Formation of Inter-Country Production Networks in East Asia: Application of International Input-Output Analysis

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Abstract:

This paper analyzes trade in East Asia and inter-industry linkages over the borders, i.e. spatial linkages, with use of the Asian international input-output tables. As a result of analysis, it was shown that intra-regional trade within the eight East Asian countries, the U.S and Japan has been driven by the intermediate goods trade. At the same time, intermediate goods, especially those of the material and machinery industries, increased their proportion of intra-industry trade. On the other hand, although the structures of spatial linkages were more or less similar to those of domestic industries, the Electric Machinery industry had strong spatial forward linkage effects. Also it was shown that the percentage of intra-industry spatial linkages increased, particularly in the Electric Machinery industry, implying that the international division of labor between different stages of production or fragmentation had progressed rapidly. Finally, machinery industry clusters, especially those of the Motor Vehicles and Electric Machinery industries, expanded significantly, and the production network of the Electric Machinery industry had expanded with industries in Japan, East Asia, and the U.S. respectively located in the upstream, midstream, and downstream of roundabout production.

Keywords: Asian international input-output tables, production network, spatial linkages

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Introduction

In East Asia, international production sharing or fragmentation, where stages of production leading to final goods are fragmented and located in more than one country, has been a driving force of economic integration. Therefore, it would be appropriate to analyze trade in East Asia from a viewpoint of a production/distribution network and to focus on trade in intermediate goods rather than in final goods.

On the other hand, it is an important contribution of inter-industry economics to investigate the "stages of production leading to final goods" and to develop this idea into a theory from the perspectives of production technology and industrial structure. In inter-industry economics, for example, "clusters of industries" and "channels of roundabout production" are identified by an analysis of inter-industry linkages and permutations of sectors (such as triangulation) of the national input-output table. In East Asia, however, some of the stages of production that used to be undertaken by domestic industries have relocated to other countries, particularly driven by the activities of multinational firms, and hence input-output structures of industries (as well as clusters of industries and channels of roundabout production) have been affected accordingly.

Because of the expansion of production networks throughout East Asia, it is becoming inappropriate to rely on the conventional input-output analysis, which is mostly concerned about domestic issues. Overcoming this limitation requires a different analytical tool and methodology that captures not only domestic transactions but also trans-border transactions in East Asia. In this paper, I will analyze trade in East Asia and inter-industry linkages over national borders (i.e. spatial linkages) with use of the Asian international input-output tables. For the latter topic, I will, in particular, focus on the machinery industry because of its leading role in establishing a production network in East Asia.

This paper is structured as follows. In Section 1, trade in East Asia will be analyzed with particular emphasis on intermediate goods. Also the Grubel-Lloyd index will be calculated to examine the progress of intra-industry trade. In Section 2, the structure of spatial linkages will be explored, followed by an analysis of clusters in the machinery industry.

I. Trade in East Asia

1 Trend of trade in intermediate goods

First, let us examine how the trade in intermediate goods has evolved in East Asia by looking at the Asian international input-output tables for 1985 and 1995. Table 1 shows total inputs of all the industries in each East Asian country, the U.S. and Japan – endogenous countries covered in the Asian tables - as well as inputs from the region[1] (i.e. inputs from all the endogenous countries excluding its own country). Transactions of intermediate goods, consumption goods, and investment goods are respectively derived in the Asian tables from the matrices or vectors of intermediate transactions, private + government consumption, and gross capital formation, so that these data are consistent with the national accounts of all the endogenous countries[2].

Table 1 Total input and input from the region (1 billion dollars)

	Intermediate goods				Consumption goods				Capital goods			
	85		95		85		95		85		95	
	Total	Region	Total	Region	Total	Region	Total	Region	Total	Region	Total	Region
China	346.0	9.6	1,154.7	45.5	190.1	2.2	428.7	4.3	92.7	7.3	243.1	14.4
Korea	121.3	12.2	570.9	54.0	64.0	1.1	312.2	5.4	27.3	2.5	190.2	15.9
Taiwan	87.7	7.9	310.8	44.9	39.7	0.9	195.3	7.2	11.6	1.4	62.3	11.1
Singapore	29.6	8.1	140.4	42.7	10.5	1.5	41.8	4.0	7.5	1.5	27.6	7.4
Malaysia	31.1	5.0	118.3	28.0	20.2	2.0	51.7	7.7	9.3	1.8	38.2	15.7
Thailand	37.5	3.1	189.5	29.0	30.0	0.7	114.2	2.4	8.8	1.2	74.4	11.1
Philippines	26.2	1.8	68.6	9.6	24.7	0.3	63.8	1.9	5.0	0.3	16.2	3.4
Indonesia	62.1	4.2	203.8	12.0	61.6	0.4	175.9	4.2	19.6	1.1	62.4	5.4
East Asia 8	741.5	51.8	2,757.0	265.8	440.8	9.1	1,383.6	37.1	181.7	17.0	714.3	84.3
Japan	1,446.4	44.4	4,580.9	105.0	915.5	5.7	3,616.6	43.4	360.2	4.0	1,484.3	24.4
U.S.	3,395.2	42.4	6,378.1	123.9	3,430.0	45.0	5,916.9	68.7	657.9	23.3	1,286.9	61.2
Total	5,583.1	138.6	13,716.0	494.8	4,786.3	59.9	10,917.1	149.2	1,199.8	44.3	3,485.5	169.8

*1) Total input is a total of intermediate inputs, private + government consmptions, and gross capital formation in all the industries in each country.
*2) Input from the region is a total amount of input from all the endogenous countries excluding its own countrry.
*3)East Asia 8 is a subtotal of the eight East Asian countries from China through Indonesia.

Table 2. Overseas dependency and regional input ratios (%)

	Intermediate goods				Consumption goods				Capital goods			
	85		95		85		95		85		95	
	Overseas	Regional	Overseas	Regional	Overseas	Regional	Overseas	Regional	Overseas	Regional	Overseas	Regional
China	7.7	2.8	10.0	3.9	4.1	1.1	2.5	1.0	16.1	7.9	15.1	5.9
Korea	22.5	10.0	20.7	9.5	3.5	1.7	5.6	1.7	14.5	9.3	15.4	8.4
Taiwan	22.9	9.0	29.5	14.5	9.3	2.4	11.8	3.7	21.2	12.0	26.2	17.9
Singapore	53.0	27.2	45.5	30.4	28.3	14.6	17.4	9.6	30.4	19.9	35.1	26.8
Malaysia	33.8	16.1	41.5	23.7	18.6	10.1	29.8	15.0	33.4	19.1	56.9	41.1
Thailand	19.6	8.1	30.1	15.3	6.9	2.3	13.6	2.1	26.5	13.5	29.5	14.9
Philippines	17.2	7.0	30.0	14.0	6.0	1.0	10.5	3.0	11.6	5.8	32.8	20.9
Indonesia	15.1	6.7	15.0	5.9	3.8	0.6	9.6	2.4	13.6	5.4	19.0	8.6
East Asia 8	16.4	7.0	19.8	9.6	6.0	2.1	8.2	2.7	17.8	9.4	21.4	11.8
Japan	9.2	3.1	6.5	2.3	1.9	0.6	3.2	1.2	1.7	1.1	2.5	1.6
U.S.	5.9	1.2	7.6	1.9	4.7	1.3	4.5	1.2	8.5	3.5	10.6	4.8
Total	8.1	2.5	9.7	3.6	4.3	1.3	4.5	1.4	7.8	3.7	9.4	4.9

*1) Overseas dependecy ratio = (Total input - Input from the domesitic industries)/Total input X 100.
*2) Regional input ratio = Input from the region (i.e. input from the endongenous counries excluding its own counry) / Total input X 100 .

Table 1 shows that total intermediate inputs for the eight East Asian countries increased from US$741.5 billion in 1985 to US$2,757 billion in 1995. The volume of intermediate inputs mostly reflects the scale of economic activities; China, for example, had the largest intermediate inputs among the eight East Asian countries at US$1,154.7 billion. Furthermore, although Japan and the U.S. had much larger total intermediate

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[1] Although the U.S. is not a part of East Asia, all the endogenous countries covered in the Asian input-output tables - China, Korea, Taiwan, Singapore, Malaysia, Thailand, the Philippines, Indonesia, Japan, and the US. - will be treated as one region in this study.

[2] It is, of course, possible to use trade statistics to investigate the volume of trade by the purpose of usage, i.e. traded goods for intermediate input, consumption, and investment. However, there is a problem with the reliability of such data, because they are not necessarily consistent with the national accounts of the trading countries.

inputs, the eight East Asian countries had relatively large shares of intermediate inputs vis-à-vis inputs of consumption and capital goods. This is because industries such as manufacturing industry tend to have a long process of roundabout production and thereby a higher intermediate input ratio. East Asian countries have a higher share of such industries, as compared to, for example, the U.S. where the service sector is dominant.

Next, intermediate inputs from other countries in the region for the eight East Asian countries increased from US$51.8 billion in 1985 to US$265.8 billion in 1995. However, the volume of intermediate inputs for each country did not correspond to the scale of economic activities. For example, inputs for China in 1995, at US$45.5 billions, were below those of Korea, at US$54 billion, and slightly exceeded those of Taiwan and Singapore. Furthermore, the U.S. and Japan, which were of larger economic size, had much lower inputs from the region than the total of the eight East Asian countries.

The above relationships will be further clarified by comparing the regional input ratios of those countries, which are the ratios of inputs from the region to total inputs. Table 2 shows the overseas dependency ratios, which are the ratios of total inputs minus domestic inputs (=overseas inputs) to the total inputs, as well as the regional input ratios. According to Table 2, the regional input and overseas dependency ratios for the eight East Asian countries in 1995 were respectively 9.6% and 19.8%, and they both vastly exceeded the ratios of the U.S. and Japan. Furthermore, those countries which had extremely high dependency ratios were countries with small populations, such as Singapore and Malaysia, while large counties like China and Indonesia had low dependency rations, in spite of backwardness of their industries. These facts seem to reflect the empirical knowledge that large and/or mature economies tend to have high self-sufficiency.

Over the period 1985-1995, the regional input ratio of intermediate goods in the eight East Asian countries increased by 38% (from 7.0% to 9.6%), while the overseas dependency ratio grew only by 21% (from 16.4% to 19.8%). The overall dependency on regional inputs, therefore, increased in this period. Ozaki (2004) pointed out that the EC, which was composed of smaller economies than the U.S., increased self-sufficiency of intermediate goods by expanding inter-regional trade faster than trade with non-EC countries. It is interesting to find that a similar process was occurring in East Asia with the U.S. and Japan deeply involved.

Regarding final goods, inputs of consumption goods in the U.S. were overwhelmingly large for both 1985 and 1995, while the eight East Asian countries and Japan had relatively large inputs of capital goods. Inputs of consumption goods from the region for the eight East Asian countries were relatively small (US$37.1 billion), and no single country exceeded US$10 billion. Therefore the regional input and overseas dependency ratios were both extremely low, as compared to those of intermediate and capital goods. In 1995, on the other hand, inputs of capital goods from the region for the eight East Asian countries amounted to US$84.3 billion, exceeding those for the U.S. and Japan. Consequently, the regional input and overseas dependency ratios of capital goods for the eight East Asian countries were both higher than those of intermediate goods, although the latter had grown faster[3]. Singapore and Malaysia were especially highly dependent on the procurement of capital goods from the endogenous countries (26.8% and 41.1% respectively). The structure of high dependency, which is biased towards intermediate and capital goods and against consumption goods, implies that the main purpose of trade with other countries in the region was procurement of production goods, and much less the procurement of consumption goods. Finally, we may conclude that intra-regional trade for the eight East Asian countries was driven by the trade of intermediate goods, because it exceeded capital and consumption goods in terms of both the volume and growth rate of trade over the period 1985-1995[4].

2 Intra-industry trade

It was established in the 1960s that intra-regional trade in the EC countries was driven by intra-industry trade rather than inter-industry trade (Balassa 1966, Grubel 1967). In this section, we calculate the Grubel-Lloyd (G-L) index using the data from the Asian international input-output tables for 1975, 1985, and 1995, which are all convertible into the uniform sector classification (56 sectors), and then examine the progress of intra-industry trade[5]. In this analysis, traded goods will be classified into intermediate

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[3] Over the period of 1985- 1995, the regional input ratio of capital goods for the eight East Asian countries increased by 26 % (from 9.4% to 11.8%), while that of consumption goods were extremely low and grew by 29% (from 2.1% to 2.7%). In any rate, regional input ratios of intermediate goods had grown faster than these figures at 38%.

[4] Table 1 shows that inputs in 1995 from the endogenous countries of the intermediate goods, consumption goods, and capital goods were respectively 5.13, 4.08, and 4.96 times as large as those in 1985. Also, an increase in the inputs from the endogenous countries of the intermediate goods over the period 1985-1995 was US$214 billion, and it held 69% of all the increases in inputs, US$309.3 billion, which also included capital goods and consumption goods.

[5] The basic sector classifications of the Asian international input-output tables are as follows; 56 sectors for the 1975 table, 24 sectors for the 1985 table, and 78 sectors for the 1990 and 1995 tables. Among them, the sector classification for manufacturing industries in the 1985 table was not detailed enough so the 1985 table was excluded from the analyses of the Grubel-Lloyd index (in 56 sectors) and the spatial linkages (in 23 sectors). Also there is a difference in the coverage of countries in these tables; China

inputs, consumption goods, and investment goods, according to the purpose of usage of traded goods (for the details of methodology, see the Technical Note).

Table 3 clearly indicates the rising tendency of the average G-L index in all the endogenous countries. The average G-L index of intermediate goods notably increased most drastically from the lowest among the three types of traded goods in 1975 to the highest in 1995. On the other hand, the average G-L index of consumption goods was the highest in 1975, but it did not grow thereafter. This fact suggests that intra-industry trade within the eight East Asian countries plus the U.S. and Japan has been driven by production goods, especially intermediate goods. Among the countries which had high G-L indexes were industrialized countries such as Taiwan, Korea, Singapore, and Malaysia, while Indonesia and the Philippines still had low G-L indexes due to the vertical structure of trade in these counties.

Table 4 lists the top 8 intermediate goods in terms of the G-L index. Because the G-L indexes of primary goods were generally low, Table 4 lists manufactured goods only. Light manufacturing industries, such as Meat and Dairy Products, Leather Products, and Other Made-up Textile Products, had the highest G-L index ranks in 1975. Since 1990, however, the G-L indexes of material industries, such as Glass Products, Other Non-metallic Mineral Products, and Non-ferrous Metal, have risen, along with Printing and Publishing. Further, in 1995 machinery industries, in particular, Precision Machinery, Other Transport Equipment, and Electric Machinery had sharply increased G-L indexes[6].

Table 3. G-L index

	Intermediate goods			Consumption goods			Capital goods		
	75	90	95	75	90	95	75	90	95
China		0.47	0.66		0.04	0.20		0.35	0.51
Korea	0.39	0.59	0.66	0.19	0.19	0.43	0.20	0.45	0.55
Taiwan		0.60	0.75		0.32	0.64		0.69	0.76
Singapore	0.37	0.58	0.63	0.44	0.51	0.56	0.41	0.43	0.39
Malaysia	0.23	0.34	0.58	0.44	0.55	0.63	0.35	0.26	0.52
Thailand	0.19	0.45	0.55	0.25	0.25	0.31	0.04	0.38	0.39
Philippines	0.12	0.42	0.52	0.30	0.32	0.37	0.03	0.31	0.31
Indonesia	0.11	0.19	0.29	0.25	0.40	0.43	0.02	0.05	0.25
Japan	0.22	0.41	0.50	0.31	0.26	0.40	0.45	0.36	0.44
U.S.	0.30	0.46	0.57	0.29	0.19	0.33	0.50	0.56	0.61
Average	0.24	0.45	0.57	0.31	0.30	0.43	0.25	0.38	0.47

*1) Average is a simple average of GL indexes for the 10 countries.

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and Taiwan were only incorporated into the international input-output tables after 1985.

[6] Hoen (2002) calculated the Grubel-Lloyd index, using the EC input-output tables from 1975 to 1985. As a result, he found that intra-industry trade had increased its share of trade within the EC, and countries such as France, Germany and Belgium had relatively high G-L indexes, while manufacturing industries had high indexes. However, unlike this study, it was not possible to know the trend of intermediate goods in Europe, because traded goods are not classified by the purpose of usage in Howen's analysis.

Table 4. Grobel-Lloyd index (Intermediate goods)

	75		90		95	
1	Meat and dairy producs	0.70	Glass products	0.81	Non-ferrous metal	0.77
2	Leather products	0.65	Printing and publishing	0.80	Other non-metallic mineral products	0.76
3	Other textile products	0.60	Other non-metallic mineral products	0.73	Precision machinery	0.75
4	Non-ferrous metal	0.59	Other manufacturing products	0.65	Printing and publishing	0.70
5	Printing and publishing	0.58	Electric machinery	0.63	Other transport equipment	0.69
6	Electric machinery	0.57	Other rubber products	0.62	Other manufacturing products	0.68
7	Glass products	0.52	Non-ferrous metal	0.62	Glass products	0.68
8	Basic industiral chemical	0.51	Leather products	0.60	Electric machinery	0.66

*) Sector classification in the above table is in accordance with the 56 basic sector classification in the 1975 input-output table (see IDE Statistical Data Series No.39, 1982, pp. 502-3)

Ⅱ Spatial Linkages in East Asia

1 Input-Output Structure and Spatial Linkages

As shown in the Section 1, intra-regional trade within the eight East Asian countries plus the U.S. and Japan was driven by the intra-industry trade of intermediate goods. At the same time, the intra-industry trade of intermediate goods, especially those of material and machinery industries, gained weight as the East Asian economies industrialized. Then next question of interest is how these facts are relevant to the establishment of production networks in East Asia. In order to answer this question, I will first examine the spatial linkages in East Asia and then the clusters of machinery industry.

The input-output structures of industries are determined by their technologies. For example, the process of roundabout production from the material to final products can be depicted as follows (Ozaki and Ishida 1970, Ozaki 2004):

Figure 1. Process of roundabout production

Raw Material→[(Main Input → Output) → (Main Input → Output)・・・]→[Final Output]

1st Processing stage　　2nd Processing stage・・・

(Example)

Crude petroleum → [Vinylon resin → Vinylon yarn] → [Vinylon products]

Figure 1 shows the process of roundabout production starting from the raw material, then going through several stages of processing, and finally reaching the final output. When such interdependency exists among different stages of production, an increase in demand for the final output, i.e. vinylon products, would induce an increase in demand for its main input, i.e. vinylon yarn. This in turn would induce an increase in demand for its main input, i.e. vinylon resin, followed by an increase in demand for the most upstream industry, i.e. raw material - crude petroleum. On the other hand, an increase in supply of upstream industries, such as crude petroleum, would increase the production capacity of downstream industries (vinylon resin etc.), and thereby would induce an increase in the production of these industries. These effects of inducement on production are respectively called the “backward linkage effects” and “forward linkage effects.”

As can be inferred from the above discussion, backward linkage effects are strongly induced by industries with high intermediate input coefficients, such as manufacturing industries, while forward linkage effects are induced by the primary and material industries, whose outputs are utilized by the other industries as intermediate goods; in fact, Chenery and Watanabe (1958) investigated the structure of inter-industry linkages of the domestic industries in Japan, the U.S., Italy, and Norway, and then they found that (i) intermediate primary industries, such as agriculture and mining, had high forward and low backward linkage effects, (ii) intermediate manufacturing industries, such as metal and chemicals, had high forward and high backward linkage effects, (iii) final manufacturing industries, such as foods and machinery, had low forward and high backward linkage effects, and (iv) final primary industries, such as transportation, trade and services, had low forward and low backward linkage effects.

However, the actual process of production is more complex than described above. For example, in addition to main inputs, inputs processed from other materials will be utilized as well as energy, transportation, telecommunication, trade, finance and other miscellaneous services. All these inputs either directly or indirectly induce production of the relevant industries. Furthermore, some intermediate goods cannot be produced domestically, and once they are imported from abroad, spatial linkages are formed[7]. Especially in small developing countries with immature industrial structure, a large amount of intermediate goods need to be imported, and hence strong spatial

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[7] The definition of spatial linkage is as follows. A spatial linkage represents interdependence of industries over the space (or borders) which are linked through transactions of intermediate goods. For example, when intermediate goods produced by a domestic industry are utilized by an industry in another country, spatial linkages will occur. In this case, as the output of the industry in the other country increases, production of the domestic industry will be induced by the spatial backward linkage effect. On the other hand, production in the domestic industry will be induced by the spatial forward linkage effects, when the industry in the other country provides intermediate goods for the domestic industry and hence enhances the latter’s production capacity.

linkages will be generated.

2 Interdependency and Spatial Linkages in East Asia

As shown above, there is a distinct regularity with regard to the input-output structure of industry, which is largely determined by the production technology and industrial structure of each country. It is therefore expected that the position of a certain industry (in a certain country) relative to the entire production process can be known by investigating the input-output structure of industry. Focusing on the interdependency of industries across borders, the magnitude of spatial forward and backward linkage effects were computed by using the Asian international input-output tables, which had been converted into the uniform 23 sectors. Table 5 indicates the numbers of spatial linkages with magnitudes exceeding 5%, i.e. those spatial linkages through which output of the recipient industry increased by more than 5% of output of the inducing industry (see the Technical Note for details of the methodology). Due to limited space, Table 5 neglects the names of countries that either induce or receive the strong linkage effects, and only the combination of industries are indicated.

Table 5. Spatial linkages, 1995 (Industry X Industry)

	Agriculture	Crude petroleum	Mining	Food	Spinning	Textile	Wooden prod.	Paper & pulp	Basic chemicals	Chemical prod.	Refined petroleum	Rubber prod.	Non-metallic min.	Iron & non-ferrous	Metal prod.	Industrial machinery	Electric machinery	Motor vehicles	Other trans. equip.	Precision machinery	Other manuf. prod.	Trade & trans.	Services, etc.	Total
Agriculture				1			1																	2
Crude petroleum											2													2
Mining																								
Food	<1>			**1**																				1<1>
Spinning					**1<1>**	2			<2>															3<3>
Textile																								
Wooden prod.	<1>						**3<2>**																	3<3>
Paper & pulp								**3**																3
Basic chemicals					1				**7<2>**	5	<1>										5			18<3>
Chemical prod.																								
Refined petroleum		<4>									**1<1>**													1<5>
Rubber prod.												**<1>**												<1>
Non-metallic min.													**1**											1
Iron & non-ferrous			<3>											**6<5>**	6	3		2	2					19<8>
Metal prod.			<1>											<1>										<2>
Industrial machinery			<1>													**5**								5<1>
Electric machinery										<1>				<1>		2<1>	**16<15>**			1				19<18>
Motor vehicles			1<1>									<1>					<1>	**6<1>**						7<4>
Other trans. equip.																			**2**					2
Precision machinery																				**2**				2
Other manuf. prod.														<1>						<1>				<2>
Trade & trans.		<2>									<2>							2		1				3<4>
Services and Others	<2>	<5>	<3>				<6>		<2>		<1>	<2>		<2>	<2>	<3>	2<6>	2	<1>	1<4>	<2>	<1>		5<42>
Total	<4>	<11>	1<9>	2	2<1>	2	4<8>	3	7<6>	5<1>	3<5>	<4>	1	6<10>	6<2>	10<4>	18<22>	12<1>	4<1>	5<5>	5<2>	<1>		96<97>

*1) Looking at the table column-wise (i.e. vertically), we can find what sectors (in columns) give strong spatial linkage effects on what sectors (in rows).
*2) Figures in the parentheses indicate the numbers of spatial forward linkage effects with magnitudes exceeding 5%.
*3) Services and Others are composed of Services; Electricity, Gas, and Water Supply; Construction; and Public Administration.

Table 5 shows that primary industries, such as Crude Petroleum and Natural Gas and Mining, had strong forward linkage effects, and the number of combinations of spatial linkages with magnitudes exceeding 5% was about 10. Also production technology is reflected by the structure of linkages: Crude Petroleum and Natural Gas, for example, had strong forward linkage effects on Petroleum Products. Intermediate manufacturing industries, such as Basic Chemicals, and Iron and Non-ferrous Metal, had both strong backward and forward linkage effects, while final manufacturing industries, such as Industrial Machinery, Electric Machinery, and Motor Vehicles, had strong backward linkage effects. Interestingly, this structure of spatial linkages is similar to that of the domestic industries that were examined intensively by Chenery and Watanabe (see p.8). This seems to reflect the fact that similar technology is being applied whether the goods are produced domestically or through the production networks across borders. However, Electric Machinery had strong spatial forward linkage effects (as well as backward linkage effects), and hence its usage as intermediate input goods (i.e. parts and components) for other industries was strengthened accordingly. This corresponds to the fact that Electric Machinery has expanded its production network throughout East Asia, as shown below.

Looking at Table 5 row-wise, it is seen that industries that received strong backward linkage effects (i.e. those industries whose outputs were strongly induced by backward linkage effects) were mostly material industries, such as Basic Chemicals, Iron and Non-ferrous Metal. On the other hand, Services and Others received nearly a half number of strong forward linkage effects, and Electric Machinery was a recipient of strong forward linkage effects as well as of backward linkage effects.

Using the same results of analysis as Table 5, Table 6 indicates the names of countries that either induce or receive strong linkage effects, but the combinations of industries are neglected. According to Table 6, no large economies like the U.S. and Japan had an industry that induced production of another country’s industry by more than 5% of its output – note that columns of the U.S. and Japan are all blank. This is because the outputs of the U.S. and Japanese industries were so large that the ratios of induced production to outputs became negligible. In a similar vein, China had only four combinations of spatial linkages exceeding 5%. On the other hand, Taiwan and Southeast Asian countries, with the exception of Indonesia, had more than twenty combinations of strong spatial linkage effects. Malaysia and the Philippines were outstanding in creating forward linkage effects, and so were Taiwan and the Philippines in backward linkage effects. These facts reflect the general tendency that developing countries, with relatively small economies and immature industrial structures, are marked by an imbalance in the demand for and supply of intermediate goods in the domestic markets; these countries hence need to trade with other countries, especially with developed countries.

Table 6. Spatial Linkages, 1995 (Country X Country)

	China	Korea	Taiwan	Singapore	Malaysia	Thailand	Philippines	Indonesia	Japan	U.S.	Total
China		<1>		<1>	<2>	1					1<4>
Korea				1<1>	<2>		2<1>	<1>			3<5>
Taiwan					1		2				3
Singapore					1<2>	1<1>	1<1>				3<4>
Malaysia			2	3<4>		1		<1>			6<5>
Thailand				<1>	<2>		<1>				<4>
Philippines											
Indonesia			2								2
Japan	1<2>	4<1>	14<2>	10<2>	7<11>	9<4>	12<10>	6<8>			63<40>
U.S.	<1>	1<2>	4<5>	3<9>	2<6>	1<3>	3<9>	1			15<35>
Total	1<3>	5<4>	22<7>	17<18>	11<25>	13<8>	20<22>	7<10>	0<0>	0<0>	96<97>

*1) Looking at the table column-wise (i.e. vertically), we can find what countries (in columns) give strong spatial linkage effects on what countries (in rows).
*2) Figures in the parentheses indicate the numbers of spatial forward linkage effects with magnitudes exceeding 5%.

Next, looking at Table 6 row-wise, it can be seen that Japan by far received the largest number of strong backward linkage effects – Japan had 63 combinations, holding 65.6% of the total number of backward linkages. Regarding the forward linkage effects, the U.S. has increased its presence, and the difference from Japan has narrowed to only five. These results suggest that, compared with East Asian industries, Japanese industries were located in the upstream of roundabout production and hence became recipients of backward linkage effects (i.e. suppliers of intermediate goods for East Asia), while the U.S. industries became recipients of forward linkage effects (i.e. demander of intermediate goods from East Asia). In any event, Japan and the U.S. received strong spatial linkage effects from all the eight East Asian countries, and their shares as a recipient of linkage effects were very large, with a combined share as much as 79.3% of all spatial linkage effects. As shown above, the interdependency between the eight East Asian countries and the U.S. and Japan were not balanced, with much greater dependency of the former on the latter. Such a relationship, however, will be changed gradually, as the East Asian economies further industrialize, although one-sided relationships will remain in countries with small populations[8].

Returning to Table 5, we notice that the spatial linkage effects that are located

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[8] Van der Linden (1998) computed the magnitude of spatial linkages, using the EC input-output table by applying the same methodology as this study. He found that among the seven countries (i.e. Germany, France, Italy, the Netherlands, Belgium, the U.K., Denmark), Germany and France held a combined share of 71% in the number of strong spatial linkages, which is close to the 79.3% combined share of the U.S. and Japan in this study. As shown above, this structure, which results in small economies having one-sided dependency on large economies, will not change even after the former's economies develop.

on the diagonal of the table hold a large percentage of all the linkage effects. These numbers represent the linkage effects within the same industry but between different countries, and therefore reflect the progress of international division of labor between different stages of production. In order to see the progress of this effect over time, the same methodology was applied to the 1975 and 1990 tables. Table 7 indicates the numbers for these intra-industry spatial linkage effects (only the top 4 are listed) and their percentage of all the linkage effects. In 1975, the percentages of such forward and backward linkage effects were 15.5% and 29.6% respectively. But they increased drastically in the 1990s and reached 28.9% and 56.3% respectively in 1995, implying that more than a half strong backward linkage effects occurred within the same industry across borders. As shown above, the division of labor between different stages of production had progressed rapidly within the eight East Asian countries, the U.S. and Japan. Further, Table 7 shows that Electric Machinery was at the top of the list since 1990, implying that a new model of international division of labor, such as fragmentation, had proceeded particularly in this industry.

Table 7. Intra-industry Spatial linkage effects

		1	2	3	4	Total (share %)
1975	Backward	Basic chemicals (8)	Motor vehicles (7)	Metal (6)	Electric machinery (5)	46(29.6%)
	Forward	Metal (6)	Basic chemicals (1)	Chemical products (1)	Wooden products (1) etc.	13(15.5%)
1990	Backward	Electric machinery (12)	Basic chemicals (9)	Motor vehicles (7)	Precision machinery (6)	57(51.8%)
	Forward	Electric machinery (9)	Metal (6)	Basic chemicals (3)	Wooden products (1) etc.	25(21.9%)
1995	Backward	Electric machinery (16)	Basic chemicals (7)	Metal (6)	Motor vehicles (6)	54(56.3%)
	Forward	Electric machinery (15)	Metal (5)	Chemical products (2)	Wooden products (2)	28(28.9%)

*1) For example, figures in the parentheses of backward linkage effects, 1995, indicate those on the diagonal of Table 5 (only the top 4 sectors are listed) and their total (=54) and percentage of the total number of strong spatial linkages in all the sectors (=96) .

3 Clusters in the Machinery Industry

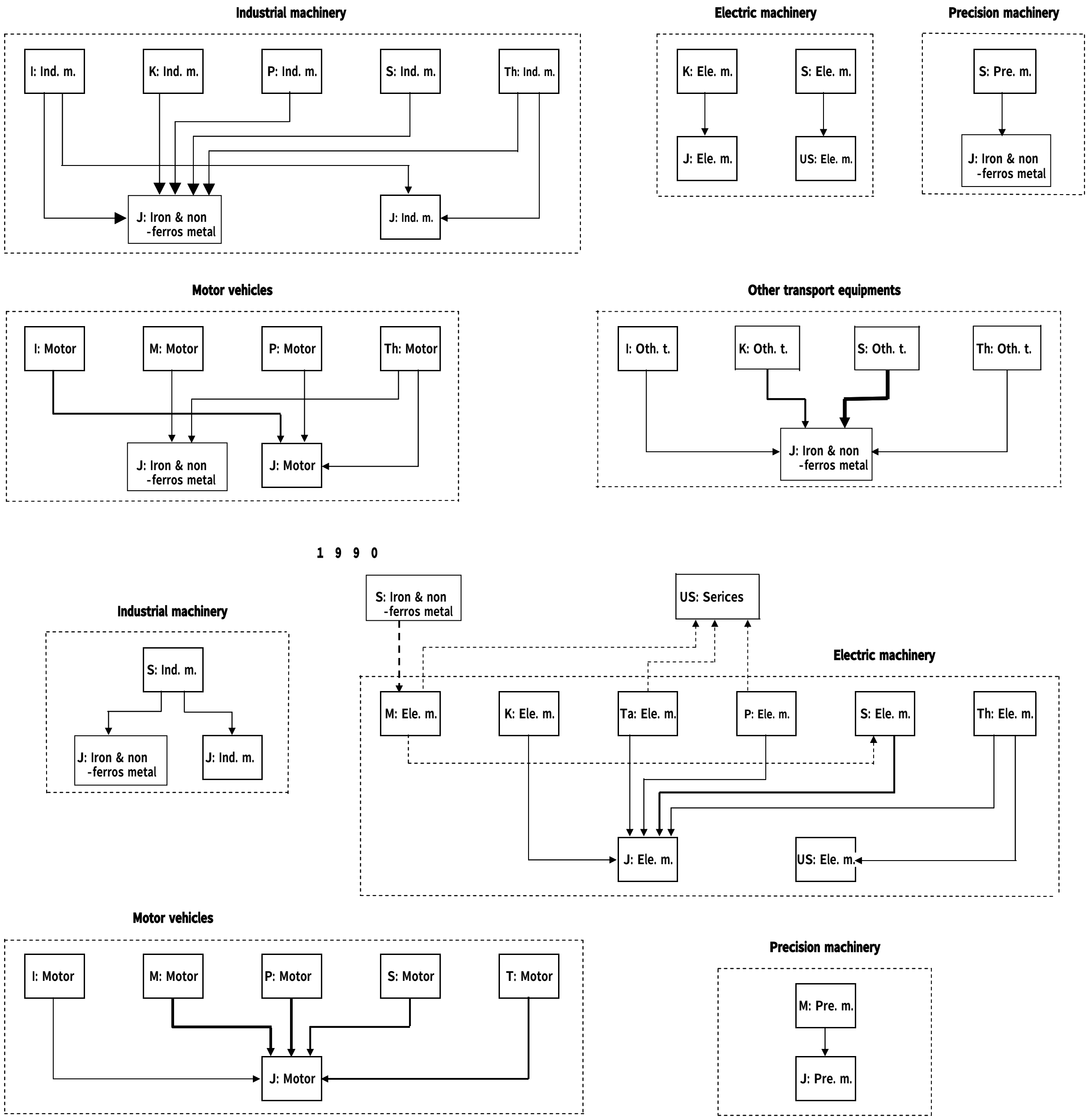
In Tables 5 and 6, industries and countries are treated separately, and hence names of industries and countries cannot be identified simultaneously. Here they will be treated together, in order to look at the development of clusters, especially those of machinery industry. Due to limited space, the criterion for including a cluster in Figure 2 will be raised from 5% to 10%. That is, only industrial clusters, where output of the recipient industry increased by more than 10% of output of the inducing industry, appear in the figure, and extremely strong linkage effects that exceed 20% of output are indicated by bold lines.

According to Figure 2, the sizes of clusters in 1975 were still small, and they were independent from each other. It is also striking that spatial linkages between different industries, especially linkages between the machinery industries and Iron and Non-ferrous Metal, were as strong as intra-industry linkages in the machinery industries. Next, looking at the figure for 1990 that covers China and Taiwan, it is clear that spatial linkages between different industries had shrunk, and most of the strong linkages effects occurred within the same industry. Needless to say, this corresponds to the fact the international division of labor between different stages of production had proceeded, as shown in Table 7. Regarding industrial clusters, the Electric Machinery cluster expanded significantly, while the Industrial Machinery and Other Transport Equipment clusters shrunk or disappeared. Above all, Electric Machinery in five East Asian countries (Korea, Taiwan, the Philippines, Singapore, and Thailand) had strong backward linkage effects on the same industry in Japan, and Electric Machinery in three East Asian countries (Malaysia, Taiwan, and the Philippines) had strong forward linkage effects on U.S. Services and other industries. This suggests that the production network of Electric Machinery expanded rapidly with industries in Japan, East Asia, and the U.S. respectively located in the upstream, midstream, and downstream of roundabout production. Regarding the interdependency in this region, conventional wisdom suggest a picture in which Japan first provides parts and components for East Asia, and then East Asia manufactures them into the final products for export to the U.S. However, this study implies that, while the interdependency between Japan and East Asia was consistent with the above-mentioned picture, the linkages between East Asia and the U.S. through the transactions of intermediate goods were strong as well.

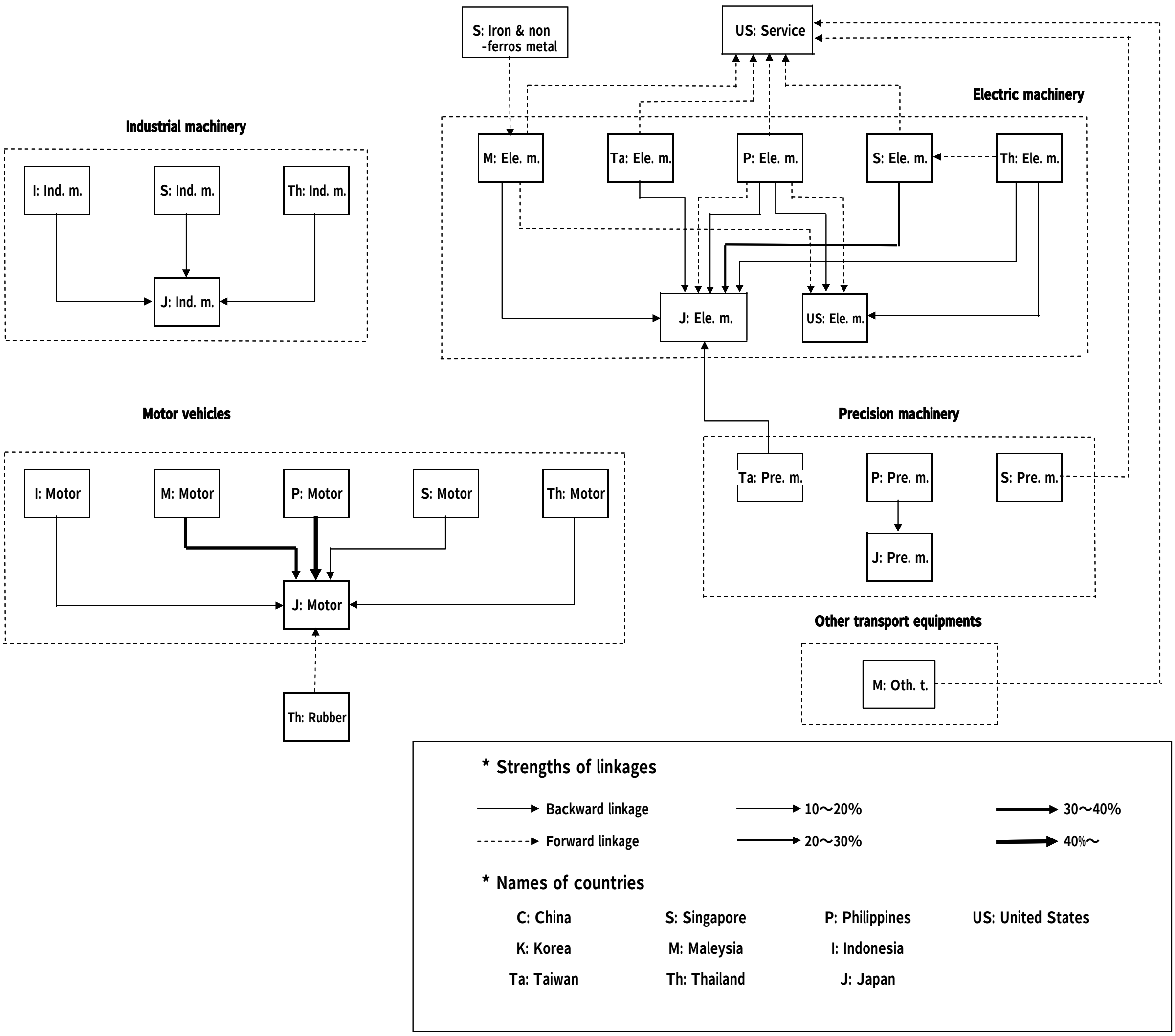
In 1995 the size of cluster as a whole had expanded, and the Motor Vehicles and Electronic Machinery industries in particular had strengthened their linkages. Within the cluster of Motor Vehicles, Indonesia, Malaysia, the Philippines, Singapore, and Thailand (where Japanese automobiles are produced except for Singapore) continued to have strong backward linkage effects on the Japanese Motor Vehicles industries with the strength of links from Malaysia and the Philippines exceeding 30% and 40% respectively. On the other hand, the Electric Machinery industry in East Asia had strengthened its linkages with the U.S., while the linkages with Japan remained dominant. The Electric Machinery industry in the Philippines notably had both strong forward and backward linkage effects on the U.S. and Japan, which in turn suggests that the Philippines came to play an important role in the production network of the Electric Machinery industry. Further, the Electric Machinery industry in Thailand had strong forward linkage effects on Singapore’s Electric Machinery industry, while Singapore’s Iron and Non-ferrous Metal industry had similar effects on the Malaysian Electric Machinery industry. These facts imply that spatial linkages had strengthened outside the U.S. and Japan, and Singapore came to play a pivotal role in this development. Finally, East Asian industries had strengthened their forward linkage effects on the U.S. Services and Others, and the latter made a significant contribution to the development of the machinery industry in East Asia.

Figure 2. Clusters in the machinery industry

1 9 7 5



1 9 9 5


S: Iron & non -ferros metal
US: Service
Electric machinery
M: Ele. m.
Ta: Ele. m.
P: Ele. m.
S: Ele. m.
Th: Ele. m.
J: Ele. m.
US: Ele. m.
Industrial machinery
I: Ind. m.
S: Ind. m.
Th: Ind. m.
J: Ind. m.
Motor vehicles
I: Motor
M: Motor
P: Motor
S: Motor
Th: Motor
J: Motor
Th: Rubber
Precision machinery
Ta: Pre. m.
P: Pre. m.
S: Pre. m.
J: Pre. m.
Other transport equipments
M: Oth. t.
* Strengths of linkages
Backward linkage
Forward linkage
10～20%
20～30%
30～40%
40%～
* Names of countries
C: China
S: Singapore
P: Philippines
US: United States
K: Korea
M: Maleysia
I: Indonesia
Ta: Taiwan
Th: Thailand
J: Japan

Conclusion

In East Asia, intra-regional trade within the eight East Asian countries, the U.S and Japan has been driven by the intermediate goods trade. At the same time, intermediate goods, especially those of the material and machinery industries, increased their proportion of intra-industry trade. These facts are consistent with the finding from spatial linkages analysis, which underpinned the progress of international division of labor between different stages of production. This is because the expansion of production networks of multinational firms had spread different stages of production throughout East Asia, and these different stages of production were connected with each other through the trade in intermediate goods. Therefore both intermediate and intra-industry trade had increased sharply.

On the other hand, although the structures of spatial linkages were more or less similar to those of domestic industries, the Electric Machinery industry had strong spatial forward linkage effects, implying that its usage as intermediate input goods (i.e. parts and components) for other industries was strengthened due to the expansion of production networks in Electric machinery. Also it was shown that the interdependency between the eight East Asian countries and the U.S. and Japan was not balanced with greater dependency of the former on the latter. Such a relationship will gradually change as the East Asian economies further industrialize, although unbalanced relationships will remain with regard to small economies. On the other hand, the percentage of intra-industry spatial linkages increased, particularly in the Electric Machinery industry, implying that the international division of labor between different stages of production or fragmentation had progressed rapidly.

Next, machinery industry clusters, especially those of the Motor Vehicles and Electric Machinery industries, expanded significantly. Further, it was shown that the production network of the Electric Machinery industry had expanded with industries in Japan, East Asia, and the U.S. respectively located in the upstream, midstream, and downstream of roundabout production.

As shown above, it is possible to incorporate the aspects of inter-industry economics into the study of production networks in East Asia with use of the international input-output tables. In the future, it is expected that further study will be conducted on this topic by applying different methodologies, such as permutation of sectors in the international input-output tables.

Technical Note

1. Measurement of the Grubel-Lloyd index

The Grubel-Lloyd (GL) index is useful to examine whether the international division of labor is driven by inter-industry trade or intra-industry trade. In this study, the G-L index was computed by using the data obtainable from the Asian international input-output tables. For example, the G-L index on intermediate goods is obtained as follows:

$$GL_{i\bullet}^{r*} = 1 - \frac{\left| \sum_{j=1}^{n_1} \sum_{s \neq r}^{s=\varphi} (z_{ij}^{rs} - z_{ij}^{sr}) \right|}{\sum_{j=1}^{n_1} \sum_{s \neq r}^{s=\varphi} (z_{ij}^{rs} + z_{ij}^{sr})}$$

where z_{ij}^{rs} represents the cross-border transaction of intermediate goods from Sector i in Country r to Sector j in Country s. Also, n_1 and φ represent the number of sectors and of endogenous countries respectively (for the G-L index on consumption and capital goods, it is just necessary to replace j in the above formula with the column vector on private plus government consumption and on the fixed capital formation respectively).

Further, the G-L index by country in Table 3 and by industry in Table 4 are obtained by calculating the average GL index weighted by the volume of trade (export + import) for industry and for country respectively.

2. Spatial Linkages

Spatial linkages came to attract an attention when Miller (1966) made an analysis of inter-regional feedback effects. In this paper, I calculated the strengths of spatial linkages by applying the “hypothetical extraction method.”

①Backward linkage effects

Since Hirschman (1958) introduced the concepts of forward and backward linkage effects and his followers (Rasmussen 1957, Chenery and Watanabe 1958) presented the methods of measuring these linkage effects, the Leontief model has been used frequently. The Leontief model, which is theoretically consistent with Keynesian economics, is suitable for the analysis of backward linkage effects[9].

[9] Characteristics of the Leontief model, such as price rigidity, stability of input coefficients and quantitative adjustment to derived demand, theoretically correspond to the Keynesian model under underemployment (Morishima 1955).

Suppose $\mathbf{Z}$ is a square matrix representing intermediate transactions in the input-output table[10] and $\mathbf{x}$ is a column vector on outputs of the sectors. Then an input-output coefficient matrix is represented by $\mathbf{A} = \mathbf{Z}\hat{\mathbf{X}}^{-1}$ (where $\hat{\mathbf{X}}$ is a diagonal matrix of $\mathbf{x}$). Next, since the relationship holds such that $\mathbf{x} = \mathbf{Zi} + \mathbf{f} = \mathbf{Ax} + \mathbf{f}$ (where $\mathbf{i}$ is an identity matrix and $\mathbf{f}$ a vector on final demand), we obtain

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \qquad (1)$$

where $(\mathbf{I} - \mathbf{A})^{-1}$ is called the Leontief inverse matrix. Further, substituting $\Delta\mathbf{f}$ into Equation (1), it can be alternatively represented by $\Delta\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\Delta\mathbf{f} = \Delta\mathbf{f} + \mathbf{A}\ \Delta\mathbf{f} + \mathbf{A}^2\Delta\mathbf{f} + \mathbf{A}^3\Delta\mathbf{f} + \ldots$. This formula expresses the process in which output $\Delta\mathbf{f}$ is first induced by an increase in final demand, then is followed by an increase in demand for intermediate goods $\mathbf{A}\ \Delta\mathbf{f}$ (i.e. derived demand by $\Delta\mathbf{f}$), that is further followed by $\mathbf{A}^2\Delta\mathbf{f}$ (i.e. derived demand by $\mathbf{A}\ \Delta\mathbf{f}$)…, provided input coefficients are stable (i.e. are fixed). Also, this is the process in which demand for intermediate goods spreads from downstream to upstream industries, corresponding to the concept of backward linkage effects. Further, this model captures a change in real output due to the assumption on the stability of prices in the model[11].

Next, we explain hypothetical extraction method. In this method, we suppose a case in which a column vector of Sector j in its own country is hypothetically extracted from the international input-output table (i.e. all the input coefficients of Sector j are replaced with zero and assume the case in which intermediate inputs for Sector j are all imported from the non-endogenous countries). Then the repercussion effects of Sector j are shut off, and consequently the outputs of the industries in the endogenous countries will be reduced. Here the reduced outputs are considered to represent the magnitude of backward linkage effects (Dietzenbacher and Van der Linden 1997).

Suppose that $\mathbf{A}(-sj)$ is a matrix in which a column vector of Sector j in Country S is hypothetically extracted. Then $\mathbf{x}(-sj) = [\mathbf{I} - \mathbf{A}(-sj)]^{-1}\mathbf{f}$ indicates the outputs induced in the hypothetical case. Then the difference from Equation (1)

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10 The number of sectors in the intermediate transaction matrix of the Asian input-output table is [number of the endogenous countries] x [number of the sectors in each country].

11 Because of the characteristics of the Leontief model, such as perfect (price) inelasticity of demand, perfect elasticity of supply, and homogeneity of product in each sector (Oosterhave, Eding, and Stedler 2001), the output is induced by a shift of the demand curve without affecting any price. Further, an assumption on the stability of input coefficients is supported by the Substitution Theorem (Samuelson 1951).

$\mathbf{x}-\mathbf{x}(-sj)$ (2)
represents the magnitude of backward linkage effects induced by Sector j in Country s.[12] In order to measure the relative strength of linkage, it is more convenient to use an index than an absolute value. Then dividing Equation (2) by x_j^s, we obtain $BL(-sj)=[\mathbf{x}-\mathbf{x}(-sj)]/x_j^s$, which is considered to represent the strength of the backward linkage effects (which actually represents the output in each sector induced by one unit of x_j^s).

② Forward Linkage Effects

For the analysis of forward linkage effects, the Leontief model that corresponds to the concept of backward linkage is not appropriate. So an alternative methodology needed to be developed for measuring forward linkages, although it has been quite controversial due to some technical difficulties. In recent years, however, the hypothetical extraction method that utilizes the output coefficients (rather than input coefficients) has taken root as a prevailing methodology.

Suppose $\mathbf{v}$ is a row vector representing value added for each sector. Then the relationship holds such that $\mathbf{x}'=i'\mathbf{Z}+\mathbf{v}'$. Next, by substituting an output coefficient matrix $\mathbf{B}=\hat{\mathbf{X}}^{-1}\mathbf{Z}$ into the above formula, we obtain $\mathbf{x}'=\mathbf{x}'\mathbf{B}+\mathbf{v}'$. Then solving for $\mathbf{x}'$, we get $\mathbf{x}'=\mathbf{v}'(\mathbf{I}-\mathbf{B})^{-1}$, where $(\mathbf{I}-\mathbf{B})^{-1}$ is called the Ghosh matrix. Further, substituting $\mathbf{\Delta v'}$ into the above formula, it can alternatively be represented by $\mathbf{\Delta x'}=\mathbf{\Delta v'}(\mathbf{I}-\mathbf{B})^{-1}=\mathbf{\Delta v'}+\mathbf{\Delta v'}\mathbf{B}+\mathbf{\Delta v'}\mathbf{B}^2+\mathbf{\Delta v'}\mathbf{B}^3+\mathbf{...}$. In this formula, provided that the output coefficients are stable (i.e. fixed), the same amount of output $\mathbf{\Delta v'}$ will first be induced with an increase in value added. Then the newly created output will be distributed to other sectors as intermediate input goods according to the fixed output coefficients, and will induce an increase in output by $\mathbf{\Delta v'B}$. After this process is repeated infinitely, output will be increased as determined by the Ghosh matrix. As shown above, output changes of the downstream industry in the Ghosh model are induced by supply changes in intermediate goods from the upstream industry, and this process theoretically corresponds to the concept of forward linkage effects[13].

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12 For $\mathbf{x}-\mathbf{x}(-sj)$ and $\mathbf{x}'-\mathbf{x}(-ri)'$, further mathematical development is possible by using the linear algebraic techniques. For details, see Milller and Lahr (2000).

13 As a precondition for the Ghosh model, inputs must be non-essential and must be perfectly substitutable with any other inputs, including primary inputs (Gruver 1989).

Next, analogous to Equation (2), let us consider a case in which a row vector of Sector i in Country r is hypothetically extracted from the international input-output table (i.e. all the output coefficients of Sector i in Country r are replaced with zero and assume the case in which intermediate outputs of the above sector are all exported to the non-endogenous countries). Then $\mathbf{x}(-ri)' = \mathbf{v}'[\mathbf{I} - \mathbf{B}(-ri)]^{-1}$ (where $\mathbf{B}(-ri)$ is an output coefficient matrix in which a row vector of Sector i in Country r is hypothetically extracted) represents output induced in a hypothetical case, and hence the magnitude of forward linkage effects is measured by $FL(-ri) = [\mathbf{x}' - \mathbf{x}(-ri)'] / x_i^r$ (which is equal to output for each sector induced by one unit of x_i^r).

Finally, the spatial linkage is a part of $BL(-sj)$ (column vector) and $FL(-ri)$ (row vector) that corresponds to the linkages with the other endogenous countries. For example, a cell of Sector *k* in Country *t* in Vector $BL(-sj)$ represents the strength of spatial backward linkage effects of Sector j in Country s on Sector *k* in Country *t*.

Further, as the output is delivered to each sector according to the fixed output coefficients, inputs coefficients of these sectors are changed accordingly. This is obviously not consistent with an assumption of fixed input coefficients in the Leontief model. Hence, in order to justify the usage of the Ghosh model, the new concept of relative joint stability was developed by Chen and Rose (1986, 1991); Rose and Allison (1989). Further, Dietzenbacher (1997) presented a proposal to reinterpret the Ghosh model as a price model to avoid the inconsistency with the Leontief model.

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