TOPIC 10
FREIGHT AND LOGISTICS

AN INTER-REGIONAL TRADE MODEL CONSIDERING I/O FRAME AND PRICE EQUILIBRIUM

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Abstract

A development of the demands forecasting method for interregional trade has become one of the important subjects in not only urban land-use and transportation planning but also environment management. In practice, the same forecasting process has been applied correspondingly to traditional interregional trade demands as well as to person trip demands.

INTRODUCTION

Interregional trade is a series of 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 a manufactured goods is made of the intermediate products which is in turn, shipped to wholesalers or retailers, by whom, it is finally distributed to households. Interregional trade differs from a person's trip, ie transportation of people (travel). 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 in 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 demand forecasting model should essentially be based upon an analysis 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 location. Particularly, when there is a business transaction between two regions due to the differentials in price of the same goods in two regions, it is significant to employ the above-mentioned framework in the demand forecasting model.

As an attempt to express the essential characteristics of interregional trade mentioned above, we propose a demand forecasting model based on the analytical frameworks of regional interindustry 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 a model.

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 equations and solve them for 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, Brocker 1988; Batten et al. 1985). Recently, this model was integrated into the network equilibrium models by considering a traffic system such as transportation facilities and traffic networks 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 interregional freight demand itself. We will keep a detailed review and prospects in the field for another occasion (see, for example, Harker 1988; Batten 1992).

In our study,

1. we treat output, price and interregional trade pattern as the variables. At the same time, the model is based upon the framework of general equilibrium analysis, in which all the variables are interdependent with each other among all industries and that the supply and demand of each product are in equilibrium, and
2. we will try to develop a practical demand forecasting method which utilizes the statistical data and the survey data of net freight flows that are usually inadequate in reliability but which can directly measure the amount of nation-wide interregional trade, and therefore,
3. in building models, we emphasized the practicality of a model for relevant sectors, by considering the reliability of usable data and the applicability of the model.

Thus, we will propose a new demand forecasting model for interregional trade, putting an emphasis on its applicability and taking economic theories into account.

To satisfy the first objective of our study, we build a demand forecasting model of interregional and interindustry trade in order to find equilibrium values of the prices of products and the amount of shipments, assumed to be equal to the total output of all industries in a market, by employing the analytical framework of the interregional interindustry linkage model. The framework of Chenery-Mosesian form of interregional and interindustry 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. The prices are usually given and the input coefficients are normally fixed in interregional and interindustry linkage models. Our model has the distinct characteristic in its structure that it gives the equilibrium values of the total output and prices under conditions of a perfect competition. As the production price changes the price of raw materials, the optimum level of inputs will change as a result of rational production behavior in the industries, and this in turn it changes the input coefficients (see Figure 1a). At the same time, as interregional trade coefficients change, the total amount of demand will be determined (see Figure 1b). Under these situations, the production prices are adjusted such that profits in all industries are equal to zero, and the supply and the demand are met according to the framework of the interindustry linkage model. Thus, the market is in equilibrium. Finally, we find the quantities demanded in the final use and the production prices at the origin of production through the equilibrium mechanism. 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 in interregional trade. In investigating the amount of interregional trade among all industries in Japan, we can use data of the national survey of net flow of freight. However, in order to apply the analytical framework of the interregional and interindustry linkage model to demand forecasting in interregional trade, it is necessary for us to classify the types of industries and the areas of regions. The national survey of the net flow of freight is not sufficient in specifying a model, since it is not clear how much and where industries with large seasonal fluctuations in shipments send their products. Thus, we attempt to make a database for the estimation of the model by modifying existing statistical data to fit the model. Finally, to satisfy the second and the third objectives of our study, we specify a part of the model using 1985 data and run the model to test reliability of the whole model.

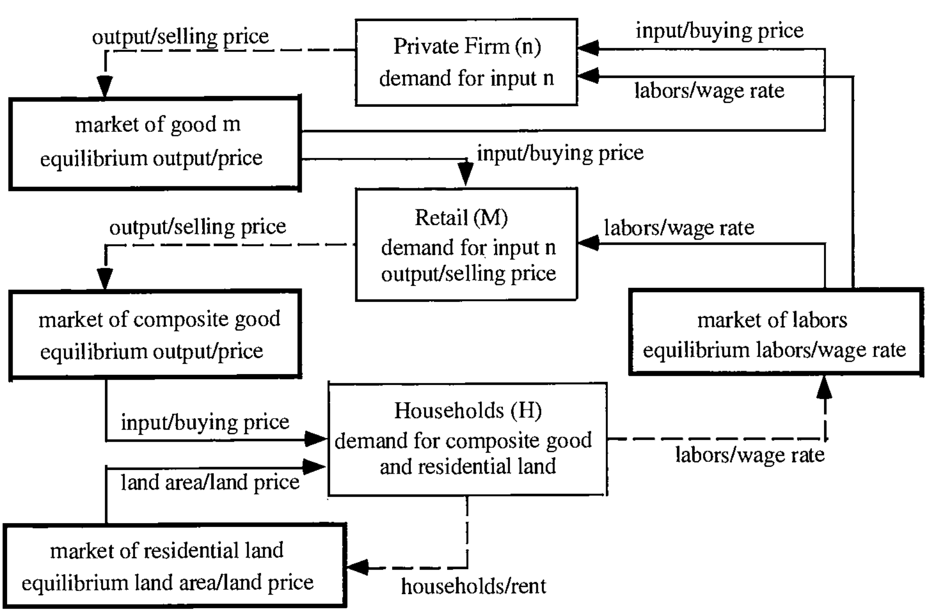

Figure 1a General equilibrium framework

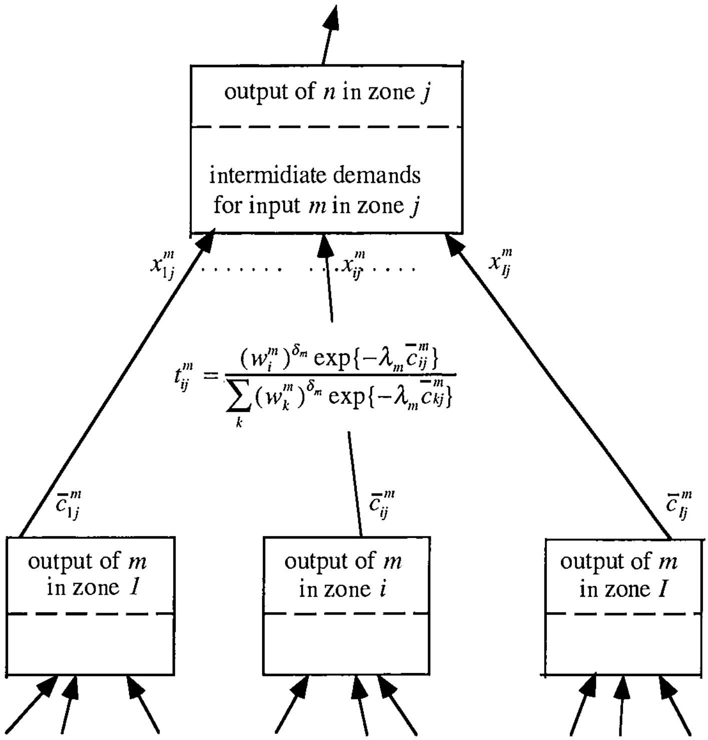

Figure 1b Concept of inter-regional and inter-industry

MODEL FOR INTERREGIONAL TRADE AND INTERINDUSTRY LINKAGE

The structure of the model

The structure of the model is in Figure 2. First, we will explain the mechanism to reach an equilibrium of production prices and the total amount of shipments among industries, and calculation method of the equilibrium values will be discussed in the next section. The superscripts m (m=1,...,M+1) and n (n=1,...,M) denote a shipping industry and a receiving industry, respectively, and the subscripts i (i=1,...,I) and j (j=1,...,I) denote a shipping zone and a receiving zone, respectively. Labor calculated in terms of an additional worth is expressed as m = M + 1. At the same time, we assume that each industry produces only one product.

1. The behavior of an industry and the optimum amount of inputs

There are the studies using the Gravity-type model in which people try to build a model concerning the behavior of an industry, provided that each industry takes the optimum strategy, ie determines the amount of output and inputs simultaneously. But, in our model, the pattern of trade is statistically determined by the logit-type inter-regional trade coefficient model, and successively the optimum amount of intermediate products is decisively determined by the profit-maximization behavior of businesses at their factories.

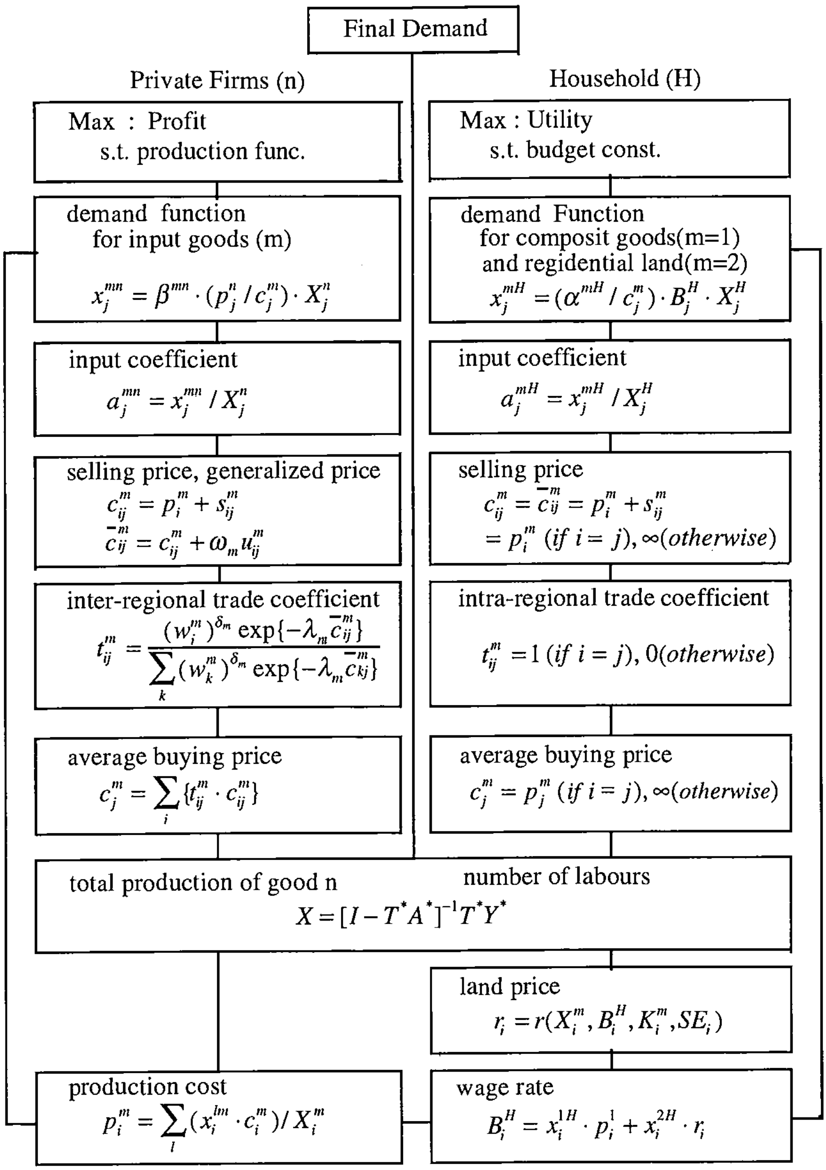

Figure 2 Model structure

Given that the production price, $p = \{p_j^n\}$ and the input price $c = \{c_j^m\}$, the nth industry determines the optimum amount of intermediate product from the mth industry, $\{x_j^{mn}\}$, and the amount of labor input, $x_j^{M+1,n}$ under the assumption that it produces the total output, $X = \{X_j^n\}$ at the equilibrium. Assuming that a Cobb-Douglas production function and a linear cost function, we can set up the following optimization problem:

$$\max_{x_j^{mn}}: \pi_j^n = p_j^n X_j^n - \sum_m x_j^{mn} \cdot c_j^m \qquad (1)$$

$$\text{s.t. } \beta^{0m} \prod_m \left(x_j^{mn}\right)^{\beta^{mn}} = X_j^n \tag{2}$$

$$(\text{assuming that } \sum_m \beta^{mn} = 1 \text{).}$$

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

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

We used the Cobb-Douglas production function that is homogeneous of degree one, however in order to increase the adaptability of the model, it is advisable to use a CES (Constant Elasticity of Substitution) production function or a Trans-log production function. If we employ a CES or a Trans-log production function, the following calculations will be different accordingly.

2. Regional input coefficient

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 interregional input coefficient in the Chenery-Mosesian interregional and interindustry linkage table.

3. Sale price and generalized sale price

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 cost, 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, and the time length of transportation, can be written as:

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

where ω_m is a value conversion parameter.

4. Interregional trade coefficients

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 mth intermediate product by the nth 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 a logit model. The ratio, t_{ij}^m of the amount of intermediate product received from the ith zone to the total amount of intermediate product received by the mth industry in the jth zone is represented as a utility function of the generalized sale price c_{ij}^m and a zone potential unique to the ith zone, w_i^m which can be obtained by aggregating small zones such that:

$$t_{ij}^{m} = \frac{(w_i^m)^{\delta_m} \exp\left\{-\lambda_m c_{ij}^{-m}\right\}}{\sum_k (w_k^m)^{\delta_m} \exp\left\{-\lambda_m c_{kj}^{-m}\right\}} \tag{7}$$

This value is considered to be the interregional trade coefficient of the Chenery-Mosesian interregional and interindustry linkage model.

5. Average purchasing price

The average purchasing price of the mth product in the jth 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 as follows:

$$c_j^m = \sum_i \left\{t_{ij}^m \cdot c_{ij}{}^m\right\} \tag{8}$$

6. The total output

The column vector, $Y_j = \left(Y_j^1, \cdots, Y_j^m, \cdots, Y_j^M\right)^t$ consists of the final demand 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, Y^*. Given that $X_i = \left(X_i^1, \cdots, X_i^m, \cdots, X_i^M\right)^t$, the column vector of the total output by zone and industry is $X = (X_1, \cdots, X_i, \cdots, X_I)^t$. And it can be obtained by

$$X = \left[I - T^* A^*\right]^{-1} T^* Y^* \tag{9}$$

A^* is a diagonal matrix of interregional input coefficients and its jth diagonal element is a matrix consisting of $\{a_j^{mn}\}$ given in the equation (4). T^* is a matrix of interregional trade coefficients and its (i, j) element is a diagonal matrix consisting of $\{t_{ij}^m\}$ in the equation (7).

7. The determination of production price

At the equilibrium under the perfect competition, the profit of all firms in the jth industry at the ith producing region is equal to zero. Thus, the price, p_i^m is determined such that

$$p_i^m = \sum_l \left(x_i^{lm} \cdot c_i{}^l\right) / X_i^m \tag{10}$$

In the price determination model (10) that is the dual problem of the output determination model (9), it is reasonable that we find equilibrium prices by solving a system of equations that is explained later, I * M, given the wage rate, c_i^{M+1} exogenously or that we find the relative prices by normalizing a price of an arbitrary product.

8. The inter-regional and inter-industrial trade flows

In consequence, we find that the inter-regional and inter-industrial trade flows x_{ij}^{mn} can be obtained such that

$$x_{ij}^{mn} = a_j^{mn} \cdot X_j{}^n \cdot t_{ij}{}^m \tag{11}$$

The calculation process of the equilibrium values

In the previous section, in order to build the model, we treat the production price, p_i^m (and the input price, c_j^m which is a function of p_i^m) as given. However, in reality, we should treat p_i^m as a variable which is simultaneously determined together with the total amount of output, X_i^m. In order to determine p_i^m endogeneously, we first determine the temporary equilibrium values of p_i^m and X_i^m by reiterate calculation of 3) through 7), and then we determine the true equilibrium values by reiterate calculation of 1) through 7). We explain a simple method of calculation by which we determine only the values of p_i^m by fixing the values of X_i^m in reiterate calculation, and then we revise the values of X_i^m .

We put the superscripts on the values of all variables obtained by the kth reiterate calculation, then we obtain the following equation for $X_i^{m(k)}$ from the equation (10):

$$p_i^{m(k)} = \sum_l \left(x_i^{lm(k)} \cdot c_i^{\,l(k)}\right) / X_i^{m(k)} \tag{12}$$

The unknown values are $p_i^{m(k)}$and $c_i^{m(k)}$, but from the equation (5) and the equation (8) we obtain:

$$c_i^{l(k)} = \sum_r \left\{\text{Prob}\left[x_{ri}^{l(k)}\right] \cdot \left(p_r^{l(k)} + s_{ri}^{l}\right)\right\} \tag{13}$$

Thus, only $p_i^{m(k)}$ is unknown. By substituting the equation (13) into the equation (12), we obtain:

$$p_i^{m(k)} = \cdot \sum_l \left[x_i^{lm(k)} \cdot \sum_r \left\{\text{Prob}\left[x_{ri}^{l(k)}\right] \cdot \left(p_r^{l(k)} + s_{ri}^{l}\right)\right\}\right] / X_i^{m(k)} \tag{14}$$

As the equation (12) is linear, we can solve the equation (14) easily, since it is a system of linear equations, I*M in which only $p_i^{m(k)}$ (m=1, ...,M, i=1,...,I) is unknown. Another way of obtaining the values is to solve the equation (12) and the equation (13) for $X_i^{m(k)}$ alternatively until the value of $p_i^{m(k)}$ converges. By performing the above-mentioned procedures in the convergence calculation of 1) through 7), we obtain the equilibrium values of the amount of output, X_i^m and the production price, p_i^m of the mth product in the ith region.

It is difficult to prove the existence of the equilibrium values analytically. However, it is intuitively reasonable to assume that the values converge, since the process of finding the value of p_i^m by fixing the value of X_i^m is the same process as that in the price determination model in the interindustry linkage analysis and the process of finding the value of X_i^m by fixing the value of p_i^m is equivalent to that in the output determination model.

DATA COLLECTION AND MODEL ESTIMATION

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 input-output table prepared by the Ministry of International Trade and Industry, which uses the volume of trade of inputs as a source of data, instead of the physical amount of inputs. 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 would be better to use original data so that data are consistent and contain fewer statistical errors. This national survey of net flow of freight started in 1970 and has been carried out every five years. While number of observations are 33,002 which cover only 3.5% of all establishments, their total weight of 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 60 sectors. The retail sector is assumed to ship nothing and to only receive goods from other intermediate sectors. Then the I/O frameworkof this model results in a kind of open type model as shown in Figure 3. The basic spatial unit of regions is a prefecture.

	intermediate sectors					final demand		export	output
	1 2	3 16	17 24	25	26	27	28	29	
1 agriculture 2 mining						0			X_i^1 X_i^2
3 manufacture 16						0			X_i^3 X_i^{16}
17 wholesale 24						0			X_i^{17} X_i^{24}
25 warehouse									X_i^{25}
26 retail	0	0	0	0			0	0	X_i^{26}

Figure 3 I/O Framework of the model

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 linkage 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 ;

$$X_j^n = \left(\sum_i \sum_m X_i^m\right) \cdot \left(\sum_i \sum_m f_{ij}^{mn} / \sum_i \sum_j \sum_m \sum_n f_{ij}^{mn}\right) \tag{15}$$

In estimating some partial models which will be represented in the next section, x_{ij}^{mn} is a basic data-set. The other kinds of data-sets are prepared according to the procedure as shown in Figure 4. In our empirical study, intermediate products were reclassified into 26 sectors and labor in terms of an additional worth is ignored for the reasons mentioned above. There are nine regions.

Model estimation

The partial models which we should estimate in advance are

1. Inter-regional trade coefficients model,
2. Production function, and
3. Production price function.

1. Inter-regional trade coefficients model

The inter-regional trade coefficients model is a kind of aggregated logit type model expressed as equation (7). s_{ij}^m is observed by monetary term from the transport tariff table. Since we can not observe p_i^m from the market, we set p_i^m as a normative term calculated as (a total amount of output from the SNA) / (a total amount of shipping from the annual survey). We rewrite equation (5) using a transfer parameter μ_m as follows:

$$c_{ij}^m = p_i^m + \mu_m \cdot s_{ij}{}^m \qquad (16)$$

and estimate μ_m and other parameters λ_m, ω_m, δ_m of equation (5) simultaneously.

2. Production function

It is general practice to estimate β^{mn} (m=1,....,M) of the production function (2) using x_j^{mn} and X_j^n. However, the number of parameter M (=26) is larger than the number of zone J (=9). We estimate β^{mn} of the demand function (3) by individual industry which satisfies the constraint $\Sigma\beta^{mn}$=1 by using the non-linear least square method.

3. Production price function

We do not introduce the labor into the I/O framework and we employ the method that we estimate the equilibrium production prices by the production price determination model (17) that is specified by data beforehand and is written as,

$$p_i^m = r\left[\sum_{1}^{M} \left(x_i^{lm} \cdot c_i{}^l\right) / X_i^m,\ X_i{}^m / K_i^m\right] \qquad (17)$$

In the above equation, K_i^m is the amount of inputs like labors, and the equilibrium price is determined by a function of the relative ratio of K_i^m to the total amount of demand X_i^m, and production cost.

The reasons for using the production price determination model (11) are as follows: (a) In order to estimate the parameters in the production function and the interregional trade coefficient model as we mention later, we need the actual values for all prices of all the products, and (b) the production prices depend on not only wage rates but also the prices of the other inputs such as land, but we do not include these variables in our interindustry linkage model, and (c) it is expected that there will be a difference between the actual data for the prices used in a part of our model and the equilibrium prices determined by the price determination model because of (a) and (b), and (d) we will investigate the efficiency of the method that determines the amount of employment and the wage rate simultaneously by including the household in the model, and (e) since the production price determination model (11) is a function of production costs, the total amount of demand, and the amount of inputs, it is reasonably sound as a method of equilibrium price determination in terms of economics.

It is difficult to determine the real value of the average purchasing price c_i^m from the market. Therefore, c_{ij}^m is calculated from equation (17) and an estimated value is used which is obtained by substituting c_{ij}^m for equation (8) in place of c_i^m. A regression analysis is carried out using c_i^m, $X_i^m$and K_i^m.

The estimation results of the inter-regional trade coefficients model are shown in Table 1. It gives only the estimated values for the coefficients which are significant statistically, and their t-ratios. The signs are not illogical and "transportation cost" and "zone potential" are significant, in particular, for all sectors. The F-value and the multiple correlation are fairly high for all sectors, thus we obtain the statistically reliable inter-regional

X_i^m: Y = 0.5111X + 84278 (R-value=0.73, F-value= 270.1),

p_i^m: Y = 1.0342X + 0.5524 (R-value=0.92, F-value=1321.7).

It is not too much to say that the fit of the model for p_i^m is satisfactory because its R-value and F-value are high and the hypothesis H_0: the parameter of X is equal to 1.0 is not rejected statistically. On the other hand, X_i^m tends to be underpredicted 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 1 Estimation results for inter-regional coefficients models

Sector	Agriculture	Mining	Foods	Manuf. non-steel	Textiles	Chemicals	Warehouse	Retail
constant	-0.225	-0.124	-2.782	0.375	-3.064	0.863	-3.185	-2.899
production	-4.296	-151.383	-6.176	-7.218	-0.004	-0.422	-89.142	-0.002
price	(2.67)	(1.98)	(0.75)	(2.17)	(2.94)	(2.36)	(0.69)	(0.37)
transportation	-0.622	-2.099	-1.326	-0.786	-1.480	-2.814	-1.458	-1.521
cost	(4.81)	(7.79)	(16.02)	(3.12)	(7.91)	(7.95)	(12.17)	(7.73)
transportation				-0.895	-0.024	-1.970	-0.121	
time				(2.32)	(0.10)	(1.26)	(0.76)	
zone potential	1.245	0.386	1.642	0.646	1.232	2.944	0.715	0.501
	(6.01)	(1.03)	(8.12)	(2.01)	(4.00)	(3.63)	(5.35)	(1.05)
F-value	12.02	14.12	75.02	29.42	16.42	23.88	68.60	13.35
multi-correlation	0.835	0.895	0.965	0.937	0.904	0.949	0.965	0.874

Table 2 Estimation results for production functions

Sector	Agriculture	Mining	Foods	Manuf. nonferrous	Textiles	Chemicals	Warehouse	Retail
Input sector								
1.agriculture	6.22E-02	2.45E-02	5.92E-02	1.34E-02	3.90E-03	1.20E-01	3.67E-02	6.48E-04
2.mining	8.44E-05	2.76E-01	2.80E-04	7.51E-03		1.30E-15		1.09E-03
3.foods	2.29E-01	8.16E-04	4.28E-01	1.30E-04	3.23E-07	1.34E-02	8.64E-02	1.16E-02
4.textiles	9.53E-04	1.58E-03	4.45E-04	4.67E-03	1.68E-02	2.30E-03	2.25E-02	2.87E-03
5.woods	2.54E-02	7.70E-04	6.75E-04	7.47E-03	4.58E-07	1.57E-03	5.57E-03	1.33E-03
6.paper,pulp	3.79E-02	3.00E-03	4.93E-02	6.36E-03	2.32E-05	9.57E-04	1.19E-02	4.11E-03
7.chemicals	2.44E-02	5.72E-03	2.84E-02	1.85E-02	1.13E-04	2.87E-01	3.76E-02	1.10E-03
8.plastic prod.	1.49E-02	9.71E-04	1.28E-02	2.49E-03	1.02E-04	4.09E-02	2.80E-02	1.14E-03
9.ceramics	8.33E-03	4.92E-01	2.60E-02	9.08E-02	3.06E-06	6.97E-02	7.02E-02	3.05E-03
10.steel	1.89E-03	9.82E-04	1.83E-04	1.64E-02		1.10E-04	6.79E-03	1.55E-04
11.non-ferrous		4.61E-03	1.76E-03	4.49E-01		6.40E-03	1.99E-02	1.20E-04
12.metal prod.	8.58E-04	7.30E-02	4.36E-02	4.83E-02	1.06E-07	1.00E-03	4.66E-03	2.28E-03
13.machinery	1.03E-02	1.16E-02	2.48E-02	2.80E-02	1.88E-05	5.18E-03	2.10E-02	1.59E-03
14.elect.mach.	1.53E-03	5.14E-03	4.88E-03	5.92E-02	2.25E-03	4.46E-03	4.41E-01	1.53E-02
15.transp. mach.	1.11E-03	7.49E-03	1.64E-04	1.05E-02		4.67E-04	3.65E-02	6.34E-03
16.precis. mach.	1.51E-02	8.16E-04	4.57E-02	3.04E-03	1.79E-03	5.62E-02	3.77E-02	8.83E-03
17.textiles			1.86E-08		8.04E-01	1.30E-15		2.60E-01
18.chemicals	5.45E-02	6.42E-03	9.29E-03	1.61E-01	1.67E-03	3.67E-01	1.42E-05	4.89E-03
19.metal,mining	1.51E-02	8.63E-02	8.67E-02	7.03E-02	1.97E-05	1.72E-02	3.95E-03	6.02E-02
20.apparel			4.91E-04		1.63E-01	2.66E-04		4.07E-01
21.farm products	7.03E-02		7.08E-02	3.58E-19	2.29E-06	1.30E-15	1.42E-05	4.53E-02
22.foods	2.60E-02	8.16E-04	3.87E-02		1.03E-06			5.59E-02
23.furniture	7.52E-09		6.83E-04		1.01E-04	6.63E-04		1.50E-02
24.other	3.38E-01	1.12E-03	3.97E-02	1.62E-03	1.82E-04	1.18E-02	2.24E-02	5.11E-02
25.warehouse	8.68E-04	5.00E-04	1.74E-02	1.79E-03	3.34E-05	7.89E-04	2.26E-02	2.93E-04
26.retail		8.16E-04	1.12E-02		6.27E-03	9.36E-03	8.96E-02	3.93E-02

Table 3 Estimation results for production price functions

Sector	Function. type	Constant	$\sum x_i^{lm} \cdot c_i^l$	x_i^m/K_i^m	K_i^m	R	F
1.agriculture	2	0.493E+00	0.287E-01	-0.133E+00		0.79	5.1
2.mining	1	0.236E+00	0.161E+01	-0.181E-06		0.87	9.1
3.foods	4	0.212E+01	0.251E-01	-0.279E-01	0.760E-02	0.42	0.3
4.textiles	3	0.182E+01	0.695E-03	-0.264E-01	-0.729E-01	0.90	7.4
5.woods	1	0.162E+00	0.961E-01	-0.545E-03		0.95	25.3
6.paper, pulp	2	0.772E+00	0.462E-01	-0.127E+00		0.96	34.6
7.chemicals	3	-0.174E+00	0.135E+00	-0.171E-03	0.351E-01	0.97	33.7
8.plastic prod.	3	0.609E+00	-0.377E-01	-0.845E-02	0.233E-01	0.86	4.8
9.ceramics	2	0.690E-01	0.151E+00	-0.819E-02		0.92	16.0
10.steel	3	0.246E-01	0.180E-01	-0.524E-04	0.781E-02	0.87	5.2
11.non-ferrous	2	0.109E+01	0.526E-01	-0.161E+00		0.99	78.3
12.metal prod.	3	0.321E+00	0.107E-01	-0.276E-02	0.105E-01	0.73	1.9
13.machinery	3	0.159E+00	0.334E-01	-0.175E-01	0.925E-01	0.84	4.0
14.elect. mach.	1	0.304E+00	0.147E-01	-0.983E-01		0.83	6.7
15.transp.mach.	3	-0.565E+00	0.111E+00	-0.419E-03	0.876E-01	0.93	17.8
16.precis. mach.	1	0.239E+01	0.502E-01	-0.123E+00		0.91	14.6
17.textiles	2	0.489E+03	0.331E-01	-0.155E+03		0.87	9.5
18.chemicals	2	0.258E+02	0.659E+00	-0.366E+01		0.92	16.2
19.metal,mining	2	0.961E+01	0.122E+01	-0.955E+00		0.83	6.8
20.apparel	2	0.134E+03	0.169E+00	-0.315E+02		0.91	13.6
21.farm prod.	3	-0.684E+00	0.511E-01	0.258E-04	0.150E+00	0.83	3.8
22.foods	3	-0.465E+00	0.184E+00	0.271E-03	0.606E-01	0.78	2.5
23.furniture	3	-0.383E+00	0.719E-02	0.485E-03	0.190E+00	0.65	1.2
24.other	3	-0.173E+02	0.552E+00	-0.523E-03	0.245E+01	0.74	2.0
25.warehouse	2	0.209E-01	0.834E-01	-0.243E-02		0.83	6.4
26.retail	1	0.324E+03	0.342E-01	-0.201E+03		0.91	15.2

Note

Functional type

1. $p_i^m = r\left[\sum_1^M \left(x_i^{lm} \cdot c_i^{\,l}\right)/X_i^m,\ x_i^m/K_i^m\right]$ 2. $p_i^m = r\left[\sum_1^M \left(x_i^{lm} \cdot c_i^{\,l}\right)/X_i^m,\ x_i^m/K_i^m\right]$

3. $p_i^m = r\left[\sum_1^M \left(x_i^{lm} \cdot c_i^{\,l}\right)/X_i^m,\ \ln\left(x_i^m/K_i^m\right)\right]$ 4. $p_i^m = r\left[\sum_1^M \left(x_i^{lm} \cdot c_i^{\,l}\right)/X_i^m,\ \ln\left(x_i^m/K_i^m\right),\ \ln\left(K_i^m\right)\right]$

CONCLUDING REMARKS

This model seems to be useful in predicting inter-regional freight demands in conditions of open and short-term equilibrium, that is to say, 1) the final demand is given by another econometric model exogenously and 2) there is no change in industrial and residential location. The traditional simple models of transportation demand and land use forecasting originated by analogy from results of other research fields. The most recent models have undergone improvements which combine behavioral analysis and the equilibrium theory. It is certain that practical interregional freight demand forecasting models must be trace such a path. In this sense, the present model 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 aspect, it is necessary to raise the reliability of our model by improving the database system and individual partial models. And finally, we have to carry out the feasibility analysis for the intercity highway construction projects which may change patterns of inter-regional freight flow on a great scale as far as we evaluate its availability.

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