_s^i = \left\{ \sum_r \int_0^{n_r^i} \left(p_{rs}^i(\kappa)\right)^{1-\sigma^i} d\kappa \right\}^{\frac{1}{1-\sigma^i}} \tag{2}$$

where n_r^i and p_{rs}^i denote the number of variety of the commodity i produced in r and CIF price of the variety at region s respectively. σ^i represents elasticity of substitution across differentiated commodity of sector i. According to iceberg transport cost concept assumption, the CIF price of the variety is represented by the product of FOB price (mill price) of the variety in the region of origin p_r^i and τ_{rs}^i. Another assumption that each variety of the commodity belonging to same sector has symmetric technology, namely similar cost function, gives convenient simplicity of the model. This simplification can drop the label κ from the above equations and gives the following form of price index,

$$g_s^i = \left\{ \sum_r n_r^i \left(p_r^i \tau_{rs}^i\right)^{1-\sigma^i} \right\}^{\frac{1}{1-\sigma^i}}. \tag{3}$$

Applying Shepard's lemma to (1) with (3) yields real demand fonction for consumption of each variety of the commodity,

$$c_{rs}^{i}=\left(\frac{p_{r}^{i}\tau_{rs}^{i}}{g_{s}^{i}}\right)^{-\sigma^{i}}\mu_{s}^{i}\left(1-\xi_{s}\right)\frac{I_{s}}{g_{s}^{i}}. \tag{4}$$

Assuming common structure of the substitution technology of aggregation of variety for investment goods demand, real demand for regional investment k_{rs}^{i} is derived similar way, namely

$$k_{rs}^{i}=\left(\frac{p_{r}^{i}\tau_{rs}^{i}}{g_{s}^{i}}\right)^{-\sigma^{i}}\nu_{s}^{i}\xi_{s}\frac{I_{s}}{g_{s}^{i}}, \tag{5}$$

where ν_{s}^{i} denotes the technological share parameter for aggregation of investment demand.

2.3 Firm

Production sector is immobile and labeled by region of production s and industrial sector $j\in\mathcal{I}$. Every firm has increasing return to scale technology and faces monopolistic competition market so-called Dixit-Stiglitz format. Indeed, each firm exclusively produces a variety of single sectoral commodity which is differentiated by production firm.

Stemming the pooled intermediate input of sector i and value added by Cobb-Douglas technology makes composite input of upper tier. The price index of composite input for the production of a variety of sector j in region s is given by the function

$$h_{s}^{j}=\eta_{s}^{j}w_{s}^{1-\sum\limits_{i\in I}\alpha_{s}^{ij}}\prod_{i}\left(g_{s}^{i}\right)^{\alpha_{s}^{ij}}. \tag{6}$$

Where w_{s}, α_{s}^{ij} and η_{s}^{j} denote factor price, cost share parameter of intermediate input commodity i for production sector j in region s and a scaling parameter to adjust the unit of variables practically respectively. Elasticity of substitution across varieties of the commodity for production technology is assumed to be same as that for consumption preference. Therefore g_{s}^{i} has common form with (3).

Let C_{s}^{j} denote the cost function for the production of a variety i at region s. Since we assume increasing return to scale at firm level, the production needs to input fixed amount of composite input ϕ_{F}^{j} which is indepent of the level of production as well as variable one depending on the level of production. The fixed component assumed to be common accros the region of production. Thus the cost function is written as

$$C_{s}^{j}\left(x_{s}^{j}\right)=\left(\phi_{F}^{j}+\phi^{j}x_{s}^{j}\right)h_{s}^{j} \tag{7}$$

where ϕ^{j} denotes marginal input of the composite input.

Firm's profit maximization taking into account of the same elasticity in the variety of the commodity demand for consumption and intermediate gives the individual firm's mark up price over marginal cost as

$$p_s^j = \frac{\sigma^j}{\sigma^j - 1} \phi^j h_s^j. \tag{8}$$

Free entry and exit assumption in the monopolistic competition market imposes zero profit condition. Hence average cost should be equal to mill price and then the real production amount of each variety x_s^j is derived by

$$x_s^j = \frac{\phi_F^j}{\phi^j} \left(\sigma^j - 1\right) = \zeta^j, \tag{9}$$

which is a constant (hereafter denoted by ζ^j), independent from price level. Substituting the demand into cost function yields the relationship between FOB price and production cost

$$C_s^j = \zeta^j p_s^j. \tag{10}$$

Total output value of commodity j in s, S_s^j, is the product of the number of firms and the production cost of the variety,

$$S_s^j = n_s^j C_s^j = n_s^j p_s^j \zeta^j \tag{11}$$

Applying Shepard's lemma to (3) and (6)-(11), as well as consumption demand, real demand fonction for intermediate input of each variety of the commodity,

$$m_{rs}^{ij} = \left(\frac{p_r^i \tau_{rs}^i}{g_s^i}\right)^{-\sigma^i} \alpha_s^{ij} \frac{S_s^j}{g_s^i} \tag{12}$$

is derived.

2.4 Trade and regional accounts

The aggregated real demand for the commodity i at region s is the sum of final demand and intermediate input demand. Since we adopt iceberg transport cost concept, τ_{rs}^i amount has to be shipped from region of origin r for the unit demand at region of destination s. Therefore the aggregated trade value of the commodity i from region of origin, r, to region of destination, s, including transport cost component Q_{rs}^i is represented by

$$Q_{rs}^i = n_r^i p_r^i \left(c_{rs}^i + k_{rs}^i + \sum_j m_{rs}^{ij} \right) \tau_{rs}^i. \tag{13}$$

Substituing (3), (4), (5) and (12) to (13) yields other form of the trade value, the product of regional share of the demand and expenditure for the commodity

$$Q_{rs}^{i}=\frac{n_{r}^{i}\left(p_{r}^{i}\tau_{rs}^{i}\right)^{1-\sigma^{i}}}{\sum\limits_{r}n_{r}^{i}\left(p_{r}^{i}\tau_{rs}^{i}\right)^{1-\sigma^{i}}}E_{s}^{i}. \tag{14}$$

Where E_s^i is the aggregated value of the demand for the commodity i at region s.

$$E_{s}^{i}=\mu_{s}^{i}\left(1-\xi_{s}\right)I_{s}+\nu_{s}^{i}\xi_{s}I_{s}+\sum_{j}\left(\alpha_{s}^{ij}S_{s}^{j}\right), \tag{15}$$

The first term and the second term represent two components of final demand, consumption and investment, and the third term denotes intermediate demand.

By assumption, real net export of commodity i produced in r to rest of the world, $\overline{z_r^i}$, is predetermined. Payment from rest of the world to the firm in r is measured by FOB price p_r^i at region of production because international trade cost is not explicitly handled and also assumed to be implicitly included in the real net export. the Summing Q_{rs}^i over the region of destination plus net export value to rest of the world yields total sales of the commodity i produced in r

$$S_{r}^{i}=\sum_{s}\left[\frac{n_{r}^{i}\left(p_{r}^{i}\tau_{rs}^{i}\right)^{1-\sigma^{i}}}{\sum\limits_{r}n_{r}^{i}\left(p_{r}^{i}\tau_{rs}^{i}\right)^{1-\sigma^{i}}}E_{s}^{i}\right]+p_{r}^{i}\overline{z_{r}^{i}}. \tag{16}$$

Balance of regional accounts must be strictly kept in order to secure the closure of general equilibrium model. Regional expenditure, equivalent to disposal income for consumption and saving, is the sum of factor income minus net income transfer to out of the region. Income transfer has two components, net transfer to other region in the economy and net transfer to rest of the world. Net transfer to rest of the world is equal to the sum of net export to rest of the world in value term. As already mentioned, real amount of net export of each commodity is exogenously given.

A discussion about how we model the inter-regional net income transfer can take place in building a multiregional economic model. Payment for inter-regional trade to other region often differs from inflow of inter-regional trade. From one point of view, we can assume that net income transfer between regions is predetermined and inter-regional trade volume is endogenously determined consistent with the regional balance of payment. On the other hand, the regional income transfer can be regarded as flexible elements, namely endogenous variables. When the latter assumption is adopted, other rules to determine the income transfer need to be imposed in order to secure the unique solution of simultaneous equations system. Regional income transfer, as an aggregated value of regional accounts, is observed when commuting to other region or capital rending to other region exists. Since static SCGE model usually assumes no migration and no capital movement, our model adopts the assumption that value of net inter-regional transfer[1] is unchanged even if the equilibrium changes.

Thus the relationship between regional expenditure for final demand and factor income,

$$I_s = \sum_j w_s^j l_s^j - \sum_i p_s^i \overline{z_s^i} - \overline{G_s} \qquad \left(\sum_s \overline{G_s} = 0\right) \tag{17}$$

should be kept. $\overline{G_s}$ denotes the constant value of aggregated inter-regional income transfer payment for regional households in s. Sum of $\overline{G_s}$ over region equals to zero because net income transfer to rest of the world is separated.

2.5 Equilibrium

Combining the descriptions of economic behavior as mentioned above yields market equilibrium conditions. The model eventually includes four types of endogenous variables, w_s: factor price at s, p_s^j: price of variety of sector j produced in s, g_s^i: price index of aggregate commodity i in s and n_r^i: number of variety of sector i produced in r respectively.

Factor market clearing condition is

$$w_s L_s = \sum_j \left(1 - \sum_i \alpha_s^{ij}\right) \zeta^j n_s^j p_s^j, \tag{18}$$

where L_s denotes factor endowment in region s. Right hand side of (18) represents the sum of factor demand in value term because $\zeta^j n_s^j p_s^j \left(= S_s^j\right)$ denotes the aggregated output value of commodity j produced in s.

Rewriting (16) as the function of endogenous variables yields market clearing condition of each commodity,

$$\begin{aligned} \zeta^i n_r^i p_r^i \quad &= \sum_s \left[\frac{n_r^i \left(p_r^i \tau_{rs}^i\right)^{1-\sigma^i}}{\sum_r n_r^i \left(p_r^i \tau_{rs}^i\right)^{1-\sigma^i}} \cdot \right. \\ &\left\{ \left(\left(1-\xi_s\right)\mu_s^i + \xi_s \nu_s^i\right) \left(w_s L_s - \sum_i p_s^i \overline{z_s^i} - \overline{G_s}\right) \right. \\ &\left.\left. + \sum_j \alpha_s^{ij} \theta^j n_s^j p_s^j \right\} \right] + p_r^i \overline{z_r^i}. \end{aligned} \tag{19}$$

Price index of the aggregates of commodity i in region s is defined as a function of p_r^i and n_r^i (3). We show this definition here as one of the equilibrium conditions,

$$g_s^i = \left\{ \sum_r n_r^i \left(p_r^i \tau_{rs}^i\right)^{1-\sigma^i} \right\}^{\frac{1}{1-\sigma^i}}. \tag{20}$$

Larger number of variety contributes to reduction of the price index, which reflects property of love of variety.

[1] The value of inter-regional transfer is measured by numeraire price.

In equilibrium, price of the variety of the commodity has to satisfy

$$p_s^j = \psi_s^j (w_s)^{1-\sum_i \alpha_s^{ij}} \prod_i \left\{ \left(g_s^i\right)^{\alpha_s^{ij}} \right\}, \tag{21}$$

where $\psi_s^j \left(= \frac{\sigma^j}{\sigma^j - 1} \phi_s^j \eta_s^j\right)$ denotes the parameter with regard to markup and productivity.

3 Data processing and calibration

3.1 Benchmark data

Since our policy analysis aims to capture geographical distribution of the highway project in an urban area, the model need higher resolution of regional classification, namely municipality level in Japan. SCGE models in general use multiregional input-output table or regional social accounting matrix as the benchmark data for calibration. Unfortunately such ideal data is not available for the detailed classified economy. Some components of the benchmark data have to be estimated.

We are able to obtain regional factor income of every municipality from the officially published statistics. The factor income is only data to capture accurate value for all municipalities. Sectoral production outputs in value term by municipality are also available only in several prefectures. When the sectoral outputs by municipality are not available, we estimate the outputs value by municipality by allocating the sectoral outputs of the prefecture proportional to the number of labor of municipality. The number of labor by municipalities is available and sectoral production outputs can be obtained by input-output table of each prefecture.

Cost share data of intermediate input of each sector and factor input is not available in municipality level. We therefore assume the sectoral production technology is similar among municipalities belonging to same prefecture. Due to the assumption, input coefficient parameter is obtained from prefecture input-output tables which all prefectures in Japan publish. The sectoral demand share of final demand, consumption and investment, per prefecture are also obtained from the prefecture input-output table. However, municipality share of them is still unknown. We again assume the sectoral share of the final demand are similar in if the municipalities belong to same prefecture. Disaggregation of the consumption and investment demand of each sector proportional to the population of municipality derives the demand by municipality.

3.2 Calibration

Regional saving rate ξ_s comes from input-output table of the prefectures. The benchmark data mentioned above provides direct information for calibration of the parameters for aggregated sectoral commodity. Thus $\alpha_s^{ij}, \mu_s^i, \nu_s^i$ are easily calculate by value share of the intermediate and final demand by sector. Regional production outputs S_r^i and factor income $w_s L_s$ are yielded as well as the parameters.

Regional share of commodities traded is still unknown and actual inter-regional trade data of high resolution regional classification such as municipality level does not exist. We need some estimation process of calibration with regard to inter-regional trade.

Taking look at (14), essential elements for regional share of the trade are fob price of variety, transport margin, number of variety, and elasticity of substitution over the varieties indicated by (14). We need more informations than the benchmark data in order to specify these elements. Ishikura et al. (2018) estimates the elasticity parameter for 11 industrial sector in Japan using inter-prepecture trade data by applying the method of Head et al. (2001) and Head et al. (2004). We import the elasticity parameter of an application of Ishikura et al. (2018) to three sector version of the trade data.

Now elasticity parameter for sector i is determined, then recalling ((11) and (14) yield value of inter-regional trade commodity,

$$Q_{rs}^{i}=\frac{S_{r}^{i}p_{r}^{\sigma^{i}}\tau_{rs}^{1-\sigma^{i}}}{\sum_{r}S_{r}^{i}p_{r}^{\sigma^{i}}\tau_{rs}^{1-\sigma^{i}}}E_{s}^{i} \tag{22}$$

Ishikura et al. (2017) estimates transport margin for Japanese inter-regional trade as a function of inter-regional remoteness and geographical barrier using the form of (22) by applying Poisson pseudo maximum likelihood (PPML) method. We introduce the same method to obtain the transport margin parameters. Trade value (22) is rewritten in the fixed effect gravity function form,

$$Q_{rs}^{i}=A_{r}^{i}B_{s}^{i}\exp\left(\gamma^{i}\ln T_{rs}\right), \tag{23}$$

where $A_{r}^{i}\left(=S_{r}^{i}p_{r}^{i}\right)$ and $B_{s}^{i}\left(=\left(\sum_{r}S_{r}^{i}p_{r}^{\sigma^{i}}\tau_{rs}^{1-\sigma^{i}}\right)^{-1}E_{s}^{i}\right)$ represent fixed effects with regard to origin region and destination region respectively. Transport margin is therefore defined by

$${\tau_{rs}}^{1-\sigma^{i}}=\exp\left(\gamma^{i}\ln T_{rs}\right). \tag{24}$$

T_{rs} denotes transport, or travel, time index from r to s, comes from the generalized time calculated by user equilibrium traffic assignment problem under the situation of OD traffic demand and road network condition in 2010. We apply the PPML method to inter-regional trade data of the three sectors coming from multi-prefecture input-output table in order to estimate the parameters of (23). Although transport time index is a significant factor for all sector, both of the two geographical barrier are significant only in sector 2, manufacturing sector. Table 1 summarizes the parameters we adopted. The results reflect freeness of inter-regional trade (Baldwin et al. (2005)) is higher because of less value of σ^{i}, and the trade demand is less sensitive to transport time in manufacturing sector.

In benchmark equilibrium, we set FOB prices for all sector and factor prices to unity. This procedure does not affect to any conclusions of the model because of homogenous of degree zero for price system. The setting

Table 1: Elasticity and estimated parameters of transport margin

i: sector	σ^i	γ^i (p-value)
1(primary)	6.99	-1.18 (0.00)***
2(manufacuring)	4.40	-1.01 (0.00)***
3(service)	6.83	-1.70 (0.00)***

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

of price level determines the real value of factor endowment L_s measured by the benchmark factor price.

According to the assumption that preference and technology do not vary across municipalities in prefecture, E_s^i is obtained by summing up the demand for each commodity using (15). Combing the data of S_r^i, E_s^i, T_{rs} and parameter in Table 1 derives inter-regional trade value $Q_{rs}^i (i \in \mathcal{I}\ r, s \in \mathcal{R})$. Then exogenous real net export $\overline{z_r^i}$ can be obtained by solving equation (16) for $\overline{z_r^i}$. Since I_s is given by summing up the final demand value of benchmark data over region of production, equation (17) yields aggregated inter-regional income transfer $\overline{G_s}$.

Now $\overline{z_r^i}$ and τ_{rs}^i are given and benchmark value of p_r^i, E_s^i and S_r^i are predetermined. We are able to solve the nonlinear simultanous equations (16) for n_r^i, and obtain the solution as the equilibrium number of variety consistent with benchmark price level. Parameter with regard to the production amount of the variety ζ^i is then derived by (11). The last unknown parameter ψ_s^j is calclulated by (21).

4 Results

4.1 Simulation scenario and welfare measurement index

We evaluate the highway network project in Greater Tokyo Area comparing the situation after the completion of the project with no project situation. The analysis scheme is a comparative static analysis assuming economic conditions outside of the model is fixed as in 2010. Therefore the situation with the project and that without project vary only in the road transport network conditions.

The domain of the Greater Tokyo Area in this study includes 376 municipalities belonging 8 prefectures; Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa and Yamanashi. Current condition of the road transport network is based on Road Traffic Census in 2010, published by Ministry of Land, Infrastructure, Transport and Tourism. Using origin-destination data for vehicle travel and road section spec data, such as capacity and average speed, driving time between every origin-destination pair is calculated by traffic assignment method. The traffic assingment method is derived user equilibrium theory and established as a standard technique in transport engineering field. This technique takes into account the influence of congestion externality, travel time passing a road section in the model depends on traffic volume and capacity. We calculate shortest travel time between every municipality pairs assuming the local government office is the centroid. Replacing the road network condition after the completion of all planed highways to current road network condition obtains travel time index of the situation with the highway projects. The more road capacity and higher average speed contribute to reduce transport margin, which can be calculated quantitatively by (24).

We measure welfare effects by means of equivalent variation (EV) index, however we do not show the simple EV index. The magnitude of regional income strongly affects to the EV because EV is represented as the product of regional consumption expenditure level in benchmark equilibrium and utility change ratio caused by the project. Instead we refer “relative EV” (REV) index for regional welfare impacts,

$$REV_s = \frac{V_s^a - V_s^0}{V_s^0} \tag{25}$$

proposed by Bröcker (1998a), where V_s^0 and V_s^a representing utility of a household in region s at benchmark equilibrium and ‘after-project’ equilibrium. It is defined as the percentage change of benchmark (pre-project) income a regional representative household would need, in order to get the after-project utility under benchmark prices.

4.2 Spatial economic impacts

Spatial welfare impact, namely geographical distribution of REV, in whole Greater Tokyo Area is shown in Fig.1. The result clearly shows welfare impact is uneven. The regions near the crossing points new highway and existing highway relatively gain more. In the Northeast area (Northern Ibaraki prefecture) and West area (Kofu, local government city of Yamanashi), large effects arise despite the distance from central Tokyo. On the other hand, less welfare improvement, sometimes negative impact, is observed in the regions remote from existing highway network.

Focusing on central area (Fig.2), the distribution of benefit shows contrast between regions in urban area. Central area in inner loop roads, namely CBD of Greater Tokyo Area, gain the most, followed by connection point between new middle loop section and existing coastal highway section. Relatively large welfare impacts are brought about in the regions beside the new outer loop sections. The welfare impacts on the regions between existing outer loop and middle loop in Western Tokyo are slightly less.

Impacts on industrial activity level would vary between sectors. Fig.3, Fig.4 and Fig.5 show the percentage changes in production output value of primary sector, manufacturing sector and service sector respectively. Production outputs in primary sector and manufacturing sector decrease in most of Northeast area. Increase in amount of production of primary sector arises in North Ibaraki prefecture area and Yamanashi prefecture on which agricultural industries concentrate. The number of municipality where manufacturing output increased is relatively small. The pattern of change in outputs of sector 3, service sector, greatly differs from other twe sectors, increasing in wider area.

Parameters in Table.1 suggest service sector is hardly to trade among regions due to high value of σ^i and

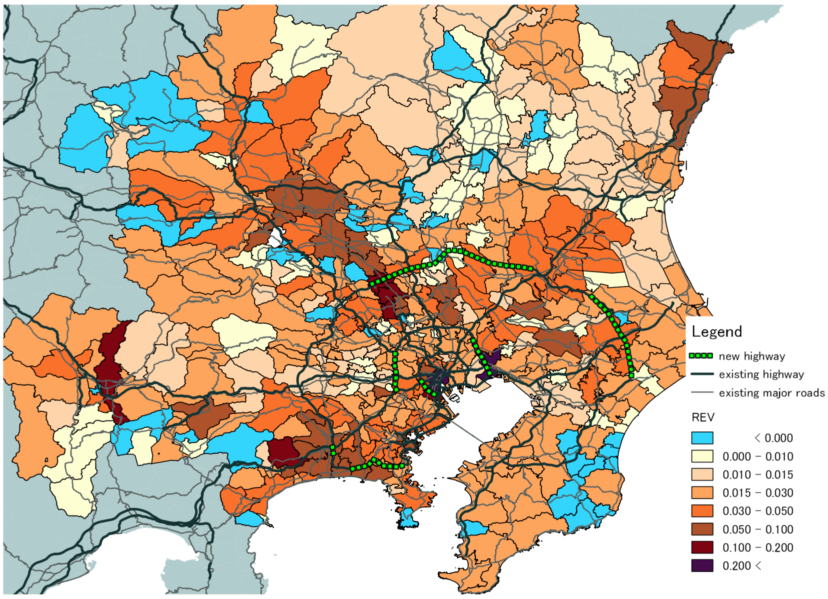

Figure 1: Distribution of REV

γ^i, and manufacturing sector has opposite aspect. If γ^i is larger value, trade of i sector tend to decay according to increase of generalized transport cost. σ^i reflects inverse of the “freeness of trade” (Baldwin et al. (2011)). herefore reduction of transport time caused by highway development would affect to inter-regional competitive relationship in manufacturing sector more, but less in service sector. This difference would cause the different spatial impacts between service sector and manufacturing sector.

Welfare impacts and changes in sectoral outputs in selected municipalities where relatively larger gain are observed are summarized in Table.2. Most of special administrative wards in Tokyo get welfare gain with increase in production outputs in all sector. However output value of specific sector in some regions other than Tokyo decreases. For example, decrease in outputs of manufacturing sector is larger than increase in outputs of service sector in Ichikawa and Kitamoto but nonetheless REV of these cities are relatively high. In municipalities improving welfare in Kanagawa prefecture such as Ebina, Aikawa, Yamato, Fujisawa, Kamakura and Kawasaki-tama, they are located near the newly opened highway sections, production of manufacturing sector increases but loses the outputs of service sector. The aspect of the result suggests that the highway project will accelerate agglomeration of economic activity in central Tokyo and regional specialization especially in peripheral region simultaneously.

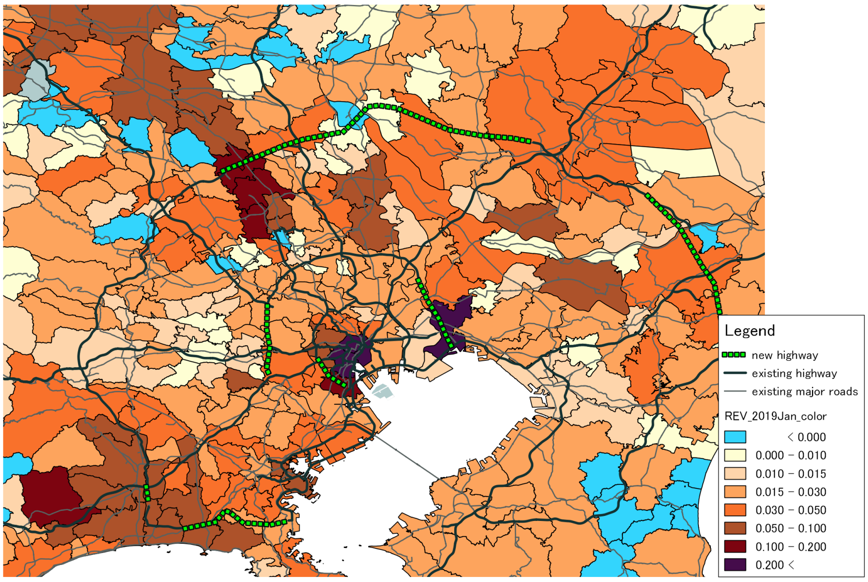

Figure 2: Distribution of REV (enlarged view)

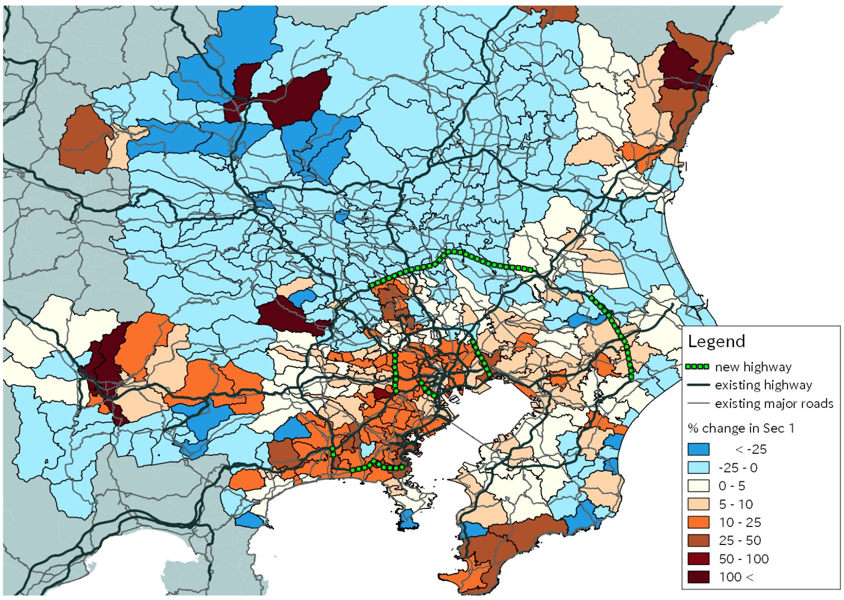

Figure 3: Percentage change in output value (sector 1: primary)

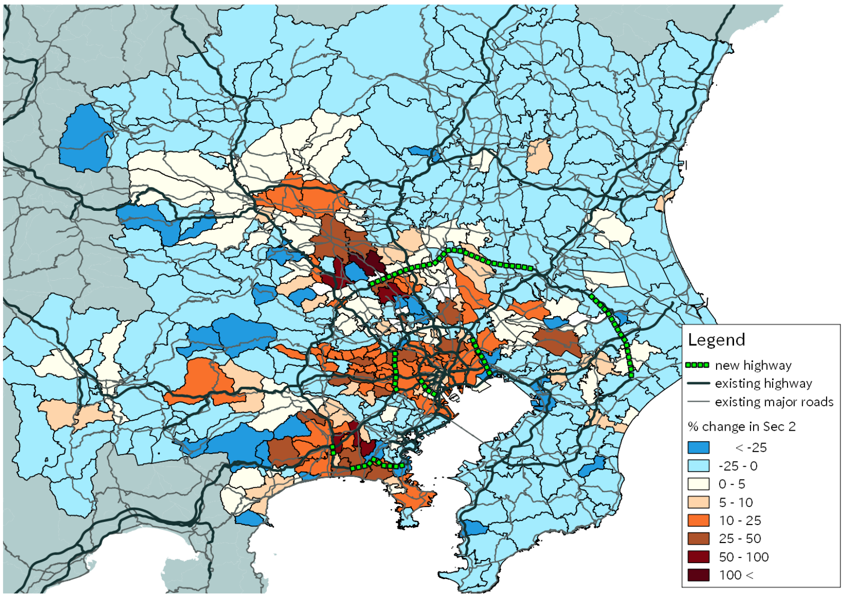

Figure 4: Percentage change in output value (sector 2: manufacturing)

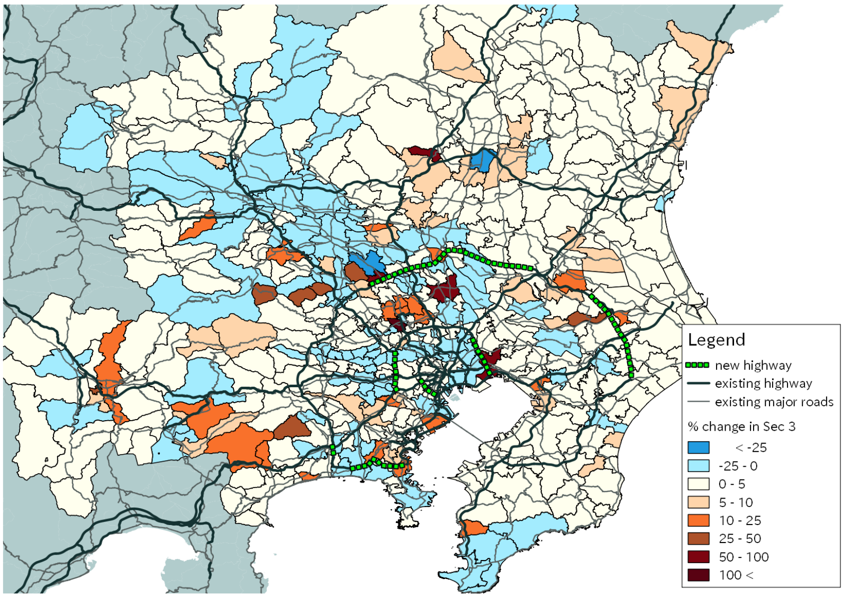

Figure 5: Percentage change in output value (sector 3: service)

Table 2: Effects in selected regions (top 30 in terms of REV)

municipality	prefecture	REV	EV*	Change in output value** sector 1 (primary)	sector 2 (manufacuring)	sector 3 (service)
Chiyoda ward	Tokyo	0.800	0.18	0.06	119.02	190.41
Ichikawa	Chiba	0.304	0.44	2.78	-842.09	786.10
Minato ward	Tokyo	0.275	0.23	0.06	163.43	254.71
Chuo ward	Tokyo	0.226	0.15	0.09	109.06	156.93
Ageo	Saitama	0.178	0.13	1.49	208.36	17.75
Okegawa	Saitama	0.124	0.03	0.45	46.49	2.72
Shinagawa ward	Tokyo	0.121	0.23	0.06	36.77	220.04
Hadano	Kanagawa	0.116	0.08	1.70	148.04	24.62
Kitamoto	Saitama	0.116	0.02	-0.12	-253.49	147.86
Saitama-nishi	Saitama	0.104	0.04	0.45	-1.68	36.69
Kofu	Yamanashi	0.101	0.11	7.60	0.21	117.96
Tsuru	Yamanashi	0.090	0.02	-0.40	-4.74	24.82
Shinjuku ward	Tokyo	0.081	0.11	0.05	150.85	64.32
Ebina	Kanagawa	0.079	0.04	0.43	164.85	-20.14
Aikawa	Kanagawa	0.076	0.02	0.19	47.22	-3.43
Yamato	Kanagawa	0.074	0.07	0.61	505.20	-123.24
Shibuya ward	Tokyo	0.072	0.06	0.05	96.61	41.05
Fujisawa	Kanagawa	0.069	0.11	1.04	481.31	-70.18
Konosu	Saitama	0.067	0.02	-0.23	424.50	-205.96
Kitaibaraki	Ibaraki	0.067	0.01	4.99	-5.37	8.73
Saitama-omiya	Saitama	0.065	0.03	0.07	-282.24	217.39
Kamakura	Kanagawa	0.065	0.04	0.22	115.41	-3.63
Kawasaki-tama	Kanagawa	0.065	0.05	1.20	316.84	-43.97
Chigasaki	Kanagawa	0.064	0.06	0.35	200.81	-28.88
Yokohama-naka	Kanagawa	0.063	0.03	0.07	-0.19	47.96
Hitachi	Ibaraki	0.063	0.04	0.97	-44.30	58.68
Yokohama-nishi	Kanagawa	0.063	0.02	0.03	19.99	26.05
Inzai	Chiba	0.063	0.02	0.15	64.38	-12.84
Gyoda	Saitama	0.060	0.02	-0.60	75.69	-30.44
Samukawa	Kanagawa	0.059	0.01	0.36	17.71	10.24

*unit of EV: trillion JPY
**unit of output value: billion JPY

5 Concluding remarks

We build a SCGE model, TMUSE, having the aspects, iceberg transport cost concept, economy of agglomeration and municipality-level regional classification to explore spatial economic effects of completion of the ring-road sections of the highway network project in the Greater Tokyo area. The Greater Tokyo area is classified to 376 municipalities with three industrial sectors in the model.

The application study presents spatial distribution of welfare impacts as well as changes in production outputs by sector. Basically, center regions of the circular road system and regions near the newly opened section gain more as expected. The results also suggest the completion of the highway system would accelerate agglomeration of central Tokyo area and regional specialization in peripheral area.

TMUSE model is oriented toward transport policy appraisal but the present version does not explicitly classify freight transport and passenger travel. Basically the iceberg transport cost concept is an approach to describe trade cost, assuming mainly freight transport cost. The Greater Tokyo Area has well developed rail transport system. Rail transport including metro network is dominant as a mode for passenger travel especially in the central area of Tokyo. Some extension projects of rail system are actually in planning phase in the area. Integration with transport modeling such as passenger's mode choice behavior is a direction of the future study.

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