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Regional economic effects of transport infrastructure development featuring trade gateway region -asymmetric spatial CGE model approach-

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Abstract

Port, or airport, is an essential infrastructure for international trade. Actually it is impossible to export/import for island countries without such port infrastructure. International freight transport system includes not only the infrastructure facilities but also the specialized procedure of international cargo handling and trading in the "trade gateway" region. It means that the situation of transport, or trade, system is asymmetric between the trade gateway region and other regions.

This paper proposes a methodology based on spatial computable general equilibrium (SCGE) model framework taking into account of the asymmetric aspects of trade gateway region explicitly. The model describes the role of export and import sector in the trade gateway region, which do not exist other hinterland regions. We then apply the model to Japanese economy divided into two regions, trade gateway (Tokyo) and rest of Japan. Some transport development scenarios are evaluated quantitatively. A sensitivity analysis remarks the discussions regarding the effects of elasticity assumptions.

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Keywords: spatial computable general equilibrium model; trade gateway; transport development; economic effects; open economy

1. Introduction

Investment to transport infrastructure contributes to improve the productivity of the infrastructure and decrease generalized transport cost. This is a typical logic to explain how the investment to transport infrastructure produces benefit. It seems valid from a point of view of traditional cost benefit analysis (CBA) measuring only the efficiency of the investment project. However the traditional CBA does not mention who may gain, or who may lose by the

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project. General equilibrium approach, considering multiple market equilibrium and multiple players, is needed to know the incidence of the benefit.

Multi-regional general equilibrium approach, e.g. spatial computable general equilibrium (SCGE) model, highlight inter-regional economic interaction through spatial transport network. When a SCGE model is applied to transport project appraisal, improving regional productivity or direct reduction of generalized transport cost caused by transport infrastructure investment is explicitly described. In many cases, the transport system described in the models are linkage between the regions classified in the models. For example, road network and rail network are assumed the transport system in the domestic or regional SCGE model, and international SCGE models often treat ocean container transport system.

This paper focuses on the domestic regional economic impacts by investment to international transport system. Port, or airport, is an essential infrastructure for international trade. Actually it is impossible to export/import for island countries without such port infrastructure. International freight transport system includes not only the infrastructure facilities but also the specialized procedure of international cargo handling and trading in the ``trade gateway'' region. It means that the condition of transport system is asymmetric between the trade gateway region and other regions. The principal purpose of this paper is to build an appropriate methodology for assessing transport investment project considering this asymmetry.

We build a spatial computable general equilibrium model featuring international transport gateway region. The model assumes one small-open country which has multiple regions. There exists only one trade gateway region in the country. International transport infrastructure such as port and airport is located on the trade gateway region. Foreign goods must enter the country through the international transport infrastructure, and domestic goods also have to be exported through that. Other regions do not have any international transport facilities, therefore direct export/import is impossible in such regions. When the tradable goods is shipped from the region other than trade gateway to foreign country, the goods must be transported to trade gateway region then it is exported. Domestic freight transport cost is imposed to price of the tradable goods in addition to international transport cost.

The above geographical structure of the country reflects asymmetry in terms of transport condition for international trade activity. Our model also considers the asymmetry in terms of industrial structure between trade gateway and other regions. Trade transport systems using container port and international airport need specific field of transport activities such as customs clearance, vanning, warehousing, loading and so on. These kind of industrial sector are usually located near the international transport infrastructure and not observed in the regions other than trade gateway. Repairing and maintenance of international transport equipment are also regionally specific industries because ship and aircraft have to stay in port/airport. In order to take the industrial asymmetry into account of the model, we explicitly classify the international transport related sector from other sector.

Since the model assumes asymmetric industrial structure namely different number of industrial sector between trade gateway region and other regions, the standard input-output table cannot be used as a benchmark equilibrium data. Export and import sectors appear only in trade gateway region, do not appear in other regions. We develop a methodology to compile the original multi-regional input-output table to the data format accommodating to our model.

This paper applies the model to Japanese two-region economy system and evaluates some virtual transport infrastructure projects. The original benchmark data is Tokyo Metropolitan I-O table which is a two-region table, classifying Tokyo and Rest of Japan. Industrial sectors, excluding international transport related sectors, are aggregated to one composite goods sector for simplicity. The system of multiple number of regions more than two is applicable, and it is the same for the number of sectors. The analysis assumes that Tokyo Metropolitan region is the gateway of Japanese international trade. Cost structures of export sector and import sector in Tokyo Metropolitan region can be derived from the modified benchmark data.

We evaluate the effects of the three infrastructure project scenarios; international transport infrastructure investment, domestic transport infrastructure investment and both of them. It is the novelty of this model that these types of policy scenario can be assessed by same platform. The domestic transport infrastructure project would contribute to nation-wide price reduction and strengthen the competitive power to foreign goods. The result actually shows that domestic infrastructure project brings positive benefit to all regions in Japan. On the other hand, international transport infrastructure project will cause different effects by region; negative benefit in trade gateway region and positive benefit in other region in this analysis. Improvement of international transport infrastructure contribute not only to price reduction of domestic goods but also to price reduction of imported foreign goods. In this case, imported goods become more competitive than the goods produced in the trade gateway region. The result moreover shows the effects of the package of the domestic and international infrastructure projects. Since SCGE model illustrates equilibrium in all markets, our model gives the change in prices and outputs for each sector in each region as well as regional benefit. The effects to export/import sector are explicitly and individually estimated by the model.

2. Literature review

Introducing explicit transport system to multi-regional CGE model is the basic idea of SCGE and it is a convenient methodology to measure economic impacts caused by transport policy with comprehensive points of view. Buckley (1992) initiated the approach highlighting explicit transport service in multi-regional computable general equilibrium model. In his model, transport service produced by transport sector is required for inter-regional trade. Direct impact of transport policy is described by productivity improvement of transport sector. Bröcker (1998b) developed the methodology combining multi-regional CGE model and Samuelson's iceberg transport cost concept consistently. Independent modeling of transport cost for each region-pair by Bröcker's approach has an advantage when transport project for specific regions or links is the interest. After these earlier works, two typical ways to introduce transport system into SCGE models become popular.

The first direction of extension is focusing on mainly productivity improvement by transport policy. Kim et al. (2004) and Kim and Hewings (2009) linked transport network model and SCGE model by aggregate index of transport accessibility of region and estimated the effects of highway construction project in Korea. The accessibility improvement contributes to the improvement of productivity of regional industries. Haddad and Hewings (2005) considered explicit production process of transport service sector and the demand for the transport service by regional sector. Transport investment reduces the production cost of transport sector then contributes to the reduction of transport margin for regional goods sector. The mechanism is almost equivalent to regional productivity improvement by transport investment.

Another stream of the extension highlights transport margin for region-pairs. Bröcker (1998a) built the basic way of calibration and estimation process to estimate the transport margin by regression approach. CGEurope model (Bröcker et al. (2010)), RAEM models (e.g. Knaap and Oosterhaven (2011), Tavasszy et al. (2011) and Thissen et al.(2010)) followed this aspect of modeling and they were applied to assess European transport investment projects such as TEN-T (CGEurope) and Netherlands' railway investment (RAEM). RAEM-Light model (Koike et al. (2009)) adopted iceberg transport cost concept and introduced stochastic element regarding the transport cost. The share of the origin for the goods purchased by regional sector is formulated by logit type model. The models included in this category have interests in the relationship between transport (generalized) cost margin and spatial remoteness. Transport policy such as infrastructure investment and elimination of the institutional barrier causes shortening of transport time or direct reduction of trade cost, which means the decrease of the spatial remoteness for inter-regional trade. The reduction of the remoteness can be explored by transport model outside of SCGE framework.

Standard scheme of SCGE model is interested in the policies about inter-regional transport or intra-regional transport, and trade with rest of the world is often treated very simply, or sometimes omitted. Assessment of international trade policy is explored by world trade model such as Whalley (1984), but the trade models do not explicitly domestic inter-regional interaction. Although some multi-scaled SCGE models (Bröcker (2010), Ishikura (2014)) consider both of international trade and domestic inter-regional trade explicitly, trade with outside of the countries handled in the model is treated quite simply. Most of existing SCGE models may not concern the effects to the export and import with rest of the world by trade/transport policy, other than some exceptions.

Haddad et al. (2010) built an open economy SCGE for Brazilian economy and explored the economic impacts of international port development policy. They represent port development as exogenous change in port service efficiency parameter, and do not take into account of input-output structure of the port related industries. Therefore the asymmetry of trade gateway region is not reflected.

Lofgren and Robinson (2002) models an open economy split multi-regions, which explicitly treat asymmetric industrial structure of the urban region linked to international market. They assume a, poor, developing country with many rural regions linked only one urban region. The model structure is interesting but the assumption that there are no links between rural regions is too unrealistic for the application to developed country.

Ishikura (2012) built a simple open economy SCGE model with asymmetric industrial structure in the trade gateway region, assuming international trade handling sector is located only on the trade gateway region. Ishikura (2012) examined economic impacts analysis of international port infrastructure investment to domestic regions and found that economic scale of the trade gateway region affects the benefit distribution pattern. The model however does not treat inter-regional transport cost and intermediate input of international trade sector. This paper extends framework of Ishikura (2012) by adding the above two aspects explicitly in order to consider not only international trade/transport policy but also domestic inter-regional transport policy simultaneously.

3. Model

3.1. Outline and assumptions

We build a static model for an open economy divided into several regions. There are two types of primary factors, labor and capital, which are owned by regional households. Endowment of factor is fixed and the factor market is closed in the region. Only one region of them has international transport infrastructure, hereafter called “trade gateway”. Each region $r \in R$ has region-specific representative households and representative firms producing composite goods. The domestic transport system links every regions, the goods can be traded between regions with transport cost.

When domestic firms export the goods to foreign country, the goods has to pass the trade gateway region because international trade needs to use international transport infrastructure. Imported goods from foreign countries are similarly shipped through the trade gateway region. The goods is demanded by not only domestic economy but also foreign countries. However, the goods has to be converted to tradable goods when it is exported. Only export sector located in the trade gateway city is able to convert domestic goods to tradable export goods. When domestic households and industries demand foreign goods, they cannot get from foreign country directly. Foreign goods have to be converted to import goods “for domestic use” by the import sector, also located in the trade gateway city. The model considers the trade transport sector to consist of the Export and Import sectors as trade transport sector. Trade or transport related industries such as warehouse, international cargo terminal, and custom agent are necessary for export and import activity.

In the model, international trade sector exclusively supplies the international tradable goods. We assume export sector and import sector individually and both of them exist only in trade gateway region. Export sector inputs primary factor and intermediate input and sells the goods to foreign countries. Value added for the export sector is generated by the value of transport service and other handling services related to international trade. Import sector inputs primary factor, intermediate input and raw import goods from foreign countries and sells the import goods modified for domestic use. Value added for the import sector is also equivalent to transport service and other handling services related to international trade. Productivity of export/import sector depends on the efficiency of international transport infrastructure facility.

Sectors other than export/import sector exist in all regions. They produce the goods by inputting primary factor, domestic-made intermediate input and foreign-made intermediate input. The foreign-made intermediate input consists of imported goods for domestic use. Demanding for intermediate input needs domestic transport cost for delivery in addition to the mill price of the goods if the goods are not produced in the own region. We adopt Samuelson's iceberg transport cost concept for domestic transport, which means that a certain portion of the transported goods itself is consumed for shipping. The spatial economic system of the model is shown in Fig.1.

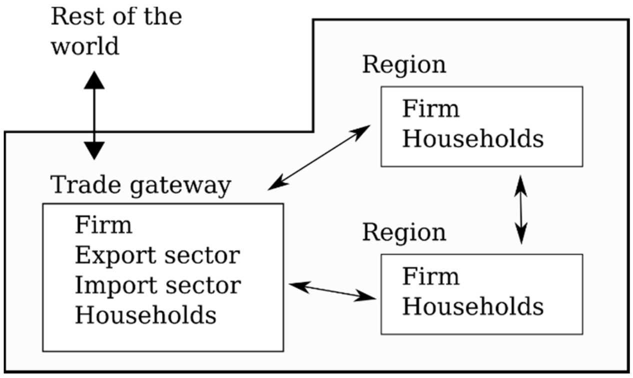

Fig. 1. Spatial economic system of the model.

3.2. Firm

The composite goods production firm in each city has a nested CES (constant elasticity of substitution) technology as shown in Fig.2. The firm demands composite production factor ant two types of intermediate inputs, domestic goods and import goods for domestic use in the upper tier of the production tree. Composite factor consists of a certain mixture of labor input and capital input. Domestic intermediate input goods supplied in domestic regions are aggregated into the composite domestic intermediate input with CES technology.

Cost minimization problem of the firm yields derived demand for aggregated intermediate input x_s, aggregated factor input y_s and import goods for domestic use m_s subject to the level of production of composite goods in s, X_s, as

$$x_s = \left(\frac{\gamma_s}{p_{Xs}} \right)^{\sigma_s} X_s \left(p_s \right)^{\sigma_s} \tag{1}$$

$$y_s = \left(\frac{\gamma_s}{p_{Ys}} \right)^{\sigma_s} X_s \left(p_s \right)^{\sigma_s} \tag{2}$$

and

$$m_s = \left(\frac{\gamma_s}{p_{Ms}} \right)^{\sigma_s} X_s \left(p_s \right)^{\sigma_s} \tag{3}$$

respectively. Price index of aggregate intermediate goods is

$$p_{Xs} = \left\{ \sum_{r=1}^{R} \left(\beta_{rs} \right)^{\sigma_{Xs}} \left(p_{rs} \right)^{1-\sigma_{Xs}} \right\}^{\frac{1}{1-\sigma_{Xs}}} \tag{4}$$

and price index of aggregate factor input is

$$p_{Ys} = \left(\alpha_{Ls}^{\sigma_{Ys}} w_s^{1-\sigma_{Ys}} + \alpha_{Ks}^{\sigma_{Ys}} r_s^{1-\sigma_{Ys}} \right)^{\frac{1}{1-\sigma_{Ys}}}, \tag{5}$$

where p_{rs} denotes price of composite goods produced in r and demanded in s. w_s and r_s denote price of labor and

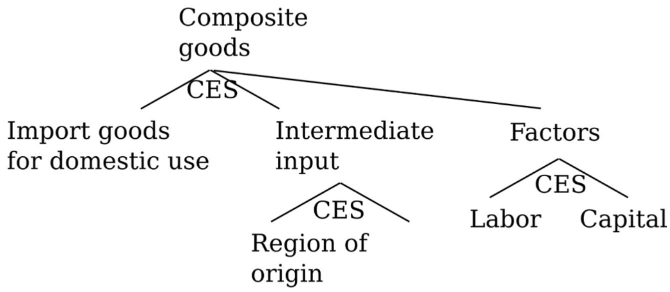

Fig. 2. Production tree of composite goods sector.

capital respectively. σ_s , σ_{Xs} and σ_{Ys} are elasticity of substitution for aggregation technology of upper tier of production tree, intermediate input and factor input respectively. γ_s , γ_{Ys} , γ_{Ms} , β_{rs} , α_{Ls} and α_{Ks} are parameters with regard to CES cost share.

Mill price of composite goods is derived as

$$p_s = A_s \left(\gamma_s^{\sigma_s} p_{Xs}^{1-\sigma_s} + \gamma_{Ms}^{\sigma_s} p_{Ms}^{1-\sigma_s} + \gamma_{Ys}^{\sigma_s} p_{Ys}^{1-\sigma_s} \right)^{\frac{1}{1-\sigma_s}}, \tag{6}$$

where A_s denotes a scale parameter to adjust the price level, which reflects productivity of the firm. By assumptions, when the goods is delivered to other region even in domestic inter-regional trade, transport cost is needed. Therefore goods price at region of destination is defined as the product of mill price and transport margin,

$$p_{rs} = p_r \cdot \tau_{rs} . \tag{7}$$

Solving cost minimization problem subject to production of the aggregate inputs, namely lower tier of the production tree, yields demand for intermediate input

$$x_{rs} = \left(\frac{\alpha_{rs}}{p_{rs}} \right)^{\sigma_{Xs}} \left(p_{Xs} \right)^{\sigma_{Xs}} x_s , \tag{8}$$

demand for each production factor

$$l_{Xs} = \left(\frac{\alpha_{Ls}}{w_s} \right)^{\sigma_{Ys}} \left(p_{Ys} \right)^{\sigma_{Ys}} y_s , \tag{9}$$

and

$$k_{Xs} = \left(\frac{\alpha_{Ks}}{r_s} \right)^{\sigma_{Ys}} \left(p_{Ys} \right)^{\sigma_{Ys}} y_s . \tag{10}$$

3.3. Export sector

Label of trade gateway region is set to one (s=1). Firms in hinterland, namely other than trade gateway region, are not able to sell their products directly to foreign countries. Only export sector in the trade gateway region can deliver the domestic goods to oversea customers because export sector is assumed to be an agent who can access and utilize international transport infrastructure. Export sector inputs intermediate goods produced in each region and aggregate

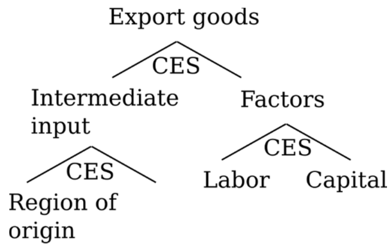

Fig. 3. Production tree of export sector.

factor and produces composite “export goods for foreign use” with nested CES technology illustrated by Fig.3. The intermediate input includes “raw” export goods produced in each domestic region and actual intermediate input demand for the production activity.

Solving cost minimization of upper tier subject to production of export goods (for foreign use) yields demand for composite goods,

$$x_E = \left(\frac{\gamma_{XE}}{p_{XE}}\right)^{\sigma_E} \left(p_E\right)^{\sigma_E} E, \tag{11}$$

and demand for aggregate factor,

$$y_E = \left(\frac{\gamma_{YE}}{p_{YE}}\right)^{\sigma_E} \left(p_E\right)^{\sigma_E} E \cdot \tag{12}$$

σ_E is elasticity of substitution for aggregation technology of upper tier of the production tree. γ_{XE} and γ_{YE} are parameters with regard to CES cost share.

Using above demand functions of the inputs, price of the product of export sector, namely aggregate export goods, is derived as

$$p_E = \left(\gamma_{XE}{}^{\sigma_E} p_{XE}{}^{1-\sigma_E} + \gamma_{YE}{}^{\sigma_E} p_{YE}{}^{1-\sigma_E}\right)^{\frac{1}{1-\sigma_E}}. \tag{13}$$

Price index of aggregate factor,

$$p_{YE} = \left(\alpha_{LE}{}^{\sigma_{YE}} w_1^{1-\sigma_{YE}} + \alpha_{KE}{}^{\sigma_{YE}} r_1^{1-\sigma_{YE}}\right)^{\frac{1}{1-\sigma_{YE}}} \tag{14}$$

and price index of composite intermediate input,

$$p_{XE} = \left\{\sum_{r=1}^{R} \left(\beta_{rE}\right)^{\sigma_{XE}} \left(p_{XE}\right)^{1-\sigma_{XE}}\right\}^{\frac{1}{1-\sigma_{XE}}}. \tag{15}$$

are derived by solution of cost minimization problems with regard to lower tier of the production technology.

Lower tier cost minimization yields demand for regional goods

$$x_{rE} = \left(\frac{\beta_{rE}}{p_{r1}} \right)^{\sigma_{XE}} \left(p_{XE} \right)^{\sigma_{XE}} x_E \tag{16}$$

and each factor demand. The derived demands for labor and capital are

$$l_E = \left(\frac{\alpha_{LE}}{w_1} \right)^{\sigma_{YE}} \left(p_{YE} \right)^{\sigma_{YE}} y_E \tag{17}$$

and

$$k_E = \left(\frac{\alpha_{KE}}{r_1} \right)^{\sigma_{YE}} \left(p_{YE} \right)^{\sigma_{YE}} y_E \tag{18}$$

respectively.

σ_{XE} and σ_{YE} are elasticity of substitution for aggregation technology of intermediate input and factor input respectively. γ_{XE}, γ_{YE}, β_{rE}, α_{LE} and α_{KE} are parameters with regard to CES cost share.

3.4. Import sector

Imported goods from foreign country is not delivered to regional households and industries directly, instead import sector located on trade gateway handles whole “raw” import goods at first. Our model assumes that import sector reproduces import goods “for domestic use” inputting the raw import goods, production factors and intermediate goods (see Fig.4). Similar to composite goods firm and export sector, import sector has nested CES technology. Input framework of intermediate goods, including import goods for domestic use, and factors is same as composite goods firm.

Cost minimization of the upper tier of the production tree yields demand for aggregate intermediate demand

$$x_M = \left(\frac{\gamma_{XM}}{p_{XM}} \right)^{\sigma_M} \left(p_M \right)^{\sigma_M} X_M , \tag{19}$$

aggregate factor input

$$y_M = \left(\frac{\gamma_{YM}}{p_{YM}} \right)^{\sigma_M} \left(p_M \right)^{\sigma_M} X_M , \tag{20}$$

demand for raw import goods

$$M = \left(\frac{\gamma_M}{q_M} \right)^{\sigma_M} \left(p_M \right)^{\sigma_M} X_M , \tag{21}$$

and demand for import goods for domestic use itself, as intermediate input,

$$m_M = \left(\frac{\gamma_{mM}}{p_M} \right)^{\sigma_M} \left(p_M \right)^{\sigma_M} X_M , \tag{22}$$

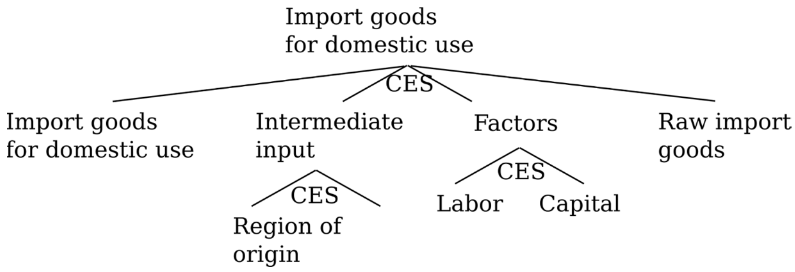

Fig. 4. Production tree of import sector.

where X_M is quantity of production of import goods for domestic use. Price of raw import goods, q_M, is regarded as world price and assumed to be exogenously given. The model treats the world price constant, which means domestic economic activity does not influence to the world price because of small open assumption.

Combining the above derived demand function yields price of import goods for domestic use,

$$p_M = A_{YM} \left\{ \gamma_{XM}{}^{\sigma_M} pp_M{}^{1-\sigma_M} + \gamma_{YM}{}^{\sigma_M} p_{yM}{}^{1-\sigma_M} + \gamma_M{}^{\sigma_M} q_M{}^{1-\sigma_M} + \gamma_{mM}{}^{\sigma_M} p_{mM}{}^{1-\sigma_M} \right\}^{\frac{1}{1-\sigma_M}} . \tag{23}$$

Price index of aggregate intermediate input,

$$p_{XM} = \left\{ \sum_{r=1}^{R} \left(\beta_{rM}\right)^{\sigma_{XM}} \left(p_{rM}\right)^{1-\sigma_{XM}} \right\}^{\frac{1}{1-\sigma_{XM}}} \tag{24}$$

and price index of aggregate factor input,

$$p_{YM} = \left(\alpha_{LM}{}^{\sigma_{YM}} w_1^{1-\sigma_{YM}} + \alpha_{KM}{}^{\sigma_{YM}} r_1^{1-\sigma_{YM}} \right)^{\frac{1}{1-\sigma_{YM}}} \tag{25}$$

are derived by solutions of the cost minimization with regard to the lower tier of the production tree. Intermediate input demand for composite goods to produce aggregate intermediate input is

$$x_{rM} = \left(\frac{\beta_{rM}}{p_{r1}} \right)^{\sigma_{XM}} \left(p_{XM}\right)^{\sigma_{XM}} x_M \, . \tag{26}$$

Each factor demand for making aggregate factor y_m is formulated by

$$l_M = \left(\frac{\alpha_{LM}}{w_1} \right)^{\sigma_{YM}} \left(p_{YM}\right)^{\sigma_{YM}} y_M \tag{27}$$

for labor and

$$k_M = \left(\frac{\alpha_{KM}}{r_1} \right)^{\sigma_{YM}} \left(p_{YM}\right)^{\sigma_{YM}} y_M \tag{28}$$

for capital respectively.

σ_M, σ_{XM} and σ_{YM} are elasticity of substitution for aggregation technology of upper tier of the production tree, intermediate input and factor input respectively. γ_{XM}, γ_{YM}, γ_M, γ_{mM}, γ_{rM}, α_{LM} and α_{KM} are parameters with regard to CES cost share.

3.5. Households

Regional households consume domestic composite goods and import goods with the preference described by nested CES utility function,

$$U_s = \left(\varepsilon_s c_s^{\frac{\sigma_{us}-1}{\sigma_{us}}} + \varepsilon_{Ms} c_{Ms}^{\frac{\sigma_{us}-1}{\sigma_{us}}} \right)^{\frac{\sigma_{us}}{\sigma_{us}-1}} \tag{29}$$

where c_s denotes aggregate consumption of composite goods defined by

$$c_s = \left(\sum_{r=1}^{R} \delta_{rs} c_{rs}^{\frac{\sigma_{cs}-1}{\sigma_{cs}}} \right)^{\frac{\sigma_{cs}}{\sigma_{cs}-1}}. \tag{30}$$

Utility maximization yields the demand function for aggregate domestic composite goods consumption

$$c_s = \left(\frac{\varepsilon_s}{p_{cs}} \right)^{\sigma_{us}} p_{us}^{\sigma_{us}-1} I_s \tag{31}$$

and for import goods for domestic use,

$$c_{Ms} = \left(\frac{\varepsilon_{Ms}}{p_{cs}} \right)^{\sigma_{us}} p_{us}^{\sigma_{us}-1} I_s \tag{32}$$

where I_s denotes regional consumption expenditure by households. Price index of aggregate composite goods is

$$p_{cs} = \left\{ \sum_{r=1}^{R} \left(\delta_{rs}\right)^{\sigma_{cs}} \left(p_{rs}\right)^{1-\sigma_{cs}} \right\}^{\frac{1}{1-\sigma_{cs}}}. \tag{33}$$

Therefore price index of aggregate consumption, namely total expenditure, by regional economy is derived as

$$p_{us} = \left(\varepsilon_s^{\sigma_{us}} p_{cs}^{1-\sigma_{us}} + \varepsilon_{Ms}^{\sigma_{us}} p_{Ms}^{1-\sigma_{us}} \right)^{\frac{1}{1-\sigma_{us}}}. \tag{34}$$

Consumption demand for composite goods produced in each region is

$$c_{rs} = \left(\frac{\delta_{rs}}{p_{rs}} \right)^{\sigma_{cs}} \left(p_{cs}\right)^{\sigma_{cs}} c_s \cdot \tag{35}$$

σ_{us} and σ_{cs} are elasticity of substitution of upper tier of utility function and regional goods aggregation respectively. ε_s, ε_{Ms} and δ_{rs} are parameters with regard to CES cost share.

3.6. Export demand and regional accounts

Since our model is a small open economy, economic activity in rest of the world is not explicitly modelled. Domestic economic results do not affect to world price of goods. However export demand must be given to close the general equilibrium system. We assume export demand is derived by

$$E = E_0 \left(\frac{p_E}{q_M} \right)^{-\sigma_W}, \tag{36}$$

where E_0 is sum of export amount measured by world price q_M at benchmark equilibrium in real term. It means that export demand is elastic to the relative price of export sector products to world price.

Regional expenditure by households should be equal to the factor income minus transfer to out of the region to keep regional accounts balance,

$$I_s = w_s L_s + r_s K_s - q_M N_s, \tag{37}$$

where N_s denotes real income transfer in terms of world price. The value q_M N_s means the difference between sum of regional consumption value and sum of regional factor income at benchmark state. Since our model is static and does not mention international capital market, each N_s is fixed to the benchmark value. From the point of view of balance of payment, this assumption means that aggregate net export in value term is constant throughout the model analysis, which imposes

$$\sum_s q_M N_s = p_E E - q_M M \cdot \tag{38}$$

3.7. Equilibrium

Real demand for composite goods produced in r is the sum of intermediate and consumption demand,

$$X_r = \sum_{s=1}^{R} \tau_{rs} x_{rs} + \tau_{1s} x_{1E} + \tau_{1s} x_{1M} + \sum_{s=1}^{R} \tau_{rs} c_{rs} \cdot \tag{39}$$

When all price variables are given, substituting (8)(16)(26)(35) into (39) yields X_r. Then market clearing condition of tradable goods

$$X_s = \left(\sum_{r=1}^{R} p_r \tau_{rs} x_{rs} + w_s l_{xs} + r_s k_{xs} \right) \left(p_s \right)^{-1} \tag{40}$$

is an equation system, which only prices are endogenous variables.

Real demand for import goods for domestic use is calculated similarly,

$$X_M = \sum_{s=1}^{R} \tau_{1s} m_s + m_M + \sum_{s=1}^{R} \tau_{1s} c_{Ms} \cdot \tag{41}$$

Market clearing condition of import goods for domestic use is represented by

$$X_M = \left(\sum_{r=1}^{R} p_r \tau_{r1} x_{rM} + p_M m_M + w_1 l_M + r_1 k_M \right) \left(p_M \right)^{-1} \cdot \tag{42}$$

Export demand by rest of the world is determined as the function of export sector's price. Market clearing condition of export goods for foreign use is written as

$$E = \left(\sum_{r=1}^{R} p_r \tau_{r1} x_{rE} + w_1 l_E + r_1 k_E \right) \left(p_E \right)^{-1}. \tag{43}$$

Market clearing conditions for primary factor are asymmetric depending on whether the region is trade gateway or not, namely

$$L_s = \begin{cases} l_{xs} + l_E + l_M & (s=1) \\ l_{xs} & (r \neq s) \end{cases} \tag{44}$$

for labor market and

$$K_s = \begin{cases} k_{Xs} + k_E + k_M & (s=1) \\ k_{Xs} & (r \neq s) \end{cases} \tag{45}$$

for capital market respectively.

4. Simulations

4.1. Policy simulation

We conduct a numerical simulation to explore the effects of transport system development on the economic system with the asymmetric industrial structure, trade gateway and others. The simulations assume virtual development of international and inter-city transport system in Japanese economy. Tokyo Metropolitan Region has the largest international transport infrastructure in terms of freight amount. About 40% of export/import goods, in value term, pass through customs in Tokyo and surrounding region. The share seems not dominant, but it is absolutely larger than other regions. This application study therefore regards Tokyo region as the trade gateway of Japan.

The simulation analysis uses a regional Input-Output table provided by Tokyo Metropolitan Government as the benchmark data, which is a two-region input-output table for Japanese economy classifying Tokyo and rest of Japan. Firstly we need to define the domain of trade-related industries, export sector and import sector, in order to calibrate the model. This paper adopts the concept of port-related industries by Nakano and Inamura (1982). They surveyed input-output structure of industries highlighting the relationship to port transport system and proposed a domain of industrial sectors categorized into port-related industries.

The model classifies export sector and import sector explicitly and the technologies of their sectors are independently formulated. Since the trade-related industry of the benchmark data includes both of the two sector and not classified, we have to separate the original data to the two sectors. Cost structure of each sector, namely intermediate input and value added, is necessary for calibration of the model. Therefore we compiled the original input-output table to the benchmark data format suitable to our model framework, see appendix for the detail process of the compilation.

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If the benchmark data is completely given, parameters with regard to elasticity of substitution are still unknown (Bröcker (1998a), Knaap and Oosterhaven (2011)). Here we set arbitrarily value of the parameters, $\sigma_s = \sigma_{Ys} = \sigma_E = \sigma_{YE} = \sigma_M = \sigma_{YM} = \sigma_{us} = 1.5$ and $\sigma_{Xs} = \sigma_{XE} = \sigma_{XM} = \sigma_{cs} = 2$. The setting assumes aggregation of regional goods within a sector is more substitutive and then elasticity of substitution for aggregation of regional substitution is higher. Although the value of elasticity is arbitrary, this structural assumption is quite natural. Needless to say, econometric challenges to obtain more precise parameters are necessary to apply the model for practical policy analysis.

We set three scenarios assuming transport/trade system developments; domestic inter-regional transport development, international trade system development at trade gateway region and both of the developments. In scenario 1, productivity of trade related sector, namely export sector and import sector, is assumed to be improved 5% from the benchmark. Scenario 2 assumes 5% decrease in domestic transport cost from the benchmark equilibrium. This paper gives initial value of the inter-regional transport margin τ_{rs} as 1.5, which is arbitrarily determined and will be modified appropriately in future work. A combination of exogenous impacts of Scenario 1 and Scenario 2 is implemented in Scenario 3.

Change in welfare is measured by Equivalent Variation (EV) index basically, which is defined by

$$EV_s = \frac{U_s^a - U_s^b}{U_s^b} \cdot I_s^b, \tag{46}$$

where label \$a\$ and \$b\$ mean “after” and “before” the development policy implementation respectively. We also capture the relative equivalent variation (REV),

$$REV_s = \frac{EV_s}{I_s^b}. \tag{47}$$

REV proposed by Bröcker (1998b) is a convenient index for measuring welfare impact per households, which eliminates the size of economic volume of the region in terms of sum of regional income.

Table 1 shows benefit index measured by EV and REV for each scenario analysis. Development of international trade system (Scenario 1) contributes more for Rest of Japan, non trade gateway region. The investment may be done in the gateway region, Tokyo, but Tokyo gains less than ROJ. Productivity improvement of export/import sector causes price reduction of internationally tradable goods (Table 2) and then increase in demand for export goods by foreign countries as well as increase in demand for import goods by domestic economy.

Table 1. Regional welfare impacts.

	region	EV	REV
Scenario 1	Tokyo	369	0.00552
	ROJ	3,153	0.0075
Scenario 2	Tokyo	2,559	0.0382
	ROJ	3,031	0.0072
Scenario 3	Tokyo	2,939	0.0438
	ROJ	6,224	0.0148

*EV: (billion Yen)

Table 2. Change in prices

	region	w_s	r_s	p_s	p_E	p_M
Scenario 1	Tokyo	1.0016	1.0016	0.9990	0.9506	0.9521
	ROJ	1.0021	1.0021	0.9981		
Scenario 2	Tokyo	1.0308	1.0308	1.0149	0.9605	1.0001
	ROJ	1.0134	1.0134	1.0070		
Scenario 3	Tokyo	1.0324	1.0324	1.0138	0.9131	0.9521
	ROJ	1.0155	1.0155	1.0050		

Table 3. Change in output value

	p_1x_1	p_Ex_E	p_Mx_M	p_2x_2
Scenario 1	0.27%	2.56%	2.63%	0.40%
Scenario 2	3.92%	2.03%	2.07%	1.66%
Scenario 3	4.19%	4.65%	4.75%	2.08%

As the result the force shrinking the demand for domestic goods in the home country arises because domestic industries are facing competition to oversea goods. Changes in production outputs shown in Table 3 represent decrease of sales of composite goods sector in Tokyo region is clearly larger than ROJ.

On the other hand, development of domestic inter-regional transport (Scenario 2) causes welfare improvement in all regions, as expected. The inter-regional transport cost reduction affects to the production cost in both of the regions directly. This effect rises competitiveness of domestic goods against foreign goods. REV in Tokyo is much larger in this case. In Scenario 3, assuming a combination of domestic transport development policy and international trade system development policy, both regions will gain. The effects in welfare and output value are almost similar to the sum of the results of Scenario 1 and Scenario 2.

4.2. Sensitivity analysis

The result of the above policy scenario simulation is an example of experimental study because elasticity parameters and policy shocks are not given from actual data. We analyze the sensitivity of the model outputs with regard to key parameters in order to know the characteristics of behavior of the model. The sensitivity analysis represents that the elasticity parameters regarding international trade, namely σ_{us} , σ_s and σ_W , especially influence to the results. Two of those parameters, σ_{us} and σ_s , are crucial elements to determine how domestic goods and foreign (imported) goods are substitutive. σ_W means the elasticity of export demand with regard to relative price of export goods to world price.

We highlight sensitivity analysis regarding σ_{us} here. Using exogenous shock of scenario 1, we calculate the equilibrium values under various value of σ_{us} . The analysis investigates how economic impacts vary.

Fig. 5 shows the changes in REV for both regions. The lower the elasticity σ_{us} is, the larger both regions gain welfare. Welfare impact to trade gateway region, Tokyo, varies more sensitively depending on the value of the elasticity parameter. When σ_{us} is over 2.5, Tokyo lost welfare by improvement of export/import transport sector. In

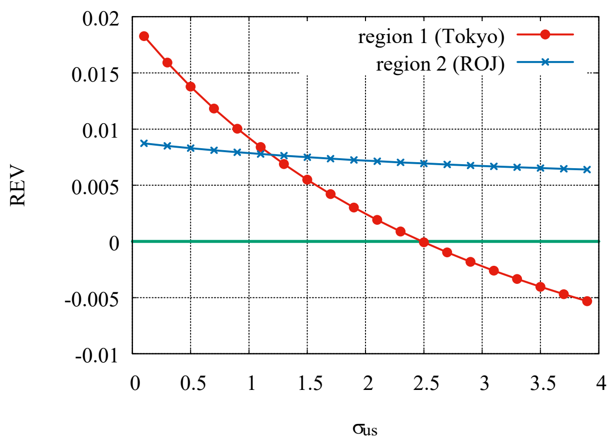

Fig. 5. Difference of welfare impact by σ_{us} (REV).

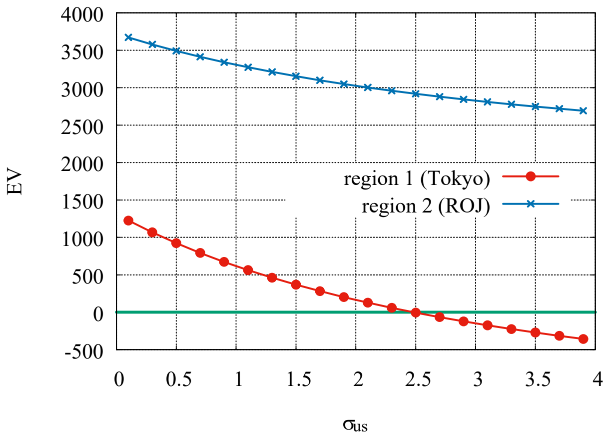

Fig. 6. Difference of welfare impact by σ_{us} (EV).

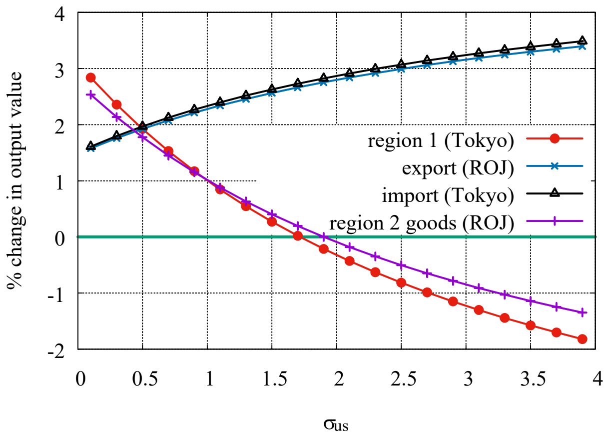

Fig. 7. Changes in output value by σ_{us}.

spite of negative benefit in Tokyo, sum of benefit over regions is still positive because of larger benefit in Rest of Japan (see Fig. 6).

Fig. 7 represents that opposite aspects of impact to output values between trade related sectors (export and import) and goods sector in both regions. When σ_{us} is higher, sectoral outputs may decrease by improvement of international transport system due to more competitive situation against foreign goods. However negative impact to output value does not mean negative benefit.

5. Concluding remarks

International transport infrastructure, such as port and international hub airport, is located on the trade gateway region. This geographical asymmetry also consequents asymmetry in the structure of industrial sector. We build a SCGE model considering trade related industries which exist only in the trade gateway region. Trade related industries, export sector and import sector, in our model have important role to describe that international freight have to pass the trade gateway region.

We apply the model to Japanese economy classified into two regions, trade gateway (Tokyo) and rest of Japan. International trade development policy and domestic transport development policy are simulated in the application study. The results represent welfare impacts to the regions as well as changes in sectoral outputs. This paper furthermore conducts sensitivity analyses with regard to elasticity of substitution. The analysis implies international trade system development may cause negative welfare effects in the trade gateway region when foreign goods are substitutive to domestic goods.

Although this paper illustrates two region model, the basic model structure is unchanged even if the number of region is more than three. Currently we assume that Japan has only one gateway region, Tokyo, but actually this is unrealistic situation. The present model may be suitable to smaller country which has a dominant international transport infrastructure handling almost all trade flow of the country. We need to improve the model to treat multiple trade gateway regions for the application to larger economy. Incorporating port choice framework is one direction of the improvement of our model.

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Appendix A. Appendix A. Compilation of benchmark input-output table

Standard input-output table is formatted as example of Tokyo-Japan Input-Output Table illustrated by Fig. 8 and this form is not directly applied to calibration of our model. We finally need a benchmark data table like Fig. 10. This appendix explains the procedure how to modify the original table to the desirable formatted benchmark data.

Output of export sector is directly demanded by foreign countries, and equal to total export value of national accounts, namely $E = e_1 + e_t + e_2$. National sum of import value is the sum of each sectoral import value, $M = -(m_1 + m_t + m_2)$, and it is intermediate input demand for raw import goods demanded by import sector in value term. Keeping these conditions the following procedure can give the final form of the benchmark data suitable to our model, Fig. 10.

- Step 1: Calculate share of export and import to sum of both of them respectively, $s_e = \frac{E}{E+M}, s_m = \frac{M}{E+M}$.
- Step 2: Calculate regional share of intermediate input demand for composite goods to sum of whole demand for composite goods, $s_{i,rs} = \frac{x_{11}}{\sum_s (x_{rs} + c_{rs})}$. Similarly calculate the share of the final demand, $s_{c,rs} = \frac{c_{11}}{\sum_s (x_{rs} + c_{rs})}$.
- Step 3: Calculate expenditure share of intermediate input demand to whole demand for composite goods produced in each region, $s_{i,s} = \frac{\sum_s x_{rs}}{\sum_s (x_{rs} + c_{rs})}$. Share of the final demand is also calculated, $s_{c,s} = \frac{\sum_s c_{rs}}{\sum_s (x_{rs} + c_{rs})}$.

			Region,Sector			Final Demand		ROW		Sum
			Tokyo		ROJ	Tokyo	ROJ	Ex	Im	
			goods	trd/trp	goods					
Region, Sector	Tokyo	goods	x_{11}	x_{1t}	x_{12}	c_{11}	c_{12}	e_1	$-m_1$	X_1
		trd/trp	x_{t1}	x_{tt}	x_{t2}	c_{t1}	c_{t2}	e_t	$-m_t$	X_t
	ROJ	goods	x_{21}	x_{2t}	x_{22}	c_{21}	c_{22}	e_2	$-m_2$	X_2
Value added	labor		l_1	l_t	l_2					
	capital		k_1	k_1	k_1					
Sum			X_1	X_t	X_2					

Fig. 8. Standard format of Input-Output table.

			Region,Sector				Final Demand		ROW	Sum
			Tokyo			ROJ	Tokyo	ROJ		
			goods	Ex	Im	goods				
Region, Sector	Tokyo	goods	$x_{11}-s_{i,11}m_1$	e_1		$x_{12}-s_{i,12}m_1$	$c_{11}-s_{c,11}m_1$	$c_{12}-s_{c,12}m_1$		X_1-x_{1t}
		Ex							E	E
		Im	$x_{t1}+s_{i,1}m_1$		x_{tt}	$x_{t2}+s_{i,2}m_2$	$c_{t1}+s_{c,1}m_1$	$c_{t2}+s_{c,2}m_2$		Z_m
	ROJ	goods	$x_{21}-s_{i,21}m_2$	e_2		$x_{22}-s_{i,22}m_2$	$c_{21}-s_{c,21}m_2$	$c_{22}-s_{c,22}m_2$		X_2-x_{2t}
ROW					M					
Value added	labor		l_1	l_ts_e	l_ts_m	l_2				
	capital		k_1	k_ts_e	k_ts_m	k_2				
Sum			Z_1	$\tilde{Z}_e$	$\tilde{X}_m$	Z_2				

Fig. 9. Modified benchmark data (after step 4).

			Region,Sector				Final Demand		ROW	Sum
			Tokyo			ROJ	Tokyo	ROJ		
			goods	Ex	Im	goods				
Region, Sector	Tokyo	goods	$x_{11}-s_{i,11}m_1$	e_1+ $+\delta_{1e}$	δ_{1m}	$x_{12}-s_{i,12}m_1$	$c_{11}-s_{c,11}m_1$	$c_{12}-s_{c,12}m_1$		X_1
		Ex							E	E
		Im	$x_{t1}+s_{i,1}m_1+\varepsilon_1$		x_{tt}	$x_{t2}+s_{i,2}m_2+\varepsilon_2$	$c_{t1}+s_{c,1}m_1$	$c_{t2}+s_{c,2}m_2$		X_m^*
	ROJ	goods	$x_{21}-s_{i,21}m_2$	e_2 $+\delta_{2e}$	δ_{2m}	$x_{22}-s_{i,22}m_2$	$c_{21}-s_{c,21}m_2$	$c_{22}-s_{c,22}m_2$		X_2
ROW					M					
Value added	labor		l_1	l_ts_e	l_ts_m	l_2				
	capital		k_1	k_ts_e	k_ts_m	k_2				
Sum			X_1	E	X_m^*	X_2				

Fig. 10. Modified benchmark data.

- Step 4: Modify the benchmark data like Fig.9 using the calculated shares.
- Step 5: Calculate the difference between calculated sum of column of export sector and actual export, $D = \tilde{Z}_e - E$.
- Step 6: Calculate adjustment factors, $\delta_{1e} = \frac{x_{1t}}{x_{1t}+x_{2t}} D, \delta_{2e} = \frac{x_{2t}}{x_{1t}+x_{2t}} D$, $\delta_{1m} = x_{1t} - \delta_{1e}$ and $\delta_{2m} = x_{2t} - \delta_{2e}$.
- Step 7: Add the residual of demand supply balance of composite goods, ε_1 and ε_2, to intermediate input demand for import sector. Then the final form of the benchmark data is derived as Fig. 10.

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