An Estimation of a Multi-Regional Input/Output table in China and the Analysis

Takaaki OKUDA[1], Takayuki HATANO[2] and Shuchang QI[3]

Abstract:

In this study, a Multi-Regional Input/Output (MRIO) table in China, which is classified into 30 regions and 38 industries, has been estimated. Chinese local governments supply each regional IO table, but there aren't enough data on commodity flow tables. Therefore, in this paper, an entropy model is proposed for the estimation of commodity flows, and an entropy optimization method is proposed to keep the balance of the MRIO table. In the later part of this paper, a MRIO table in China is really estimated by this method and regional economic structure in China is cleared through the MRIO analysis. As the results, first of all, it is shown that exports directly influenced to economic development in eastern costal area in 1997. Secondly it is cleared that economic development in eastern costal area influenced to economic development in whole China. Finally it is shown that interdependence between provinces in western inland is not progressed in comparison with eastern costal area.

Key wards:

Multi-Regional Input/Output (MRIO) table, Entropy optimization method, Regional economic structure in China

[1] Graduate School of Environmental Studies, Nagoya University, Nagoya, 464-8603, Japan.
Phone:+81-52-789-4654, Fax:+81-52-789-1462, Email:okuda@genv.nagoya-u.ac.jp
[2] Graduate School of Environmental Studies, Nagoya University, Japan.
[3] The Office of National Statistics, China.

1. Introduction

Since 1978, the reform and opening policy has been implemented in China and four modernizations (agriculture, industry, national defense and technology) have been challenged. The average annual growth rate of the real GDP per capita showed a remarkable value from 2.3 (1952- 1977) to 8.1% (1978- 2000). On the other hand, although rapid economic growth is realized in eastern costal area, development in western inland area does not progress, so that the income gap between two areas is being expanded. As shown in Fig. 1, it turns out that high-income regions are located in eastern coastal area, and that low-income regions are located in western inland area.

For improving the inequity between two areas, the Chinese government declared "western development" in the 10th five-year development plan (2001- 2005). However about $ 0.1 trillion is needed to make an investment for this purpose over ten years. And it must be shown what kind of investment contributes to development in the western inland area, based on scientific basis. A Multi-Regional Input/Output (MRIO) analysis is a method for showing quantitatively the influence that the investment to a specific area affects the surrounding area. In addition, CGE models can be developed for the analysis of the investment effect, if MRIO tables are supplied.

MRIO tables in China have been estimated in some research projects. For example, the development research center in China and UNCRD estimated a MRIO table in China, which is classified into 7 regions. Shibata and Ando (1989) tried the estimation of a MRIO table in China from the national IO table and other regional statistics. The Institute of Developing Economies (2003) estimated a MRIO table in China, which is classified into 8 regions and 30 industries.

In this study, a Chinese MRIO table is estimated by using the regional input/output (RIO) tables supplied by local governments in China. It's classified into 30 regions and 38 industries. And the regional economic structure in China is cleared through MRIO analysis. In chapter 2, we explain the RIO tables supplied by 30 local governments and we describe problems for estimating the MRIO table in China, In chapter 3, we show how to estimate the MRIO table in China using the RIO tables supplied by local governments. In chapter 4, a MRIO analysis is performed using the estimated MRIO table and the regional economic structure in China is cleared by this analysis.

Fig.1 Index of GDP per capita in China

2. RIO tables in China

The Office of National Statistics in China has estimated the national IO tables in 1987, 1992, and 1997. In addition, 30 local governments have estimated each RIO table, when the national IO tables had been estimated. Table 1 shows the form of the RIO tables. Table 2 expresses the industrial classifications and table 3 expresses regional classifications.

The local governments in China separately estimate exports, domestic outflows, imports, and domestic inflows as it is shown in Table 1. However, the total of domestic outflows estimated in the RIO tables is not the total of domestic inflows. Each local government has independently estimated the RIO tables and they haven't been adjusted in whole China. That is the reason why the total of domestic outflows is not equal to the total of domestic inflows.

Therefore, we have the following problems for the estimation of the MRIO table in China, 1) domestic outflows and domestic inflows have to be separately estimated by regions in each RIO table, 2) domestic outflows and inflows have to be adjusted, so that the total domestic outflows is equal to the total domestic inflows in whole China, 3) the RIO tables must be adjusted to keep the balance as a MRIO table.

Table 1　RIO tables in China

Region r	industry j	Final Demand	Exports	Domestic Outflows	Imports	Domestic Inflows	Total Output
industry i	$\cdots\; x_{ij}^{r} \;\cdots$	F_i^r	E_i^r	DE_i^r	$-M_i^r$	$-DM_i^r$	X_i^r
Value Added	$\cdots\; V_j^r \;\cdots$						
Total Input	$\cdots\; X_j^r \;\cdots$						

Table 2　Industrial classifications

1	Agriculture, forestry and fisheries	14	Steel and nonferrous metal goods	27	Transportation
2	Coal	15	Metal goods	28	Communication and broadcast
3	Oil and a natural gas	16	Common machine	29	Commerce
4	Metal mining	17	Machine for transportation	30	Catering trade
5	Nonmetallic mining	18	Electric machine	31	Passenger transport
6	Food	19	Electronic machine	32	Finance and insurance
7	Fiber	20	Business machine	33	Real estate
8	Clothes and leather	21	Apparatus repair	34	Service
9	Wood and wooden goods	22	Other manufacturing industry	35	Medical treatment and health
10	Pulp and paper	23	Electric power and heat supply	36	Education and culture
11	Oil and coal	24	Gas	37	Research
12	Chemistry	25	Water service	38	Official business
13	Soil and stone	26	Construction		

Table 3　Regional classifications

1	Beijing	12	Anhui	23	Guizhon
2	Tianjin	13	Fujian	24	Yunnan
3	Hebei	14	Jiangxi	25	Shaanxi
4	Shanxi	15	Shandong	26	Gansu
5	Inner Mongolia	16	Henan	27	Qinghai
6	Liaoning	17	Hubei	28	Ningxia
7	Jilin	18	Hunan	29	Xinjiang
8	Heilongjiang	19	Guangdong	30	Other regions
9	Shanghai	20	Guangxi		
10	Jiangsu	21	Chongqing		
11	Zhejiang	22	Sichuan		

3. Estimation method of MRIO tables

(1) Basic Concept for the estimation

To estimate a MRIO table, we have to estimate the Table 4 and Table 5. Table 4 is a RIO table and Table 5 is a commodity flow table. Then we can use the RIO tables estimated by local governments as the primary estimation of RIO tables (Table 4). On the other hand, we don't have enough data for the estimation of commodity flow tables. But the domestic outflows and inflows have been given in the RIO tables (Table 1), so that, if we use an entropy model with double constraints, we can estimate primary data of commodity flow tables (Table 5). But the MRIO table composed by the primary estimation is not balanced. Therefore entropy optimization problem is used to find a balanced MRIO table.

Table 4 RIO table

Region s	industry j	Final Demand	Regional Demand
industry i	$\cdots\ x_{ij}^{s}\ \cdots$	F_i^s	Y_i^s
Value Added	$\cdots\ V_j^s\ \cdots$		
Total Input	$\cdots\ X_j^s\ \cdots$		

Table 5 Commodity flow table

Commodity i	Region s	Exports	Total Output
Region r	$\cdots\ y_i^{rs}\ \cdots$	E_i^r	X_i^r
Imports	$\cdots\ M_i^s\ \cdots$		
Regional Demand	$\cdots\ Y_i^s\ \cdots$		

(2) Primary estimation

As the primary estimation of intermediate inputs $\bar{x}_{ij}^{s}$ in RIO tables, we use the RIO tables supplied by local governments in China. On the other hand, the following method can be used for the primary estimation of domestic trade $\bar{y}_i^{rs}$.

In the RIO tables supplied by local governments in China, exports, imports, domestic outflows and domestic inflows are separately estimated. In the first step, we estimate the domestic trade $\bar{y}_i^{rs}$ by using the following equation,

$$\bar{y}_i^{rr} = X_i^r - E_i^r - DE_i^r \qquad (1)$$

where domestic outflows DE_i^r and domestic inflows DM_i^s are known in the RIO table estimated by local governments in China. Then, we can estimate the commodity flow table by the entropy model with double constraints, based on distance between regions d^{rs} [11)、12)].

$$\bar{y}_i^{rs} = A_i^r B_i^s DE_i^r DM_i^s \left(d^{rs}\right)^{-\gamma_i} \qquad (2)$$

$$A_i^r = 1 \Big/ \sum_{s \neq r} B_i^s DM_i^s \left(d^{rs}\right)^{-\gamma_i} \qquad (3)$$

$$B_i^s = 1 \Big/ \sum_{r \neq s} A_i^r DE_i^r \left(d^{rs}\right)^{-\gamma_i} \qquad (4)$$

The total of domestic outflows isn't equal to the total of domestic inflows. Therefore each domestic outflows and import are adjusted by the means of two totals.

(3) Balancing

The primary estimation of the MRIO tables isn't balanced. In the next step, the entropy is introduced as a measurement of distance between MRIO tables. Then we define the following optimization problem for estimating a balanced MRIO table.

Objective function:

$$\sum_s \sum_i \sum_j x_{ij}^s \left(\ln \frac{x_{ij}^s}{\bar{x}_{ij}^s} - 1 \right) + \sum_i \sum_r \sum_s y_i^{rs} \left(\ln \frac{y_i^{rs}}{\bar{y}_i^{rs}} - 1 \right) \to \min \tag{5}$$

Constrains:

$$\sum_i x_{ij}^s + V_j^s = X_j^s \tag{6}$$

$$\sum_j x_{ij}^s + F_i^s = Y_i^s \tag{7}$$

$$\sum_r y_i^{rs} + M_i^s = Y_i^s \tag{8}$$

$$\sum_s y_i^{rs} + E_i^r = X_i^r \tag{9}$$

$$x_{ij}^s, Y_i^s, y_i^{rs} \geq 0 \tag{10}$$

Fig. 2 shows entropy function. This function takes the smallest value at $x = x_0$. Therefore, objective function (5) takes the smallest value at primary estimation $\bar{x}_{ij}^s$, $\bar{y}_i^{rs}$ and it will take a gradually big value as it separates from the primary estimation. On the other hand, constrains (6) and (7) mean that the vales $\bar{x}_{ij}^s$ have to be balanced in RIO tables and constraints (8) and (9) mean the values $\bar{y}_i^{rs}$ have to be balanced in commodity flow table. Constraints (10) mean non-negative conditions.

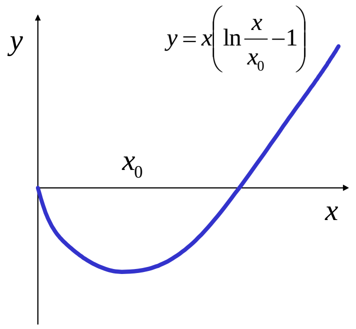

Fig. 2 Entropy function

(4) The optimization condition

The first order conditions of this optimization problem are follows,

$$x_{ij}^s = R_i^s \bar{x}_{ij}^s S_j^s \tag{11}$$

$$\sum_i x_{ij}^s = X_j^s - V_j^s \tag{12}$$

$$\sum_j x_{ij}^s = Y_i^s - F_j^s \tag{13}$$

$$y_i^{rs} = A_i^s \bar{y}_i^{rs} B_i^r \tag{14}$$

$$\sum_r y_i^{rs} = Y_i^s - M_i^s \tag{15}$$

$$\sum_s y_i^{rs} = X_i^r - E_i^r \tag{16}$$

$$R_i^s = \frac{1}{A_i^s} \tag{17}$$

where A_i^s, B_i^r are balancing factors of RIO tables and R_i^s, S_i^r are balancing factors of commodity flow tables. Equation (11) - (13) mean that RIO tables have to be estimated by RAS method, and Equation (14) - (16) means that commodity flow tables have to be estimated by RAS method, too. These 2 types of RAS methods should be combined by Equations (17).

The following equations are introduced form equations (11)-(17).

$$\sum_j (X_j^s - V_j^s) \frac{R_j^s \bar{x}_{ij}^s}{\sum_i R_j^s \bar{x}_{ij}^s} + F_j^s = \sum_r (X_i^r - E_i^r) \frac{\frac{\bar{y}_i^{rs}}{R_i^s}}{\sum_s \frac{\bar{y}_i^{rs}}{R_i^s}} + M_i^s \tag{18}$$

Variables R_i^s are obtained by solving this simultaneous equations and Variables S_i^r, x_{ij}^s, A_i^s, B_i^r, y_i^{rs} are obtained from variables R_i^s .

4. An analysis of regional economic structure in China

(1) A MRIO model

A MRIO analysis was performed using the MRIO table estimated by chapter 3. In this analysis, the following Chenery - Moses type model is used.

$$X = \left\{I - A(I - \overline{M})T\right\}^{-1}(F + E) \tag{19}$$

$$V = BX \tag{20}$$

where X is a production vector, F is a final-demand vector, E is a export vector, A is an input coefficient matrix, T is an domestic trade coefficient matrix, $\overline{M}$ is an import coefficient matrix and B is an added value coefficient matrix

In addition, the final-demand vector F can be decomposed by final-demand vector F^s of each region.

$$F = \sum_s F^s \tag{21}$$

From the equations (19) - (20),

$$V = \sum_s V^s + V^E \tag{22}$$

where,

$$V^s = B\left\{I - A\left(I - \overline{M}\right)T\right\}^{-1} F^s$$

$$V^E = B\left\{I - A\left(I - \overline{M}\right)T\right\}^{-1} E$$

V^s means the value added by the final demand of region s, and V^E means the value added by exports. Therefore value added can be decomposed by the equation (22).

(2) Value added by export

Fig. 4 shows the rate that the value added by exports occupies in the value added of the region. Guangdong is the region where the rate of the value added by exports is the highest (41.3%). In Guangdong, exports of electric machine, electronic machine and business machine are remarkable in addition to exports of clothes and leather, pulp and paper etc. Consequently, high value added is produced by the productions of these industries. Moreover, Shanghai (26.7%), Fujian (23.2%) and Tianjin (21.1%) have the high rate of the value added by exports. These areas are all located in eastern coastal area. On the other hand, in western inland area the rate of the value added by exports is not filled to 10%. It is cleared that the economic growth on the eastern coastal area in 1997 depended upon the foreign demand.

(3) Value added by final demand in big cities

Figs. 5-6 show the rate of the value added by the final demand of Beijing and Shanghai. Although the final demand of Beijing has induced many value added to the surrounding areas, Hebei (5.4%) and Tianjin (3.1%), but it dose not have so big influence on the other regions. Although it isn't shown in the figures, the relations of interdependence of three regions are relatively strong. It can be said that these three regions form one economic bloc. On the other hand, as for Shanghai, the influence has reached to whole China, not only the surrounding area, Jiangsu (3.8%), Zhejiang(3.3%), and Anhui(3.1%), but also Hebei(2.4%), Shanxi (2.3%), etc. This also shows that Shanghai has wider influences than Beijing.

(4) Value added by the final demand in eastern coastal regions

Figs. 7-8 show the rate of the value added by the final demand of Jiangsu and Guangdong. The final demand of Jiangsu has affected on not only the surrounding area, Anhui(11.7%), Shanghai (5.1%) and Shandong (5.1%), but also Hebei(7.9%), Henan(3.8%), Shanxi (3.2%) and Inner Mongolia(3.1%). The final demand of Guangdong also have wide influence to not only the surrounding area, Jiangxi(4.1%), Honan (4.3%) and Guangxi (12.1%), but also other regions of whole country, Chongqing(5.9%), Yunnan(3.0%) and Xinjiang(3.0%). These eastern coastal regions have big economic influence to whole China. That is, it is cleared that the economic growth of the eastern coastal area has produced new production in whole China.

(5) Value added by final demand in western inland regions

Figs. 9-10 show the rate of the value added by the final demand of Shaanxi and Sichuan, which located in western inland area. Although the final demand of Shaanxi has influenced on the surrounding area, Ningxia (3.4%), Chongqing(1.4%) and Gansu(1.2%), it is less than the eastern coastal area. Similarly, although the final demand of Sichuan has influence on the surrounding areas, Chongqing (3.1%) and Shaanxi(1.9%), the influence is relatively smaller than the eastern costal area. It is cleared that economic activities in the inland area are smaller than the costal area, and that the influence on the surrounding regions is relatively smaller.

(6) Regional economic structure in China

The analysis of Chinese regional economic structure has cleared the following three points. The first point is that in 1997 exports mainly produced much value added to the eastern costal area. The second point is that the final demand on the eastern costal area has wide influence to whole China. The third point is that the final demand in the inland area has only small influence to other regions.

Before the reform and opening policy in China, it is said that Chinese government continued the industrial policy in which each province have full-set industries. But after the reform and opening policy, in the eastern costal area the economic development is changing the regional economic structure. On the other hand, in western inland area there are many regions that have old regional economic structure.

However, it is expected that regional structure will be changing due to economic developments on the inland area. In order to realize economic development in the inland area, it is necessary to improve the transportation networks connecting costal area and inland area, or connecting inner inland area. Furthermore, it is expected that energy consumption in transportation sector will be increasing in the inland area and it is necessary to improve the transportation efficiency in this area.

Fig. 3 Regions

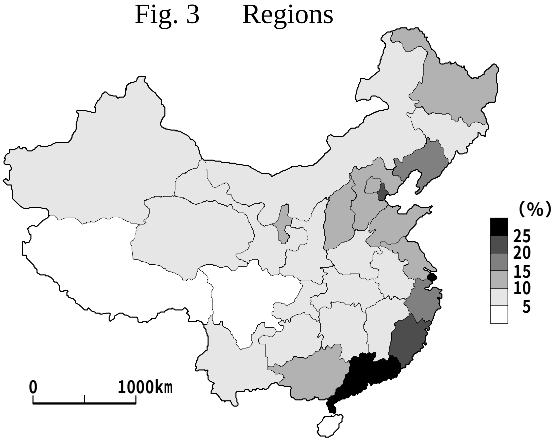

Fig. 4 Value added by export

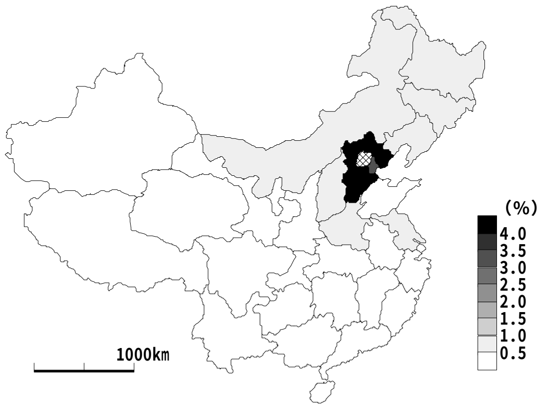

Fig. 5 Value added by final demand of Beijing

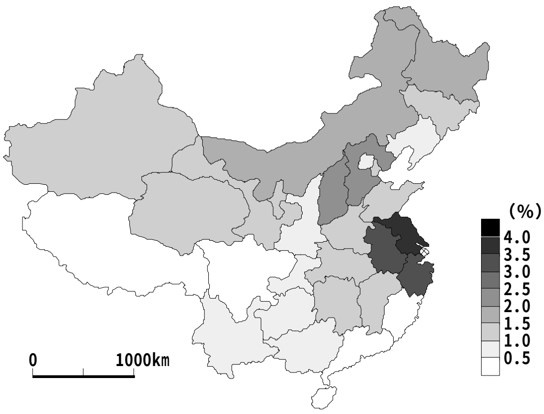

Fig. 6 Value added by final demand of Shanghai

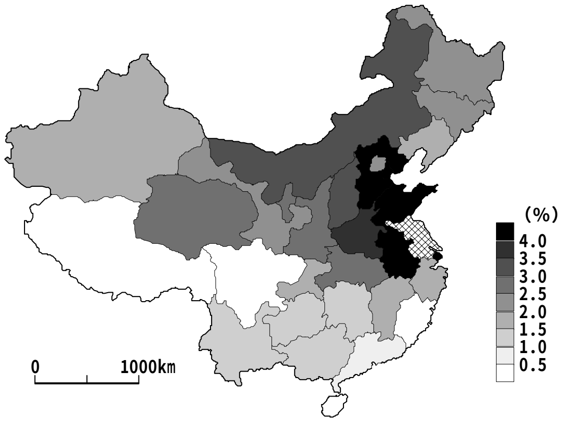

Fig. 7 Value added by final demand of Jiangsu

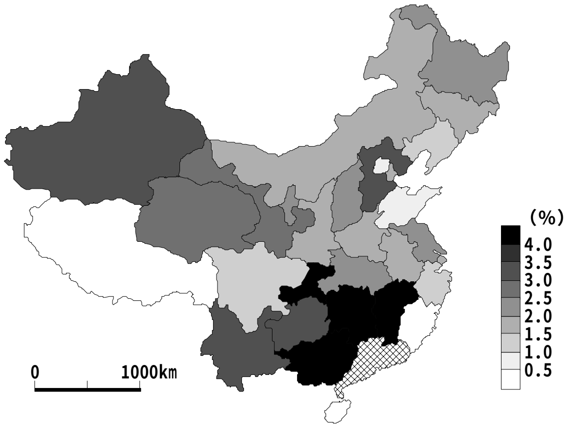

Fig. 8 Value added by final demand of Guangdong

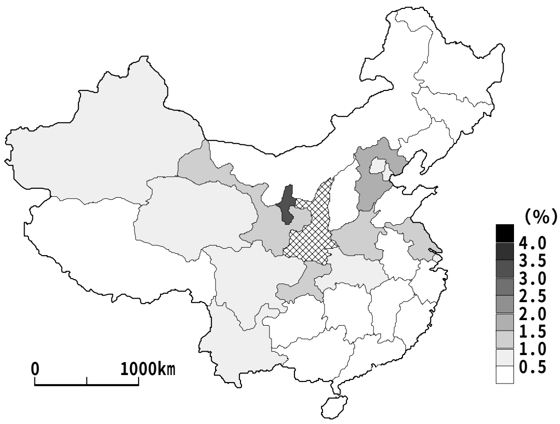

Fig. 9 Value added by final demand of Shaanxi

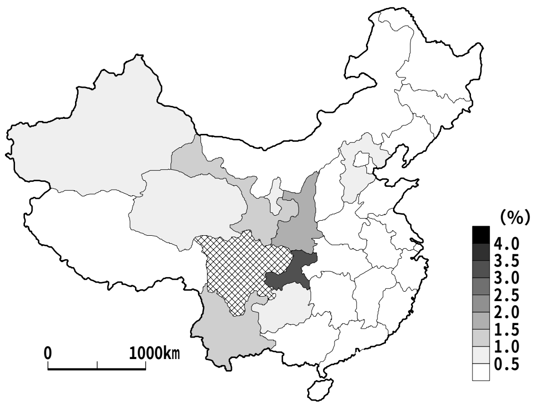

Fig. 10 Value added by final demand of Sichuan

5. Conclusion

In this study, a MRIO table in China, which is classified into 30 regions and 38 industries, has been estimated. Then, Chinese local governments supply the regional IO tables, but there aren't enough data on commodity flow tables. Therefore, in this paper, an entropy model is proposed for the estimation of commodity flow, and an entropy optimization method is proposed to keep the balance of the MRIO table.

In the later part of this paper, a MRIO table in China is really estimated by this method, and regional economic structure in China is cleared through the MRIO analysis. As the results, first of all, it is shown that exports influenced on economic development on eastern costal area in 1997. Secondly it is cleared that economic development on eastern costal area influenced to economic development on whole China. Finally it is shown that interdependence between provinces in western inland is not progressed in comparison with eastern costal area.

Generally it is possible to get commodity flow tables in international trade, but it is difficult to get the commodity flow tables in domestic trade. China has big area, so it is very important to estimate the commodity flow table to clear the regional economic structure. In this study, we proposed one non-survey method for the estimation of MRIO tables. But to improve the accuracy of this table, it is necessary to try the big survey of commodity flows in China, which is similar to commodity flow survey in Japan.

Appendix Estimation of distance coefficient

In order to estimate commodity flow tables from the equation (2)-(4), distance coefficients γ_i is needed. From the equation (2),

$$\ln \frac{\bar{y}_i^{rs}}{\bar{y}_i^{r's}} = a_i^0 + \sum_{l=1} a_i^l \delta_{lr} - \gamma_i \ln \frac{d^{rs}}{d^{r's}} \tag{A1}$$

where $$\ln \frac{A_i^r DE_i^r}{A_i^{r'} DE_i^{r'}} = a_i^0 + \sum_{l=1} a_i^l \delta_{lr} \qquad \delta_{lr} = \begin{cases} 1 & (l = r) \\ 0 & (l \neq r) \end{cases}$$

Table A1 Estimation of distance coefficients

Commodity	Coefficient(t-value)	Commodity	Coefficient(t-value)
Agriculture, forestry and fisheries	3.56(15.9)	Business machine	3.38(18.7)
Coal	3.24(13.9)	Apparatus repair	2.90(13.7)
Oil and a natural gas	3.28(12.2)	Other manufacturing industry	2.58(15.3)
Metal mining	3.36(14.6)	Electric power and heat supply	2.26(14.5)
Nonmetallic mining	2.85(12.8)	Gas	0.66(2.6)
Food	2.73(18.3)	Water service	0.46(2.5)
Fiber	2.84(17.2)	Construction	-
Clothes and leather	2.67(19.9)	Transportation	2.87(19.0)
Wood and wooden goods	2.91(16.8)	Communication and broadcast	-
Pulp and paper	3.35(17.3)	Commerce	2.96(17.0)
Oil and coal	2.56(20.0)	Catering trade	-
Chemistry	2.44(17.1)	Passenger transport	-
Soil and stone	2.58(15.3)	Finance and insurance	-
Steel and nonferrous metal goods	2.00(16.8)	Real estate	-
Metal goods	3.20(16.7)	Service	-
Common machine	2.93(19.1)	Medical treatment and health	-
Machine for transportation	2.80(20.5)	Education and culture	-
Electric machine	2.90(18.0)	Research	-
Electronic machine	2.44(20.2)	Official business	-

Therefore, if the commodity flow tables and distance between regions is obtained, it is possible to estimate distance coefficients. Table A1 is the result of this estimation. For this estimation, we used the commodity flow tables between 8 regions, which can be calculated from the Chinese MRIO table by IDE (Institute of Developing Economics) and distance between regions, which can be calculated from the time table for Chinese railway. But the distance coefficients of construction, communication and broadcast, etc cannot be estimated, because it is assumed that domestic trade is zero in the MRIO tables estimated by IDE. In this study, it is also assumed that the domestic trade of the commodities is zero.

Bibliography

1) Osamu Tanaka (2001): the tenth 5 year plan on economic development, So-so-sya.
2) A research group on transportation strategy for western development in China (2001): A study on the transportation strategy for western development in China.
3) Yasutoshi Nakato (2003): Regional structure in China, Yu-shin-do.
4) Takeo Ihara (1996): Economic Analysis on Region, Chuo-keizai-sya.
5) Commity of Inflastrucure planning in Japan Society of Civil Engineers (1998): Application to public investment evaluation of an applied general equilibrium model, JSCE.
6) Takatoku Shibata and Asao Ando (1989): Opening policy and urbanization in China, an Inter-regional Input/Output Analysis, City planning, No. 401, pp.33-40.
7) Institute of Developing Economics, Japan External Trade Organization: Multi-regional Input-Output Model for China 2000, I.D.E. Statistical Data Series, No.86, 2003.
8) Office for National Statistics in China (1999): Chinese Input/Output table in 1997, the China statistics publication.
10) Takaaki Okuda and Hiroyoshi Hashimoto (2003): An estimation of inter-regional Input/Output table using entropy optimization method, the 27th meeting on Infrastructure planning, JSCE.
11) Wilson, A. G (1970): Interregional commodity flows: entropy maximizing approaches, Geographical analysis, No.2, pp.255-282.
12) Yoshio Sugiura (1989): location, spatial action, Kokon-shoin.
13) Office for National Statistics in China (2001): the China statistical yearbook 2001, the China statistics publication.