Production Networks and Spatial Economic Interdependence: An International Input-Output Analysis of the Asia-Pacific Region

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Production Networks and Spatial Economic Interdependence: An International Input-Output Analysis of the Asia-Pacific Region*

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Abstract

The Asia-Pacific Region has enjoyed remarkable economic growth in the last three decades. This rapid economic growth can be partially attributed to the global spread of production networks, which has brought about major changes in spatial interdependence among economies within the region. By applying an Input-Output based spatial decomposition technique to the Asian International Input-Output Tables for 1985 and 2000, this paper not only analyzes the intrinsic mechanism of spatial economic interdependence, but also shows how value added, employment and CO2 emissions induced are distributed within the international production networks.

Keywords: Production networks, spatial economic interdependence, input-output table
JEL classification: C67, F02

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1 Introduction

The Asia-Pacific Region has experienced tremendous economic growth in the last 30 years. The annual GDP growth rate in the region between 1985 and 2005 was about 6%. In fact, with the maturing of the NIEs, the catch-up of the ASEAN countries, and the rise of China, the region has come to be regarded as one of the most dynamic economic centers of the world.

The most important forces that enabled the region to achieve this relatively high economic growth are considered to be globalization, regional integration and domestic market-oriented economic reforms undertaken in some developing countries. Driven by these forces, market openness and international competition have been promoted by the so-called multinational corporations and their products. The success of multinational corporations should mainly be credited to the geographical spread of their worldwide production networks, which make the spatial allocation of resources more efficient and rational. At the same time, the spatial extension of production networks naturally shifts the spatial interdependence among economies within the region.

In order to give a more intuitive image of how spatial economic interdependence has changed in the Asia-Pacific Region, we examine the share of bilateral trade to the total value of trade among the economies covered in the Asian International Input-Output (AIO) Tables for 1985 and 2000, excluding intra-country trade, as shown by contour maps in Figure 1. The horizontal and vertical axes in Figure 1 show the countries of destination and origin, respectively. From the changes in color and scope of contour lines between 1985 and 2000, it is easy to grasp how economic interdependence changed in the Asia-Pacific region. For example, in 1985, the main international trade flows within the region were the following: China's imports from Japan, Japan's imports from the USA, the USA's imports from Taiwan and Japan. However, in 2000, China, the NIEs and the ASEAN countries expanded their presence rapidly, making the trade structure of the Asia-Pacific region flatter and more borderless. This dynamic change can also be confirmed from the calculation results of the Coefficient of Variation (CV) for each contour map: CV (1985) = 2.89, CV (2000) = 1.56. The decline of the CV can be interpreted as showing increasing variation in international trade or an expansion of spatial economic interdependence among the economies within the region.

This dynamic change in the international trade structure raises two concerns. The first is how to measure spatial economic interdependence accurately and effectively. Up to now, a number of studies have focused on this topic. The early research can be traced to Dutta (1995), who presents a comprehensive analysis of economic interdependence in the Asia-Pacific region. From the viewpoint of the new geographical economics, Fujita (2007) examines the recent evolution of regional integration in the world, and emphasizes changing economic interdependency within East Asia. For the logic approach of recent economic regionalism, one can refer to Kawai (2005), who emphasizes that deeper economic integration in trade, investment and finance and further institutionalization of such integration can be mutually reinforcing. In addition, Petri (2006) reviews the evolution of the intensity of interdependence in East Asia, and also shows that this interdependence has increased after the 1980s for most countries as well as on average. However, the problem with existing papers is that the concept of production network has not generally

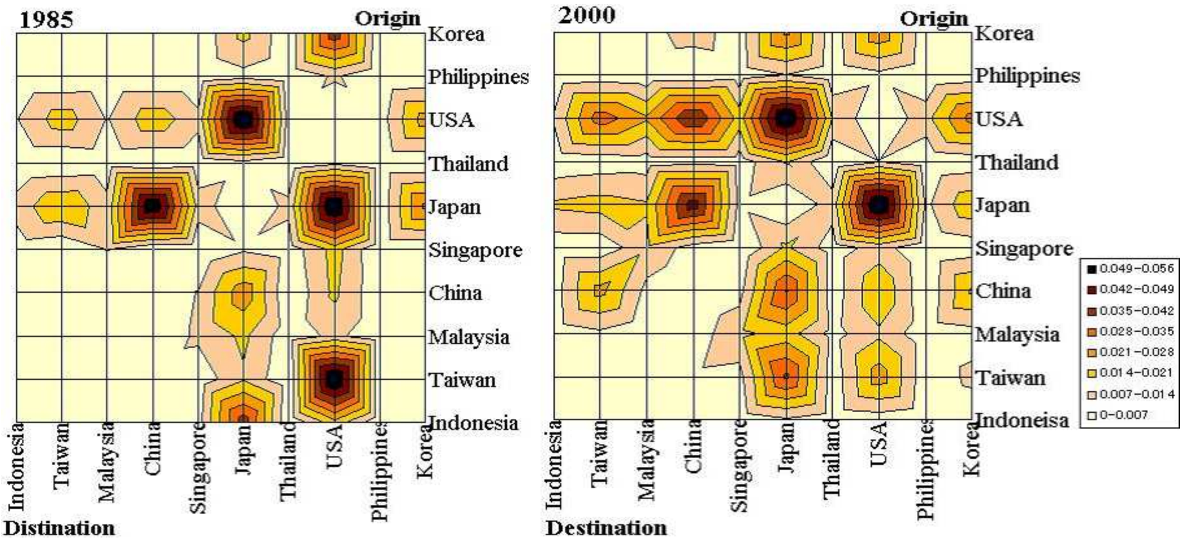

Figure 1: Spatial Economic Interdependence in the Asia-Pacific Region

been explicitly considered or used for the measurement of spatial interdependence.

The second concern involves how to measure and appreciate the existing distribution pattern of value added induced within the international production networks. In relation to this issue, a number of researches have been done from different approaches, such as Global Value Chain (GVC), Supply Chaining, Fragmentation, and Outsourcing (see Ernst and Guerrieri (1998), Wakasugi (2007) and Kimura and Ando (2003)). However, their views on the international distribution pattern of value added are divided. The relatively positive view emphasizes spillover effects, knowledge diffusion, employment creation effects and new opportunities for capital formation by local suppliers in developing countries (see Ernst and Kim (2002)). On the other hand, the relatively skeptical view underlines the uneven distribution of global value, and argues that the developing countries tend to be locked into low margin production activities (see Henderson (1998), Gereffi (1999), Kaplinsky (2000)). These differences may be caused by differences in the data they used. The most widely used data are trade data, on imports or exports, which can be easily obtained from UN statistics or national foreign trade statistics. However, these data cannot provide detailed information on the overall structure of international production networks. For example, trade data show which country imports or exports how many goods or services from or to where, but do not show which industry uses them in the country of destination. The other widely used data are firm-based data, especially multinational corporation-based data. These data provide details on international production processes or production chains for individual firms or their products, but do not give a systematic image of the whole inter-industrial trade by commodity among countries. In this sense, International Input-Output (IIO) data should be an ideal data source, as they illustrate the detailed flows of goods and services between all the individual sectors (industries) among countries. However, it seems that IIO data and IO techniques have not been effectively used in this field except in the following few papers.

Oikawa and Michael (2006) use AIO tables to examine the international value distribution structure among East Asian economies and the United States. It is a positive development that the traditional IO technique is exploited to measure the induced value added among economies. However their paper only focuses on the electronics and automobile industries, and does not give an overall perspective of how international value is distributed in the Asia-Pacific region. From a different viewpoint, Kuroiwa (2006) uses a similar IO technique to calculate local content as well as cumulative local content of East Asian economies, with the use of AIO tables. However, in both papers, in measuring the induced value added, the traditional IO assumption is implicitly used, that there the same one unit of final demand increase takes place for each sector within each economy. Under this assumption, evaluation at the absolute level becomes difficult, since the influence of the real economic scale of each economy is not explicitly considered.

In this paper, an IO based decomposition technique is used for the measurement of international interdependence. In addition to the traditional IO assumption, the real economic scale of each target economy is introduced for the evaluation of international value added, employment and CO2 emissions at the absolute level.

This paper proceeds as follows: Section 2 shows the standard IO decomposition technique based on an Isard-type 2-region 2-sector IO model. Section 3 gives a brief introduction of the data used. In Section 4, we apply the technique shown in Section 2 to the AIO tables and then measure the spatial interdependence, and discuss the distribution of international value added, employment and CO2 emissions in detail. The concluding remarks are given in Section 5.

2 Spatial IO Decomposition Technique

Considering the features of the AIO table, which are compiled as Isard-type with noncompetitive imports from the rest of the world, we provide an international IO model with 2 countries and 2 sectors to show how the decomposition technique is used to measure spatial interdependence.

A 2-country 2-sector GDP (value added) related IO open model can be described as follows:

$$GDP = V \cdot X = V \cdot (I - A)^{-1} \cdot Y = V \cdot B \cdot Y = G \cdot Y \tag{1}$$

where V, X, A, Y, B and G are, respectively, the diagonal matrix constructed by the value added rates, vector of output, matrix of inter-country input coefficients, vector of final demand, matrix of inter-country Leontief inverse, and GDP related inter-country Leontief inverse, which are defined as the following forms:

$$V = \begin{pmatrix} V^r & 0 \\ 0 & V^s \end{pmatrix},\ X = \begin{pmatrix} X^r \\ X^s \end{pmatrix},\ A = \begin{pmatrix} A^{rr} & A^{rs} \\ A^{sr} & A^{ss} \end{pmatrix},\ Y = \begin{pmatrix} Y^r \\ Y^s \end{pmatrix},$$

$$B = \begin{pmatrix} B^{rr} & B^{rs} \\ B^{sr} & B^{ss} \end{pmatrix}, G = \begin{pmatrix} G^{rr} & G^{rs} \\ G^{sr} & G^{ss} \end{pmatrix};$$

$$X^r = (X_1^r, X_2^r)',\ Y^r = (Y_1^r, Y_2^r)',$$

$$V^r = \begin{pmatrix} v_1^r & 0 \\ 0 & v_2^r \end{pmatrix},\ A^{rs} = \begin{pmatrix} a_{11}^{rs} & a_{12}^{rs} \\ a_{21}^{rs} & a_{22}^{rs} \end{pmatrix},\ B^{rs} = \begin{pmatrix} b_{11}^{rs} & b_{12}^{rs} \\ b_{21}^{rs} & b_{22}^{rs} \end{pmatrix},\ G^{rs} = \begin{pmatrix} g_{11}^{rs} & g_{12}^{rs} \\ g_{21}^{rs} & g_{22}^{rs} \end{pmatrix}.$$

From equation (1), the marginal effect of newly increased final demand on GDP can be formulated in the following form:

$$\Delta GDP = G \cdot \Delta Y. \tag{2}$$

From equation (2), it is easy to understand that G^{rs} can be explained as the amount of GDP induced in country r if there is a one unit new increase of final demand for the goods produced in country s. To measure the inter-country interdependence in detail, we employ Miller and Blair's formulation (1985) to decompose matrix G as follows:

$$\begin{pmatrix} G^{rr} & G^{rs} \\ G^{sr} & G^{ss} \end{pmatrix} = \begin{pmatrix} G^{rr} & 0 \\ 0 & G^{ss} \end{pmatrix} + \begin{pmatrix} 0 & G^{rs} \\ G^{sr} & 0 \end{pmatrix}$$

$$= \begin{pmatrix} M^{r} & 0 \\ 0 & M^{s} \end{pmatrix} + \begin{pmatrix} F^{r} & 0 \\ 0 & F^{s} \end{pmatrix} + \begin{pmatrix} 0 & G^{rs} \\ G^{sr} & 0 \end{pmatrix}. \tag{3}$$

In the above equation, matrix G is first separated into two parts, namely, $G^{rs}(r = s)$ and $G^{rs}(r \neq s)$. The former can be regarded as the intra-country effect, and the latter the inter-country effects (spillover effect). G^{rr} can further be separated into two parts, namely, $G^{rr} = M^r + F^r$, where, $M^r = V^r \cdot (I - A^{rr})^{-1}$, and $F^r = V^r \cdot B^{rr} - V^r \cdot (I - A^{rr})^{-1}$. Obviously, M^r denotes the domestic multiplier effect, describing the GDP that would have been induced for Y^r if a single-country IO model has been used. F^r is nothing but the feedback effect of country r. Using this decomposition technique, the spatial economic interdependence relating to GDP can be measured in detail.

It should be noted that the GDP related inter-country Leontief inverse is used to capture the marginal impact on country r when there is one unit of newly increased final demand for the goods produced in country s, but this measurement ignores the real economic scales of the target countries. For evaluating the inter-country interdependence at the absolute level, the following measurement is introduced in this paper.

$$GDP = G \cdot Y = \begin{pmatrix} M^{r} \cdot Y^{r} \\ M^{s} \cdot Y^{s} \end{pmatrix} + \begin{pmatrix} F^{r} \cdot Y^{r} \\ F^{s} \cdot Y^{s} \end{pmatrix} + \begin{pmatrix} G^{rs} \cdot Y^{s} \\ G^{sr} \cdot Y^{r} \end{pmatrix}. \tag{4}$$

$G^{rs} \cdot Y^s$ represents the real induced GDP in country r required to fulfill the real final demand (Y^s) of goods produced in country s, which can be used to measure the inter-country interdependence at the absolute level.

In addition, the above IO model can also be applied to the measurement of employment and CO2 emission related spatial economic interdependence, as shown below:

$$EMP = L \cdot X = L \cdot (I - A)^{-1} \cdot Y = L \cdot B \cdot Y = E \cdot Y \tag{5}$$

$$CO2 = O \cdot X = O \cdot (I - A)^{-1} \cdot Y = O \cdot B \cdot Y = C \cdot Y, \tag{6}$$

where EMP and $CO2$ represent the employment and $CO2$ emission vectors, and L and O are the diagonal matrices constructed by the employment input rates and $CO2$ emission rates. The matrices E and C are defined respectively, as the employment related and $CO2$ emission related inter-country Leontief inverses. Using the same decomposition technique shown above, the matrices E and C can also be decomposed respectively, into three parts, namely the domestic multiplier effect, feedback effect and spillover effect. Then E^{rs} and C^{rs} can be explained as the amount of employment and $CO2$ emissions in country r when there is a one unit new increase of final demand for the goods produced in country s.

3 Data

The main data sources used are the 1985 and 2000 AIO tables. The AIO table is designed to depict the spatial and industrial network within the Asia-Pacific region, which covers ten endogenous economies, namely, Indonesia (I), China (C), Malaysia (M), Korea (K), Japan (J), Philippines (P), Singapore (S), Taiwan (N), Thailand (T), USA (U), and approximately 76 industrial sectors. The sectors classification used in the paper is as follows: (1) Agriculture, (2) Mining, (3) Manufacture, (4) Energy, (5) Construction, (6) Trade and transport, (7) Services. The 2000 AIO table also includes employment matrices by economy and sector, which are used to measure the employment related spatial economic interdependence in this paper. For detailed information about the AIO table, refer to IDE-SDSs(1992, 2000).

The data for measuring the CO2 emission related spatial economic interdependence are taken from each country's Inventory of Greenhouse Gas Emissions[1] published by the United Nations Framework Convention on Climate Change (UNFCCC).

In addition, to focus on real rather than nominal comparison in our analysis, the GDP related calculation results are corrected into constant prices. The GDP deflator data are based on UN statistics.

4 Empirical Analysis

4.1 Spatial Economic Interdependence at the Relative Level

As mentioned in the earlier section, by using equation (3), we can divide the value added related spatial economic interdependence at the relative level into three effects. The empirical results for the domestic multiplier effect are shown in Figure 2. This effect indicates how many units of GDP can be induced in a country if there is a one unit increase of final demand for the goods produced in the same country. In general, a country with a relatively large economic scale has a large domestic multiplier effect on its GDP, whereas a relatively small country with high openness, like Singapore and Malaysia, has a relatively small effect. Comparing 1985 with 2000, it is obvious that with the exception of Japan and Taiwan, the domestic multiplier effects decreased. This also implies that Japan and Taiwan promoted high value added industry and kept the value inside their domestic areas.

From Figure 3, the features of the feedback effect can be summarized as follows: (1) with the exception of Indonesia and Malaysia, the feedback effects increased rapidly during the period of 1985-2000; (2) as smaller countries with relatively high openness, Malaysia and Singapore show extremely large feedback effects compared with the other economies. This means that exports from Malaysia and Singapore induce relatively large effects on their own GDP. Using more detailed information, we can understand Malaysia's feedback effect as being mainly achieved by the way of Singapore's import demand for intermediate goods, the same pattern can be used to explain why Singapore has a similar large feedback effect.

[1] The CO2 emission data for Taiwan are not available from UNFCCC. For simplicity, Korea's CO2 emission rates are used as a proxy data source for Taiwan in the paper.

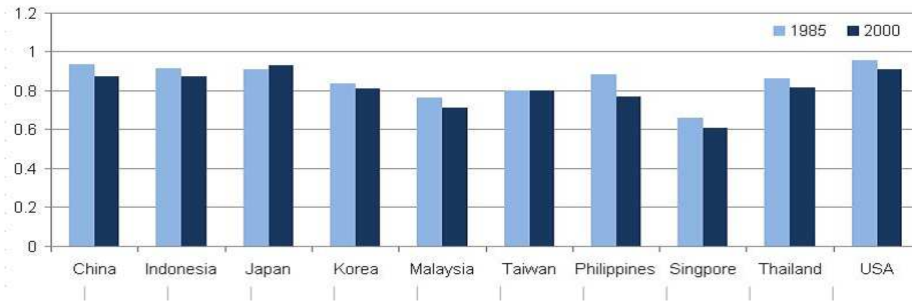

Figure 2: Domestic Multiplier Effect at Relative Level

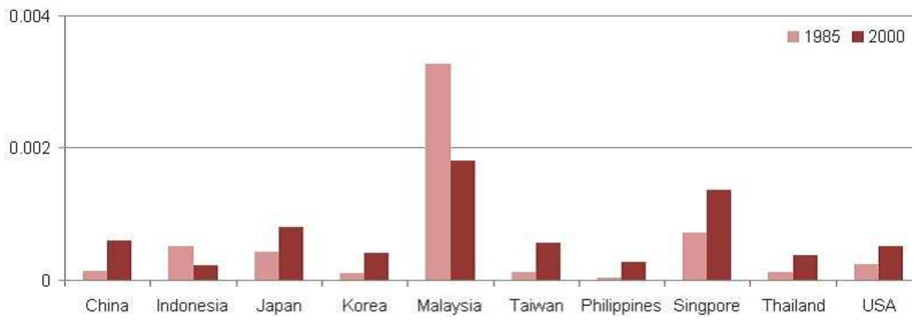

Figure 3: Feedback Effect at Relative Level

In this sense, it can be concluded that there are very strong feedback linkages between Malaysia and Singapore; and (3) China, Taiwan and Korea's feedback effects increased rapidly compared with the developed countries, such as Japan and the US. This means that rapid economic growth tends to be accompanied by relatively large increases in the feedback effect.

Table 1 gives a detailed view of spillover effects by origin and destination for 1985 and 2000. For example, the figure at the intersection of Japan's row and China's column for 1985 is 0.012. This indicates that a 0.012 unit increase of GDP will be induced in Japan if the final demand of goods and services produced in China increase by a one unit. In this regard, the column sum for China (0.020) represents the total spillover effect that China exerts on the other endogenous economies, which can be defined as China's degree of dispersion; The row sum for Japan (0.173) shows the total spillover effect that Japan receives from the other endogenous economies, which can be defined as Japan's degree of sensitivity. The rates of change from 1985 to 2000 are also shown in the table. With the exception of a few minus values, the change rates are positive. This implies that the Asia-Pacific region has experienced a remarkable increase in spillover effects during 1985-2000.[2] To provide a more intuitive image, we standardize the figures in the column sum and row sum using their average values. The standardized indexes are shown in Figure 4.

[2]The normalization of diplomatic relations between China and Korea in 1992 led to a large increase in the spillover effect between the two countries.

Table 1: Spillover Effects at the Relative Level

1985	C	I	J	K	M	N	P	S	T	U	Row Sum
China (C)		0.0021	0.0031	0.0003	0.0070	0.0004	0.0058	0.0304	0.0040	0.0004	0.0534
Indonesia (I)	0.0007		0.0120	0.0043	0.0042	0.0030	0.0029	0.0169	0.0016	0.0010	0.0467
Japan (J)	0.0124	0.0145		0.0247	0.0322	0.0242	0.0081	0.0345	0.0187	0.0041	0.1734
Korea (K)	0.0000	0.0010	0.0011		0.0030	0.0007	0.0025	0.0028	0.0018	0.0005	0.0134
Malaysia (M)	0.0003	0.0008	0.0036	0.0049		0.0026	0.0049	0.0257	0.0072	0.0002	0.0502
Taiwan (N)	0.0008	0.0013	0.0008	0.0014	0.0031		0.0019	0.0065	0.0020	0.0008	0.0186
Philippines (P)	0.0001	0.0002	0.0004	0.0004	0.0014	0.0009		0.0017	0.0007	0.0002	0.0059
Singapore (S)	0.0001	0.0028	0.0004	0.0005	0.0198	0.0008	0.0006		0.0044	0.0001	0.0297
Thailand (T)	0.0003	0.0003	0.0004	0.0006	0.0038	0.0006	0.0007	0.0061		0.0001	0.0130
USA (U)	0.0053	0.0118	0.0105	0.0272	0.0169	0.0322	0.0177	0.0284	0.0103		0.1603
Column Sum	0.0202	0.0347	0.0322	0.0643	0.0913	0.0653	0.0451	0.1531	0.0507	0.0074	0.5645
2000	C	I	J	K	M	N	P	S	T	U	Row Sum
China		0.0043	0.0029	0.0081	0.0082	0.0062	0.0056	0.0128	0.0078	0.0024	0.0583
Indonesia	0.0018		0.0051	0.0062	0.0057	0.0041	0.0056	0.0061	0.0039	0.0007	0.0392
Japan	0.0168	0.0117		0.0191	0.0510	0.0341	0.0315	0.0491	0.0334	0.0057	0.2524
Korea	0.0077	0.0038	0.0019		0.0081	0.0071	0.0108	0.0069	0.0046	0.0013	0.0524
Malaysia	0.0014	0.0025	0.0024	0.0028		0.0033	0.0056	0.0267	0.0048	0.0007	0.0503
Taiwan	0.0068	0.0019	0.0013	0.0022	0.0112		0.0060	0.0060	0.0047	0.0013	0.0412
Philippines	0.0005	0.0002	0.0004	0.0007	0.0027	0.0018		0.0012	0.0011	0.0004	0.0091
Singapore	0.0011	0.0015	0.0003	0.0010	0.0138	0.0025	0.0078		0.0032	0.0004	0.0315
Thailand	0.0012	0.0015	0.0007	0.0009	0.0079	0.0019	0.0039	0.0077		0.0005	0.0263
USA	0.0090	0.0076	0.0072	0.0179	0.0343	0.0201	0.0228	0.0341	0.0156		0.1687
Column Sum	0.0464	0.0349	0.0222	0.0589	0.1430	0.0812	0.0997	0.1506	0.0791	0.0134	0.7294
Change rate(%)	C	I	J	K	M	N	P	S	T	U	Row Sum
China		107	-5	2493	17	1525	-3	-58	98	509	9
Indonesia	157		-58	45	37	36	91	-64	134	-30	-16
Japan	35	-19		-23	59	41	288	42	79	39	46
Korea	17737	282	84		173	927	339	144	153	175	291
Malaysia	331	222	-32	-42		28	15	4	-34	172	0
Taiwan	795	44	62	55	260		215	-8	131	68	122
Philippines	244	18	11	61	101	93		-31	69	154	52
Singpore	782	-48	-40	89	-30	201	1121		-26	170	6
Thailand	248	343	70	49	109	233	439	27		286	102
USA	70	-36	-31	-34	103	-37	29	20	51		5
Column Sum	129	1	-31	-8	57	24	121	-2	56	80	29

Obviously, Japan and the US have the largest degrees of sensitivity, but have relatively small dispersion effects on the outside. On the other hand, the ASEAN-4 and NIEs-3 have relatively large dispersion capacities and small degrees of sensitivity. The pattern of change of these indexes for each economy also shows a great deal of variation. In Japan and Korea, the degree of sensitivity has increased rapidly with little lose in terms of dispersion capacities from 1985 to 2000. This implies that Japan and Korea have tended to receive increasing value added related impacts from the outside as spillover effects. Malaysia, Thailand and the Philippines mainly enlarged their dispersion capacities with just a small increase in the degree of sensitivity. For China, Taiwan and Thailand, both indexes grew rapidly, especially in the case of China, the degree of sensitivity rose above the average level. It should be noted that the above evaluation is based on the assumption that there is the same one unit marginal increase of final demand for the goods or services produced in each economy. Therefore, this evaluation represents relative level rather than absolute level.

4.2 Spatial Economic Interdependence at the Absolute Level

As shown in Section 2, equation (4) is introduced for evaluating the value added related spatial economic interdependence at the absolute level. Similarly, the interdependence is measured with the three effects mentioned above. Figure 5 shows the share of the domestic multiplier effect for each economy. Since the absolute economic scale is reflected in the evaluation, it is easy to understand that the US and Japan cover the majority of the

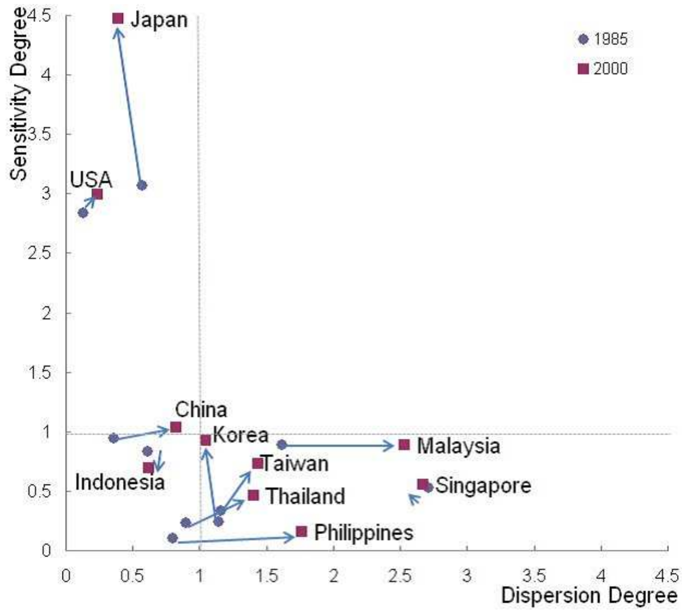

Figure 4: Spillover Effects at the Relative Level

total share. Compared with the decrease in the US, the economies of Asia enlarged their shares rapidly during the period of 1985-2000. A similar pattern can also be observed for the feedback effect (see Figure 6).

Table 2 shows the value added related spillover effect at the absolute level. For example, the figure at the intersection of Japan's row and China's column for 1985 is US$ 5,055 million. This indicates that the value added of US$ 5,055 million was induced inside Japan to meet the real final demand for goods or services produced in China in 1985. From the rates shown in the table, it is easy to see that the total spillover effect estimated in constant prices increased by 311% in the period of 1985-2000. However, there is much more variation in the increasing tendency by economy. Figure 7 gives a more visual image of the changing pattern of spillover effects assessed by the dispersion index and

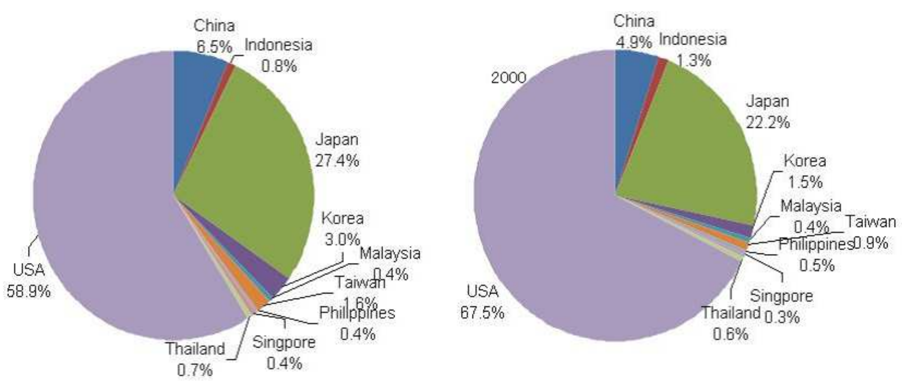

Figure 5: Percentage Share of Domestic Multiplier Effect

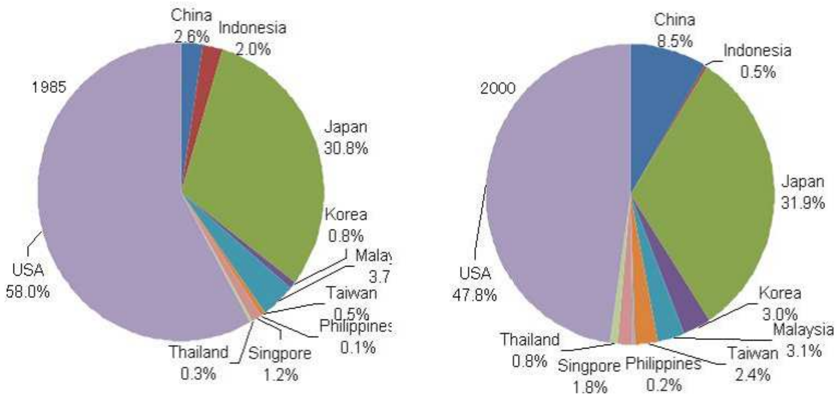

Figure 6: Percentage Share of Feedback Effect

Table 2: Spillover Effect at the Absolute Level

(million US$, in constant prices)

1985	C	I	J	K	M	N	P	S	T	U	Row Sum
China		196	4853	50	218	36	193	1091	175	1742	8555
Indonesia	313		8714	712	135	325	100	618	70	4222	15209
Japan	5055	1482		4044	1325	2569	251	1183	932	19711	36551
Korea	18	102	1766		112	71	71	98	83	2393	4714
Malaysia	140	68	3183	868		279	168	860	415	1312	7292
Taiwan	328	133	1355	204	120		65	199	113	3643	6159
Philippines	66	17	690	76	65	62		59	27	937	1998
Singpore	49	190	530	83	429	70	18		169	639	2176
Thailand	159	34	650	109	172	63	24	109		607	1926
USA	2220	1033	16618	3981	715	2567	607	1014	464		29218
Column Sum	8347	3254	38358	10125	3290	6042	1499	5232	2447	35205	113798
2000	C	I	J	K	M	N	P	S	T	U	Row Sum
China		943	12690	5177	1500	2563	517	1685	1753	20739	47568
Indonesia	3961		14313	4488	1340	2208	600	1117	1118	5757	34901
Japan	13723	1462		8688	4668	8799	1945	4043	4172	30459	77960
Korea	7259	511	4904		931	2087	628	669	676	8384	26049
Malaysia	2357	569	5623	1913		1655	496	3485	1169	6971	24238
Taiwan	6987	289	3917	1181	1207		423	569	699	8470	23742
Philippines	643	37	1605	478	483	742		126	210	3627	7951
Singpore	1055	207	825	536	1665	716	387		517	2747	8656
Thailand	1671	341	2947	649	1313	852	353	839		4450	13416
USA	9725	1332	23613	10491	4673	6914	1928	3661	2691		65028
Column Sum	47381	5692	70437	33602	17781	26537	7277	16193	13006	91604	329510
Change rate(%)	C	I	J	K	M	N	P	S	T	U	Row Sum
China		423	184	11176	647	7543	191	68	989	1195	505
Indonesia	896		29	397	683	435	371	42	1155	7	81
Japan	417	88		309	571	553	1379	551	753	194	306
Korea	69586	751	371		1314	4884	1391	1052	1286	494	837
Malaysia	1583	744	77	121		495	194	306	182	432	233
Taiwan	3354	253	369	841	1528		958	363	905	277	525
Philippines	1171	178	205	729	883	1479		181	935	408	422
Singpore	3356	74	148	926	519	1523	3275		388	585	534
Thailand	1098	1053	415	578	767	1445	1556	775		734	692
USA	529	85	104	278	838	286	356	418	732		219
Column Sum	782	158	124	362	708	554	619	327	682	281	311

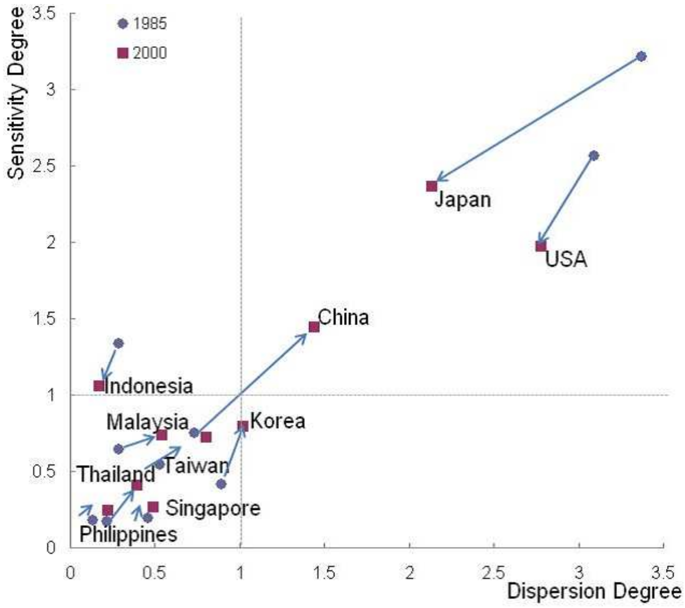

Figure 7: Spillover Effect at the Absolute Level

sensitivity index. In general, Japan and the US have relatively large capacities for both dispersion and sensitivity, but they have rapidly fallen. On the other hand, these two capacities increased for China, and it has approached Japan and US. A similar pattern can also be observed in the other Asian economies with the exceptin of Indonesia. This can be regarded as empirical evidence that the regional integration of the Asian region had significant economic impacts on the ASEAN countries, NIEs and China.

As mentioned earlier, understanding the distribution of international value among economies is also one of our main concerns. In fact, Table 2 simply shows the distribution pattern of value added induced in the process of international trade. Here, the Gini's Coefficient (GC) is employed to give a more accurate evaluation of the distribution of international value added. The result is shown below:

$GC(1985) = 0.776 > GC(2000) = 0.741.$

The absolute level of GC is extremely high, meaning that the distribution of international value added is uneven. However, the GC decreased from 1985 to 2000. This implies that this uneven distribution pattern within the Asia Pacific region has been mitigated during this period.

4.3 Employment Related Spatial Economic Interdependence

As a supplement data source in the 2000 AIO table, the employment matrix is available. This makes it possible to measure the employment related spatial interdependence in detail using equation (5).

Table 3 shows the effect on employment by way of the spillover effect. For example, the figure at the intersection of China's row and Japan's column is 7,702,691. This means that China gained 7,702,691 job opportunities (persons) from the real final demand of

Table 3: Employment Related Spillover Effect at Absolute Level

(thousand persons)

2000	C	I	J	K	M	N	P	S	T	U	Row Sum
China		632	7703	3586	1003	1408	383	936	1030	11415	28097
Indonesia	1321		2951	862	602	654	241	485	469	2713	10298
Japan	392	42		249	131	250	56	114	118	867	2219
Korea	369	26	262		47	105	32	34	34	422	1332
Malaysia	209	38	380	125		143	42	359	94	642	2032
Taiwan	382	16	218	65	64		23	31	38	465	1302
Philippines	326	18	875	246	231	355		61	102	1773	3988
Singapore	34	7	28	18	54	23	13		17	90	284
Thailand	518	97	931	217	456	296	120	262		1420	4317
USA	210	30	526	226	100	151	42	78	58		1421
Column Sum	3763	906	13873	5593	2688	3386	950	2361	1961	19807	55289

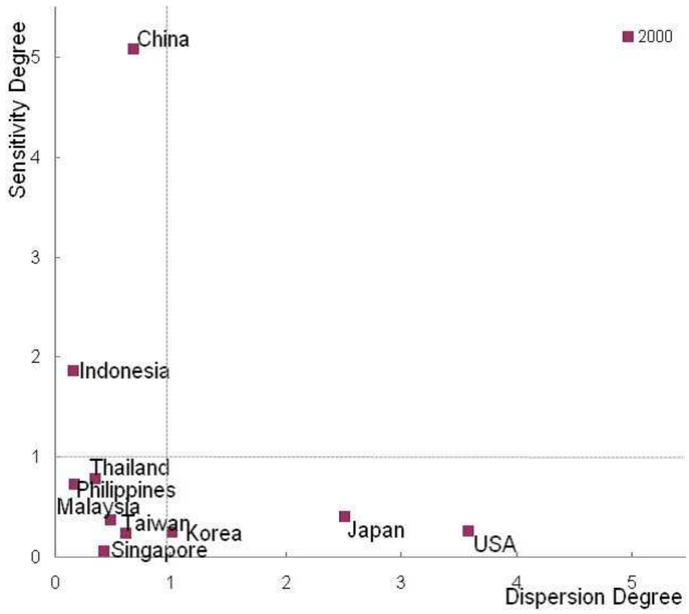

Figure 8: Employment Related Spillover Effect at Absolute Level

goods and services produced in Japan. From the row sum, it is easy to see that China received a total of 28,096,553 job opportunities from outside, and that by Indonesia received 10,297,648. The column sum shows that the greatest number of job opportunities is provided by the US with 19,807,080, followed by Japan with 13,872,900. The employment related interdependence based on the indexes of dispersion and sensitivity calculated from the standardized column sum and row sum are presented in Figure 8. Clearly, China with the biggest population, has the highest employment related degree of sensitivity. The US and Japan can be regarded the largest providers of job opportunities. From the viewpoint of employment creation, it can be concluded that the developing countries, with their large population scales, gained relatively large benefits from the developed countries through international trade in the Asia-Pacific region.

Table 4: CO2 Emission Related Spillover Effect at the Absolute Level

(Gg: Gigagram)

2000	C	I	J	K	M	N	P	S	T	U	Row Sum
China		5997	84418	33407	10306	17822	3383	12213	12345	148184	328075
Indonesia	2126		4449	1300	979	1067	376	801	782	3622	15502
Japan	10538	1121		6669	3374	6766	1492	3106	3208	23417	59691
Korea	13911	975	9152		1736	3973	1197	1274	1294	15970	49483
Malaysia	3028	514	4719	1734		2006	629	4350	1382	9405	27768
Taiwan	12376	508	6650	2044	1856		743	988	1230	14804	41200
Philippines	1063	61	2366	779	802	1241		210	359	6059	12940
Singpore	788	144	584	400	1241	537	290		382	2064	6431
Thailand	2189	393	3908	843	1675	1128	465	1130		6005	17738
USA	13842	2317	40185	14792	5910	10649	2800	4765	3898		99157
Column Sum	59862	12031	156433	61968	27880	45189	11377	28836	24881	229529	657985

4.4 CO2 Emission Related Spatial Economic Interdependence

It is easy to derive CO2 emission-related data by country and industry from the UNFCCC. This makes it possible to evaluate the CO2 emission-related economic interdependence in detail using equation (6).

Table 4 shows the amounts of CO2 emissions induced by the way of spillover effects. To give an example, we use the figure 148,184 which is located at the interaction of China's row and the US's column. This figure indicates that 148,184 Gg of CO2 emissions are generated from the production process of intermediate goods in China to meet the final demand for goods and services produced in the US. The distribution pattern of international CO2 emissions shown in the table, mainly depends on (1) the structure of spatial production networks stretched among trade partners, (2) each country's economic scale, and (3) the production technologies applied in each economy. To give a more intuitive image, we plot the indexes of sensitivity and dispersion in Figure 9. The main features of the figure can be summarized as follows: (1) the US and Japan have the largest degrees of dispersion. This is because the majority of CO2 emissions from developing economies are induced from the US and Japan's import demands, as can be confirmed from the above table. (2) China has the largest degree of sensitivity. This is because China is one of the largest exporters of intermediate goods in the world, but its production technique is still energy-dependent with relatively high CO2 emissions; (3) compared with the US, Japan's degrees of sensitivity is extremely low, and is just slightly larger than Korea's. This is because Japan's production techniques are relatively energy-saving, with relatively low CO2 emissions; (4) the NIEs-3 and ASEAN-4 can be aggregated into a single group, as they have both relatively low degrees of sensitivity and dispersion.

In order to evaluate the magnitude of CO2 emissions per unit of GDP induced, we divide the figures in Table 4 by the those in Table 2. The results are shown in Table 5. As shown in the column sum, to get 1 million US$ value added from the outside through spillover effect, China emits 6.9 Gg of CO2, which is about 8.6 times Japan's level, and 4.6 times the US's level. As the largest developing country, China is undergoing a process of rapid industrialization and urbanization. Within this process, environmental problems have been a serious bottleneck to sustainable economic growth. At the same time, as a member of WTO, China also faces various international competition. Therefore, maintaining competitive advantage under environmental constraints has been an important challenge for the Chinese government. On the other hand, it should be noted that CO2 emissions

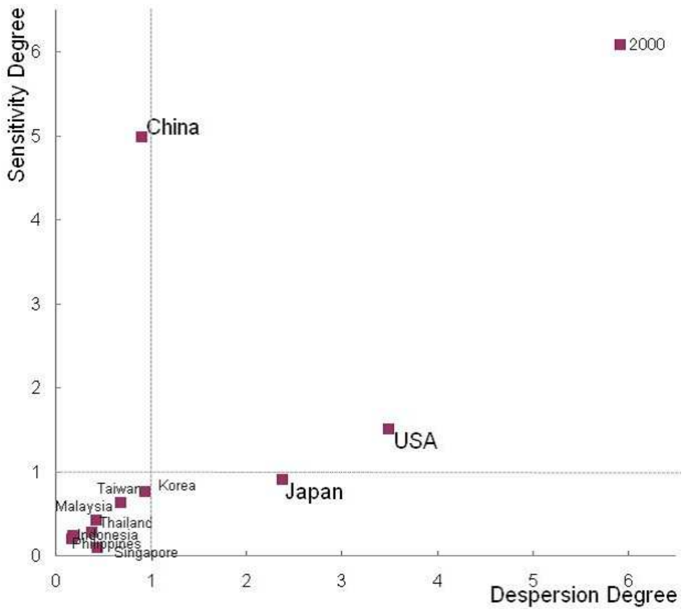

Figure 9: CO2 Emission Related Spillover Effect at the Absolute Level

Table 5: CO2 Emissions per Unit of GDP Induced

(Gg/Million US$)

2000	C	I	J	K	M	N	P	S	T	U	Row Sum
China		6.4	6.7	6.5	6.9	7.0	6.5	7.2	7.0	7.1	6.9
Indonesia	0.5		0.3	0.3	0.7	0.5	0.6	0.7	0.7	0.6	0.4
Japan	0.8	0.8		0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8
Korea	1.9	1.9	1.9		1.9	1.9	1.9	1.9	1.9	1.9	1.9
Malaysia	1.3	0.9	0.8	0.9		1.2	1.3	1.2	1.2	1.3	1.1
Taiwan	1.8	1.8	1.7	1.7	1.5		1.8	1.7	1.8	1.7	1.7
Philippines	1.7	1.6	1.5	1.6	1.7	1.7		1.7	1.7	1.7	1.6
Singpore	0.7	0.7	0.7	0.7	0.7	0.8	0.7		0.7	0.8	0.7
Thailand	1.3	1.2	1.3	1.3	1.3	1.3	1.3	1.3		1.3	1.3
USA	1.4	1.7	1.7	1.4	1.3	1.5	1.5	1.3	1.4		1.5
Column Sum	1.3	2.1	2.2	1.8	1.6	1.7	1.6	1.8	1.9	2.5	2.0

are a kind of external diseconomy, which can only be solved within the international framework. Therefore, in addition to the introduction of an international environment tax and international cooperation for exchanging environment-friendly production technologies, efforts should be devoted to establishing a practicable FTA framework, in which a mechanism for the internalization of external diseconomies is explicitly considered.

5 Concluding Remarks

Along with the geographical spread of worldwide production networks, spatial economic interdependence among the economies of the Asia-Pacific region has been rapidly shifting. To analyze the intrinsic mechanism of spatial economic interdependence with explicit consideration focused on international production networks, we applied an input-output based spatial decomposition technique to the Asian International Input-Output Tables. The main features of our research can be summarized as follows: (1) spatial economic interdependence is evaluated from three different viewpoints, namely, value added, employment, and CO2 emissions; (2) using the decomposition technique, the interdependence is decomposed into three factors, namely, the domestic multiplier effect, feedback effect, and spillover effect; and (3) in addition to using the traditional evaluation method, we also estimated the magnitude of the economic interdependence at the absolute level, by introducing the real economic scale into the estimation.

From the simulation results, we conclude that (1) the GDP-based spillover effects increased rapidly in the Asia-Pacific region from 1985 to 2000, not only at the relative level but also at the absolute level. In particular, the interdependence among the ASEAN countries, NIEs and China has grown deeper and more subtle; (2) the distribution of value added induced within the international production networks is uneven, but has improved within the ongoing process of globalization and regional integration; and (3) developed countries with relatively large economic scales seem to enjoy much more value added benefits from international trade. On the other hand, developing countries with relatively large population scales seem to be the largest beneficiaries of employment creation effects caused by the demand of developed countries; and (4) the distribution of CO2 emissions induced by international trade is extremely uneven. This uneven situation depends not only on the production technology applied in each country, but is also subject to the position the country holds within the international production networks.

Appendix: More Detailed Decomposition

Since the AIO tables consist of the inter-country trade for final demand by origin and destination, it is possible to define the final demand item in detail as follows:

$$Y = \begin{pmatrix} Y^r \\ Y^s \end{pmatrix} = \begin{pmatrix} Y^{rr} \\ Y^{sr} \end{pmatrix} + \begin{pmatrix} Y^{rs} \\ Y^{ss} \end{pmatrix} + \begin{pmatrix} EX^{ro} \\ EX^{so} \end{pmatrix}, \tag{7}$$

where, $Y^{rs} = (y_1^{rs}, y_2^{rs})'$ represents the domestic final demand of country s for the goods produced in country r, and $EX^{ro} = (ex_1^{ro}, ex_2^{ro})'$ represents exports of goods produced in country r to the rest of the world. Then, equation (4) can be rewritten in the following form:

$$\begin{aligned} GDP &= G \cdot Y \\ &= \begin{pmatrix} M^r \cdot Y^{rr} \\ M^s \cdot Y^{sr} \end{pmatrix} + \begin{pmatrix} M^r \cdot Y^{rs} \\ M^s \cdot Y^{ss} \end{pmatrix} + \begin{pmatrix} M^r \cdot EX^{ro} \\ M^s \cdot EX^{so} \end{pmatrix} \\ &+ \begin{pmatrix} F^r \cdot Y^{rr} \\ F^s \cdot Y^{sr} \end{pmatrix} + \begin{pmatrix} F^r \cdot Y^{rs} \\ F^s \cdot Y^{ss} \end{pmatrix} + \begin{pmatrix} F^r \cdot EX^{ro} \\ F^s \cdot EX^{so} \end{pmatrix} \\ &+ \begin{pmatrix} G^{rs} \cdot Y^{sr} \\ G^{sr} \cdot Y^{rr} \end{pmatrix} + \begin{pmatrix} G^{rs} \cdot Y^{ss} \\ G^{sr} \cdot Y^{rs} \end{pmatrix} + \begin{pmatrix} G^{rs} \cdot EX^{so} \\ G^{sr} \cdot EX^{ro} \end{pmatrix}. \end{aligned} \tag{8}$$

The above formation gives more detailed measurements for the spatial economic interdependence. For example, $M^s \cdot Y^{sr}$ shows the GDP induced in country s to satisfy the final demand of country r for the goods produced in country s by the way of the domestic multiplier effect, and $G^{rs} \cdot Y^{sr}$ means the GDP induced in country r to meet the final demand of country r for the goods produced in country s by the way of the spillover effect.

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