Inter-regional Freight Transport Model based on Spatial Price Equilibrium: Empirical Analysis of Japan

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Abstract: This paper formulates an inter-regional freight transport model based on the spatial price equilibrium and applies it to Japan. This model covers twenty-three types of goods with eleven different regional industrial structures under the economic equilibrium theory. The unknown parameters of the model are calibrated in the iterative computation process. At each iterative process, both of the prices of the consumption regions and the prices of the production regions are revised based on the estimation results the regression analyses for the freight flow data. The estimated model is applied to the inter-regional domestic freight transport of Japan. The national survey data of freight traffic flow of Japan is used for calibration. The good results of calibration are successfully achieved. Finally we simulate the case of Niigata-Chuetsu Earthquake.

Key Words: Freight transport, Spatial price equilibrium model, Inter-regional, Case of Japan

1. INTRODUCTION

To evaluate an investment for freight transport facilities, it is important to estimate the impact and the benefit stemming from the investment. In general, the freight transport system is so complicated that the investment for the freight system may impact various industries and various places. For instance, the improvement of port facilities will change the transport time and cost of maritime transport directly. Then this may increase the freight demand of sea transport while it may decrease the freight demand of the alternative transport mode like rail and road traffic. The change of freight transport may affect the supply of some goods because the manufacturers may change their production plan. Due to the change of supply of goods, the consumer’s demand will also change towards the market equilibrium. This might change the price of goods as well. In addition, as the investment of the specific transport facilities in the network could improve transport patterns connecting to various places, the impact will spread widely via transportation network. Therefore, to understand the mechanism of
investment’s impact, we need to use the comprehensive and consistent methodology which can take account of inter-regional and inter-industrial impacts. As one of these methodologies, an approach of the Spatial Computable General Equilibrium Modeling can be very useful. The Computable General Equilibrium (CGE) modeling has the theoretical background of the Walras-Arrow-Debreu theory of general equilibrium (Broecker, 2004), in which the numerical analysis is possible to simulate the market equilibrium. Because the change of equilibrium can be simulated computationally, recently the CGE has been widely used in the discussion of various economic policies (Shoven, J.B. and J. Whalley, 1992; Hosoe, N, Gasawa, K. and Hashimoto, H., 2004). We will apply the Spatial CGE (SCGE) to the inter-regional trade, which is expanded from the original CGE (the model applied to the inter-regional trade is sometimes referred as ICGE; Buckley, 1992). By applying the SCGE model, we can consider not only that the transportation demand flow will change due to the change of transportation service but also that the local economy will change due to the service change. In addition, we can consider that the change of production and consumption of a local economy impacts the production and consumption of the other local economy.

This paper aims to formulate a spatial computable general equilibrium models for freight transport and applies it to the inter-regional freight transport in Japan. This model covers twenty-three types of goods with the variety of different regional industrial structure under the economic equilibrium theory. The model can analyze the impact of developing transport infrastructure on the freight-transport flow. We formulate the model by modifying and extending the model of Mizokami (1994).

Section 2 provides a formulation of the computable general equilibrium model applied into Japan, Section 3 illustrates the computational method to calibrate the model by using the market dataset. Section 4 presents the data used for the calibration and its process. Then Section 5 shows the example case study in which the developed model is applied to evaluate the damage of Niigata-Chuetsu earthquake. The final section discusses the need for additional improvement of the model.

2. MODEL

2.1. Basic Structure of the Model

First, we divide Japan into regions: \( i = 1, 2, \ldots, J (J = 11) \) shown in Figure 1. Any region has \( M - 1 \) \( M = 24 \) types of industries including the retail industry. The classification of industries used in the model is shown in Table 1. We assume that there exists a unique representative firm for each industry in a region. This means that there are \( M - 1 \) firms in each region. The representative firm in a region will input the products transported from other regions, the products of own region and the labor force of the representative household in order to output the new products. It is assumed that the firms will maximize their profit under the given technical constraints. The freight-transport operators will transport all kinds of goods including original material goods, intermediary goods and consumption goods between different regions. In our model, the freight-transport operators can choose the transportation
modes by maximizing their profits. The goods will circulate from one industry of one region to other industries of other regions in the market. At the end, the final products are transported to the retailers and the retailers will sell the goods to the households. We assume a unique representative household in any region. The representative household will consume the goods by purchasing the consumption goods from retailers whereas it provides the labor force to the firms and the retailers. It is assumed that the households maximize their utilities under the budget constraints.

In this model, the same types of goods can have different prices between at the original region and at the other region, because the transport cost is considered into the consumption price

<table>
<thead>
<tr>
<th>No.</th>
<th>Industry type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mining (Metal, Non-metallic material, Coal, Petroleum, Natural gas)</td>
</tr>
<tr>
<td>2</td>
<td>Food, Beverage, Feed, Tabacco</td>
</tr>
<tr>
<td>3</td>
<td>Textile, Clothes, Fiber product</td>
</tr>
<tr>
<td>4</td>
<td>Woods, Wooden product, Furniture</td>
</tr>
<tr>
<td>5</td>
<td>Pulp, Paper, Paper product, Publication, Printing</td>
</tr>
<tr>
<td>6</td>
<td>Chemical product, oil product, coal product</td>
</tr>
<tr>
<td>7</td>
<td>Plastic product, Rubber product</td>
</tr>
<tr>
<td>8</td>
<td>Ceramics, Soil and stone</td>
</tr>
<tr>
<td>9</td>
<td>Steel, Non-steel materials</td>
</tr>
<tr>
<td>10</td>
<td>Steel products</td>
</tr>
<tr>
<td>11</td>
<td>Machinery products (general machine, electrical machine and transport machine)</td>
</tr>
<tr>
<td>12</td>
<td>Precision machinery product</td>
</tr>
<tr>
<td>13</td>
<td>Other manufacture</td>
</tr>
<tr>
<td>14</td>
<td>Wholesale of Textile, Clothes</td>
</tr>
<tr>
<td>15</td>
<td>Wholesale of agricultural/foodery products and foods/beverages</td>
</tr>
<tr>
<td>16</td>
<td>Wholesale of architectural materials</td>
</tr>
<tr>
<td>17</td>
<td>Wholesale of chemical products</td>
</tr>
<tr>
<td>18</td>
<td>Wholesale of mine/metalic materials</td>
</tr>
<tr>
<td>19</td>
<td>Wholesale of machines</td>
</tr>
<tr>
<td>20</td>
<td>Wholesale of furniture and utensils</td>
</tr>
<tr>
<td>21</td>
<td>Wholesale of medicines and cosmetics</td>
</tr>
<tr>
<td>22</td>
<td>Other wholesales</td>
</tr>
<tr>
<td>23</td>
<td>Warehousing, Warehouses/storages/tank/refrigerator</td>
</tr>
</tbody>
</table>
when the goods produced at one region are input into the economic activities at the other region. As far as the market equilibrium is concerned, two conditions are used based on the Walrasian theorem: one is the weight-based flow equilibrium of goods and the other is the price-based flow equilibrium of goods. The flows of goods in the equilibrium are depicted in Figure 2. The model seems to satisfy the general equilibrium condition. However, strictly speaking, this cannot be the general equilibrium modeling because the model includes the artificial input factors called as the added-value in the production function of the firm which is determined exogenously, discussed later in more details.

2.2. Behavior of firms

A representative firm determines the amount of intermediary inputs by maximizing its profit when the prices of goods and the amount of products from all industries of all regions are given under the market equilibrium. Suppose a vector of production prices of goods is \( p_j^m \) and a vector of consumption prices of goods is \( q_j^m \). Again suppose a vector of the amount of products of all industries and all regions is \( X_j \). Then, the firm of industry \( n \) in the region \( j \) will determine the amount of material inputs \( x_j^{mn} \) from various industries \( m(=1,2,\cdots,M-2) \) and the amount of labor input \( x_j^{Ln} \) from households.

If the Cobb-Douglas type of production function is applied, the behavior of firm can be formulated as follows:
\[
\text{max} : x^n_j = p^n_j X^n_j - \sum_{m=1}^{M} x^m_j q^m_j
\]
\[
s.t. \prod_{m=1}^{M} (x_j^m)^{\beta^m_j} = X^n_j
\]
where \(\sum_m \beta^m_j = 1\)

By solving this constrained maximization problem, the following optimum input can be derived:

\[
x^m_j = \beta^m_j \cdot \left( \frac{p^n_j}{q^n_j} \right) \cdot X^n_j.
\]

In this model, we assume that the amount of inputs needed to produce a unit output of product by the firm \(n\) of region \(j\), that is known as an input index, is constant as \(a^n_j = x^m_j / X^n_j\).

### 2.3. Behavior of freight-transport operators

A freight-transport operator transports the products from one region to a region. This operator is identified as the other industry than \(M - 1\) types of industries. The freight-transport operator chooses a transportation mode from the alternative choice set. As the alternatives of transport modes, three modes are taken into account: surface transport (mainly trucks), air transport and sea transport.

Suppose \(q^n_{i,j,k}\) is the local consumption price of goods \(m\) of the region \(j\), which is produced at the production price \(p^n_i\) in the region \(i\) and is transported from region \(i\) to region \(j\) by the transportation mode \(k\). The local consumption price of goods is formulated as the sum of the production price \(p^n_i\) and the unit transport cost \(s^n_{i,j,k}\), which is shown as:

\[
q^n_{i,j,k} = p^n_i + s^n_{i,j,k}
\]

Then the generalized consumption price \(c^n_{i,j,k}\) is defined as the linear function of the consumption price \(q^n_{i,j,k}\) and the transport time \(u^n_{i,j,k}\).

\[
c^n_{i,j,k} = q^n_{i,j,k} + \omega^m_{i,j,k} = p^n_i + s^n_{i,j,k} + \omega^m_{i,j,k}
\]
where \(\omega^m_{i,j,k}\) means the value of time of goods.

Suppose \(t^n_{i,j,k}\) is the transportation modal share of goods \(m\) of mode \(k\) from region \(i\) to region \(j\), that is,

\[
t^n_{i,j,k} = \frac{x^n_{i,j,k}}{\sum_i \sum_k x^n_{i,j,k}}
\]

The average consumption price of goods \(m\) at the region \(j\) is formulated as:
\[
q^m_j = \sum_k \sum_i t^m_{i,j,k} \cdot q^m_{i,j,k}
\]  

(8).

When transporting the unit amount of goods \( m \) by transportation mode \( k \) from region \( i \) to region \( j \), the profit of freight-transport operators per unit weight (ton) is formulated as:

\[
\pi^{m}_{i,j,k} = q^m_j - c^m_{i,j,k} = q^m_j - \left( p^m_j + s^m_{i,j,k} + \omega^m_{i,j,k} \cdot u^m_{i,j,k} \right)
\]  

(9).

Then, the freight-transport operator chooses both a transportation mode and a destination region simultaneously and discretely by maximizing the unit profit per weight. The probability of choosing the specific alternative is derived from unit profit function with the error term following the i.i.d. Gumbel. This choice is formulated as the two-step nested multinominal logit model consisting of destination choice and transportation modal choice.

When the origin and the destination are given as region \( i \) and \( j \), respectively, the transportation modal share \( t^m_{i,j,k} \) is shown as:

\[
t^m_{i,j,k} = \frac{\exp \left[ \lambda^{m}_{i,j,k} \left( -s_{i,j,k} + \omega_{i,j,k} \cdot \pi^{m}_{i,j,k} / x_{i,j,k} \right) \right]}{\sum_k \exp \left[ \lambda^{m}_{i,j,k} \left( -s_{i,j,k} + \omega_{i,j,k} \cdot \pi^{m}_{i,j,k} / x_{i,j,k} \right) \right]}
\]  

(10)

where \( \lambda^{m}_{i,j,k} \) and \( \omega_{i,j,k} \) are the parameters.

On the other hand, the probability of choosing the destination \( i \), \( u^m_{i,j} \) is shown as

\[
u^m_{i,j} = \frac{\exp \left[ \phi^{m}_{i,j} \left( q^m_j - p^m_j + \Lambda^{m}_{i,j} + \phi^{m} \right) \right]}{\sum_k \exp \left[ \phi^{m}_{i,j} \left( q^m_j - p^m_j + \Lambda^{m}_{i,j} + \phi^{m} \right) \right]}
\]

(11)

where \( \phi^{m}_{i,j} \) is the region-specific factor that means the local attractiveness or the local potential of economic activities of the region \( i \). \( \Lambda^{m}_{i,j} \) means that the expected average maximum profit per unit weight when the freight-transport operator transports the unit amount of goods \( m \) from region \( i \) to region \( j \), which is formulated as:

\[
\Lambda^{m}_{i,j} = \frac{1}{\lambda^{m}_{i,j}} \ln \sum_k \exp \left[ \lambda^{m}_{i,j} \left( -s_{i,j,k} + \omega_{i,j,k} \cdot \pi^{m}_{i,j,k} / x_{i,j,k} \right) \right]
\]  

(12)

Finally the transport share of goods \( m \) of mode \( k \) from region \( i \) to region \( j \) is derived from the following equation:

\[
t^m_{i,j,k} = u^m_{i,j} \cdot t^m_{i,j,k}
\]  

(13).

2.4. Behavior of households

A household of region \( j \) provides the labor force \( x^m_{j,i} \) for the industry \( n=1,2,\cdots,M-1 \) by
the labor price of $q^w_j$, that is equal to the wage rate. Because the households in a region are simplified as the unique representative households, the total labor force in the region $\sum_n x_{jn}^h$ is equal to the total amount of products from households. Then we assume that the representative household consumes only retailer’s products ($m = M - 1$). If the household maximizes its utility under the budget constraint of $q^w_j \sum_n x_{jn}^h$, the household’s utility is maximized when and only when the amount of consumption of retailer’s goods is maximized under the budget constraint. The optimal amount of consumption of retailer’s products is derived as:

$$q^w_j x_{jn}^w - q^w_j (\sum x_{jn}^w)$$

where $q^w_j$ is the average consumption price of retailer’s products. The average consumption price of retailer’s products $q^w_j$ is equal to the production price $p^w_j$ if we assume that the products of retailers are never transported between regions, that means they are always consumed in the same region as the producing region.

### 2.5. Equilibrium conditions

We formulate the equilibrium conditions based on Mizokami (1994) and Mizokami et al. (2003). There are two conditions: one is the weight-based condition and the other is the price-based condition.

#### 2.5.1. Weight-based equilibrium condition

First, suppose $A_j$ is the square matrix whose element $(m,n)$ is defined as $a^w_{jn}$. Then we define $A^*$ as the inter-regional input-index matrix whose $j$-th diagonal block is $A_j$, which is expressed as

$$A^* = \begin{bmatrix} A_1 & O \\ A_2 & \ddots \\ O & A_j \end{bmatrix}$$

Second, suppose $T_{ij}$ is the square matrix whose $m$-th diagonal element is $u^w_{ij}$: the destination share of goods $m$ transported from region $i$ to region $j$. $T_{ij}$ is shown as

$$T_{ij} = \begin{bmatrix} u^1_{ij} & O \\ u^2_{ij} & \ddots \\ O & \ddots \end{bmatrix}$$
Then we define $T^*$ as the inter-regional trade-index matrix whose $(i,j)$ element block is defined as $T_{ij}$, which is expressed as

$$
T^* = \begin{bmatrix}
T_{11} & \cdots & T_{ij} & \cdots & T_{1U} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
T_{11} & \cdots & T_{ij} & \cdots & T_{1U} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
T_{11} & \cdots & T_{ij} & \cdots & T_{1U}
\end{bmatrix}
$$

(17).

Third, suppose $y_j = (y_{j1},\ldots,y_{jn},\ldots,y_{j,M-1})$ is the vector whose element is the final demand $y_{jm}$ of the products of industry $m$ of destination region $j$. Then we define $y^* = (y_{j1},\ldots,y_{jn},\ldots,y_{j,M-1})$ as the final demand vector whose $j$-th line is $y_j = (y_{j1},\ldots,y_{jn},\ldots,y_{j,M-1})$. In the same way, suppose $x_i = (x_{i1},\ldots,x_{in},\ldots,x_{i,M-1})$ is the vector whose element is the final demand $y_{jm}$ of the products of industry $m$ of original region $i$. Then we define $x^* = (x_{i1},\ldots,x_{in},\ldots,x_{i,M-1})$ as the final demand vector whose $j$-th line is $x_i = (x_{i1},\ldots,x_{in},\ldots,x_{i,M-1})$.

Finally, the weight-based equilibrium condition is shown as the following equation:

$$
X^* = [I - T^*A^*]^T Y^*
$$

(18).

### 2.5.2 Price-based equilibrium condition

The firm of region $j$ produces the amount $x_{jn}$ of products $n$ which is sold at the price of $p_{jn}$ by inputting the amount $x_{jm}^m$ of goods $m=1,2,\ldots,M-1$ whose price is $q_{jm}^m$. The value of total products is $p_{jn}x_{jn}$ whereas the value of total cost is $\sum_m q_{jm}^m x_{jm}^m$. Then, the gross profit is shown as follows:

$$
\pi_j^n = p_{jn}x_{jn} - \sum_m q_{jm}^m x_{jm}^m
$$

(19).

If the market satisfies the price-based equilibrium condition, the total profit of all industries should be equal to zero, that is $\pi_j^n = 0$. However, it does not hold true when observing the real market. Therefore, in order to adjust this differences, we introduce a constant new term to the industry $n$ of region $j$, which is defined as the added-value term $V_j^n$ shown as:

$$
p_{jn}x_{jn} = \sum_m q_{jm}^m x_{jm}^m + V_j^n
$$

(20).

This added-value means the value of exogenous input factor which is specific to the region. It
is assumed that this value is not traded in the market. Then, we introduce the imaginary intermediary input goods which is equal to the added-value. At the same time, we introduce a new parameter in terms of the added-value into the production function shown as

$$p_j^{M+1} = \frac{V_j^p}{p_j^1 X_j^p}$$

(21).

We can revise the parameter constraints into the following equation from equation (3):

$$\sum_{m=1}^{M} \beta_j^m = 1$$

(22).

As for the other goods $m=1,\ldots,M$, the parameters in the production function is derived from the following equation:

$$p_j^{m} = \frac{q_j^{m} x_j^{m}}{p_j^{1} X_j^{n}}$$

(23).

3. COMPUTATIONAL ALGORITHM FOR EQUILIBRIUM SOLUTION

We calibrate the model in order to estimate the unknown parameters and to achieve the optimal amount of goods and prices. The conceptual structure of the calibration process is depicted in Figure 3. The process of the calibration is as follows:

STEP 0: Set $s = 1$ as an iterative counter.

STEP 1: Give the initial production prices $p = \{p_j^n\}$ based on the real market data.

STEP 2: Standardize the production price and transport cost by setting the production price of a specific region $j$ and industry $n$.

STEP 3: Derive the consumption prices $q_{ij}^n$ and the generalized consumption prices $c_{ij}^n$ from equations (5) and (6).

STEP 4: Estimate the unknown parameters in the equations (10) and (11) by multi-regression analysis based on the consumption prices, the generalized consumption price and previous iteration’s results of destination/transportation-modal shares.

STEP 5: Revise the destination/transportation-modal shares of equation (10) and (11) by using the estimated results of STEP 4.

STEP 6: Substitute the estimated $a_v^n$ for equations (16) and (17) to calculate the inter-regional transport-index matrix $T^*$.

STEP 7: Calculate the inter-regional input-index matrix $A^*$ from equation (15) by using the input-index $a_i^n$, which is estimated in advance.

STEP 8: Calculate the vector $x^*$ from equation (18) by using $T^*$, $A^*$ and the final demand vector of original regions $Y^*$.

STEP 9: Calculate $t_{ij}^n :$ the transportation modal share of goods $m$ from region $i$ to region $j$ by the transportation mode $k$ based on the equation (11). Then calculate the
average consumption price $q_j^m$ by using the modal share and consumption price $q_j^m$, based on the equation (8).

STEP 10: Calculate $\beta_j^m$: the parameters of production function by the equations (21) and (23).

STEP11: Estimate the production price $p_j^m$ by the following equation (24):

$$p_j^m = \frac{\sum m q_j^m x_j^m}{\beta_j^m X_j^m} \quad (24)$$

As $p_j^m$ is estimated by $m$ types of industries based on $\beta_j^m$, the production price is $p_j^*$ which is defined as the average of these prices. Then revise the production price $p_j^*$ based on the estimation result.

STEP 12: Terminate the process if the gap of production prices between before and after the revision satisfies the convergence condition. Else set $s = s + 1$ and return to STEP 2.

In STEP 4, we estimate the parameters of the nested MNL by the multi-regression analysis instead of maximum likelihood method. This is because the dataset used in STEP 4 is the aggregated share of modal choice and destination choice.
4. DATA AND ITS PROCESS

4.1 Freight Flow Data

We use the National Freight Traffic Survey 1995 of Japan as the freight flow data, including the dataset of the annual survey and the three-day survey. First, we define the forty-six types of industries. Next we process the weight-based freight transport flow data by origin region, by transportation mode and by origin’s industry type based on the annual survey data. Then, we process the weight-based freight transport flow data by transportation mode from origin region to destination region and from origin’s industry type to destination’s industry type based on the three-day survey data. When expanding the three-day survey data to the annual data, the Flator method is applied both to the inter-regional flow matrix and to the inter-industrial flow matrix.

4.2 Transportation cost, transportation time and production price

The average transportation cost and time are estimated from the three-day survey data of the National Freight Traffic Survey 1995. The initial value of the production cost is set by dividing the price-based gross product derived from the Commercial Statistical Data and the Mining Statistical Data by the weight-based gross product. The region-specific factor in equation (12) is estimated by the number of regional enterprises.

5. ESTIMATION OF UNKNOWN PARAMETERS

We estimate the unknown parameters by the process shown in chapter 3 based on the data processed in chapter 4. Then, we compare the simulated results and the observed data in order to verify the estimation. The comparison of the regional consumption price, the comparison of the amount of regional products by types of industry and the comparison of the inter-regional freight flow by types of industry are shown in Figure 4, 5, 6, respectively. The correlation

![Figure 4 Regional consumption price: observed data vs. simulated results](image)
coefficients of these comparisons are 0.931, 0.965 and 0.937, respectively.

6. SIMULATION ANALYSIS BY THE MODEL

We apply the model to a simple case. We simulate the case of the damage of the earthquake in Hokuriku region to the domestic freight transport. In this simulation, the freight transport costs of rail and truck to and from Hokuriku region are assumed to be ten-time larger than the ordinary situation due to the damage of the earthquake. First, the simulated results of change of freight transport flow to and from Hokuriku region by transportation modes is shown in Figure 7. As the simulated results, the transport flows by rail and truck decrease in almost all regions. The rail traffic decreases especially in Hokkaido, Tohoku, North-Kanto, Kinki and Okinawa regions while the truck traffic decreases in Hokkaido and Kinki regions. On the other hand, the traffic flows of both rail and truck increase in Kyusyu region by about 10 percent and the traffic flow of ship increases in Okinawa region by about 7 percent. As far as the intra-regional traffic flow of Hokuriku region is concerned, the flows of rail and truck do
not decrease so much but the flows of ship and other modes decrease pretty much.

Figure 7 Change of freight transport flow to and from Hokuriku region in the simulation case

Figure 8 Change of amount of products of each region in the simulation case
Then the simulated results of the amount of products of all types of industries in eleven regions are shown in Figure 8. We find the decrease of products of all types of industries, especially the steep decrease of steel and non-steel metal industry, machinery industry. On the other hand, the products of warehousing in Hokuriku region increase by more than 15 percent and the products of food, beverage, feed and tobacco industry increases by more than 6 percent. As for the other region than Hokuriku region, the sharp decrease of precision machinery products in Hokkaido and the sharp decrease of warehousing in Southern-Kanto are found.

The Niigata-Chuetsu Earthquake occurred in November 2004. But actually the period of transport service fault is just about one month due to the quick rehabilitation of transportation facilities. This short fault of transportation service may result into the smaller impact on the regional or the national industrial market than expected. On the other hand, the simulation results of the model is expect to be larger impacts than real situation because the model assumes the market equilibrium in which the change of equilibrium may take quite long period. Therefore, we need to consider these results as the long fault of transportation service, which should be different from the real impact of the Niigata-Chuetsu Earthquake.

7. CONCLUSIONS

This paper formulates a spatial price equilibrium model for freight transport and applies it to the inter-regional freight transport in Japan. This model covers twenty-three types of goods and eleven regions under the economic equilibrium theory. The model can analyze the impact of developing transport infrastructure on the freight-transport flow. In the model, the behaviors of four main actors in the market are formulated: firms, retailers, households and freight-transport operators. First, the firms produce the various types of goods by inputting the intermediary/original goods. Then, the retailers will sell the consumption goods to consumers by inputting the products from various industries. The households will consume the goods by purchasing the consumption goods from retailers whereas they provide the labor force to the producers and the retailers. Finally, the freight-transport operators will transport all kinds of goods including original material goods, intermediary goods and consumption goods between different regions. The unknown parameters of the model are calibrated in the iterative computation process. At the each iterative process, both of the prices of the consumption regions and the prices of the production regions are revised based on the estimation results the regression analyses for the freight flow data. The estimated model is applied to the inter-regional domestic freight transport of Japan. The national survey data of freight traffic flow is used for calibration. The good results of calibration are successfully achieved. Finally we simulate the case of Niigata-Chuetsu Earthquake.

For the further research, first, the modification of the model in behavior of households is desirable. We simplify the behavior of households as just consuming the final products of retailers, but in general households consumes other goods like land as well. To consider the consumption of land, the land market should be taken into an account. Second, the international trade should be considered as well. We assume the equilibrium of domestic
market, but actually the market is not closed in the country. We may need to expand our model to the international market especially when discussing the international transportation facilities. Third, the further discussion is required for the added-value in the production function introduced in the equation (20). Due to this value, the model cannot be the complete and closed general equilibrium. However, this treatment could be very useful from the practical viewpoint even though it does not follow the strict equilibrium theory. We may need to discuss the meaning of the added-value furthermore. Fourth, the behavior of freight transport operator is assumed in the model as the two-stage structure, in which the upper-level is destination choice and the lower-level is modal choice. However, there is no clear evidence for this structure. The careful examination for the structure may be needed. Finally, the model assumes no movement of households and firms. However, the households and the firms may make the decision of changing their location due to the change of transportation service. To incorporate these location choices should be taken into an account as well.

REFERENCES


