AN INTER-REGIONAL FREIGHT DEMAND MODEL BY SPATIAL APPLIED GENERAL EQUILIBRIUM ANALYSIS

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Abstract: As an attempt to express the essential characteristics of inter-regional trade, we propose a demand forecasting model based on the analytical frameworks of inter-regional and inter-industry linkage analysis and the spatial price equilibrium model. This model seems to be useful in predicting inter-regional freight demands in conditions of semi-open and middle-term equilibrium, that is to say, 1) the final demand except for the household consumption is given by another econometric model exogenously and 2) it permits change in residential location and differences in production prices and wage rate by zone. At the same time, we explain the kind of data to be considered for practical use, using a complementary model and an estimation of a model. Furthermore, we show an application of the results to a motorway improvement project in Japan and to verify the applicability of our model.

Key Words: inter-regional trade, freight demand model, I/O, SCGE

1. INTRODUCTION

Inter-regional trade is a series of physical movements of goods among various industries and within certain regions in the process of production activities and commercial transactions. For example, a product is transported by a producer to other producers as an intermediate product, and manufactured goods is made of the intermediate products which is turn, shipped to wholesalers or retailers, by whom, it is finally distributed to households. Compared with passenger trips, in interregional trade, there are such unique characteristics as: 1) indefiniteness in the unit of measurement and transportation; 2) the variety of goods transported; 3) a change in the appearance of a package in the process of transportation; 4) a variety in transport purposes; and 5) a variety in transport cycles. Nonetheless, in past research on demand forecasting of the amount of interregional trade, it has been common to apply the results of research in demand forecasting of person's trip, which has relatively distinct characteristics, to its analysis. However, a freight demand analysis should essentially be based upon a framework that is consistent with economic theories and which is able to cope with the industrial and economic structure of an economy as well as a change in residential allocation. Particularly, when there is a business transaction between two regions due to the differentials in price of the same goods in these regions as seen in developing countries, it is significant to employ the above-mentioned framework on demand forecasting.

As an attempt to express the essential characteristics of an inter-regional trade, we propose a demand forecasting model based on the analytical frameworks of inter-regional and inter-industry linkage analysis and the spatial price equilibrium model in our study. At the same time, we explain the kind of data to be considered for practical use, using a complementary model and an estimation of the model. Furthermore, we show an application of the results to a motorway improvement project in Japan to verify the applicability of our model. Inventory is the important factor in making a fright demand model when the capacity of warehouse is limited in volume. However, this model is only a static and flow estimation model, so an effect of inventory is not taken into account in our model.

2. REVIEW OF THE MODELS AND OUTLINE OF OUR MODEL

Samuelson (1952) and Takayama et al (1971) developed the spatial price equilibrium model in which they employed the concept of space separating two markets into an economic model. The main objective of the spatial price equilibrium model in interregional trade was to formulate mathematical equilibrium values so as to satisfy the condition that interregional trade takes place only when there is a difference in price, transportation costs included, providing that there is only one product and two regions (see, for example, Broker, 1988; Batten et al, 1985). Recently, this model was integrated into network equilibrium models by considering traffic systems such as transportation facilities and traffic network as a network. Harker (1987) and the other scholars have further advanced these models. However, it is unusual that a model is built to describe the inter-regional physical movement of goods, so called freight demand, itself. We will keep a detailed review and prospects in the field for another occasion (see, for example, Harker, 1988; Batten, 1992). On the other hand, Mizokami (1996) proposed a practical inter-regional trade model considering I/O frame and price equilibrium. In this study, output, price and inter-regional trade pattern were treated as variables. The model used was based on the framework of general equilibrium analysis, in which all the variables are interdependent among all industries and that the supply and demand of each product are in equilibrium. Although practical, this model seems to be somewhat weak in economic theories. Both MEPLAN, an integrated model for land-utilization and traffic, developed by Echenique (1986) and econometric models in regional economics (Sasaki, et al, 1987) employ the same concept as ours. However, these models do not seem to deal with demand forecasting of inter-regional trade.

To improve our previous study, we rebuild the demand-forecasting model of inter-regional and inter-industry trade in order to find equilibrium values of the production prices and the amount of shipment, assumed to be equal to the total output of all industries in an intermediate goods market, by employing the spatial general equilibrium framework of the inter-regional and inter-industry linkage model. The framework of Chenery-Mosesian inter-regional and

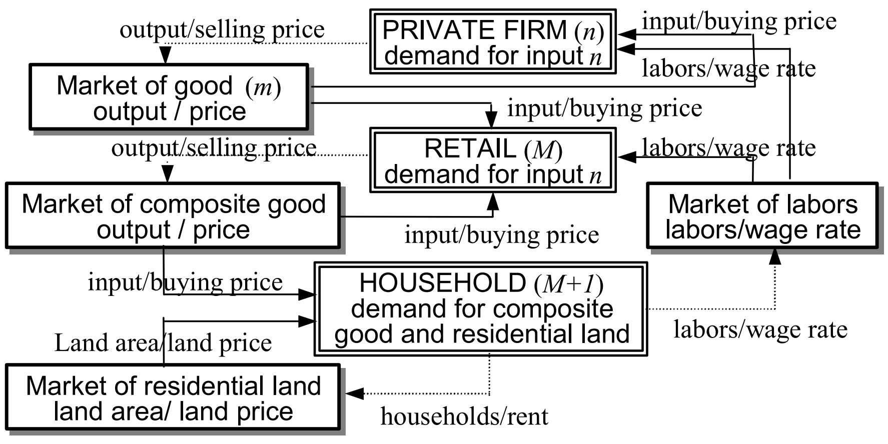


Figure 1. Mechanism of inter-industrial linkage

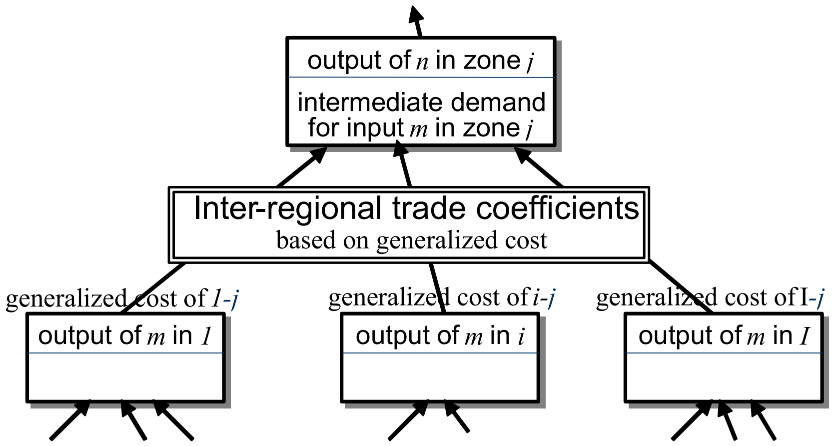


Figure 2. Mechanism of inter-regional linkage

inter-industry linkage model is used to describe the flow of products, and, thus, the equilibrium condition for supply and demand is satisfied in terms of the quantities. In the same manner, households are treated as an intermediate sector that provides labos to the other sectors and requires composite goods as well as residential land service. Land service is decided in its own market mechanism. This market mechanism is shown in Figure 1.

In the normal I/O technique, the prices are usually given and the input coefficients are generally constant. Our model has a distinct characteristic in its structure as it gives variable input coefficients. As the production price changes the price of intermediate materials, the optimum level of inputs will change as a result of rational production behavior in the industries, and in turn it changes the input coefficients as well. At the same time, as inter-regional trade coefficients change because of the change in the generalized cost, which consists not only with production and transportation cost but also with non-price factors, the total amount of demand will be determined. A brief outline on the inter-regional and inter-industrial linkage system is shown in Figure 2.

Under these situations, the supply and the demand are met according to the framework of the inter-industry linkage model in terms of quantities, and the production prices are adjusted such that profits in all industries are equal to zero in terms of production prices. Thus, the market is in equilibrium.

3. MODEL FOR INTER-REGIONAL TRADE AND INTER-INDUSTRY LINKAGE

The structure of the model is briefly shown in Figure 3. We assume that there are two types of sectors in the economy. They are the private firms and the households which are identified by $m=1,\ldots,M-1$ and $m=M$, respectively. The superscripts m and n denote the shipping and receiving industries, respectively, and the subscripts i and j $(=1,\ldots,I)$ denote a shipping and receiving zone, respectively. Land service in terms of additional worth is expressed as $m=M+1$. At the same time, we assume that each industry produces only one product.

3.1 The behavior of a private firm

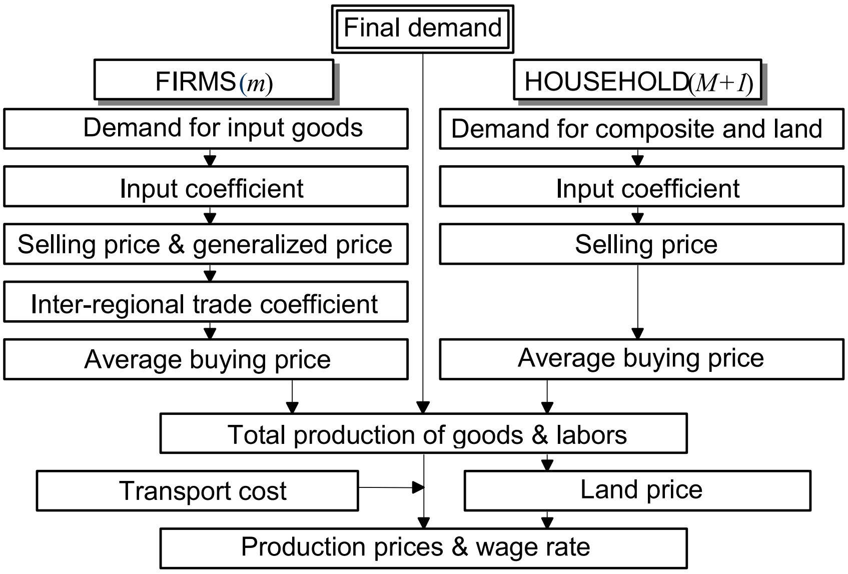


Figure 3. Framework of the model

Assuming the logit-type inter-regional trade coefficient model statistically determines the pattern of trade, successively the optimum amount of intermediate products is decisively determined by the profit-maximization behavior of businesses in their factories. Given that the tentative production price, $\mathbf{p}=\{p_j^n\}$, and the input price $\mathbf{c}=\{c_j^m\}$, the nth industry determines the optimum amount of intermediate product from the mth industry, x_j^{mn}, and the amount of labor input x_j^M, under the assumption that it produces the total output, $\mathbf{X}=\{X_j^n\}$ at the equilibrium. Assuming that a Cobb-Douglas production function and linear cost function, we can set up the following optimization problem:

$$max:\pi_j^n = p_j^n X_j^n - \sum_{m=1}^{M} x_j^{mn} c_j^m \tag{1}$$

$$s.t.\ \prod_{m=1}^{M} \left(x_j^{mn}\right)^{\beta_{mn}} = X_j^n \qquad \text{(Assuming that } \sum_{m=1}^{M} \beta^{mn} = 1.\text{)} \tag{2}$$

By solving this optimization problem, the optimum amount of intermediate product and the labor input, x_j^{mn} are determined as follows:

$$x_j^{mn} = \beta^{mn} \cdot \left(p_j^n / c_j^m\right) \cdot X_j^n \tag{3}$$

The input coefficient of intermediate product of the mth industry to be used to produce one unit of output of the nth industry in the jth zone are given as:

$$a_j^{mn} = x_j^{mn} / X_j^n \tag{4}$$

We consider this value as the inter-regional input coefficient in the Chenery-Mosesian inter-regional and inter-industry linkage table under the tentative production prices.

The sale price, c_{ij}^m in the jth zone of the output produced by the mth industry in the ith zone is the sum of the production price, p_i^m, in the ith shipping zone and the transportation margin, s_{ij}^m between the ith zone and the jth zone such that:

$$c_{ij}^m = p_i^m + s_{ij}^m \tag{5}$$

The generalized sale price, $\bar{c}_{ij}^m$, which includes non-price factor of production, u_{ij}^m, such as the transportation time can be written as:

$$\bar{c}_{ij}^m = c_{ij}^m + \omega_m u_{ij}^m = p_{ij}^m + s_{ij}^m + \omega_m u_{ij}^m \tag{6}$$

where ω_m is a value conversion parameter.

The average purchasing price of the *m*th product in the *j*th zone, c_j^m, is the expected value of the sale price, c_{ij}^m, that is a probability function of the interregional coefficient, t_{ij}^m, shown as flows:

$$c_j^m = \sum_i \left\{ \text{Prob}\left[x_{ij}^m\right] \cdot c_{ij}^m \right\} = \sum_i \left\{ t_{ij}^m \cdot c_{ij}^m \right\} \tag{7}$$

In traditional spatial price equilibrium model, products are bought from the zones where the marginal profits are positive and, thus, the pattern of interregional is endogenously determined. In our model, due to the fact that there are imperfect information about markets and the existence of non-price factor of production, the purchase of the *m*th intermediate product by the *n*th producing industry are assumed to be statistically made from all substitutive zones based on the amount of generalized cost including error terms and also in accordance with logit-model. The ratio, t_{ij}^m, of the amount of intermediate product received from the *i*th zone to the total amount of intermediate product received by the *m*th industry in the *j*th zone is represented as a utility function of the generalized sale price $\bar{c}_{ij}^m$ and a zone potential unique to the *i*th zone, W_i^m which can be obtained by aggregating small zones such that:

$$t_{ij}^m = \text{Prob}\left[x_{ij}^m\right] = \frac{(W_i^m)^{\delta_m} \exp\left(-\lambda_m \bar{c}_{ij}^m\right)}{\sum_i (W_i^m)^{\delta_m} \exp\left(-\lambda_m \bar{c}_{ij}^m\right)} \tag{8}$$

This value is considered to be the inter-regional trade coefficient of the Chenery-Mosesian inter-regional and inter-industry linkage model.

3.2 The behavior of a household

Given that the total number of households X_j^N, household's income p_j^N, land rent c_j^{M+1}, and input price of composite goods c_j^m, a household attempts to distribute its income, which is the value for its labor, into the consumption of both the optimal amount of land input (=*M+1*) and a composite goods (=*M-1*) from the retail sector. We apply a Cobb-Douglas utility function and a linear budget constraint to describe the behavior of a household as follows:

$$max: \; U_j^N = \left(x_j^{M-1,N}\right)^{\alpha_1} \cdot \left(x_j^{M+1,N}\right)^{\alpha_2} \tag{9}$$

$$s.t. \; p_j^N X_j^N = c_j^{M-1} x_j^{M-1,N} + c_j^{M+1} x_j^{M+1N} \quad (\text{Assume that } \alpha_1 + \alpha_2 = 1) \tag{10}$$

The optimal solution to this problem results that a household allocates the sum of his income for both inputs in a constant ratio. So, put it that the total amount of consumption of land per household, x_j^{M+1} / X_j^N, is fixed in the short term. By solving this optimization problem with above assumption, the optimum amount of composite goods is determined as:

$$x_j^{mN} = (p_j^N X_j^N - c_j^{M+1} x_j^{M+1N}) / c_j^m \tag{11}$$

In consequence, the input coefficient of the composite goods is given as:

$$a_j^{mN} = x_j^{mN} / X_j^N = (p_j^N - c_j^{M+1} x_j^{M+1N} / X_j^N) / c_j^m \tag{12}$$

Regarding the land rent, we estimate a land price function in advance. This function has been introduced based on the equilibrium theory that the supply and the demand of land service are met in its market within each zone and it is shown as following functional form:

$$R_i^{M+1} = a + b\frac{X_i^M}{K_i^{M+1}} + c\frac{p_i^M X_i^M}{K_i^{M+1}} + d\frac{SE_i}{K_i^{M+1}} \tag{13}$$

where K_i^{M+1} is available land space and SE_i is the vector of socio-economic attributes in the ith zone. The land rent c_i^{M+1} is introduced by following transformation:

$$c_i^{M+1} = \frac{\mu}{(1+\mu)^t - 1} \cdot R_i^{M+1} \tag{14}$$

μ is the growth rate of the annual household's income and t is the term of use.

3.3 Equilibrium conditions

(1) Equilibrium condition in terms of the quantities

The equilibrium condition in terms of quantities means that the amount of supply and the demand are met in every row of the I/O table. $\mathbf{A}^*$ is a diagonal matrix of intra-regional input coefficient shown as follows:

$$\mathbf{A}^* = \begin{pmatrix} \mathbf{A}_1 & & & & & \\ & \mathbf{A}_2 & & & 0 & \\ & & \ddots & & & \\ & & & \mathbf{A}_j & & \\ & 0 & & & \ddots & \\ & & & & & \mathbf{A}_J \end{pmatrix} \tag{16}$$

And its jth diagonal element $\mathbf{A}_j$ is a matrix consisting of $\{a_j^{mn}\}$ given in the equations (4) and (12) which is as follows:

$$\mathbf{A}_j = \begin{pmatrix} a_j^{11} & a_j^{12} & \cdots & a_j^{1n} & \cdots & a_j^{1N} \\ a_j^{21} & & & \vdots & & \vdots \\ \vdots & & & \vdots & & \vdots \\ a_j^{m1} & \cdots & \cdots & a_j^{mn} & \cdots & a_j^{mN} \\ \vdots & & & \vdots & & \vdots \\ a_j^{M1} & \cdots & \cdots & a_j^{Mn} & \cdots & a_j^{MN} \end{pmatrix} \tag{17}$$

The column vector, $\mathbf{Y}_j = (Y_j^1, \cdots, Y_j^m, \cdots, Y_j^M)^t$, consists of the final demand Y_j^m in the jth zone for intermediate product produced by the mth industry, and then it is the jth element of the column vector of the final demand, $\mathbf{Y}^* = (\mathbf{Y}_1, \cdots, \mathbf{Y}_j, \cdots, \mathbf{Y}_J)^t$. Given that

$\mathbf{X}_i = \left(X_i^1, \cdots, X_i^m, \cdots, X_I^M\right)^t$, column vector of the total output by zone and industry is $\mathbf{X}^* = \left(\mathbf{X}_1, \cdots, \mathbf{X}_i, \cdots, \mathbf{X}_I\right)^t$. And it can be obtained by

$$\mathbf{X}^* = \left[\mathbf{I} - \mathbf{T}^*\mathbf{A}^*\right]^{-1}\mathbf{T}^*\mathbf{Y}^* \tag{18}$$

This is just the equilibrium condition in which supply and demand is satisfied in terms of the quantities under the temporally given production prices. $\mathbf{T}^*$ is a matrix of inter-regional trade coefficient as follows:

$$\mathbf{T}^* = \begin{pmatrix} \mathbf{T}_{11} & \mathbf{T}_{12} & \cdots & \mathbf{T}_{1j} & \cdots & \mathbf{T}_{1J} \\ \mathbf{T}_{21} & & & \vdots & & \vdots \\ \vdots & & & \vdots & & \vdots \\ \mathbf{T}_{i1} & \cdots & \cdots & \mathbf{T}_{ij} & \cdots & \mathbf{T}_{iJ} \\ \vdots & & & \vdots & & \vdots \\ \mathbf{T}_{I1} & \cdots & \cdots & \mathbf{T}_{Ij} & \cdots & \mathbf{T}_{IJ} \end{pmatrix} \tag{19}$$

and its (i,j) element $\mathbf{T}_{ij}$ is a diagonal matrix consisting of $\{t_{ij}^m\}$ given in the equation (8)as follows:

$$\mathbf{T}_{ij} = \begin{pmatrix} t_{ij}^1 & & & & & \\ & t_{ij}^2 & & & 0 & \\ & & \ddots & & & \\ & & & t_{ij}^m & & \\ & 0 & & & \ddots & \\ & & & & & t_{ij}^M \end{pmatrix} \tag{20}$$

(2) Equilibrium condition in terms of the monetary values

The equilibrium condition in terms of the monetary values means that the monetary value of input and output by each sector are met in every column. The equilibrium condition of private firm is given as:

$$p_j^n X_j^n = \sum_i \sum_m x_{ij}^{mn} p_i^m + \sum_i \sum_m x_{ij}^{mn} s_{ij}^m \tag{21}$$

The left hand side shows the total amount of products by the *n*th industry in the *j*th zone. The first and second terms of right hand side mean the total production cost of the intermediate inputs and total transportation cost, respectively. Our model is distinct in its structure as it regards the unit price of transportation cost as a kind of added value. On the other hand, the budget constraints shown in the equation (10) corresponds to the equilibrium condition of household. The household assumes to purchase the composite goods through the retail sector located in the same zone, so $c_j^m = p_j^m$, and we can rewrite equation (10) as follows:

$$p_j^N X_j^N = p_j^m x_j^{mN} + c_j^{M+1} x_j^{M+1} \tag{22}$$

Equations (21) and (22) are rewritten as follows:

$$p_j^n = \sum_i \sum_m \left(x_{ij}^{mn} \big/ X_j^n\right) \cdot p_i^m + \left(\sum_i \sum_m x_{ij}^{mn} s_{ij}^m\right) \Big/ X_j^n \tag{23}$$

$$p_j^N = p_j^m \cdot (x_j^{mN} \big/ X_j^N) + c_j^{M+1} \cdot (x_j^{M+1} \big/ X_j^N) \tag{24}$$

The second terms of above both equations are considered to be the vectors of added value, so we write them as follows:

$$V_j^n = \left(\sum_i \sum_m x_{ij}^{mn} s_{ij}^m \right) \Big/ X_j^n \tag{25}$$

$$V_j^N = c_j^{M+1} \cdot (x_j^{M+1} / X_j^N) \tag{26}$$

The column vector, $\mathbf{V}_j = \left(V_j^1, \cdots, V_j^n, \cdots, V_j^N \right)^t$, consists of the added value V_j^n in the *j*th zone for intermediate product produced by the *n*th industry, and then it is the *j*th element of the column vector of the final demand, $\mathbf{V}^* = \left(\mathbf{V}_1, \cdots, \mathbf{V}_j, \cdots, \mathbf{V}_J \right)^t$. Given that $\mathbf{P}_i = \left(p_i^1, \cdots, p_i^m, \cdots, p_I^M \right)^t$, column vector of the production price is $\mathbf{P}^* = \left(\mathbf{P}_1, \cdots, \mathbf{P}_i, \cdots, \mathbf{P}_I \right)^t$. And it can be obtained by

$$\mathbf{P}^* = \left[\mathbf{I} - \left(\mathbf{T}^* \mathbf{A}^* \right)^t \right]^{-1} \mathbf{V}^* \tag{27}$$

This is just as the equilibrium condition in terms of the monetary values under the temporally given the total amount of production.

Consequently, we can determine the inter-regional and inter-industrial freight flows as follows:

$$x_{ij}^{mn} = a_j^{mn} \cdot X_j^n \cdot t_{ij}^m \tag{28}$$

4. DATA COLLECTION AND MODEL ESTIMATION

4.1 National survey of net flow of freight

The national survey of the net flow of freight seems to be the only usable data in determining the amount of trade among all industries in the country. It is possible to use the regional

	Intermediate demand				Final demand		Output
	1 agriculture	2 ……. 25	26 retail	27 household	28	29 export	
1. agriculture				0			
2. mining				0			
3. manufacture 16.				0			
17. wholesale 24.				0			X_i^n
25. warehouse				0			
26. retail	0	0	0			0	
27. household				0		0	
Adding Value	Transport			Land			

Figure 4. I/O framework of the model

input-output table prepared by the Ministry of Economy, Trade and Industry, which uses the volume of trade of input instead of the physical amount of inputs as a source of data. Since the figures in the table are taken from several surveys and statistical data such as data from the national survey of net flow of freight, it must be considered secondary data. It is better to use original data for consistency and fewer statistical errors. This national survey of net flow of freight started in 1970 and has been carried out every five years. While there are a total of 33,002 establishments, the sample covers only 3.5 percent. The total weight of their shipping covers 41.7% of the total output. Its reliability on weight is considered to be very high. In accordance with the standard industrial classification of Japan, sampled industries are divided into 61 sectors. The retail sector is assumed to ship nothing and to only receive goods from other intermediate sectors. Then the I/O framework of this model results in a kind of semi-open type model as shown in Figure 4. The basic spatial unit of regions is a prefecture.

The national survey of the net flow of freight consists both of the annual shipping trend survey (the annual survey) and of the three-days-flow survey (the three-days-survey). From the annual survey, the annual amount of net shipping by zone and industry is obtainable, and the net flow of inter-regional and inter-industrial over a three-days periods, f_{ij}^{mn}, from the three-days survey. We can regard the former value as X_i^m, that is to say the total output by zone and sector, and the latter f_{ij}^{mn} as the inter-regional and inter-industrial linkage pattern. By using the Frator-method, we transfer f_{ij}^{mn} into the annual amount x_{ij}^{mn} whose marginal distribution is consistent with X_i^m and X_j^n. X_j^n is not observable from the annual survey, thus we assume as follows;

$$X_j^n = \left(\sum_i \sum_m X_i^m \right) \cdot \left(\sum_i \sum_m f_{ij}^{mn} \Big/ \sum_i \sum_j \sum_m \sum_n f_{ij}^{mn} \right) \tag{29}$$

In estimating some partial models, which will be represented in the next section, x_{ij}^{mn} is a basic data set and the other kinds of datasets are prepared as well. In our empirical study, intermediate products including the household were reclassified into 27 sectors. The 28th and 29th sectors are assigned for the final demand and the export, respectively. The number of regions is eight except for Okinawa area.

4.2 Model Estimation and Evaluation of Total Test

The partial models which we should estimate in advance are a) Production function of industries, b) Inter-regional trade coefficients model, c) Land price function and 3) Utility function of household. We show the example of estimation results of these models in Table 1 to Table 4, respectively.

A total prediction test of our model, which consists of partial models above mentioned, was conducted. The iteration is terminated if the relative change in the X_i^m is below 5.0% together with the production price p_i^m determination procedure. The results of goodness-of-fit between estimated and observed on total output X_i^m and production price p_i^m are shown in Table 5. It is not too much to say that the fit of the model for p_i^m is satisfactory because its correlation coefficient is high and the hypothesis H_0: the regression coefficient is equal to 1.0 is not rejected statistically. On the other hand, X_i^m tends to be

Table 1. Example of the Estimation Results for Production Functions

	Output sectors (*n*) / Input sectors (*m*)	Mining	Manufacture			Wholesale		Warehouse	Retail
			Ceramics	Steel	Transpn. Machinery	Textiles	Chemicals		
	1 Agriculture	0.00E+00	1.99E-03	6.12E-06	3.23E-04	0.00E+00	0.00E+00	0.00E+00	3.14E-05
	2 Mining	5.30E-01	4.39E-01	4.12E-02	2.61E-04	0.00E+00	0.00E+00	0.00E+00	2.07E-03
Manufacture	3 Foods	0.00E+00	1.15E-06	2.38E-07	9.17E-05	0.00E+00	0.00E+00	1.16E-02	9.65E-02
	4 Fabrics	0.00E+00	0.00E+00	2.49E-07	4.56E-04	3.97E-01	2.99E-01	2.41E-03	8.55E-03
	5 Woods	0.00E+00	4.65E-06	9.13E-06	7.30E-05	4.51E-08	2.12E-04	9.82E-05	8.00E-03
	6 Paper, Pulp	2.66E-06	7.47E-06	3.51E-05	5.93E-03	2.14E-04	4.64E-03	2.93E-03	1.45E-02
	7 Chemicals	1.37E-02	4.11E-04	1.70E-02	2.48E-04	3.15E-03	1.33E-05	1.46E-01	1.09E-02
	8 Plastic products	3.31E-06	1.07E-05	7.77E-06	4.86E-03	4.83E-02	8.37E-02	1.97E-02	6.25E-03
	9 Ceramics	2.67E-03	2.68E-01	3.03E-02	1.48E-02	1.86E-06	0.00E+00	1.92E-02	1.28E-02
	10 Steel	1.50E-04	2.98E-05	1.71E-01	1.97E-02	0.00E+00	0.00E+00	4.82E-03	6.33E-07
	11 Non-ferrous	4.22E-04	2.05E-04	9.32E-04	3.59E-02	0.00E+00	0.00E+00	4.88E-05	4.69E-05
	12 Metal products	0.00E+00	7.11E-04	1.66E-02	9.38E-03	3.61E-06	0.00E+00	4.29E-05	3.35E-04
	13 Machinery	8.11E-04	2.95E-04	5.69E-02	3.02E-02	0.00E+00	2.28E-06	1.82E-03	1.15E-03
	14 Elect. Machinery	1.70E-06	8.61E-06	2.55E-04	2.17E-02	8.52E-08	1.12E-04	5.64E-03	1.47E-03
	15 Transpn. Machinery	0.00E+00	3.95E-05	8.80E-03	7.85E-01	1.52E-07	1.75E-06	9.07E-02	9.09E-03
	16 Precis. Machinery	4.01E-07	4.75E-06	3.17E-05	5.25E-03	1.92E-04	9.99E-03	1.36E-04	7.30E-03
	17 Textiles	0.00E+00	0.00E+00	0.00E+00	1.63E-08	4.63E-01	6.64E-02	1.33E-03	1.06E-02
Wholesale	18 Chemicals	8.87E-07	1.14E-04	1.07E-03	3.88E-03	1.20E-04	8.39E-04	1.07E-05	3.14E-02
	19 Metal, Mining	1.32E-02	3.02E-04	5.81E-01	8.24E-03	1.02E-05	0.00E+00	7.80E-05	1.07E-01
	20 Apparel	0.00E+00	0.00E+00	1.31E-07	1.15E-07	5.36E-02	4.69E-01	1.06E-04	5.35E-02
	21 Farm Products	0.00E+00	0.00E+00	1.66E-06	8.67E-09	0.00E+00	0.00E+00	0.00E+00	7.84E-02
	22 Foods	0.00E+00	0.00E+00	4.40E-09	0.00E+00	0.00E+00	1.24E-03	1.57E-05	9.34E-02
	23 Furniture	0.00E+00	7.38E-04	2.25E-06	9.81E-08	1.13E-03	6.39E-04	4.87E-03	5.69E-02
	24 Other	0.00E+00	9.95E-05	3.53E-04	7.59E-03	1.08E-02	1.82E-02	5.57E-05	3.10E-01
	25 Warehouse	5.15E-07	9.95E-06	1.92E-04	1.74E-04	7.62E-04	3.29E-04	2.05E-04	4.05E-04
	26 Retail	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.40E-03
	27 Household	4.39E-01	2.88E-01	7.46E-02	4.58E-02	2.10E-02	4.56E-02	6.88E-01	7.52E-02

Table 2. Example of Estimation Results for Inter-regional Coefficients Models

Sector (*n*) / Variables		Agriculture	Mining	Manufacture			Wholesale		Warehouse
				Ceramics	Steel	Transpn. Machinery	Textiles	Chemicals	
Constant		-1.711 (-3.759)	-3.479 (-1.609)	-2.445 (-2.22)		-0.927 (-2.909)		-1.661 (-1.705)	-4.925 (-5.087)
Production Price	$(-\lambda_M)$	-0.877 (-2.627)	-4.871 (-0.359)	-1.475 (-1.106)	-0.697 (-2.798)	-0.015 (-1.090)	-0.005 (-1.971)	-0.008 (-1.502)	-8.137 (-2.296)
Transportation Cost	$(-\lambda_M \mu_M)$	-0.507 (-4.413)	-4.521 (-3.310)	-0.910 (-1.725)	-1.595 (-6.191)	-1.440 (-3.076)	-1.697 (-6.284)	-1.427 (-5.882)	-1.071 (-4.204)
Transportation Time	$(-\lambda_M \omega_M)$		0.115 (1.881)	-0.055 (-1.705)		-0.034 (-1.185)			
Zone Potential	(δ_M)	0.881 (3.848)	1.123 (1.204)	1.215 (1.702)		0.726 (2.495)	1.317 (3.213)	1.717 (4.462)	1.657 (1.858)
Zone Dummy	Region-1	0.050 (0.085)	1.738 (0.524)	-0.256 (-0.174)	-3.336 (-2.933)	0.601 (0.629)	0.979 (0.678)	-1.532 (-1.170)	0.988 (0.831)
	Region-2	-0.179 (-0.306)	-0.894 (-0.325)	-0.241 (-0.174)	-3.545 (-2.933)		-0.699 (-0.594)	-1.154 (-0.853)	2.410 (2.076)
	Region-3	0.811 (1.525)	4.210 (1.512)	2.880 (2.266)	-2.083 (-2.169)	0.857 (0.825)		2.462 (1.866)	2.633 (1.844)
	Region-4	-0.416 (-0.500)	1.417 (0.504)	0.890 (0.577)	-2.731 (-2.640)	-1.217 (-1.297)	-1.734 (-1.664)	0.874 (0.780)	2.195 (1.862)
	Region-5	0.733 (1.272)	2.520 (0.899)	1.998 (1.308)	-2.322 (-2.425)	0.659 (0.739)	-1.611 (-1.343)	1.809 (1.367)	2.045 (1.607)
	Region-6	-0.335 (-0.574)	1.406 (0.548)	0.710 (0.553)	-2.653 (-2.602)	-0.719 (-0.828)		0.549 (0.440)	2.986 (2.174)
	Region-7	-0.478 (-0.845)	0.835 (0.302)	-0.897 (-0.620)	-3.273 (-3.247)		-3.203 (-2.733)	-2.012 (-1.677)	0.652 (0.542)
F-Value		5.778	1.842	6.101	32.483	7.656	15.081	8.638	4.221
Multi-Correlation		0.722	0.629	0.757	0.920	0.778	0.853	0.793	0.666

underestimated because the Cobb-Douglas production function, which is homogeneous of degree one, lowers the reliability of regional input coefficients. Overall, however, it seems that the validity of this model is satisfactory. These empirical results are sufficiently encouraging to apply the model to practical inter-regional trade demand forecasting.

Table 3. Estimation Results for Utility Function of Household

Variables	Parameter
Composite goods (α_1)	0.667
Land service (α_2)	0.333
Σ	1.0

Table 4. Estimation Results for Land price Function

Variables	Parameters (t-value)
Constant	4.181 (5.13)
X_i^M / K_i^{M+1}	-0.0391 (6.20)
$p_i^M X_i^M / K_i^{M+1}$	0.0000199 (12.4)
Multi-correlation	0.99

Table 5. Goodness-of-Fit on Total Test

	Evaluation Indices	
Total Output (X_i^m)	Correlations Coefficient Regression Coefficient (t-value)	0.80 0.243 (21.9)
Production price (p_i^m)	Correlations Coefficient Regression Coefficient (t-value)	0.99 0.998 (283.)

5. CASE STUDY FOR MOTORWAY IMPROVEMENT PROJECTS

We applied our model to a case study on two alternative motorway improvement policies shown in Figure 5. First policy is to improve the motorway connecting Tokyo and Osaka metropolitan areas, where are the biggest and second biggest cities, by way of Nagaya. This policy means that the investment will be done into the accessibility improvement between two metropolitan areas. Second policy is to improve the motorway between rural area and these two metropolitan areas. This policy encourages the decentralization. We assume that these improvements can reduce the time length of transportation between all pairs of zones by 10% and 20%.

Figure 6 shows the economic benefit by region evaluated by the equivalent variation against both motorway improvement policies. The amount of the equivalent variation per household is calculated by following equation that is consistent with its utility functional form:

$$EV_j = \left(\frac{c_j^{mN}}{\hat{c}_j^{mN}}\right)^{\alpha_1} \left(\frac{c_j^{M+1N}}{\hat{c}_j^{M+1N}}\right)^{\alpha_2} \hat{p}_j^N - p_j^N \tag{30}$$

where ^ of variables means the symbol for the values after projects. We find that

1) For the both policies, benefit of Kanto and Kansai regions, where includes Tokyo and

Osaka metropolitan areas, respectively, increases.

2) The benefit of regions where place on the way of improved motorway tends to decrease.
3) The total amount of benefit from second policy is bigger than that from first one. Then the decentralization policy seems to be maintained only from the viewpoint of economic benefits.

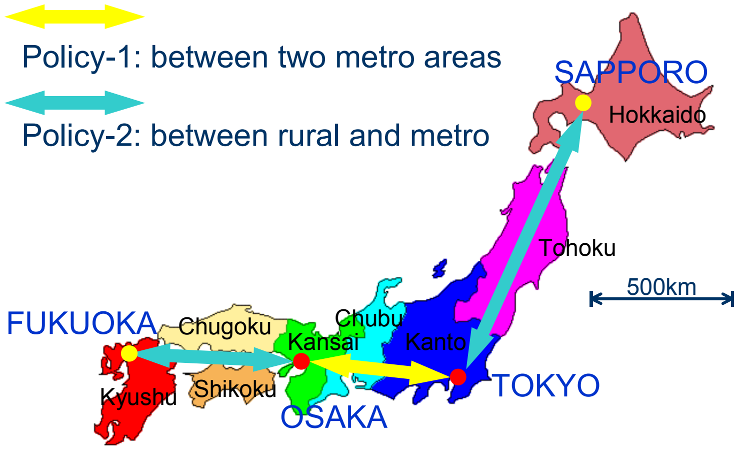
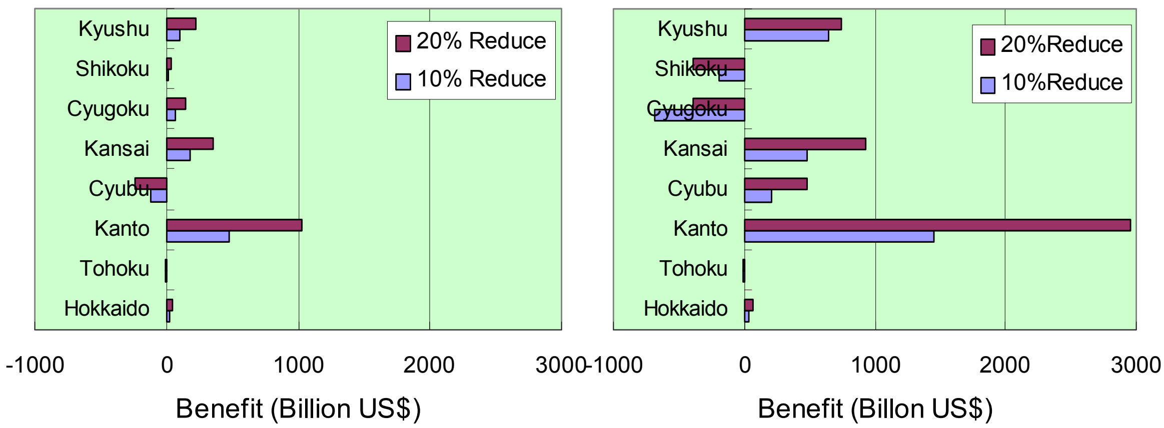


Figure 5. Alternative motorway improvement policies



(a) Policy-1 (b) Policy-2

Figure 6. Economic benefit for motorway improvement

6. CONCLUDING REMARKS

This model seems to be useful in predicting inter-regional freight demands in conditions of semi-open and middle-term equilibrium, that is to say, 1) the final demand except for the household consumption is given by another econometric model exogenously and 2) it permits change in residential location and differences in production prices and wage rate by zone. The traditional simple models of transportation demand and land use forecasting originated from the analogy of results of other research fields. The most recent models, which combine behavioral analysis and the equilibrium theory, have undergone improvements. It is certain that practical inter-regional freight demand forecasting models must trace such a path. In this sense, the model presented in this study may come to mark the first step in this direction. This model, however, can only provide tentative theoretical and practical conclusions. From a theoretical aspect, we must make it consistent with the economic theory on the behavior of firm and general equilibrium analysis in great detail. From a practical point of view, it is necessary to raise the reliability of our model by improving the database system and individual partial models. Finally, we have to carry out the feasibility analysis for the intercity highway construction projects that may change patterns of inter-regional freight flow on a great scale as far as we evaluate its availability.

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