Analysis of International Interdependence between China and Japan from the Perspective of Interregional Economic and Environmental Interactions

Shinji Kaneko[*] *and Masaru Ichihashi*

The study is motivated by a simple question that what interregional economic relations between two cities in different countries would be and what the environmental implications can be drawn, particularly in the case of cities at different development stages. This study aims to empirically measure the changes in economic interdependence and induced CO_2 emissions between Beijing and Tokyo from the early to mid-1990s using multidimensional input-output tables. The study finds that although the trade volume from Beijing to Tokyo was just two or three times larger than the flow in the opposite direction, the induced CO_2 emissions in Beijing were approximately 90 times larger than in Tokyo. This is partly explained by the larger size of demand in Tokyo, the larger induced production coefficient and higher carbon intensity in Beijing, and a larger portion of energy-intensive goods exported from Beijing. Export from Tokyo to Beijing is growing because of the increase in demand from Beijing. As a result, although the imbalance of induced environmental burdens between two cities is decreasing, it still remains quite large. The study also shows that large environmental imbalance may arise between cities that are different stages of development.

1. INTRODUCTION

There is a growing call for greening the present unsustainable pattern of consumption and production. To this end, holistic views on economic causalities between demand and supply in various spatial dimensions are required to clearly articulate its overall environmental consequences. Due to the rapid expansion and intensification of economic activities in Asia through globalization, interdependence among economies in the region has strengthened. To an increasing extent, the environmental burden caused by the production and consumption in a country are also directly and indirectly related to the activities in another country. Intensive consumption and production are taking place in cities. With urban development, generally the economic characteristic of a city shifts

[*] Hiroshima University (Associate Professor in Graduate School for International Development and Cooperation), 1-5-1 Higashi Hiroshima, Japan 739-8529; +81-(82)-424-6916; email: kshinji@hiroshima-u.ac.jp.

from a production oriented structure to being consumption-oriented. This dynamics brings an increase in the external dependency of a city on an outside economy, which leads to an increase in the induced environmental burden on the outside economy. Economic and environmental interdependent relations between nations through international trade or domestic regions are often analyzed, but interregional relations beyond the bounds of the country are not highlighted. It is interesting to know what these interregional relations would be and what the environmental implications can be drawn, particularly from the case of cities in different development stages. This study aims to empirically measure the changes in economic interdependence and mutual induced CO_2 emissions between Beijing and Tokyo from early to mid- 1990s using multidimensional input-output tables.

The analytical methodology employed by this study is a combination of the methodologies of Imura and Moriguchi (1995) (an analysis applied to international trade that considers energy and CO_2 emissions embodied in goods traded between different economic entities) and Ichihashi (2000) (an analysis of international interdependency between two regions in two countries). Already there is a large body of research on analysis of country-to-country aspects, as well as interdependency and technology impacts using regional input-output tables within a given country. This paper is unique in its comparative analysis of induced economic and environmental linkages between two regions—across national boundaries—using cities' input-output tables.

The structure of this paper is as follows. Section 2 describes the data used and how it was prepared. Section 3 describes the methods to estimate trade between regions, as well as the estimation results. Section 4 calculates and compares the values of induced production and induced environmental impacts, based on previous sections. Section 5 conducts a factor analysis of changes between two points in time, and offers some additional discussion. Finally, the paper closes with a brief summary and touches upon topics for the future.

2. DIRECT, INDIRECT, AND INDUCED EFFECTS ASSOCIATED WITH CITY-TO-CITY TRADE

Here we consider a case in which there are economic interactions (trade) between City A and City B. Take the case of an automobile manufactured in City A exported to City B. This occurrence is considered a direct production effect (consisting of one automobile) that demands in City B created in City A. More specifically, this direct production effect occurs in the motor vehicles sector of City A. Energy is required for the production of one automobile (usually for manufacturing and assembly), and CO_2 is emitted in the process of energy consumption. These are referred to as the "direct energy effects" and "direct environmental effects," respectively, created by demand in City B and affecting the motor vehicles sector in City A ("environmental effect" is defined as CO_2 emissions below, as this paper uses CO_2 as an indicator). Meanwhile, in order to manufacture products, the motor vehicles sector in City A procures a variety of materials and parts manufactured in other sectors for automobile production, for example, metal plating, plastics, glass, meters, and batteries. In addition, software to conduct a multitude of complex operations might be subcontracted to a software company. In this study, we do consider whether the other sectors providing these items are inside or outside City A. These can be considered to be indirect production effects of demand in City B, created indirectly through the motor vehicles sector in City A. In addition, energy is also required for indirect production in other sectors such as these, leading to the release of CO_2 emissions. These are defined as the indirect energy effect and indirect environmental effect, respectively. The indirect production effects in other sectors, through procurement activities such as for raw materials in other sectors, also have a series of ripple effects caused by production effects in sectors further up the chain of production. The combination of the direct effects described above and all of these sequentially-linked indirect effects is defined as the "induced effects" of demand of City B. Induced effects, include induced production effects, induced energy effects, and induced environmental effects in this study. Among these induced effects, those that are generated for each production sector in City A are defined as the induced effects of City A.

Meanwhile, it is customary to consider the fact that there are economic interactions in the reverse direction, between City B and City A, in other words a flow of goods from City B to City A. This reverse flow also accompanies the direct effects, indirect effects, and induced effects on City B in relation to demand in City A. Thus, where economic interactions (trade) occur in both directions between City A and City B, this means that they both create their respective direct, indirect, and induced effects. The present study refers to these relationships as mutual interdependence, and analyzes economic, energy, and environmental interdependence.

3. DATA PREPARATION

Comments on Data Used

This analysis uses the Tokyo Input-Output Tables (1990 and 1995 editions) and the Beijing Input-Output Tables (1992 and 1997 editions), and in order to determine Japan-China trade volume, uses the Japan-China International Input-Output Table (1990 edition) and the Asian International Input-Output Table (1995 edition), supplemented by the China Input Output Tables (1992 and 1997 editions). A gap arises between Japan and China in the timing of preparation of the input-output tables. Because there is no choice but to conduct the analysis based on a combination of data from

Table 1 Unified Sector Classification.

1	Agriculture and livestock	21	Non-ferrous metal products
2	Forestry	22	Metal products
3	Fishery	23	Machinery
4	Crude petroleum and matural gas	24	Electric machinery
5	Metallic ore	25	Moter vhicles
6	Non-metallic ore and quarrying	26	Other transport equipments
7	Food product	27	Precision machines
8	Beverage, animal feeding, tobacco	28	Plastic products
9	Fiber and spinning	29	Other manufacturing products
10	Wearing apparel and other textile products	30	Electricity, gas and water supply
11	Leather and furs and its products	31	Construction
12	Timber and wooden products	32	Wholesale and retail trade
13	Pulp and paper	33	Transportation
14	Printing and publishing	34	Telephone and telecommunication
15	Chemical products	35	Finance and insurance
16	Drugs and medicine	36	Education and researches
17	Refined petroleum and its products	37	Other services
18	Rubber products	38	Public administration
19	Cement and construction materials	39	Unclassified
20	Iron and steel products		

1990 and 1992, and 1995 and 1997, hereinafter we indicate the target periods for analysis as "90/92" and "95/97," respectively.

Three regions are covered in this analysis: the cities of Tokyo and Beijing, and other areas in Japan excluding Tokyo (hereinafter "Other Japan"). This paper deals with 39 sectors. This number is the outcome of combining sectors specifically for this study, after selecting the largest common sectoral groupings from the most detailed categories obtainable in the tables used. Table 1 indicates the names of the sectors. Values were converted into real prices in order to facilitate comparison between different points in time. Japanese prices in 1990 were converted to 1995 prices using the appropriate inflator for each sector from the long-term linked input-output tables published by the Research Institute of Economy, Trade and Industry. Value added was converted to real prices using the double deflation method. Beijing prices in 1992 were converted to real 1997 prices by creating an inflator for each sector based on manufacturing price indexes and service price indexes from the *China Statistical Yearbook*. For transaction values resulting from calculations, the average 1997 currency exchange rates were used, and amounts expressed in millions of yen.

Table 2 indicates the figures for total economic output. From this table it is evident that Beijing experienced rapid growth during the five-year period, whereas Tokyo experienced a slight economic contraction and Other Japan a minor expansion.

Table 2 Total Economic Outputs.

Unit: million Yen

	Beijing	Tokyo	Other Japan
90/92 (A)	6,180,558	160,535,261	789,474,497
95/97 (B)	8,803,041	157,908,875	835,469,190
(B)/(A)	1.42	0.98	1.06

Note1: Data in Beijing is in 1992 and 1997 at 1997 real price of Japanese Yen.

Note2: Data for Tokyo and Other Japan are in 1990 and 1995 at 1995 real price of Japanese Yen.

Energy Data

Energy is used as an indicator of environmental burden. What follows is a brief summary of the data sources and data preparation procedures. To begin with, for Japan, we use *Comprehensive Energy Statistics*, and for Tokyo we use the *Tokyo Energy Demand and Supply Structure Research Report*. For Beijing, we use the energy balance tables in *China Energy Statistical Yearbooks*. Industry classifications for input-output tables typically do not exactly match those used for energy data. Where industrial classifications for energy data are very detailed, it is possible to simplify the situation by combining categories. But in cases where energy data were not adequately detailed, and only the totals for multiple industry classifications in the 39 sectors of the input-output tables could be obtained, the values for each energy category were allocated with intermediate transaction values to the nearest industrial classification among the energy-related categories: (4) crude petroleum and natural gas; (17) refined petroleum and its products; and (30) electricity, gas and water supply. After preparing energy consumption data according to the 39 sectors and energy classifications, the next step was to estimate CO_2 emissions using CO_2 emissions per unit of output. For Japan and Tokyo, we use per-unit CO_2 emissions published by the Ministry of the Environment, and for Beijing we use units recommended by the Intergovernmental Panel on Climate Change. The results of sector-specific per-unit CO_2 emissions estimated by the above procedures are shown in Table 3.

Table 3 suggests that emissions per unit of output are higher in Beijing than in Japan, in almost all industries. In particular the per-unit emissions are very high in the electricity, iron/steel, chemicals, and public administration sectors. Per-unit emissions are also relatively high in the textiles, oil, and mining industries**.** On the other hand, per-unit emissions are higher in Japan than in Beijing in some sectors, including education/research. Within Japan, a large gap exists between Tokyo and Other Japan, particularly in the electricity sector.

Table 3 CO_2 Emissions per Unit of Output by Sector

Unit: Kg-C/Yen

Sector		90/92			95/97	
	Beijing	Tokyo	Other Japan	Beijing	Tokyo	Other Japan
1	6,309.6	111.8	1,065.7	9,252.3	63.7	1,133.4
2	7,378.0	48.9	2,037.7	10,603.8	45.3	2,928.5
3	10,960.4	756.9	5,339.4	9,182.2	1,835.0	7,184.8
4	4,183.2	0.0	0.0	17,977.5	0.0	0.0
5	13,134.0	299.5	260.4	17,133.9	523.1	1,169.3
6	10,861.6	266.9	1,049.5	3,036.2	682.4	2,347.5
7	2,587.3	394.9	339.8	3,387.6	477.6	363.4
8	2,309.1	238.7	226.8	6,290.8	290.8	256.0
9	6,402.8	977.4	762.2	28,827.5	812.3	1,327.7
10	779.3	47.9	439.0	1,495.4	61.1	396.3
11	2,176.0	126.9	480.3	1,988.8	110.0	795.1
12	547.2	99.9	480.1	2,787.5	123.6	713.8
13	9,255.5	1,594.7	1,539.0	11,913.2	2,074.9	1,563.1
14	3,135.8	70.2	381.1	2,693.0	76.9	579.9
15	19,019.8	221.0	4,963.7	35,874.8	256.1	5,763.5
16	536.9	123.8	717.4	14,464.9	101.8	740.7
17	9,823.5	71.9	4,340.6	18,101.0	43.0	3,808.3
18	5,772.1	461.2	1,301.7	19,154.6	553.8	1,625.5
19	12,840.9	1,474.8	3,315.2	19,739.1	1,459.9	3,755.1
20	35,593.5	1,157.1	5,290.5	40,643.7	1,074.8	5,829.7
21	1,877.8	239.1	1,670.0	4,941.6	135.6	1,491.5
22	1,299.7	226.8	203.2	2,062.9	266.3	222.8
23	2,049.8	79.1	115.1	2,799.8	85.8	128.6
24	1,322.7	56.5	187.1	1,177.2	49.0	166.5
25	622.7	219.3	113.8	2,134.4	227.5	125.4
26	1,831.2	6.7	121.0	5,184.6	9.5	155.0
27	1,139.3	49.8	159.5	1,816.5	72.6	187.1
28	1,918.1	468.9	553.2	1,780.0	245.1	714.7
29	23,439.4	36.0	5,918.5	8,321.3	44.6	7,132.8
30	31,127.8	1,955.8	15,597.8	83,767.5	1,902.3	15,438.9
31	1,097.0	3.0	182.2	992.7	2.4	197.2
32	170.3	72.2	396.0	126.9	66.5	346.2
33	13,172.4	2,257.9	1,595.4	7,790.7	2,423.6	1,604.0
34	161.5	63.7	148.1	75.6	66.3	136.0
35	126.2	34.6	54.0	159.6	38.4	83.7
36	42.6	234.7	183.2	75.1	209.7	262.5
37	694.3	115.3	207.0	210.8	145.0	224.1
38	22,261.2	273.3	222.0	31,928.7	334.1	27.3
39	5,795.2	348.5	1,366.1	7,614.6	646.6	1,973.2

3. ESTIMATING CITY-TO-CITY TRADE (DIRECT PRODUCTION EFFECTS)

The key challenge at this point is extracting the export/import transactions between each city in the study from the value of each region's export and import trade. The key difficulty is determining the value of trade between Beijing and Tokyo for each sector, but it is even a challenge to obtain the total amount of trade between the two cities from statistical data. These export and import amounts can be seen as the direct production effects on the outbound side, and they are basic external vectors for estimation of induced production. These are estimated by the following procedures.

First, the vector of exports by sector from Beijing to Tokyo is expressed as EX_B^T, and the vector of exports by sector from Tokyo to Beijing is expressed as EX_T^B, and these can be calculated as shown below:

$$EX_B^T = M\hat{S}_J^T X\hat{S}_C^J EX_B^W \tag{1}$$

$$EX_T^B = X\hat{S}_J^T M\hat{S}_C^J IM_B^W \tag{2}$$

Furthermore, for sector *i* and time period *t*, the relationship is established as follows:

$$X\hat{S}_C^J = \left\{ EX_C^J(i,t) \big/ EX_C^W(i,t) \right\} \tag{3}$$

$$M\hat{S}_J^T = \left\{ IM_T^W(i,t) \big/ IM_J^W(i,t) \right\} \tag{4}$$

$$M\hat{S}_C^J = \left\{ IM_C^J(i,t) \big/ IM_C^W(i,t) \right\} \tag{5}$$

$$X\hat{S}_J^T = \left\{ EX_T^W(i,t) \big/ EX_J^W(i,t) \right\} \tag{6}$$

Here EX_B^W is the vector for the value of sector-specific exports from Beijing to the entire world, $X\hat{S}_C^J$ is a diagonal matrix that has diagonal elements of the sector-specific export ratios to Japan within the sector-specific export amounts of China, and $M\hat{S}_J^T$ a diagonal matrix that has diagonal elements of the sector-specific import ratios of Tokyo within the sector-specific import amounts of Japan. In addition, IM_B^W is the import amount vector for Beijing, $M\hat{S}_C^J$ is a diagonal matrix that has diagonal elements of the sector-specific export ratios from Japan within the sector-specific import amounts of China, and $X\hat{S}_J^T$ a diagonal matrix that has diagonal elements of the sector-specific export ratios of Tokyo within the sector-specific export amounts of Japan.

By a similar methodology, it is also possible to calculate the sector-specific export amounts for Beijing and Other Japan, EX_B^O and EX_O^B .

$$EX_B^O = M\hat{S}_J^O X\hat{S}_C^J EX_B^W \tag{7}$$

$$EX_O^B = X\hat{S}_J^O M\hat{S}_C^J IM_B^W \tag{8}$$

$M\hat{S}_{OJ}$ is a diagonal matrix that has diagonal elements for the sector-specific import ratios of Other

Japan within the Japan sector-specific import amounts, and $X\hat{S}_{OJ}$ is a diagonal matrix that has diagonal elements for the sector-specific export ratios of Other Japan within Japan sector-specific export amounts.

The export values estimated above (total amounts) are shown in Table 4. The table indicates that the size of trade in both directions increased over the five-year period from 90/92 to 95/97. The increase in exports from Japan to Beijing is relatively larger, and where the increase is almost double for EX_B^T and EX_B^O, it roughly quadrupled for EX_T^B and increased 2.6 times for EX_O^B. In addition, whereas Tokyo's share of Japan's *imports* from Beijing is about 17-percent, Tokyo's share of Japan's total *exports* to Beijing is about 5 percent.

Table 4 Estimated Intercity Trades as Direct Production Effects.

Unit: million Yen

From Beijing	EX_B^T	EX_B^O	$EX_B^T/\left(EX_B^T+EX_B^O\right)$
90/92 (A)	6,151	31,220	16.5%
95/97 (B)	11,370	53,108	17.6%
(B)/(A)	1.85	1.70	

To Beijing	EX_T^B	EX_O^B	$EX_T^B/\left(EX_T^B+EX_O^B\right)$
90/92 (C)	1,655	36,116	4.4%
95/97 (D)	6,532	93,847	6.5%
(C)/(D)	3.95	2.60	

From/To Beijing	EX_B^T/EX_T^B	EX_B^O/EX_O^B
(A)/(C)	3.72	0.86
(B)/(D)	1.74	0.57

4. ESTIMATION OF INDUCED EFFECTS

While the trade demand in both directions, estimated in the section above, in itself has a direct production effect on the export sides, it induces indirect production effects that ripple upstream sequentially, via industrial backward linkages, due to its direct production. These repercussion effects also ripple to local industry in their respective local areas, and to industry outside the region, through the inflow/import of intermediate inputs. Here, we evaluate the CO_2 emissions generated in connection with the local repercussion effects for each production area.

Induced Production Effects

By multiplying a Leontief inverse matrix for each region to equations (1), (2), (7) and (8) calculated in above sections as the direct production effects of each city and region, it is possible to calculate the induced production effects as follows:

$$\begin{aligned} X_T^B &= \left[I - (I - \hat{M}_T) A_T \right]^{-1} EX_B^T \\ &= \left[I - (I - \hat{M}_T) A_T \right]^{-1} M\hat{S}_J^T X\hat{S}_C^J EX_B^W \end{aligned} \tag{9}$$

$$\begin{aligned} X_O^B &= \left[I - (I - \hat{M}_O) A_O \right]^{-1} EX_O^B \\ &= \left[I - (I - \hat{M}_O) A_O \right]^{-1} X\hat{S}_J^O M\hat{S}_C^J IM_B^W \end{aligned} \tag{10}$$

$$\begin{aligned} X_B^T &= \left[I - (I - \hat{M}_B) A_B \right]^{-1} EX_T^B \\ &= \left[I - (I - \hat{M}_B) A_B \right]^{-1} X\hat{S}_J^T M\hat{S}_C^J IM_B^W \end{aligned} \tag{11}$$

$$\begin{aligned} X_B^O &= \left[I - (I - \hat{M}_B) A_B \right]^{-1} EX_B^O \\ &= \left[I - (I - \hat{M}_B) A_B \right]^{-1} M\hat{S}_J^O X\hat{S}_C^J EX_B^W \end{aligned} \tag{12}$$

Here, X_T^B is the vector of induced production by sector in Tokyo due to exports to Beijing, X_O^B is the vector of induced production by sector in Other Japan due to exports to Beijing, X_B^T is the vector of induced production by sector in Beijing due to exports to Tokyo, and X_B^O is the vector of induced production by sector in Beijing due to exports to Other Japan. Meanwhile, $\hat{M}$ is a diagonal matrix that has diagonal elements for the export/outflow ratios of each region indicated by the lower right suffix, and it is used to deduct the contribution of import/inflow goods in order to calculate the induced production effects within the region in the Leontief inverse matrix. A is the technical coefficient matrix for each region indicated by the bottom right suffix.

Table 5 Induced Production Effects.

Unit: million Yen

From Beijing	X_B^T	X_B^O	$X_B^T/\left(X_B^T+X_B^O\right)$
90/92 (A)	12,042	62,140	16.2%
95/97 (B)	20,686	103,630	16.6%
(B)/(A)	1.72	1.67	

To Beijing	X_T^B	X_O^B	$X_T^B/\left(X_T^B+X_O^B\right)$
90/92 (C)	2,277	82,379	2.7%
95/97 (D)	8,988	178,088	4.8%
(C)/(D)	3.95	2.16	

From/To Beijing	X_B^T/X_T^B	X_B^O/X_O^B
(A)/(C)	5.29	0.75
(B)/(D)	2.30	0.58

Table 6 Induce Coefficients of Production.

From Beijing	X_B^T / EX_B^T	X_B^O / EX_B^O
90/92 (A)	1.96	1.99
95/97 (B)	1.82	1.95

To Beijing	X_T^B / EX_T^B	X_O^B / EX_O^B
90/92 (C)	1.38	2.28
95/97 (D)	1.38	1.90

From/To Beijing	$\left(X_B^T / X_T^B\right) / \left(EX_B^T / EX_T^B\right)$	$\left(X_B^O / X_O^B\right) / \left(EX_B^O / EX_O^B\right)$
(A)/(C)	1.42	0.87
(B)/(D)	1.32	1.03

Table 5 is a summary of the total induced amounts from the above equations, as well as changes between two points in time. The inducement coefficients of estimated export amounts (ratios of induced production effects to direct production effects) are shown in Table 6. Table 5 indicates that, first of all, regarding the size of induced amounts, the induced amount for Other Japan in 1995 was the largest, at 178.1 billion yen, whereas the induced amount for Tokyo in 1990 was the smallest, at 2.3 billion yen. Second, the induced amounts increased in all regions over the five-year period, and the ratio of the increase was about the same as for estimated direct exports. Because the inducement coefficient for Other Japan dropped from 2.28 to 1.90 times, the change in direct production effects over time was 2.60 times, whereas change in induced amount over time for Other Japan due to exports to Beijing was 2.16 times.

Third, if we compare the scale of the induced amount between Beijing and Japan, the scale of the induced amount in Beijing in relation to that of Tokyo contracted considerably from about 5.3 (90/92) to 2.3 times (95/97). There was a similar relationship between Beijing and Other Japan, with a minor contraction from 0.75 (90/92) to 0.58 times (95/97). A similar comparison of direct export amounts between Beijing and Tokyo based on Table 4, results in 3.7 (90/92) and 1.7 times (95/97), so this means that the induced effect in Beijing due to exports to Tokyo is relatively larger. Meanwhile, the comparison of induced amounts converted to units per million yen of direct exports in each region is about 1, so the difference is not particularly large.

Fourth, the results of calculation of inducement coefficient due to exports to each region are shown in Table 6. According to this table, the multiplier effect ranges from 1.3 to 2.3 times. It should be noted, however, that the multiplier in Tokyo is lower than in the other regions. Generally, there is a tendency for the multiplier effects to be lower with greater development of the service sector, and it is possible that the low value for Tokyo may reflect that tendency.

Induced Environmental Effects

Here we estimate the extent of environmental burden induced in connection with the direct and induced production effects described above. By multiplying the above-calculated sector-specific energy consumption per unit of output and CO_2 emissions per unit of output, by their respective economic effects, it is possible to estimate their direct, indirect, and induced effects. Table 7 shows a summary of estimation results for (1) direct energy effects, (2) direct environmental effects, (3) induced energy effects, (4) induced environmental effects, (5) indirect energy effects, and (6) indirect environmental effects. Indirect effects can be calculated by subtracting direct effects from induced effects.

First we consider direct effects. Regarding direct energy impacts, over the five-year period, whereas the effects in Beijing of exports to Tokyo decreased slightly, the effects of exports to Other

Table 7 Summary of Energy and Environmental Effects.

(1) Direct energy effects

Unit: TJ(=10^12 J)

From Beijing	X_B^T	X_B^O	$X_B^T/(X_B^T+X_B^O)$
90/92 (A)	478.6	2,562.2	15.7%
95/97 (B)	447.5	5,103.9	8.1%
(B)/(A)	0.93	1.99	

To Beijing	X_T^B	X_O^B	$X_T^B/(X_T^B+X_O^B)$
90/92 (C)	8.3	674.0	1.2%
95/97 (D)	11.6	853.6	1.3%
(C)/(D)	1.40	1.27	

From/To Beijing	X_B^T/X_T^B	X_B^O/X_O^B
(A)/(C)	57.65	3.80
(B)/(D)	38.61	5.98

(2) Direct environmental effects

Unit: Gt-C (=10^9 t-C)

From Beijing	X_B^T	X_B^O	$X_B^T/(X_B^T+X_B^O)$
90/92 (A)	37.8	211.8	15.1%
95/97 (B)	39.3	466.0	7.8%
(B)/(A)	1.04	2.20	

To Beijing	X_T^B	X_O^B	$X_T^B/(X_T^B+X_O^B)$
90/92 (C)	0.5	45.6	1.2%
95/97 (D)	0.7	53.7	1.3%
(C)/(D)	1.31	1.18	

From/To Beijing	X_B^T/X_T^B	X_B^O/X_O^B
(A)/(C)	69.29	4.65
(B)/(D)	54.84	8.68

(3) Induced energy effects

Unit: TJ(=10^12 J)

From Beijing	X_B^T	X_B^O	$X_B^T/(X_B^T+X_B^O)$
90/92 (A)	832.9	4,694.2	15.1%
95/97 (B)	1,446.6	11,695.1	11.0%
(B)/(A)	1.74	2.49	

To Beijing	X_T^B	X_O^B	$X_T^B/(X_T^B+X_O^B)$
90/92 (C)	11.1	2,146.3	0.5%
95/97 (D)	23.8	3,336.5	0.7%
(C)/(D)	2.14	1.55	

From/To Beijing	X_B^T/X_T^B	X_B^O/X_O^B
(A)/(C)	74.77	2.19
(B)/(D)	60.77	3.51

(4) Induced environmental effects

Unit: Gt-C (=10^9 t-C)

From Beijing	X_B^T	X_B^O	$X_B^T/(X_B^T+X_B^O)$
90/92 (A)	68.1	395.3	14.7%
95/97 (B)	129.1	1,061.9	10.8%
(B)/(A)	1.89	2.69	

To Beijing	X_T^B	X_O^B	$X_T^B/(X_T^B+X_O^B)$
90/92 (C)	0.7	141.8	0.5%
95/97 (D)	1.5	214.4	0.7%
(C)/(D)	2.06	1.51	

From/To Beijing	X_B^T/X_T^B	X_B^O/X_O^B
(A)/(C)	93.70	2.79
(B)/(D)	86.03	4.95

(5) Indirect energy effects

Unit: TJ(=10^12 J)

From Beijing	X_B^T	X_B^O	$X_B^T/(X_B^T+X_B^O)$
90/92 (A)	354.3	2,132.0	14.2%
95/97 (B)	999.1	6,591.2	13.2%
(B)/(A)	2.82	3.09	

To Beijing	X_T^B	X_O^B	$X_T^B/(X_T^B+X_O^B)$
90/92 (C)	2.8	1,472.3	0.2%
95/97 (D)	12.2	2,482.9	0.5%
(C)/(D)	4.31	1.69	

From/To Beijing	X_B^T/X_T^B	X_B^O/X_O^B
(A)/(C)	124.88	1.45
(B)/(D)	81.79	2.65

(6) Indirect environmental effects

Unit: Gt-C (=10^9 t-C)

From Beijing	X_B^T	X_B^O	$X_B^T/(X_B^T+X_B^O)$
90/92 (A)	30.3	183.4	14.2%
95/97 (B)	89.8	595.9	13.1%
(B)/(A)	2.96	3.25	

To Beijing	X_T^B	X_O^B	$X_T^B/(X_T^B+X_O^B)$
90/92 (C)	0.2	96.2	0.2%
95/97 (D)	0.8	160.7	0.5%
(C)/(D)	4.32	1.67	

From/To Beijing	X_B^T/X_T^B	X_B^O/X_O^B
(A)/(C)	167.13	1.91
(B)/(D)	114.50	3.71

Japan roughly doubled. If we consider the fact that during the same period there was also roughly a doubling of direct production effects for exports to Other Japan, we could surmise that there was a large change in the composition of exports to Tokyo, with a shift toward items that required less energy per unit of output. This trend is the same for direct environmental effects. Conversely, the direct energy impacts in Tokyo of exports to Beijing were 1.40 times, whereas the figure for Other Japan was 1.27 times. If we consider the fact that the corresponding direct production effects were 3.95 and 2.60 times, respectively, it is possible that the energy efficiency of production increased considerably, also of roughly double to Other Japan, or that there was a shift toward export composition having items that required less energy per unit of output. This trend is even greater for direct environmental effects. In other words, one could say that the carbon intensity (carbon content of energy use) improved in Tokyo and Other Japan.

Thus, although the relative increase in export amounts from Tokyo to Beijing was greater, the direct energy effect in Beijing, decreased from 57.65 to 38.61 times that of Tokyo, indicating that the difference between the two became smaller. By comparison, for Other Japan, there was an increase in the difference from 3.80 to 5.98 times. In addition, the direct environmental effects declined similarly from 69.29 to 54.84 times for Beijing–Tokyo, and increased from 4.65 to 8.68 for Beijing–Other Japan.

Second, if in a similar fashion we compare the induced energy effects and induced environmental effects, in the relationship in Beijing toward Tokyo, the direct effects did not change considerably for energy or environment, although the increase in induced effects for energy and environment were large, at 1.74 times and 1.89 times, respectively. This may be because the composition of traded items from Beijing to Tokyo shifted toward items that have a larger induced production effect. Similarly, for trade from Beijing to Other Japan, the increase of induced effects was greater than for direct effects. Meanwhile, for transactions from Tokyo to Beijing and Other Japan to Beijing, the increases in induced effects for both energy and environment were larger than the increases in direct effects. This may be due to an increase in the proportion of products with a large induced effect. As for the difference in the interrelationship between Beijing and Tokyo, for energy induced effects decreased from 74.77 to 60.77 times, and for environment they decreased from 93.70 to 86.03 times. Conversely, as for the difference in the interrelationship between Beijing and Other Japan, for energy induced effects increased from 2.19 to 3.51 times, and for environment they increased from 2.79 to 4.95 times. These increases are smaller, however, than the widening of the difference of direct effects (from 3.80 to 5.98 times, and from 4.65 to 8.68 times, respectively).

A comparison of *indirect* effects (induced minus direct effects), indicates that the *indirect* effects increased for both energy and environment over time. As for the difference in interrelationship for indirect effects, larger gaps are indicated compared to direct effects and induced effects, as indirect energy effects from the trading relationship between Beijing and Tokyo decreased from 124.88 to 81.79 times, and for *indirect* environmental effects, from 167.13 to 114.50 times. Meanwhile, regarding Beijing and Other Japan, *indirect* effects for energy increased from 1.45 to 2.65 times, and for environment they increased from 1.91 to 3.71 times.

5. FACTORS FOR THE MUTUAL ENVIRONMENTAL IMBALANCE

This study used multiple input-output tables arranged identically for 39 industrial sectors, and conducted a comparison of mutual economic transactions between Beijing and Tokyo, and Beijing and Other Japan, as well as their resulting induced environmental effects. Calculations revealed large differences in induced environmental effects, of 93.70 times in 90/92 and 86.03 times in 95/97. Stated differently, almost 100 times the CO_2 emissions are emitted in Beijing compared to Tokyo, as a result of mutual trade between the two cities. In a sense, this is simply related to the fact that the value of direct trade from Beijing to Tokyo compared to exports in the opposite direction is larger than in the opposite direction from Tokyo to Beijing (3.72 times larger in 90/92 , and 1.74 times in 95/97). What crated the change over this period? Here we attempt a factor analysis based on the results in Table 7. Three factors are analyzed: (1) induced production coefficient factor, (2) energy intensity factor, and (3) carbon content factor. With the direct production effects factor (value of direct transactions), we can decompose the disparity of induced environmental effects into four factors. The results are shown in Table 8.

The first observation is that, for the Beijing–Tokyo pair the disparity in induced environmental effects is large but declining, while the disparity for the Beijing–Other Japan pair is relatively small but growing rapidly. For the Beijing–Tokyo pair, the difference in trade amounts and difference in induced production coefficient contributes to a shrinking of the difference in induced environmental effects, but conversely, contributes to an expansion of the disparity in energy intensity and carbon intensity. The disparity in energy intensity is particularly large, and it grew significantly from 90/92 to 95/97. By way of explanation, it is possible that energy productivity worsened in the 39 industries, or that the composition of trade shifted toward items that have poor energy efficiency,

Table 8 Decomposition of the Gaps for Induced Environmental Effects.

Gaps	Induced environmental effects	Carbon content	Energy intensity	Induced production coefficient	Direct production effects
Beijing/Tokyo (90/92)	93.70	1.25	14.14	1.42	3.72
Beijing/Tokyo (95/97)	86.03	1.42	26.41	1.32	1.74
Beijing/Other Japan (90/92)	2.79	1.27	2.90	0.87	0.86
Beijing/Other Japan (95/97)	4.95	1.41	6.02	1.03	0.57

but at this point the extent to which each factor influenced the situation is not clear. To clarify the situation, it would be necessary to utilize a factor analysis model that incorporates structure effects, but we do not indicate it here due to the space limitation.

Regarding the disparity in the Beijing–Other Japan pair, even though the amount of exports from Other Japan to Beijing is large, it is important to point out that the induced environmental effects are larger in Beijing. In the opposite direction, similar to the situation with the Beijing–Tokyo pair, the large disparities in energy intensity and carbon intensity are factors to consider. The disparities in energy intensity are smaller compared to the Beijing–Tokyo pair, however, and may be influenced by the composition of items being traded more than by differences in energy efficiency due to the technology gap between China and Japan. This may be because Tokyo has a larger service component, so economic transactions of the service industries are relatively larger. In other words, in cases where cities at differing stages of development and with different industrial structure are conducting economic transactions across national borders, these results suggest that large environmental imbalances could be created.

6. CONCLUDING REMARKS

This report analyzed the scale and situation of economic interdependency and induced environmental burden between Tokyo, Beijing and the rest of Japan (Other Japan), at two points in time, using input-output tables for multiple industries in Tokyo, Beijing, and Asia.

Some of the conclusions are as follows:

- Direct exports between each region over the five years studied grew by a factor of about 2 to 4 times, but the relative increase in exports from Tokyo to Beijing was larger.
- Over the five years studied, the disparity in environmental burden generated for Beijing and Tokyo was greater than the disparity in export value, and in particular, in Beijing it was more than 100 times the indirect environmental burden from induced effects.
- Between Beijing and Tokyo, the disparity in induced environmental impacts was extremely large, at about 90 times.

A factor analysis of the disparity of induced environmental impacts over the five years studied, showed that the disparity in the energy efficiency factor is the largest.

ACKNOWLEDGEMENTS

This report is one outcome of the fiscal 2004–06 Ministry of the Environment "Global

Environment Research General Fund" project titled "Research on Methodologies to Evaluate Achievement of Sustainable Production and Consumption based on Material Flow Models" (Lead organization: National Institute for Environmental Studies).

REFERENCES

Beijing Metropolitan Government (1996). Input-Output Table of Beijing 1992, Statistical Bureau, Beijing Metropolitan Government.

Beijing Metropolitan Government (1999). Input-Output Table of Beijing 1997, Statistical Bureau, Beijing Metropolitan Government.

Ichihashi, Masaru (2000). "Reexamination on Interregional Dependent Structure of Multi-sectoral Economies: Empirical Findings from Japan-China International Input-Output Table, *Proceedings of the 3rd International Conference on Japan-China Socioeconomic Statistics*, pp. 195-203, Capital Economy and Trade University Publishing House., Beijing, China. (in Chinese).

Imura, Hidefumi and Yuichi Moriguchi (1995). "Economic interdependence and eco-balance: accounting for the flow of environmental loads associated with trade", *Toward Global Planning of the Sustainable Use of the Earth Development of Global Eco-Engineering*, S. Murai (ed.), pp. 189-208, Elsevier Science B. V.

Institute of Developing Economies (1997). *International Input-Output Table China-Japan 1990*, Tokyo, Japan.

Institute of Developing Economies (2001). *Asian International Input-Output Table 1995*, Chiba, Japan.

Statistical Bureau of China (1996). *China Input-Output Table 1992*, China Statistics Press, Beijing, China.

Statistical Bureau of China (1999). *China Input-Output Table 1997*, China Statistics Press, Beijing, China.

Tokyo Metropolitan Government (1995). *Input-Output Table of Tokyo 1990*, Department of Statistics, Administrative Office, Tokyo Metropolitan Government.

Tokyo Metropolitan Government (2000). *Input-Output Table of Tokyo 1995*, Department of Statistics, Administrative Office, Tokyo Metropolitan Government.