THEORETICAL AND EMPIRICAL VERIFICATION OF THE INTER-REGIONAL TRADE MODELING IN THE SPATIAL CGE MODEL FOR TRANSPORT IMPROVEMENTS

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ABSTRACT

Mun(1997), Tsuchiya et al. (2006) and Koike et al. (2008) proposed a highly versatile Spatial CGE model to analyse in small region such as municipality by combining the basic framework of Spatial CGE models with the inter-regional trade coefficient derived by techniques of empirical analysis based on the aggregate discrete choice model developed as a distributed traffic volume forecasting model in the field of traffic demand forecasting. This model can provide an accurate description of the extent to which shortening of travel time by the improvement of traffic routes affects inter-regional trade. In addition, it can measure the process by which these effects influence regional economies in the framework of microeconomic general equilibrium. The inter-regional trade coefficient in these models is not consistent with a general equilibrium theory in the strict sense because it is a function of transport engineering. The Walrasian general equilibrium system essentially requires the equations contained in the system to satisfy the homogeneity of degree zero in prices.

On the other hands, a conventional Spatial CGE analysis uses the techniques of defining inter-national or regional trade by the constant elasticity of substitution (CES) type and the mark-up of generalization cost to prices. In this case, the extent to which shortening of the travel time is reflected in demand will depend on the time value used for the generalization costs and parameters of CES-type elasticity of substitution. These parameters, however, have not estimated in the regional scale although we have many studies of parameter estimations on the world trade model such as GTAP.

In this paper, firstly, the empirical validation of the CES model which is consistent with the general equilibrium theory is conducted at the municipality. Secondly, two type discrete choice models are verified from the theoretical and empirical viewpoints. One is Harker type Logit model, and the other is MCI (Multiplicative Competitor Interaction) model. Finally, we show the characteristics and the problem should be improved on each model as inter-regional trade coefficient at the municipality level.

Keywords
Spatial Computable General Equilibrium, Inter-regional Trade Model and Infrastructure Development

1. Introduction

A quantitative understanding of what sort of people in which regions are affected or burdened and to what extent by implementing a policy measure is increasingly important for ensuring accountability for policy implementation. One approach to such a problem is applied general equilibrium (AGE) analysis, which takes into account the concept of space. Broadly, there are two types of AGE models that deal with space. One is a world trade model that connects countries around the world according to their trade. This model was originally developed by Whalley (1985). Currently, versions of this model (e.g., GTAP model) have become established as very versatile tools. These models analyse policies such as protectionist measures that are based on tariff and non-tariff barriers. The other is called the spatial computable general equilibrium (Spatial CGE) model. This model is geared towards smaller regions than the world trade model. The regions targeted by this model are connected economically through physical distribution. Originally developed by Roson (1996), this set of models has been developing in parallel with the field of transport engineering. These two types of theoretical models are based on different spatial scales but share the same basic structure. In other words, the only differences are that either households or businesses in different spatial locations are modelled on the general equilibrium theory proposed by Léon Walras, and either exogenous tariffs or transportation costs are modelled on the price of goods or inter-regional trade coefficients. The availability of data, however, differs significantly when conducting an empirical analysis of these models with different spatial scales. Empirical analysis is relatively easy for a world trade model with the use of an international input-output table. A Spatial CGE model, on the other hand, needs to have inter-regional input-output tables readily available for the targeted regions. However, except for nine inter-regional input-output tables developed in Japan, all officially released inter-regional input-output tables worldwide have published estimated results only at the research level. Consequently, models that do not depend on the availability of inter-regional input-output tables are needed if Spatial CGE models are to be used widely.

In the existing literature, Mun(1997), Tsuchiya et al. (2006) and Koike et al. (2008) proposed a highly versatile Spatial CGE model to analyse in small region such as municipality by combining the basic framework of Spatial CGE models with the inter-regional trade coefficient derived by techniques of empirical analysis based on the aggregate discrete choice model developed as a distributed traffic volume forecasting model in the field of traffic demand forecasting. This model can provide an accurate description of the extent to which shortening of travel time by the improvement of traffic routes affects inter-regional trade. In addition, it can measure the process by which these effects influence regional economies in the framework of microeconomic general equilibrium.

The inter-regional trade coefficient in these models is not consistent with a general equilibrium theory in the strict sense because it is a function of transport engineering. The Walrasian general equilibrium system essentially requires the equations contained in the system to satisfy the homogeneity of degree zero in prices.

On the other hands, a conventional Spatial CGE analysis uses the techniques of defining inter-national or regional trade by the constant elasticity of substitution (CES) type and the mark-up of generalization cost to prices. In this case, the extent to which shortening of the travel time is reflected in demand will depend on the time value used for the generalization costs and parameters of CES-type elasticity of substitution. These parameters, however, have not estimated in the regional scale although we have many studies of parameter estimations on the world trade model such as GTAP.

In these contexts, Miyagi (1994), Miyagi and Honbu (1996) and Miyagi and Honbu(1998) have been derived the CES type and the Logit (Entropy) type as the discrete choice model for the inter-regional trade coefficient not depending on the Input-Output table. Anderson (1998) has been also indicated that the discrete choice model is consistent with the micro economic theory by the representative consumer approach. This paper aims to verify the validity of the CES model and the discrete choice model as inter-regional trade coefficient for Spatial CGE model from the theoretical and empirical viewpoints.

In this paper, firstly, the empirical validation of the CES model which is consistent with the general equilibrium theory is conducted at the municipality. Secondly, two type discrete choice models are verified from the theoretical and empirical viewpoints. One is Harker type Logit model, and the other is MCI (Multiplicative Competitor Interaction) model. Finally, we show the characteristics and the problem should be improved on each model as inter-regional trade coefficient at the municipality level.

2. CES Model

2.1 Model Formulation

Most of the Spatial CGE models apply the Constant Elasticity of Substitution (CES) model based on the Armington assumption (Armington, 1969) in order to represent the differentiation of domestically produced and imported products and the differentiation of imported goods by country or region of origin.

The value of the inter-national or regional elasticities of substitution σ is crucial for the determination of transport development effects in the Spatial CGE framework as the effects of travel time saving effects. There are two ways to calibrate those elasticities: statistical analysis or taking values from similar studies in the literature. Due to data problems, most Spatial CGE models in the regional scale take the elasticities from the existing literature. Hence, the lack of statistical validation of these parameters is one of the major critiques to Spatial CGE models. This paper shows the statistical validation of Inter-regional elasticities of substitution by using transport OD data in Japan.

This paper defines the following cost minimization problem. The relationship between d_i and z_{ij} is assumed by the CES type formulation. In this constraint, we assumed that region *i* determines the input (z_{ij}) from region *j* based on the cost minimization behaviour.

$$p_i d_i = \min_{z_{ij}} \sum_j q_j (1+\tau_{ij}) z_{ij}$$
$$s.t. \quad d_i = \left\{ \sum_j \beta_{ij} (z_{ij})^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}} \tag{1}$$

p_i : C.I.F price at region i , d_i : product demand at region i , q_j : F.O.B price at region j , τ_{ij} :Transport cost among region ij , σ : inter-national or regional elasticities of substitution, β_{ij} :Share parameter

The following demand equation is derived by the Lagrange multiplier.

$$p_i = \left\{ \sum_j \beta_{ij} (1+\tau_{ij})^{1-\sigma} \right\}^{\frac{1}{1-\sigma}} \tag{2}$$

$$z_{ij} = \beta_{ij} \left(\frac{(1+\tau_{ij})}{p_i} \right)^{-\sigma} d_i \tag{3}$$

2.2 Parameter Estimation Methodology

The share parameter β_{ij} and the Inter-regional elasticities of substitution σ are required to estimate to identify the above equation (2) and (3). The share parameter β_{ij} is calculated by the calibration method by substituting equation (4) for the benchmark equilibrium data. This model satisfies with reflecting the current condition completely.

$$\beta_{ij} = \frac{(1+\tau_{ij})^{\sigma} z_{ij}}{\sum_j (1+\tau_{ij})^{\sigma} z_{ij}} \tag{4}$$

On the other hands, the empirical problem on this model is how to identify the parameter of Inter-regional elasticities of substitution σ . This parameter, in general, is estimated by the econometrics approach using the panel data with the price and the amount of the goods. Although the existing literature such as Thomas, H. et al. (2003) is estimated the Inter-national elasticities of substitution among countries, the parameter on the inter-regional trade among regions in one country have been not studied enough without Koike et al (2012) in Japan (see Table1).

Table1. Studies about the Inter-national or regional Elasticities of Substitution

	International Trade		Inter-regional Trade	
	Author	Area	Author	Area
Import and Export for one country	Alaouze, C. M et al. (1997)	Australia	Bilgic, A. et al (2002)	In side U.S.
	Reinert and Roland-Holst (1992)	U.S.A		
	Kepuscinski and Warr (1999)	Philippine		
	Heinz (2007)	UK, France, Denmark and Italy		
Among countries or regions	Thomas, H. et al. (2003)	NAFTA and New Zealand	Koike et al (2012)	In side Japan

Koike et al (2012), however, uses nine inter-regional I-O tables as one of the panel data. This paper focuses on the municipality level which doesn't have both of the inter-regional I-O tables and the panel data. In this paper, we substitute the traffic OD data for the inter-regional I-O data, and also apply the cross-section data not panel data because of the statistical constraint.

The following demand function is derived from the equation (1) by solving the cost minimization problem.

$$\frac{z_{ij}'}{z_{ij}} = \frac{\beta_{ij}'}{\beta_{ij}} \left\{ \frac{q_j'(1+\tau_{ij'})}{q_j(1+\tau_{ij})} \right\}^{-\sigma} \tag{5}$$

Here, Assuming $\tau_{ij} = \varphi t_{ij}$, and taking a logarithm of both side on the above equation, the following logarithm equation is derived. We set $\ln(1+\varphi t_{ij}) \approx \varphi t_{ij}$ in order to be the linier estimated formula.

$$\ln z_{ij}' - \ln z_{ij} = \ln \beta_{ij}' - \ln \beta_{ij} - \sigma(\ln q_j' - \ln q_j) - \sigma\varphi(t_{ij}' - t_{ij}) \tag{6}$$

z_{ij}', β_{ij}' and q_j' are the average value on each index

It is possible to estimate the parameter with the equation (6) by the linear regression analysis. But, we need several settings for the estimation as shown as followings.

a) Setting for the share parameter β_{ij}

We can't estimate the share parameter β_{ij} directly. The following two cases are applied.

Table2. Setting of the share parameter β_{ij}

Case 1: $\ln \beta_{ij}' - \ln \beta_{ij}$ is set as α
$\ln z_{ij}' - \ln z_{ij} = \alpha - \sigma(\ln q_j' - \ln q_j) - \sigma\varphi(t_{ij}' - t_{ij})$ (7)
Case 2: β_{ij} is substituted by the product volume Y_j^{θ}
$\ln z_{ij}' - \ln z_{ij} = \theta(\ln Y_j' - \ln Y_j) - \sigma(\ln q_j' - \ln q_j) - \sigma\varphi(t_{ij}' - t_{ij})$ (8)

b) Setting of the internal travel time t_{ii}

The internal travel time t_{ii} is not consistent with the internal trade data because of the aggregation data. The following two cases are applied.

Table3. Setting of the internal travel time t_{ii}

Case 1: The internal travel time t_{ii} is set as the average travel time among the centre of district in each municipality.
Case 2: The internal travel time t_{ii} is not considered (The internal trade data is not considered in the parameter estimation)

c) Setting of the F.O.B price q_j

The F.O.B price is not developed as statistical data. We have to substitute by another data. The following two cases is applied

Table4. Setting of the F.O.B price q_i

Case 1: The amount of salary per employee
$q = w_i = \dfrac{W_i}{L_i}$ (9)
W_i : the amount of salary of manufacturing industry at region i, L_i : the number of employee of manufacturing at region i
Case 2: The unit price[8)] derived from the Cobb-Douglass production function
$q = \dfrac{w_i^a r_i^{1-a}}{\delta a^a (1-a)^{1-a}}$ (10)
w_i : the amount of salary per the employee at region i (same as the data from the equation (9)), r : the capita rent (=1), δ : the efficiency parameter (calibration from the I-O table),

a : the share parameter (calibration from the I-O table)	

The derived data on each price index is shown as Fig1. The salary per employee is gradually increasing depending on the amount of the value added on each area.

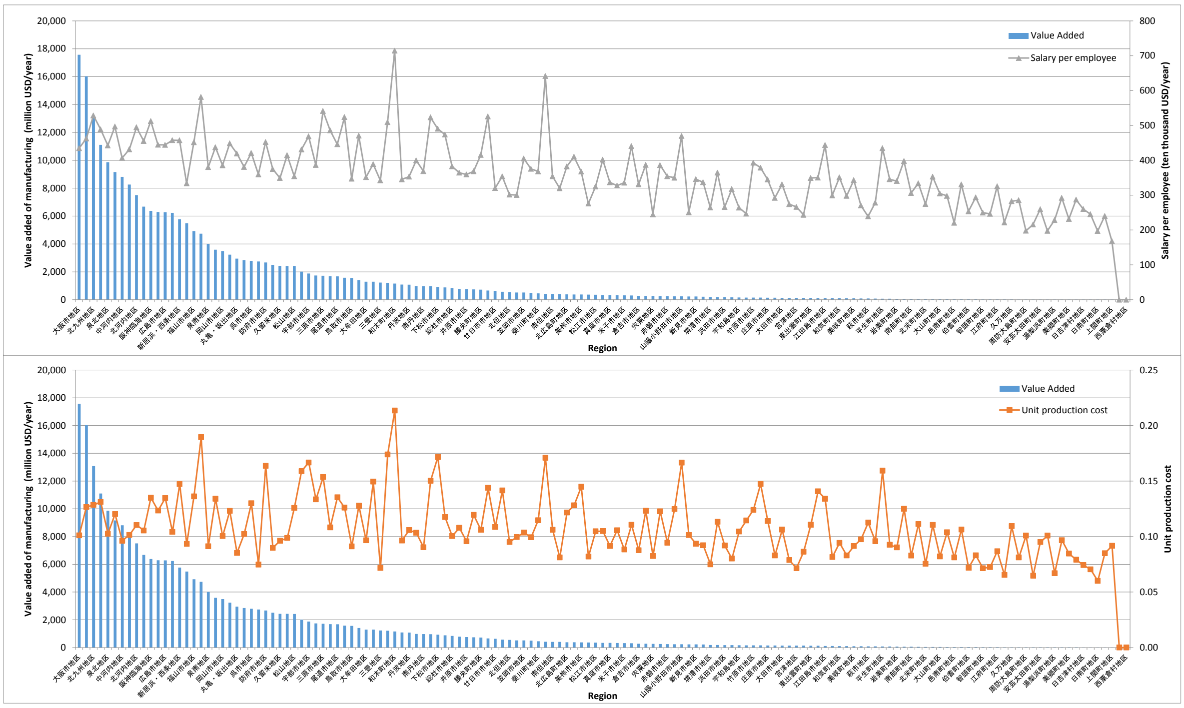

Fig1. Value Added and each Price Data (Salary per Employee and Unit Production Cost)

2.3 Data Settings

The basic condition for the parameter estimation is shown as Table5.

Table5. Basic Condition

	Contents of Setting
Study area	The West part of Japan (See Fig2)
Level of zone	147 zones (Municipality) (See Fig2)
Industrial Sector	Manufacturing

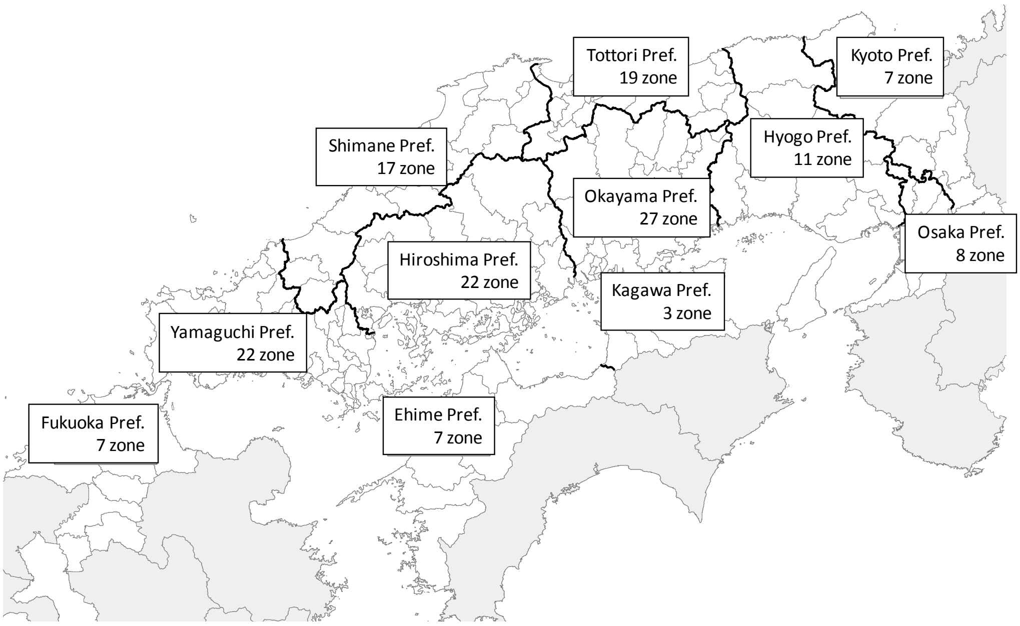

Fig2. Study Area

The statistical data for the parameter estimation is shown as Table6.

Table6. Data Settings

Data	Source
Inter-regional trade z_{ij} (= inter-regional freight traffic OD)	Traffic OD census 2005
The amount of salary of manufacturing industry W_i	Census of Manufactures 2010
The number of employee of manufacturing L_i	Census of Manufactures 2010
Inter-regional travel time t_{ij}	Estimated by the Dijkstra methodology based on the traffic OD census 2005
The production volume at region j : y_j	Census of Manufactures 2010

According to see Fig3, the freight traffic OD among municipalities has zero OD data which is 16,694 samples (77%) in the whole sample (21,609). This study is not covered this zero OD data to estimate the parameter.

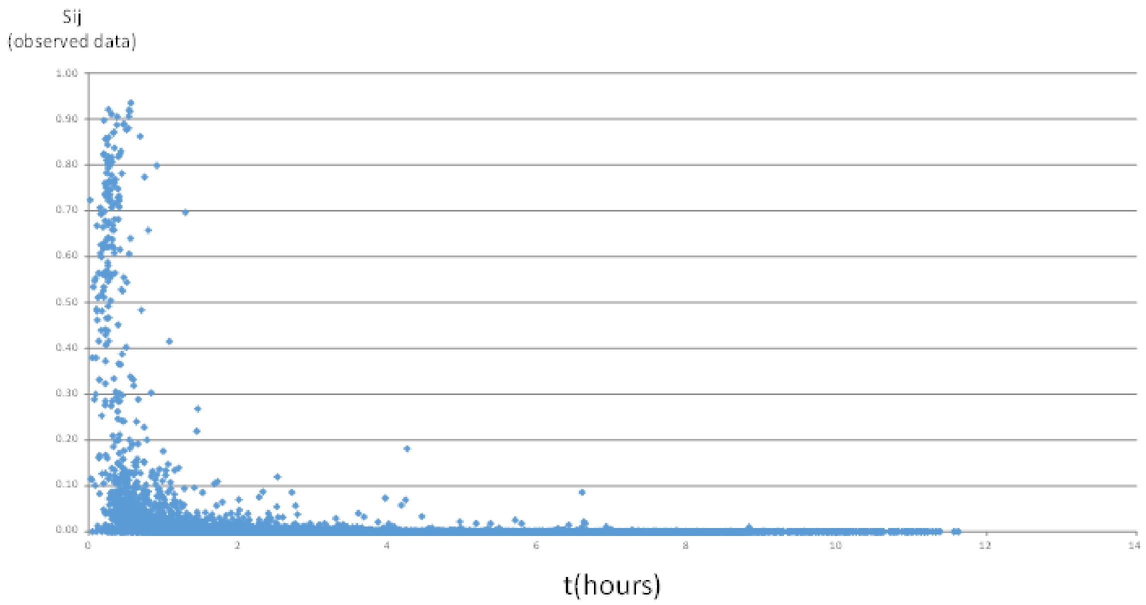

Fig3. Inter-regional travel time and observed OD data

2.4 Estimation Output

Inter-regional elasticities of substitution show the inter-regional trade demand changing ratio to the price index changes by 1%. The output of parameter estimation is shown as Table7. Inter-regional elasticities of substitution is appropriate value in the setting case which is substituted Y_j^{θ} (product volume) for β_{ij} . Especially, the case which is substituted Y_j^{θ} for β_{ij} and uses salary per employee as F.O.B price has the highest t statistic. Koike et al (2012) estimates this parameter at around 0.5-1.0 on each industrial sector by using panel data with inter-regional I-O table (Nine regions in Japan). Although this is similar value with our study, we have to recognize that the cross-section data which is omitted the time series data is used to estimate in this study. In the future study, we need to verify more and more on the empirical effectiveness of estimated parameter by changing data settings under the statistical constraint.

Table7. The Output of Parameter Estimation for CES Function

Setting of Share Parameter	Setting of Internal Travel Time	Setting of F.O.B Price	σ		σφ	
			Estimation	t statistic	Estimation	t statistic
Substitute α (constat value) for β	Average Time	Salary per Employee	-0.13	-3.26	0.69	45.52
		Unit Price	-0.07	-1.84	0.69	45.41
	Not Considered	Salary per Employee	-0.12	-2.97	0.61	40.27
		Unit Price	-0.06	-1.55	0.60	40.17
Substitute Y (product volume) for β	Average Time	Salary per Employee	1.12	14.29	0.87	32.19
		Unit Price	0.58	8.16	0.86	31.43
	Not Considered	Salary per Employee	1.13	14.54	0.84	30.60
		Unit Price	0.59	8.36	0.83	29.90

3. Discrete Choice Model

The discrete choice model is derived from the random utility maximization theory. Anderson (1998) shows that the discrete choice model is also derived from the following direct utility function with entropic term as the representative consumer approach.

$$\min \sum_j T_{ij} z_{ij} + \frac{1}{\theta} \sum_j z_{ij} \ln \frac{z_{ij}}{d_j} \qquad (11)$$
$$s.t. \quad \sum_j z_{ij} = d_j$$

T_{ij}: Transport Cost, θ: Scale Parameter

The inter-regional trade demand function is derived as shown as following. This is the general discrete choice model.

$$z_{ij} = \frac{\exp\left(-\theta T_{ij}\right)}{\sum_j \exp\left(-\theta T_{ij}\right)} d_j \qquad (12)$$

In this paper, we study about the Harker Logit model and MCI (Multiplicative Competitor Interaction) model which can improve the theoretical problem on the Harker Logit model.

3.1 Harker Logit model

(1) Model Formulation

The Spatial CGE model for the municipality level such as Mun (1997) and Koike et al (2008) base the formularization on the Harker Logit model (Harker,1987) as inter-regional trade coefficient. This model constructs an inter-regional trade model by introducing stochastic factors into the spatial price equilibrium model. The inter-regional trade pattern is determined by the price of goods and transportation costs in each region. Consumers in each region are assumed to choose the producing region that minimizes the C.I.F price.

Suppose a representative consumer in region *i* chooses a representative firm located in producing region *j* from which to purchase goods (see Fig4). The choice behaviour of this consumer is expressed as follows:

$$q_j \left(1 + \varphi t_{ij}\right) + \varepsilon_{ij} < q_k \left(1 + \varphi t_{ik}\right) + \varepsilon_{ik} \qquad for\ all\ k \neq j \qquad (13)$$

where t_{ij}: the travel time between regions i, j, q_j : F.O.B price of goods, φ: parameter of travel time, ε_{ik}: random variable.

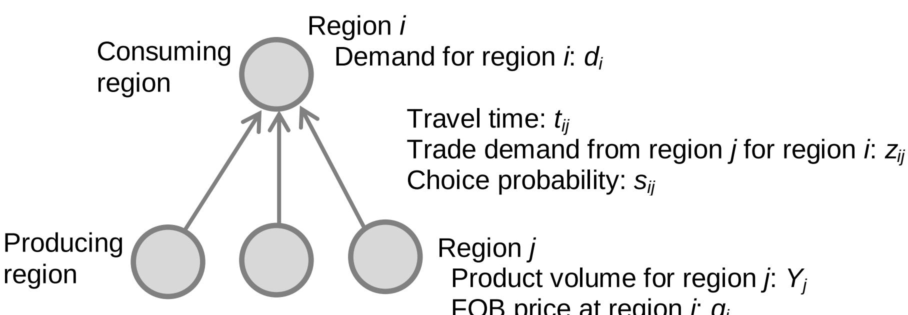

Fig4. Inter-regional trade structure

Accordingly, the cost of transporting one unit of goods is φq_j per unit distance which is known as Ice-berg type transport cost. Assuming that ε_{ij} conforms to the Gumbel distribution having the parameters (0, λ), s_{ij}, the probability that the consumer living in region i will choose producing region j to purchase the goods, is calculated by the following discrete choice expression:

$$s_{ij} = \frac{y_j \exp\left[-\lambda q_j (1+\varphi t_{ij})\right]}{\sum_{k\in K} y_k \exp\left[-\lambda q_k (1+\varphi t_{ik})\right]} \qquad (14)$$

where λ : parameter for F.O.B price q_j , φ : parameter for travel time t_{ij}
Using the above probability, the volume of trade between regions i, j, i.e., the quantity of goods produced in region j and consumed in region i can be calculated by the following expression:

$$z_{ij} = d_i \, s_{ij} \qquad (15)$$

where $\mathrm{d_i}$ is the consumption demand of goods in region i.

(2) Theoretical Problem

As mentioned previously, the Harker Logit model is not satisfied with the homogeneity of degree zero in the price q_j. This is the theoretical problem on this model. In other words, when the price q_j at equation (14) is multiplied k times, k at the RHS is not disappeared and inter-regional trade coefficient s_{ij} is changed. This shows that this model is not consistent with the general equilibrium theory in Walrus. The Harker Logit model, however, is not always inconsistent with the homogeneity of degree zero depending on the analytical condition. The detail on this part will be discussed at chapter 5.

(3) Parameter Estimation Methodology

The equation (14) is transformed to the following equation. The estimated parameter is λ and $\lambda\varphi$.

$$s_{ij} = \frac{y_j \exp(-\lambda q_j - \lambda\varphi q_j t_{ij})}{\sum_{k\in K} y_k \exp(-\lambda q_j - \lambda\varphi q_j t_{ij})} \qquad (16)$$

Here, we put another parameter η for the production volume y_j to increase the reflection of current condition shown as following.

$$s_{ij} = \frac{y_j^{\eta} \exp(-\lambda q_j - \lambda\varphi q_j t_{ij})}{\sum_{k\in K} y_k^{\eta} \exp(-\lambda q_j - \lambda\varphi q_j t_{ij})} \qquad (17)$$

The price index q_j equals one at the benchmark equilibrium condition in the CGE model. In this case, the explanatory valuable at the equation (17) is only t_{ij} and we cannot estimate two parameters λ and φ separately. Therefore, Koike et al (2012) have applied the grid-search methodology to estimate the several combination of λ and φ. This methodology, however, cannot estimate the parameter considered the change of F.O.B price q_j. On the other hand, Mun (1997) estimates λ and φ by input the unit production cost function exogenously to the F.O.B price q_j by also using the grid search methodology. Although the merit of using this methodology is to be able to identify the optimized parameter in the range of any grid which is set by the analyst, this methodology will be an ad-hoc. Thus, this paper applies the maximum likelihood estimation methodology to identify the unique value.

The data settings for the estimation are shown as followings.

a) Setting of the internal travel time t_{ii}

The internal travel time t_{ii} is not consistent with the internal trade data because of the aggregation data. The following three cases are applied.

Table8. Setting of the internal travel time t_{ii}

Case 1: The internal travel time t_{ii} is set as the average travel time among the centre of district in each municipality.
Case 2: The internal travel time t_{ii} is given as dummy variable γ .
Case 3: The internal selection term $y_j^{\eta}\exp(-\lambda q_j - \lambda\varphi q_j t_{ij})$ is given as $y_i^{\eta}\exp(-\lambda q_i - \lambda\varphi q_i t_{ii}) + \gamma$ with dummy variable γ .

b) Setting of the F.O.B price q_j

The F.O.B price is not developed as statistical data. We have to substitute by another data. The following two cases are applied.

Fig9. Setting of the F.O.B price q_i

Case 1: The amount of salary per the employee
$$q = w_i = \frac{W_i}{L_i}$$
W_i : the amount of salary of manufacturing industry at region i , L_i : the number of employee of manufacturing at region i
Case 2: The unit price function[8)] derived from the Cobb-Douglass production function
$$q = \frac{w_i^a r_i^{1-a}}{\delta a^a (1-a)^{1-a}}$$
w_i : the amount of salary per the employee at region i (same as the data from the equation (9)), r : the capita rent (=1), δ : the efficiency parameter (calibration from the I-O table), a : the share parameter (calibration from the I-O table)

The log-likelihood function is defined as following same as aggregated Logit model.

$$\ln L = \sum_i \sum_j s_{ij}^* \ln s_{ij} \tag{18}$$

where s_{ij}^* : Traffic OD share (observed data).

(4) Data Settings

Basic analytical condition and data settings are same as the case of CES type function.

(5) Estimation Output

The output of estimation is shown as Table10. φ is derived by $\lambda\varphi/\lambda$. The parameter λ and φ should be positive value. Especially, φ is significant value which means the distribution cost described by the mark-up ratio to the price of goods, and this parameter is also affected directly to the magnitude of benefit to evaluate the transport investment in the Spatial CGE model. If this value takes over one, this means that the distribution cost is over 100% of price of goods. According to see the estimated parameter in this study, φ is estimated at around 1.0 in Dummy variable type1 case and around 5.0 in Dummy variable type2. This is unrealistic value as the inter-regional trading cost because of the general distribution cost per the goods price is less than 10%. But the distribution cost may be considered not only visible cost but also invisible and potential cost. In the future study, the validity of the value of parameter considered the realistic inter-regional trade should be verified from the empirical viewpoint.

Table10. The Output of Parameter Estimation for Harker Logit model

Setting of Internal Travel Time	Setting of F.O.B price	λ	φ	η	γ (Dummy Variable)	Correlation Efficient
Average Time	Salary per Employee	-7.76	-10.16	0.31	-	0.78
	Unit Price	-5.46	-4.86	0.21	-	0.77
Dummy Variable type1	Salary per Employee	38.44	1.02	0.35	-1.20	0.93
$t_{ii} = \gamma$	Unit Price	9.93	1.39	0.30	-1.11	0.92
Dummy Variable type2	Salary per Employee	8.54	4.77	0.40	38.10	0.92
$y_j^\eta \exp(-\lambda q_j - \lambda\varphi q_j t_{ij}) + \gamma$	Unit Price	-6.54	-2.12	0.27	49.28	0.92

3.2 MCI model

(1) Model Formulation

Tsuchiya and Tatano (2009) have proposed the MCI (Multiplicative Competitor Interaction) model (Nakanishi and Cooper, 1974) can improve the problem which Harker Logit model has. MCI model is generally defined the following equation.

$$s_{ij} = \frac{\prod_m X_{ij}^{\mu_m}}{\sum_k \prod_m X_{mik}^{\mu_m}} \tag{19}$$

where X_{mik} : the m -th variable describing the attraction at region i , μ_m : the parameter of m -th variable.

Here, if the inter-regional trade is defined by the gravity model, MCI function is defined as following equation by using the product volume y_j at consumption region and transport cost T_{ij} to the consuming region.

$$s_{ij} = \frac{y_j^\eta T_{ij}^{-\lambda}}{\sum_{k \in K} y_k^\eta T_{ik}^{-\lambda}} \tag{20}$$

Furthermore, the Ice-berg type transport cost is applied the MCI model same as Harker Logit model, and we can derive the following equation which is satisfied with the homogeneity of degree zero.

$$s_{ij} = \frac{y_j^\eta \left[q_j(1+\varphi t_{ij})\right]^{-\lambda}}{\sum_{k \in K} y_k^\eta \left[q_k(1+\varphi t_{ik})\right]^{-\lambda}} \tag{21}$$

where η: the parameter for the product volume y_j at consuming region j, λ: the parameter for the C. I. F price, φ: the parameter for the travel time t_{ij}

(2) Parameter Estimation Methodology

The estimated parameters are three η, λ and φ. λ and φ is not able to be estimated individually same as Harker Logit model. The data settings for the estimation are shown as followings.

a) Setting of the internal travel time t_{ii}

The internal travel time t_{ii} is not consistent with the internal trade data because of the aggregation data. The following three cases are applied.

Table11. Setting of the internal travel time t_{ii}

Case 1: The internal travel time t_{ii} is set as the average travel time among the centre of district in each municipality.
Case 2: The internal travel time t_{ii} is not considered because the case given as dummy variable γ is not able to be calculated.
Case 3: The internal selection term $y_j^{\eta}\exp(-\lambda q_j - \lambda\varphi q_j t_{ij})$ is given as $y_j^{\eta}\exp(-\lambda q_j - \lambda\varphi q_j t_{ij}) + \gamma$ with dummy variable γ.

b) Setting of the F.O.B price q_j

The F.O.B price is not developed as statistical data. We have to substitute by another data. The following two cases is applied

Table12. Setting of the F.O.B price q_j

Case 1: The amount of salary per employee
$q = w_i = \dfrac{W_i}{L_i}$
W_i: the amount of salary of manufacturing industry at region i, L_i: the number of employee of manufacturing at region i
Case 2: The unit price function[8] derived from the Cobb-Douglass production function
$q = \dfrac{w_i^a r_i^{1-a}}{\delta a^a (1-a)^{1-a}}$
w_i: the amount of salary per the employee at region i (same as the data from the equation (9)), r: the capita rent (=1), δ: the efficiency parameter (calibration from the I-O table), a: the share parameter (calibration from the I-O table)

The log-likelihood function is defined as following same as aggregated Logit model.

$$\ln L = \sum_i \sum_j s_{ij}^* \ln s_{ij}$$

where s_{ij}^*: Traffic OD share (observed data).

c) Estimation Output

The output of parameter estimation for MCI model is shown as Table13. The estimated parameter φ is higher than Harker Logit model. Even if φ is minimum, that value takes

18.38. This means that the distribution cost is 18 times price of goods. It's not realistic value although the correlation efficient is high.

Table13. The Output of Parameter Estimation for MCI model

Setting of Internal Travel Time	Setting of F.O.B price	λ	φ	η	γ (Dummy Variable)	Correlation Efficient
Average Time	Salary per Employee	1.55	48,161.52	0.59	-	0.58
	Unit Price	2.08	201.82	0.59	-	0.72
Not Considered	Unit Price	1.33	18.38	0.57	-	0.93
	Salary per Employee	1.12	34.62	0.51	-	0.92
Dummy Variable	Salary per Employee	1.38	285.88	0.60	61.81	0.90
$y_j^{\eta}\left[q_j(1+\varphi t_{ij})\right]^{-\lambda}+\gamma$	Unit Price	1.13	127.44	0.51	53.04	0.89

Let us check the likelihood curved surface (see Fig5) on this equation. The eigenvalue of hessian matrix is negative in this estimation. The bottom of likelihood curved surface, however, is very slow toward axis of parameter φ. Therefore, the parameter φ changes depending on the data settings such as the price data and the internal travel time data.

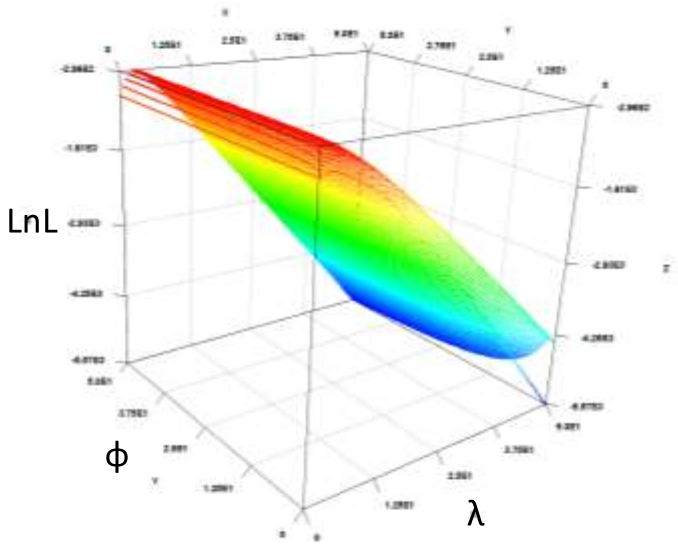

Fig5. Likelihood Curved Surface on MCI model

The maximum likelihood estimation methodology is assumed that the selection probability as inter-regional trade coefficient at each region should be independent each other. However, the probability to select the region A for the consumer living in region B is not always independent with the probability to select the region B for the consumer living in region A. Therefore, the simple maximum likelihood estimation using for aggregated Logit model estimation is not appropriate methodology.

3.3 Condition to be satisfied with Homogeneity of Degree Zero for Harker Logit model

We compare the relationship between Harker Logit model and MCI model. When the price q_j equal one as benchmark equilibrium condition, the equation of each model is followings.

Harker Logit model

$$s_{ij} = \frac{y_j^{\eta} \exp(-\lambda \varphi q_j t_{ij})}{\sum_{k \in K} y_k^{\eta} \exp(-\lambda \varphi q_j t_{ij})} \tag{22}$$

MCI model (Gravity type model)

$$s_{ij} = \frac{y_j^{\eta} (1+\varphi t_{ij})^{-\lambda}}{\sum_{k \in K} y_k^{\eta} (1+\varphi t_{ik})^{-\lambda}} \tag{23}$$

In these equation, Bröcker (2001) indicates that the equation (22) and (23) takes an approximate value when $\exp(-\lambda \varphi_j t_{ij})$ and $(1+\varphi t_{ij})^{-\lambda}$ is in the vicinity of one. For example, Fig6 shows the relationship $\exp(-\lambda \varphi_j t_{ij})$ and $(1+\varphi t_{ij})^{-\lambda}$ at each travel time t_{ij} applied in this study when the parameter λ=3 and φ=0.5. Therefore, Harker Logit model is an approximate relationship with MCI model (Gravity type model) and is approximately satisfied with the homogeneity of degree zero in the price. This relationship, however, is not completed when the price data q_j is given exogenously in this study. If we can propose the model structure that the term of EXP equal one at Harker Logit model, that model will be approximately satisfied with the homogeneity of degree zero.

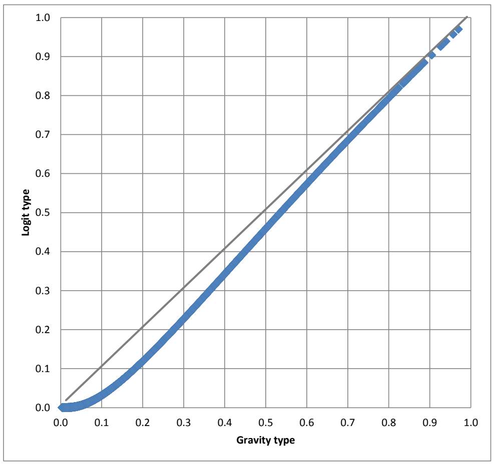

Fig6. The relationship between $\exp(-\lambda \varphi t_{ij})$ and $(1+\varphi\ t_{ij})^{-\lambda}$

3.4 Comparison with the Parameter Estimation in the Existing Study

Here, Let us show the comparison of estimation methodology and estimation output for the Harker Logit model and the MCI model in the existing studies (see Table14). The existing study estimates the parameter by using the Grid-search methodology. Mun(1997) estimates the parameter considered the influence of travel time and price since the price data is given. But, the model structure in this case is not satisfied with the homogeneity of degree zero as indicated previously. On the other hand, Although Nomura (2009) and Koike and Sato (2012) is satisfied with the homogeneity of degree zero since the price is set as the benchmark equilibrium value (q=1), this is not estimated the parameter considered the influence of price.

This paper estimated the parameter for the travel time and the price based on the MCI model which is satisfied with the homogeneity of degree zero. But, the estimated value is not described the realistic inter-regional trade activity because of the un-appropriate estimation methodology.

Table14. The Comparison of Estimation Methodology and Output in the Existing Study

	Mun (1997)	Nomura (2009)	Koike and Sato (2012)
Model	Harker Logit model	Harker Logit model MCI model	Harker Logit model
Estimation Methodology	Grid-search	Grid-search	Grid-search
Setting of price	q_j is given as unit production cost	$q_j = 1$	$q_j = 1$
Zone size	Tohoku region 37 local living-sphere	Whole Japan 9 region	West part of Japan 147 municipalities
The number of Industrial Sector	20 sectors	40 sectors	18 sectors
Inter-regional trade data	Freight Traffic OD Census	Inter-regional I-O table	Traffic OD Census
Output of estimation	λ=0.0~28.6 φ=0.1~1.7	Harker Logit model λ=-0.02~1.2 φ=-3.7~4.6 MCI model λ=0.162~5.485 φ=0.001~0.511	λ=1.1~7.4 φ=0.1~0.4
Correlation Coefficient	0.28~0.87	Harker Logit mode 0.613~1.000 MCI model 0.897~1.000	0.22~0.41
OD data cleaning	Aggregation of origin area	-	-
Note	In the case of λ=0, λ is given to increase the goodness of fit about the whole CGE model	-	The parameter is estimated under the constraint of the decrease of C.I.F price. Grid is λ=0-1, φ=0-10.

4. Conclusions

- This paper analyses the theoretical and empirical verification about the CES model and the discrete choice model (Harker Logit model and MCI model) as the inter-regional trade coefficient which is required for the SCGE model with the small scale region such as municipality.
- This paper derived the appropriate parameter of CES model for small region by using traffic OD data in this study. But we have to recognize that the cross-section data which is omitted the time series data is used to estimate in this study, although the panel data should be used for the desirable estimation. In the future study, we need to verify more and more on the empirical effectiveness of estimated parameter by changing data settings under the statistical constraint.
- The discrete choice model which is consistent with the traffic data is verified in the theoretical and empirical viewpoints for the Spatial CGE model. Although the Harker Logit

model doesn't satisfy the homogeneity of degree zero as the model structure, this model satisfies with this condition approximately when the term of EXP is in the vicinity of one, for example, in the case of F.O.B price equal one as the benchmark equilibrium condition. This case, however, cannot describe the change of price by estimated parameter λ and φ. Therefore, the model structure should be changed that the term of EXP may be approximately one under the price data is considered, in order to satisfy with the homogeneity of degree zero in the Harker Logit model.

- On the other hand, MCI model is satisfied with the homogeneity of degree zero. And we estimated the parameter for the travel time and price by using the maximum likelihood maximization methodology. But, the estimated value is not realistic. Especially, the parameter φ describing the travel time changes is unrealistic value. Although the maximum likelihood maximization methodology requires the independent condition among each selection probability, the analytical case on this study doesn't always satisfy with this condition. Therefore, the simple maximum likelihood estimation using for aggregated Logit model estimation may not be appropriate methodology. Therefore, we should revise this methodology considered the economic inter-regional trade characteristics.

REFERENCES

- Anas. A. (1983). Discrete Choice Theory, Information theory and the multinomial Logit and Gravity Models, "Transportation Research B, 17, pp.13-23.
- Anderson S. P, A. de Palma and J.F. Thisse. (1992). Discrete Choice Theory of Product Differentiation, MIT Press.
- Alaouz, C.M., Marsden, J.S., Zeitsch, J. (1977) Estimates of the elasticity of substitution between imported and domestically profuced commodities at the four digit ASIOC level, Working paper No.0-11, Industries Assistance Commission, Merboune.
- Bilgic, A., King, S., Lusby, A. Schreiner, D.F. (2002) Estimation of U.S. Regional Commodity Trade Elasticities of Substitution, The Journal of Regional Analysis & Policy, Vol.32, No2, pp79-97
- Bröcker, J, A. Kancs, C. Schürmann, and M. Wegener. (2001). IASON: Deliverable 2: Methodology for the asessment of spatial economic impacts of transport projects and policies. Technical report, Christian-Albrechts-Universität Kiel/Institut für Raumplanung, Kiel/Dortmund, IASON (Integrated Appraisal of Spatial economic and Network effects of transport investments and policies). Funded by 5th Framework RTD Programme.
- Harker, P. T. (1987). Predicting Intercity Freight Flows, VNU Science Press BV.
- Koike. A, L. Tavasszy and K. Sato. (2008) Spatial Computable General Equilibrium model "RAEM-Light" for Highway Network Projects in Japan, Proceedings for Presentation of 88th Annual Meeting of Transportation Research Board, DVD.
- Koike. and K. Sato (2012). Spatial Economic analysis on the tourism industry by development of transport network –an approach based on the estimation of value added on tourism industry by municipalities at tottori and hyog region-, Journal of Infrastructure Planning and Management, Vol.29 I_349. (in Japanese)
- Kapuscinski, C. A., Warr, P. G. (1999) Estimations of Armington Elasticities: an application to the Philippines. Economic Modeling, 16, pp257-278.
- Koike. a, K. Ito. and T. Nakao. (2012). Estimation of Armington Elasticities in Japan, Journal of Infrastructure Planning and Management, Vol 29, I_55.
- Miyagi. T. and K. Honbu. (1993). Estimation of interregional trade flows based on the SCGE model, Proc. of Infrastructure Planning, 16, pp.879-886. (in Japanese).

- Miyagi. T. (1994). The Entropy Production Function and its Application to the Multi-Commodity and Multi-Sector Model, the Annals of Regional Science, Springer Verlag, 18:345-367.
- Miyagi, T. and K, honbu. (1995). Spatial computable general equilibrium approach to generalized land use/ transportation modelling, Regional Studies, 25 (1), pp.131-146. (in Japanese).
- Mun S. (1997). Transport network and system of cities, Journal of Urban Economics, Vol.42, pp.205-221
- Nakanishi. M. and L.G.Cooper (1974). "Parameter Estimation for a Multiplicative Competitive Interaction Model-Least Squares Approach," Journal of Marketing Research, 11, 303-311.
- Nomura. T. (2009). A Study on Interregional Trade in the Spatial Computable General Equilibrium Model, Master thesis at Nagaoka University of technology.
- Reinert, K. A., Roland-Holst, D.W. (1992) Armington Elasticities for United States Manufacturing Sectors. Journal of Policy Modeling, 14, pp631-639.
- Roson. R. (1996). The macroeconomic impact of traffic congestion: A CGE analysis in Bergh, J.C.J.M. van den, Nijkamp, P. and Rietveld, P. (eds), Recent Advances in Spatial Equilibrium Modelling. Springer-Verlag, Berlin.
- Tsuchiya. S, H. Tatano and N.Okada. (2006).Measuring Economic Impacts from the Niigataken-Chuetsu Earthquake, Journal of Infrastructure Planning and Management, Vol.23, no2, pp365-372 (in Japanese)
- UEDA. T, M. Tsutsumi, S. Muto and K. Yamasaki. (2012). Unified Computable Urban Economic Model, the Annals of Regional Science, Springer.
- Welsch, H. (2008). Armington elasticities for energy policy modeling: Evidence from four European countries. Energy Economics, 30(5), 2252-2264."
- Whalley. J. (1984). The North-South Debate and the Terms of Trade: An applied General Equilibrium Approach, he Review of Economics and Statistics, Vol.6, No.2.