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Fragmentation in East Asia: Further Evidence

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Abstract: This paper analyzes the spatial pattern of production/distribution networks in East Asia. Two issues are investigated. The one is how the formation of networks has changed the intra- and inter-regional trade pattern. We find that an explosive expansion of intra-regional trade in machinery parts and components, in particular among developing countries, contributes to the current dense networking. The other is how corporate firms effectively organize fragmentation in terms of geographical distance and disintegration. The micro data of Japanese firms indicate that long-distance transactions are mainly intra-firm while transactions in local markets are predominantly arm's-length (inter-firm), suggesting the formation of agglomeration.

***Keywords*:** Fragmentation, agglomeration, intra-industry trade, multinational enterprises, outsourcing

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1. Introduction

It has by now been widely recognized that the formation of international production/distribution networks in East Asia is an extremely important phenomenon. The very recent and rapid development of production networks since the 1990s, at the same time, undermines or at least partially nullifies the applicability of a wide range of old theories and practical thought. In the context of international trade theory, the pattern of industrial location and international trade in East Asia no longer follows a typical North-South division of labor explained by traditional comparative advantage theories such as the Ricardian and Heckscher-Ohlin models, at least literally. International division of labor in terms of production processes, particularly in machinery industries, is explosively developed, while European-type horizontal intra-industry trade is rarely observed yet. [1] Transactions in production/distribution networks are often relation-specific beyond simple bidding in the spot market, location advantages of production blocks become multi-dimensional, and service links to connect production blocks enhance their importance.

Development economics has also been critically reviewed in a fundamental manner. The influential "East Asian Miracle" report by the World Bank (1993) was written before the development of production networks, and thus the analysis failed to emphasize the crucial role of foreign direct investment (FDI) in economic development for developing

[1] Fukao, Ishito, and Ito (2003) provide extensive statistical data analysis of European-type horizontal intra-industry trade, while Ando (2006) further investigates the characteristics of East Asian-type vertical intra-industry trade.

countries. The "export platform" argument now explains only a small portion of international production/distribution networks in East Asia. The flying geese pattern argument cannot be applied anymore to recent international location patterns of manufacturing sectors in the sense that they are dominated by more subtle production-process-wise location patterns, not by industry-by-industry location patterns. The classical MITI-type industrial policy is regarded as completely out-dated. East Asia is now presenting a new development strategy aggressively utilizing the mechanics of international production/distribution networks.

The recent policy discussion on East Asian economic integration has also been heavily influenced by the nature and characteristics of international production/distribution networks. *De facto* economic integration no doubt rapidly proceeds in East Asia, but in an uneven manner. Corporate activities extend beyond national borders while substantial differences in development stages across countries remain. International production/distribution networks are actually taking advantage of differences in location advantages. It is a big challenge for both academicians and policy makers to understand what is taking place in East Asia and to properly design *de jure* economic integration in East Asia.

The authors proposed a conceptual framework of two-dimensional fragmentation in their previous work (Kimura and Ando 2005). It provided a useful analytical approach to understand the mechanics of international production/distribution networks in East Asia. It well explained location patterns of fragmented production blocks across countries with different location advantages, emphasizing the importance of a service link that connects

remotely located production blocks. Moreover, it effectively described the logic of production/distribution networks extending beyond the boundary of a firm. Arm's-length (inter-firm) fragmentation is an essential element in the formation of agglomeration, and such sophisticated networks in turn provide opportunities for indigenous firms to penetrate into production networks developed by multinational enterprises (MNEs).

As an extended analysis, this paper is devoted to some of the unsolved questions on the spatial structure of international production/distribution networks. The first is how the formation of international production/distribution networks, particularly in machinery industries, has changed the spatial pattern of international trade, particularly focusing on intra-regional and inter-regional transactions. Are U.S. and EU markets becoming less important along with the expansion of East Asian market itself? How big is the "magnification" effect of parts and components trade in the expansion of East Asian intra-regional trade? The paper looks into these issues to address the first question.

The second question is how corporate firms effectively combine two kinds of fragmentation, i.e., intra-firm and arm's length, in the spatial extension of production/distribution networks. In transactions among Japan, NIEs, ASEAN, and China, is there any systemic spatial pattern of intra-firm or arm's-length transactions? Do we observe significant changes over time? Although it is difficult to comprehend these aspects of networks in statistics, analysis using the micro data of Japanese affiliates can provide us some clues.

The outline of the paper is as follows: the next section reviews the framework of two-dimensional fragmentation and establishes a link with empirical studies conducted in

the paper. Section 3 presents the overall picture of intra-regional and inter-regional trade of East Asian countries by conducting descriptive and econometric analysis using gravity model estimation. Section 4 concentrates on machinery industries and analyzes the nature of fragmentation in two dimensions, i.e., distance and disintegration, by using the micro data of Japanese affiliates abroad. The last section concludes the paper.

2. Conceptual Framework of Two-dimensional Fragmentation

The formation of international production/distribution networks has fundamentally changed the pattern of production location and international trade in East Asia. Although networks can be formulated in various industries, most important, both qualitatively and quantitatively, are those in machinery industries including general machinery, electric machinery, transport equipment, and precision machinery. Machinery industries deal with a large number of multi-layered vertical production/distribution processes, and East Asian firms including Japanese firms have a competitive edge in exploring modulation techniques and constructing vertical value chains. International production/distribution networks in East Asia are distinctive and most developed in the world at this point in time in (i) their significance in each economy in the region, (ii) their extensiveness covering a number of countries in the region, and (iii) their sophistication in subtle combinations of

intra-firm and arm's-length (inter-firm) transactions.[2]

Literature on the fragmentation theory and its empirical applications has grown since a seminal work by Jones and Kierzkowski (1990) and has proved its applicability in analyzing cross-border production sharing at the production process level.[3] International production/distribution networks in East Asia, however, have developed beyond the original idea of fragmentation, and some expansion of the analytical framework is needed in order to incorporate intra-firm and arm's-length transactions. Kimura and Ando (2005) propose the concept of two-dimensional fragmentation, in particular to analyze the mechanics of production networks in East Asia.

Figure 1 illustrates a simple version of the Maquila operation in the U.S.-Mexico nexus. Cross-border production sharing between the U.S. and Mexico is mostly a simple intra-firm fragmentation, accompanied with back-and-forth intra-firm transactions between headquarters in the U.S. and an affiliate in Maquila, Mexico. A typical pattern is as follows: parts and components are sent from the U.S. headquarters to a factory in Mexico, the assembly process is conducted there, and the finished products are sent back to the U.S. headquarters. On the other hand, production/distribution networks in East Asia contain a much more complicated combination of intra-firm and arm's-length transactions across a number of countries in the region. Figure 2 is drawn with reference to an actual example of a Japanese manufacturer in the electronic machinery industry, extending production/distribution networks all over East Asia and the U.S. The

[2] See Ando and Kimura (2005).
[3] Also see Arndt and Kierzkowski (2001), Deardorff (2001), and Cheng and Kierzkowski (2001) for the fragmentation theory.

framework of two-dimensional fragmentation tries to capture such a sophisticated structure of international production/distribution networks.

Figure 1. Typical Maquila Operation by the US MNEs: An Illustration

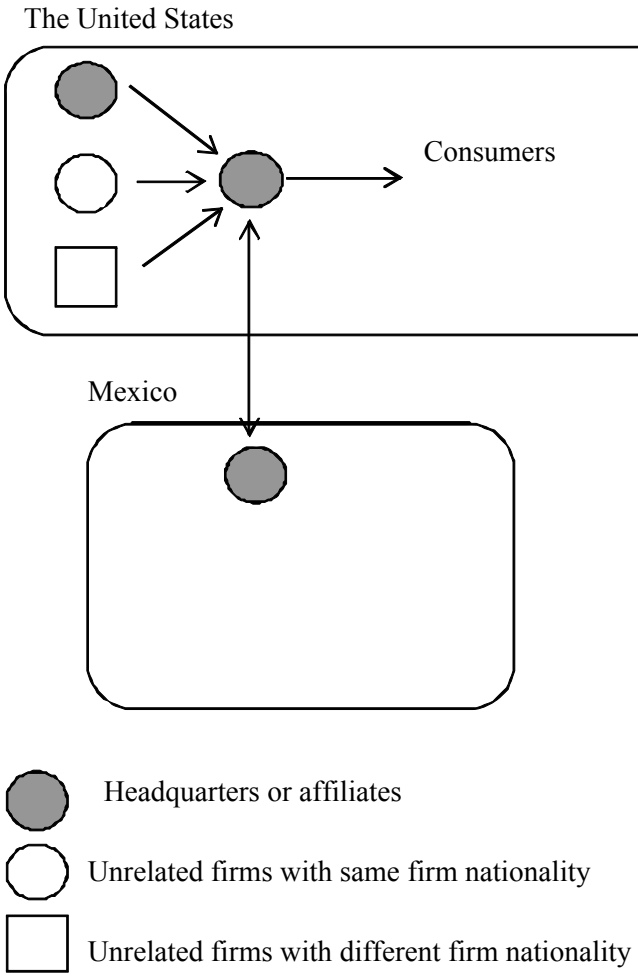


Figure 2. Typical East Asian Operation by Japanese MNEs: An Illustration

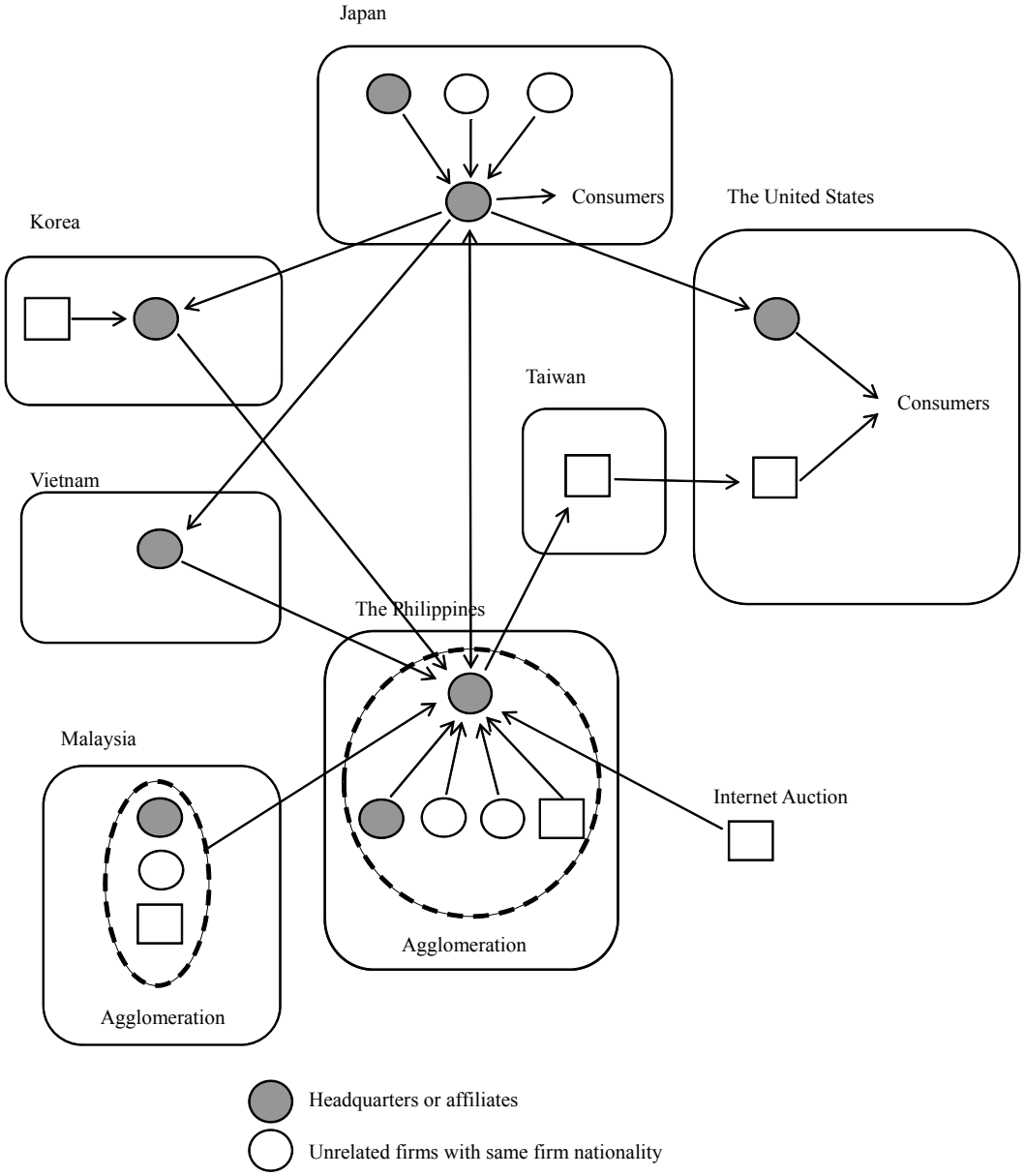
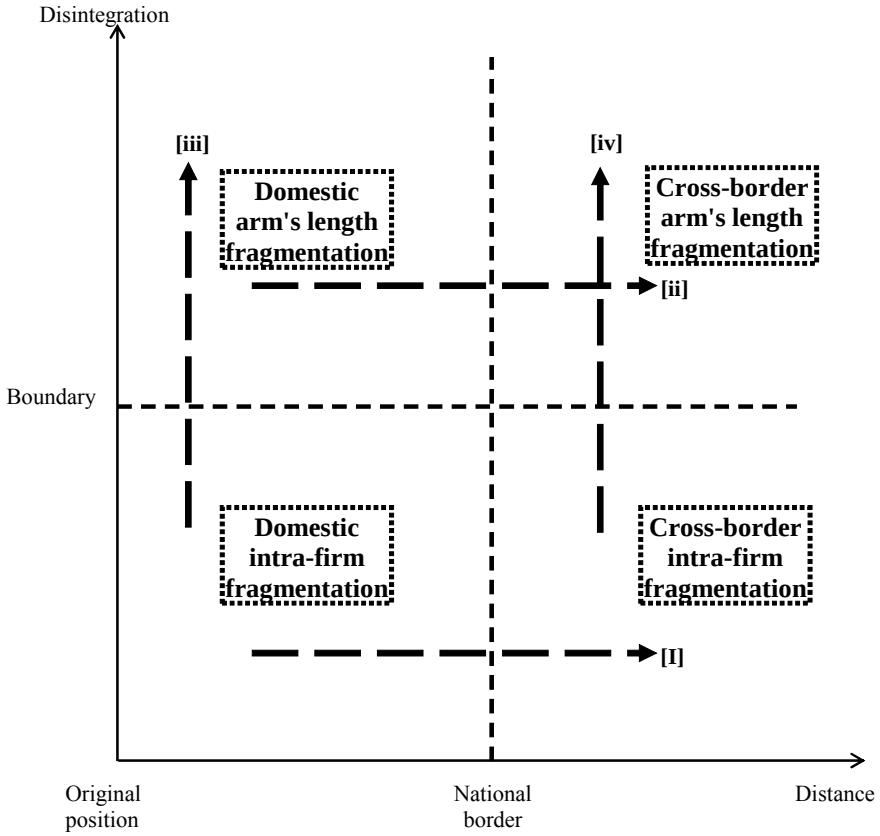


Figure 3 presents fragmentation in a two-dimensional space. The horizontal axis denotes geographical distance. From the original position, a production block can be detached and placed in geographical distance. The dotted line in the middle is a national border, which distinguishes cross-border fragmentation from domestic fragmentation.

The vertical axis, on the other hand, represents the organization (integration and disintegration) of corporate activities. A fragmented production may be conducted by either intra-firm establishments or unrelated firms. The dotted line is a boundary of a firm, distinguishing arm's-length (inter-firm) fragmentation or outsourcing from intra-firm fragmentation. [4]

Figure 3. Fragmentation in a Two-dimensional Space



[4] Disintegration and accompanied transaction costs have long been analyzed in industrial organization literature on vertical integration. For references on the Japanese subcontracting system, particularly corporate firms' choices over vertical integration, subcontracting, and spot market bidding in parts and components procurement, see Kimura (2002). For renewed interest in a global context, see, for instance, Antras (2005), Antras and Helpman (2004), and Grossman and Helpman (2005), which are based on the framework of contract theories.

When do corporate firms choose fragmentation? First, there must be a substantial cost reduction in the production of fragmented production blocks (see Table 1). Geographical distance may provide opportunities to explore different production conditions. In particular, cross-border fragmentation enables firms to enjoy diversified location advantages including workers' wages, economic infrastructure, policy environment, and others. The disintegration axis yields chances to utilize business partners' strengths. Instead of doing everything in-house, arm's-length fragmentation or outsourcing may make the entire production system more efficient. Second, service link costs to connect fragmented production blocks should not be too high. Fragmentation beyond national borders and/or a boundary of a firm is inevitably accompanied by substantial service link costs, but such costs must be low enough to result in total cost reduction.

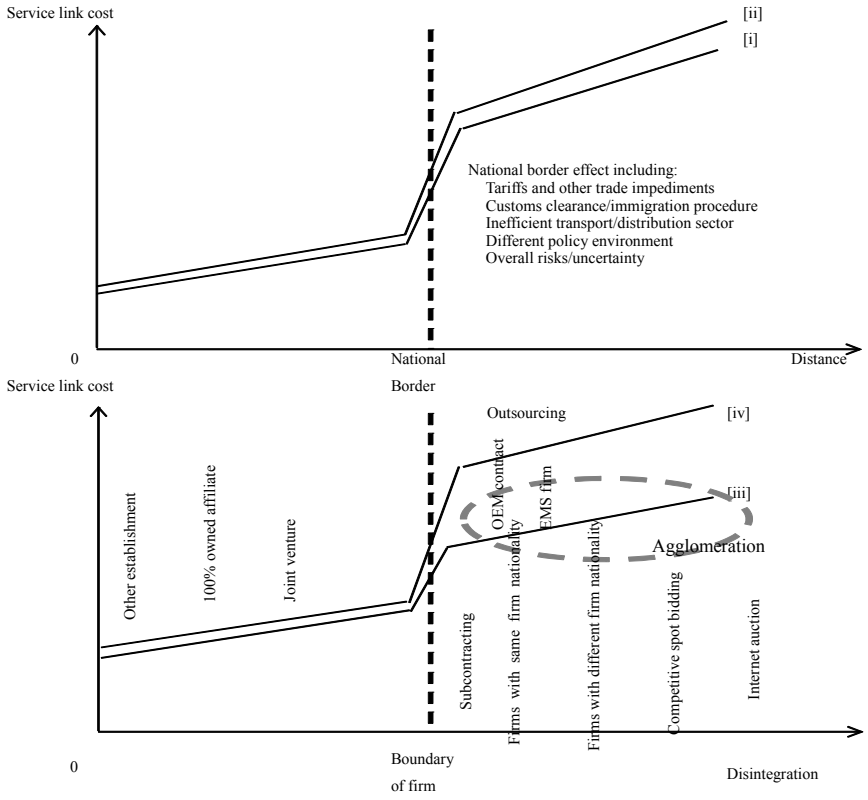
Table 1. Tradeoffs in Two-dimensional Fragmentation

	Service link cost connecting production blocks	**Production cost per se in production blocks**
Fragmentation along the distance axis	Cost due to geographical distance Elements (example): transportation, telecommunications, inefficiency in distribution, trade impediments, coordination cost	Cost reduction from location advantages Elements (examples): wage level, access to resources, infrastructure service inputs such as electricity, water and industrial estates, technological capability
Fragmentation along the disintegration axis	Transaction cost due to losing controllability Elements (example): Information gathering cost on potential business partners, monitoring cost, risks on the stability of contracts, immature dispute settlement mechanism, other deficiency in legal system and economic institutions	Cost reduction from (dis)internalization Elements (examples): availability of various types of potential business partners including foreign and indigenous firms, development of supporting industry, institutional capacity for various types of contracts, degree of incomplete information

Service link costs change as illustrated in Figure 4 when fragmentation takes place along the distance or disintegration axis. When fragmentation occurs in the horizontal

direction as [i] and [ii] in Figure 3, service link costs increase according to the distance from the original position. In particular, once fragmentation crosses a national border, service link costs jump up because of the national border effect. When fragmentation takes place in the vertical direction as [iii] and [iv], service link costs increase as the controllability of a firm over the fragmented production block becomes weaker. Various types of outsourcing along the disintegration axis from subcontracting to internet auction are illustrated in Figure 4. An important observation here is that geographical proximity saves service link costs or transaction costs, as [iii] is drawn much lower than [iv].

Figure 4. Two Kinds of Service Link Cost



In East Asia, geographical fragmentation and agglomeration go hand in hand. In contrast to market-oriented agglomeration in Europe, agglomeration in East Asia is often motivated by production-side logic.[5] The forces of fragmentation and agglomeration are countervailing in the first place; they are vectors pointing in opposite directions. In particular, when a firm decides whether to make use of intra-firm fragmentation, fragmentation or agglomeration is a binary decision. However, at the industry/aggregate level, fragmentation and agglomeration may go together.

The concentration of fragmented production blocks occurs at least through the following two channels: first, two kinds of service link costs do not have a monotonic pattern, and local minimal points of service link costs tend to attract a large number of production blocks. Particularly in cases of less developed countries (LDCs), each country, each local province, each city, or each industrial estate has a different investment climate. Service link costs are not monotonic at all in both dimensions of distance and disintegration. Moreover, a service link is often accompanied with strong economies of scale. Therefore, when a country successfully reduces two kinds of service link costs with proper policies, fragmented production blocks may rush in, and service link costs will then be pushed down even further.

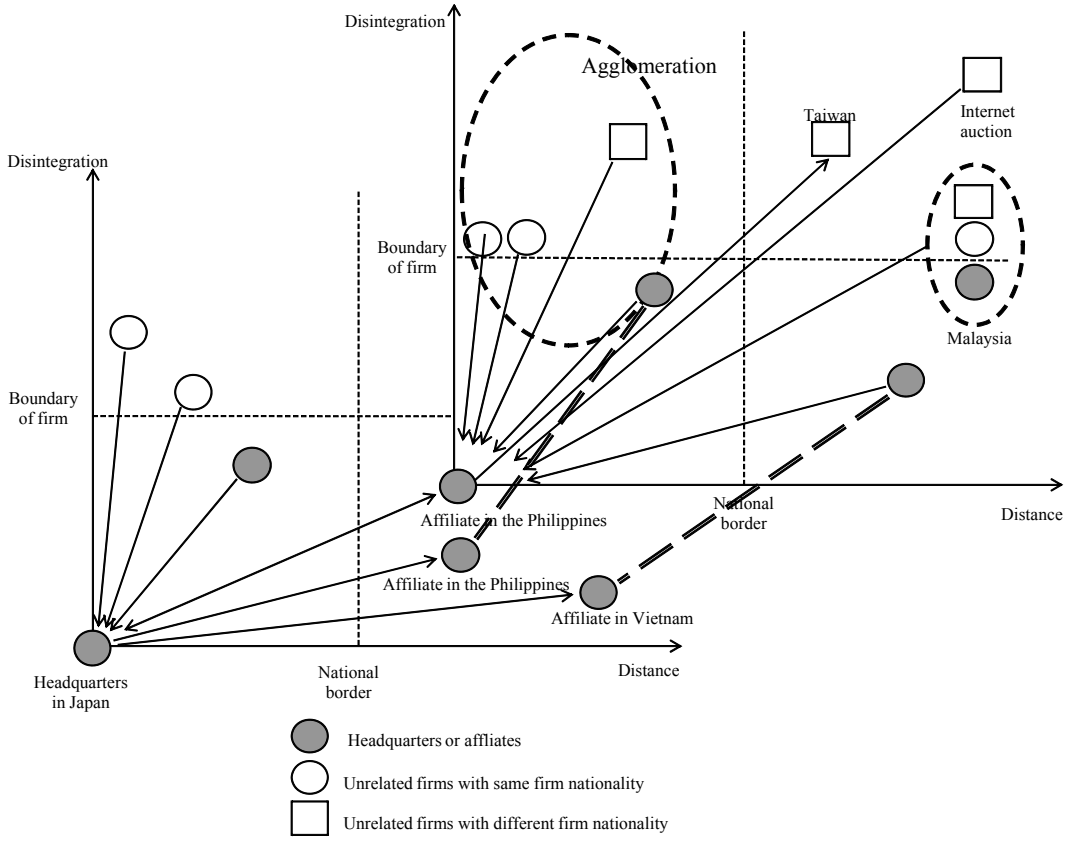
Second, the concentration of production blocks may also take place due to the close relationship between the service link cost along the disintegration axis and geographical proximity as indicated in Figure 4. The service link cost in arm's-length fragmentation is

[5] For previous literature on agglomeration, mostly in the context of developed countries such as EU and the U.S., see Fujita, Krugman, and Venables (1999) and Baldwin, Forslid, Martin, Ottaviano, and Robert-Nicoud (2003).

extremely sensitive to geographical distance. The closer the distance with business partners, the smaller the service link cost in searching potential business partners, consulting detailed specs of products, managing product quality and delivery timing, solving disputes over contracts, monitoring, and others. The northwest area in Figure 4 is a hot spot of this type of agglomeration. Here, the concentration of production blocks would reduce the service link cost, and the low service link cost would further attract production blocks; the arrows of causality would go in both directions. The concentrated production blocks in this mechanism generate interactive industrial structure among production blocks.

The two-dimensional fragmentation framework captures multilayered fragmentation as illustrated in Figure 5. By shifting the original position from the headquarters in the home country to an affiliate abroad, for example, the complicated structure of fragmentation with intra-firm and arm's-length transactions can be depicted.

Figure 5. Multilayed Fragmentation in East Asia: An Illustration



3. The Development of Intra-East Asian Trade

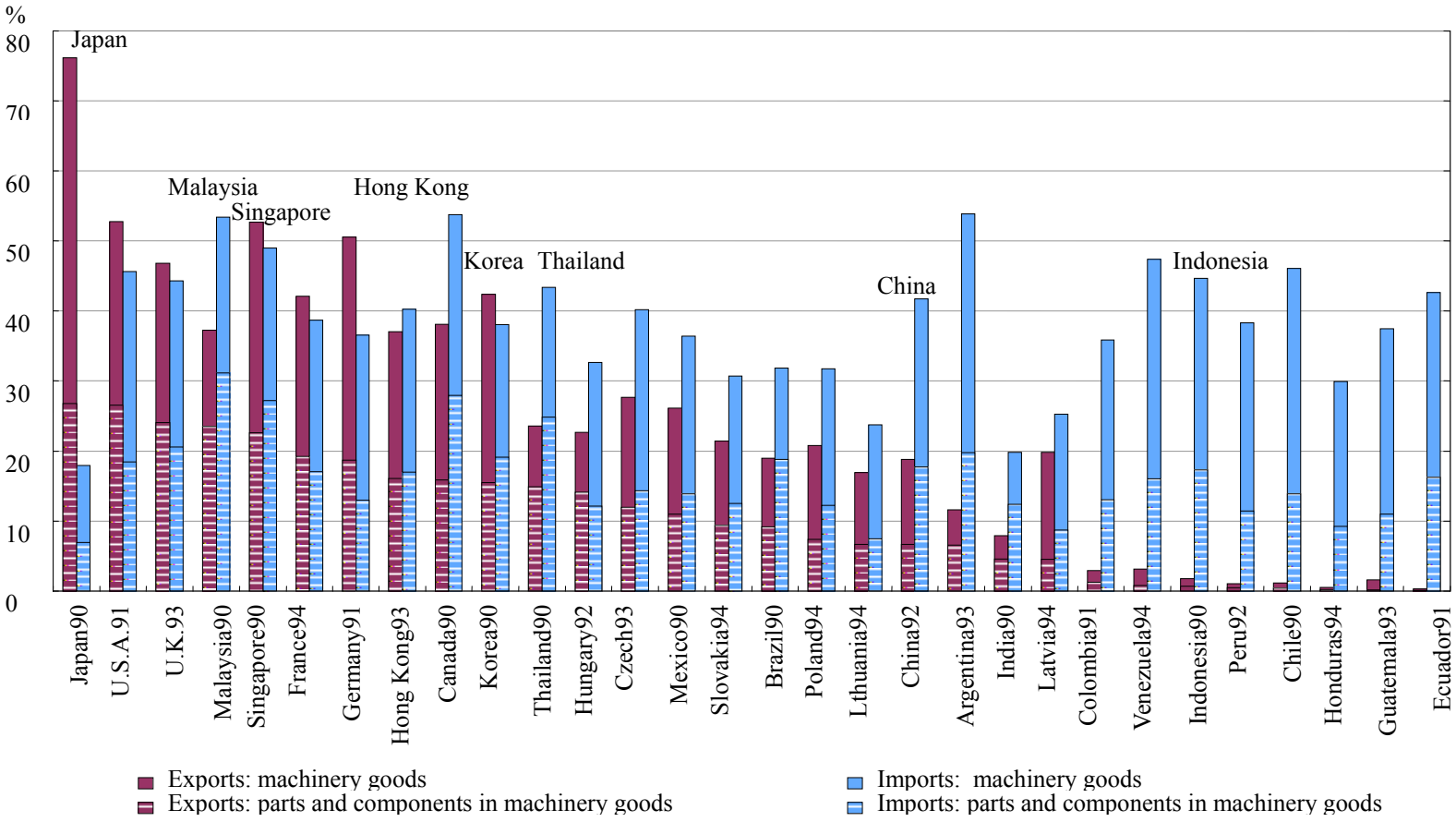
This section examines the first question: how the formation of international production/distribution networks in machinery industries has changed the spatial pattern of international trade in East Asia, particularly the pattern of intra-regional and inter-regional trade. First of all, we demonstrate the significance of machinery trade in East Asia. Figures 6 and 7 present the shares of machinery goods (i.e., Harmonized

System (HS) 84-92) and machinery parts and components in total exports to and imports from the world at the beginning of the 1990s and in 2005 for major economies in East Asia and other regions, plotting countries from the one with the highest export share of machinery parts and components.[6] As both figures vividly show, the share of machinery goods in East Asian countries drastically increased in both absolute and relative terms; while most countries on the left side were developed countries at the beginning of the 1990s, those are East Asian developing countries in 2005 with high shares of both machinery intermediate exports and imports. Moreover, the trade pattern of Japan shifted the weight from machinery final goods to machinery intermediate goods. These findings suggest drastic changes in trade and production patterns in the region as well as the existence of back-and-forth transactions among a number of countries in the region, as described below.[7]

[6] See Table A.1 for the definition of machinery parts and components at the HS classification in this paper.

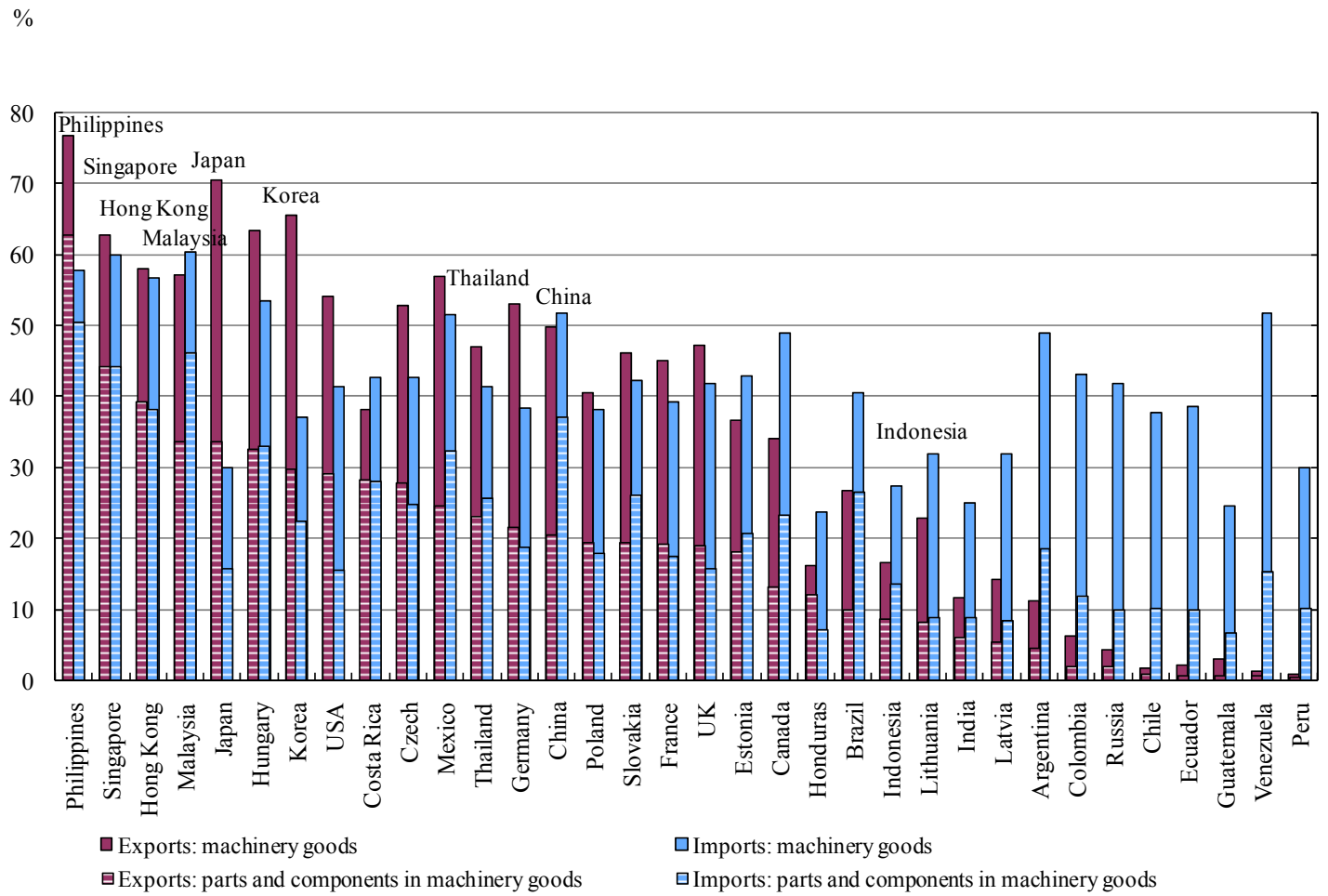
[7] Ando (2006) analyzes changes in East Asian trade structure in the 1990s by decomposing each country's machinery trade (exports plus imports) with the world at the finely disaggregated level (HS six-digit) into one-way trade, vertical intra-industry trade (vertical IIT), and horizontal intra-industry trade (horizontal IIT), and emphasizes that vertical IIT, particularly vertical IIT in machinery parts and components, expanded. The explosive expansion of machinery intermediates trade indeed resulted in changes in the main trade pattern of East Asia from one-way trade to vertical IIT.

Figure 6. Machinery Goods and Machinery Parts and Components: Shares in Total Exports and Imports in 1990-1994



Data source: Ando (2006).
Note: Data is of 1990 or close to 1990. For instance, Japan90 and U.S.A.91 indicate that data is of 1990 for Japan and 1991 for U.S.A.

Figure 7. Machinery Goods and Parts and Components: Shares in Total Exports and Imports in 2005



Data source: Authors' calculation, based on UN COMTRADE.

In other regions, in contrast, higher shares of machinery trade and those of machinery parts and components trade are observed for only some specific countries such as the U.S., Mexico, Costa Rica, U.K, Germany, Hungary, the Czech Republic, and Slovakia, suggesting the existence of production sharing between the U.S. and Mexico/Costa Rica and between U.K./Germany and Central and Eastern European countries without covering an extensive number of countries in the regions.[8] Other countries, particularly those in Latin America except Mexico and Costa Rica, are found on the right side with far lower shares of machinery exports than those of imports, indicating import-substituting-type operations of MNEs.

In the following, we first descriptively examine intra-regional trade patterns and then formally analyze them by using gravity model estimation.

3.1. The Evolution of Intra- and Inter-Regional Trade

To focus on changes in intra- and inter-regional trade patterns, Table 2(a) presents current-price exports of all products, machinery goods (total), machinery final goods, and machinery parts and components in East Asia including China, ASEAN4 (i.e., Indonesia, Malaysia, the Philippines, and Thailand), NIEs3 (i.e., Korea, Hong Kong, and Singapore), and Japan in 1990 and 2005, by distinguishing intra-East Asian exports from inter-regional exports.[9] To investigate the relative importance of the U.S. market for East Asian exports in particular, corresponding figures are also displayed in parenthesis. Note

[8] See Ando, Arndt, and Kimura (2006) for production networks in East Asia and the U.S.-Mexico nexus and Ando and Kimura (2007) for production networks in East Asia and Europe.
[9] See Tables A.2-A.5 in the Appendix for the corresponding tables for Japan, NIEs3, ASEAN4, and China.

that Taiwan, one of the most important players in international production networks of machinery industries, is not unfortunately included in East Asia due to the lack of data available from UN COMTRADE, and thus the value and share of intra-East Asian trade would be underestimated in these tables.

Table 2. Development of Intra-regional Export in East Asia

(a) Intra-and Inter-regional exports (millions US$)					**(b) Factors of growth in exports (1990-2005)**	
	1900		2005			
	Value	%	Value	%		
Machinery goods: parts and components					**<Intra-East Asian exports>**	
Intra-East Asia	54,336	39.6	399,882	52.6	(i)Growth in intra-East Asian exports	
Inter-regional	82,915	60.4	360,823	47.4	All Products	321%
(U.S.)	(39,624)	(28.9)	(108,213)	(14.2)	Machinery goods (total)	522%
Total	137,251	100.0	760,705	100.0	-Machinery final goods	400%
					-Machinery parts and components	636%
Machinery goods: final goods						
Intra-East Asia	50,932	23.2	254,738	35.6	(ii) Contribution to the growth (all products)	
Inter-regional	168,597	76.8	460,832	64.4	Machinery goods (total)	63%
(U.S.)	(70,183)	(32.0)	(188,911)	(26.4)	-Machinery final goods	23%
Total	219,529	100.0	715,570	100.0	-Machinery parts and components	40%
Machinery goods: total					**<Inter-regional exports>**	
Intra-East Asia	105,268	29.5	654,620	44.3	(i) Growth in inter-regional exports	
Inter-regional	251,512	70.5	821,654	55.7	All products	224%
(U.S.)	(109,807)	(30.8)	(297,124)	(20.1)	Machinery goods (total)	227%
Total	356,780	100.0	1,476,274	100.0	-Machinery final goods	173%
					-Machinery parts and components	335%
All products						
Intra-East Asia	270,465	38.5	1,139,821	44.9	(ii) Contribution to the growth (all products)	
Inter-regional	432,736	61.5	1,401,216	55.1	Machinery goods (total)	59%
(U.S.)	(174,978)	(24.9)	(473,093)	(18.6)	-Machinery final goods	30%
Total	703,201	100.0	2,541,037	100.0	-Machinery parts and components	29%

Data Source: Authors' calculation, based on UN COMTRADE.
Note: "East Asia" here includes China, ASEAN4, NIES3, and Japan. Due to lack of data available from UN COMTRADE, (i) Taiwan is not included in East Asia, (ii) data for China in 1992 and Hong Kong in 1993 are used in calculating intra-East Asian exports in 1990, (iii) data for the Philippines are not included in calculating intra-East Asian.

Clearly, the share of intra-East Asian exports in total exports by East Asia as a whole has risen, indicating its increasing relative importance compared to inter-regional exports.

The increasing relative importance of intra-regional trade is more vividly observed in machinery trade. In the case of machinery intermediates exports in East Asia, the intra-regional share climbed up to 53 percent in 2005 from 40 percent in 1990.[10] Moreover, the intra-regional share increased from 23% to 36% even for trade in finished machinery products. These confirm the enhancing relative significance of intra-regional trade patterns to inter-regional trade patterns in machinery industries, particularly in machinery parts and components trade. In other words, the importance of markets outside the region for East Asian exports, including the U.S. market, has relatively declined. Considering the expansion in domestic demand accompanying economic growth in East Asian countries, which has not appeared in transactions beyond national borders, the relative importance of the intra-East Asian market would have been enhanced more notably than suggested by the figures above.

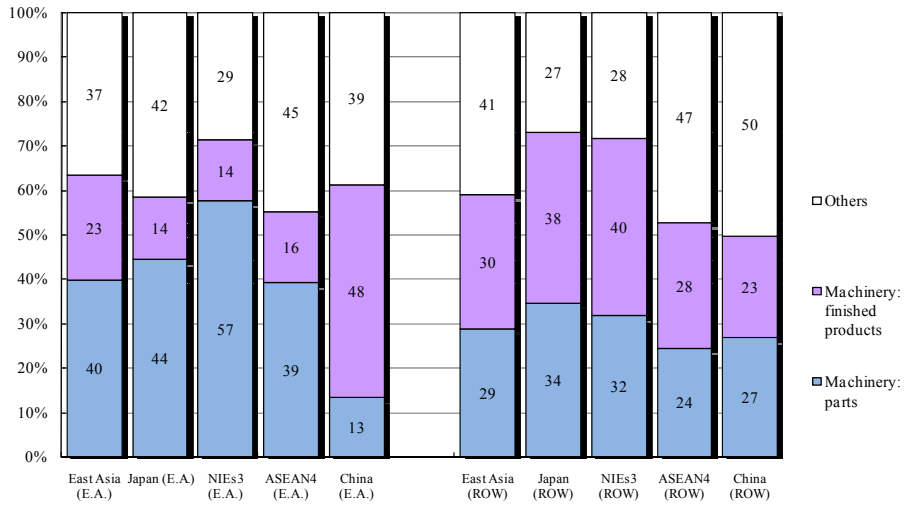
Table 2 (b(i)), in turn, presents the nominal growth from 1990 to 2005 in intra-East Asian exports and inter-regional exports. During that period, intra-East Asian exports expanded by over four times for all commodities and at much higher paces for machinery goods as a whole, particularly for machinery parts and components.[11] These figures imply how fast has intra-East Asian trade, particularly intra-East Asian machinery trade,

[10] The corresponding figures in 2003 for Japan, NIEs3, ASEAN4, and China are 48 percent in 2003, 65 percent, 60 percent, and 56 percent, respectively. Although the intra-regional share for machinery parts and components has declined in China, the value of machinery intermediate exports itself has explosively increased. Moreover, although the U.S. share reached over 20 percent from a low share of 10 percent in 1992, around a 20 percent-share of the U.S. market is more or less equivalent to the cases of other East Asian countries.

[11] The growth rates for all products, machinery goods, and parts and components are 321 percent, 522 percent, and 636 percent for East Asia, 238 percent, 218 percent, and 345 percent for Japan, 302 percent, 535 percent, and 772 percent for NIEs3, 376 percent, 1110 percent, and 1108 percent for ASEAN4, and 422 percent, 1244 percent, and 738 percent for China, respectively.

grown since the 1990s. Indeed, machinery trade significantly contributed to the growth in intra-East Asian exports from 1990 to 2005 (Tables 2 (b(ii)) and Figure 8); 63 percent of the growth in intra-East Asian exports during those 15 years, 321 percent, can be explained by machinery trade, and, more importantly, 40% of the growth by machinery parts and components. In other words, a large portion of the explosive growth in intra-East Asian trade was induced by the expansion of machinery trade, mostly that of machinery parts and components. This can be regarded as a sort of "magnification effect" of machinery intermediates trade, which is referred to by Yi (2003). In East Asia, back-and-forth transactions in international production networks exist, and they are reflected in this magnification effect.

Figure 8. Contribution to Growth in Intra- and Inter-regional Exports in East Asia: (1990-2005)



Data source: Table 2(b) and Tables A2(b)-A5(b).
Note: "E.A." and "ROW" in the figure indicate intra-regional exports and inter-regional exports, respectively.

In the case of inter-regional trade in East Asia, similarly, machinery trade explains close to 60 percent of growth. The main factor contributed to the growth, however, is an expansion of machinery final goods (30% of the growth) in addition to that of machinery parts and components (29%). This implies that machinery final goods produced in international production networks in East Asia are sold to the United States, Europe, and so on, though the relative importance of these markets are decreasing as discussed above.

3.2. Strengthened Intra-East Asian Trade Relationship: Gravity Estimation

This subsection formally analyzes changes in intra-East Asian trade patterns by conducting simple gravity model estimation for two periods, 1990 and 2005, and separately for machinery parts and components, machinery final goods, and all products. The gravity equation for each year is as follows:

$$\ln EX_{ij}^{c} = \beta_0 + \beta_1 \ln Dist_{ij} + \beta_2 \ln GDP_i + \beta_3 \ln GDP_j + \beta_4 \ln GDPPCgap_{ij} + \varepsilon_{ij}$$

where $EX_{ij}^{c}, Dist_{ij}$, GDP_i (GDP_j) , and $GDPPCgap_{ij}$ represent real export values from country i to country j for commodity c (that is, machinery parts and components, machinery final products, and all products), distance between the capital of country i and of country j, real GDP in country i (j), and real income gap, i.e., absolute value of the difference in real GDP per capita between country i and country j. To compare the results for 1990 with those for 2005, exports, GDP, and income gap used in this paper are

constant at the 2000 prices[12]. Exports are obtained from UN COMTRADE (online), GDP, GDP per capita, and the wholesale price index in the U.S. are available from World Bank Indicator (online), and distances measures are obtained from the CEPII (centre d'etudes prospectives et d' informations internationals) website.[13]

Table 3 presents export shares of China, ASEAN4, NIEs3, and Japan by destination (China, ASEAN4, NIEs3, and Japan) in 1990 and 2005 and real export growth rates in 15 years for each case, based on export data used in the gravity estimation[14].

[12] The wholesale price index in the U.S. is used to obtain export values at the 2000 prices.

[13] The CEPII's distance variables are available from the following website: http://www.cepii.fr/anglaisgraph/bdd/distances.htm. The CEPII's distance database provides four different measures: the two are simple distances (distances between the capitals and between most important cities in terms of population) and the rest are weighted distances incorporating geographical distribution of population inside each country. See the CEPII website (or "notes on CEPII's distances measures" by Thierry Mayer and Soledad Zingnago (2006)) for the details.

[14] Since export data at the HS classification in 1990 are not available for China, Hong Kong, and the Philippines, corresponding import data in 1990 are used as the substitutes. There, however, still remain some exceptions due to the lack of data; the data used as the substitutes of exports in 1990 are export values in 1992 for exports from China to Hong Kong and to the Philippines, import values in 1992 for exports from the Philippines to China, and import values in 1993 for exports from the Philippines to Hong Kong. For these bilateral patterns, independent variables in the corresponding years are used in Table 3 and gravity estimation.

Table 3. By-destination Intra-East Asian Exports: 1990 and 2005 (%)

Export		Parts and components			Machinery final goods			Total		
		Share		Real	Share		Real	Share		Real
from	to	1990	2005	growth	1990	2005	growth	1990	2005	growth
China	ASEAN4	5	13	3,038	3	9	3,145	4	11	861
	NIES3	88	64	789	94	69	581	75	60	218
	Japan	7	24	3,817	4	22	5,586	21	29	444
	East Asia	100	100	1,122	100	100	829	100	100	294
ASEAN4	China	0	13	33,332	1	16	16,530	4	15	1,133
	ASEAN4	8	18	1,743	9	19	1,560	8	19	640
	NIES3	69	49	461	68	38	368	39	39	223
	Japan	24	21	589	22	27	906	49	28	83
	East Asia	100	100	688	100	100	730	100	100	224
NIES3	China	32	54	1,457	30	43	566	30	50	622
	ASEAN4	28	20	544	26	23	318	25	22	276
	NIES3	21	17	641	25	18	240	18	15	284
	Japan	19	9	325	19	16	315	27	12	99
	East Asia	100	100	812	100	100	373	100	100	335
Japan	China	5	34	2,230	8	32	482	9	34	868
	ASEAN4	35	26	141	33	21	-6	32	23	78
	NIES3	60	40	121	59	47	20	59	43	81
	East Asia	100	100	229	100	100	48	100	100	150
East Asia	East Asia	100	100	541	100	100	323	100	100	251

Data source: Authors' calculation, based on UN COMTRADE.
Note: Growth rates are obtained on the real basis.

The results of gravity estimation provide several interesting insights (Table 4).[15] The first is the relationship between geographical proximity and parts and components trade. The coefficients for distance variables in both 1990 and 2005 are all negative as expected, and the absolute values are the highest for machinery intermediates, the next for machinery final goods, and the last for all products. It suggests that geographical proximity or agglomeration is more important for parts and components than for

[15] In the case of bilateral patterns in East Asia, distances between the capitals and distances between most important cities in terms of population are the same. We also conducted the gravity model estimation, using weighted distances instead of simple distances. However, the results are basically the same as being discussed below.

machinery final products or other products. Service link cost in fragmentation certainly includes something beyond usual transport cost, which is likely to include various kinds of coordination cost in production/distribution networks.

Table 4. Gravity Model Estimation of Intra-East Asian Exports

	Dependent variables (exports (log)):					
Variable	Machinery parts and components		Machinery final goods		All products	
(a) Year:1990	(1)		(2)		(3)	
Constant	-5.018		-14.440	***	-5.358	*
	(-1.02)		(-3.23)		(-1.81)	
Distance (log)	-0.724	**	-0.623	**	-0.429	**
	(-2.45)		(-2.32)		(-2.41)	
GDPi (log)	0.378	***	0.703	***	0.424	***
	(2.73)		(5.60)		(5.09)	
GDPj (log)	-0.155		0.043		0.292	***
	(-1.12)		(0.34)		(3.51)	
Income gap (log)	1.051	***	0.823	***	0.500	***
(difference in GDP per capita)	(7.99)		(6.89)		(6.31)	
Adjusted R2	0.595		0.635		0.634	
Number of observations	72		72		72	
(b) Year: 2005	(1)'		(2)'		(3)'	
Constant	1.974		-6.774		-1.162	
	(0.55)		(-1.79)		(-0.44)	
Distance (log)	-0.823	***	-0.792	***	-0.690	***
	(-4.21)		(-3.86)		(-4.82)	
GDPi (log)	0.351	***	0.712	***	0.495	***
	(3.83)		(7.40)		(7.38)	
GDPj (log)	0.329	***	0.438	***	0.456	***
	(3.58)		(4.54)		(6.77)	
Income gap (log)	0.341	***	0.138		0.171	***
(difference in GDP per capita)	(4.13)		(1.59)		(2.82)	
Adjusted R2	0.467		0.524		0.620	
Number of observations	72		72		72	

Data source: Authors' calculation.
Notes: Both dependent and independent variables are on the real basis for a time-series-comparison.
Numbers in parentheses are t-statistics.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

The second is the strengthened trade relationships, particularly among developing countries in East Asia. The absolute values of coefficients for distance variables are

larger in 2005 than in 1990. This should not be interpreted as a reflection of enhancing trade impediments. It rather indicates that trade became much more active in 2005 among those with substantially weaker trade relationships such as ASEAN countries in 1990. Indeed, as Table 3 clearly shows, exports among ASEAN countries explosively expanded for machinery goods, particularly machinery parts and components. On the other hand, these coefficients (absolute values) in the case of East Asia are still smaller than the case of Europe or the world.[16] Combined with these findings, our results of distance measures suggest that trade relationships are even more strengthened in East Asia, particularly among developing countries with substantially weaker trade relationships in 1990, because service link costs across borders are smaller than in other regions.

The third is the reduced importance of income gap as a determinant of trade. The coefficients for income gap are much smaller in 2005 than in 1995, while they are all positive.[17] Moreover, the coefficient for the income gap in 2005 is not statistically significant anymore for machinery final products, though it is positive, suggesting the expansion of final goods trade among developing countries, rather than between developed and developing countries.[18] These suggest that income gap as a whole country are losing the importance as a determinant of trade, thought it still works to some extent.

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[16] See Kimura, Takahashi, and Hayakawa (2007) for the results of gravity estimation of intra-Europe exports and the world exports for machinery parts and components and machinery final goods. Note that their regressions are based on export values at the SITC classification in nominal terms.

[17] Kimura, Takahashi, and Hayakawa (2007) also report that the coefficient for income gap has a positive sign, though not strongly statistically significant, in the case of intra-Europe trade, as opposed to intra-East-Asia trade. This suggests that the horizontal product differentiation model would be relevant in the case of intra-Europe trade, while it could not be appropriate in the case of intra-East-Asia trade.

[18] Export growths for machinery final products from Japan to other East Asian countries are relatively small, and even negative for exports to ASEAN countries.

4. Intra-firm and Arm's-length Transactions: Changing Behavior of Japanese Firms

The second question is how corporate firms combine two kinds of fragmentation in production/distribution networks. The intensive use of disintegration-type fragmentation or outsourcing arrangements is one of the most salient phenomena in East Asia. Firms in East Asia have indigenous traditions of inter-firm linkages. An old legendary subcontracting system existed among Japanese firms, based on the dualistic structure of large firms in the downstream and small/medium enterprises in the upstream. Taiwan had a tradition of peculiar horizontal subcontracting arrangements among machinery manufacturers. The Hong Kong Guangdong nexus developed an innovative system of processing deal trade in textile and machinery industries. These traditions certainly worked as prototypes of disintegration-type fragmentation in East Asia. The development of modulation technologies and value chain management know-how was a technological backbone facilitating outsourcing arrangements.

Formal empirical analysis of intra-firm and arm's-length transactions is plagued by a serious deficiency of statistical data. The analysis using the micro data of Japanese affiliates abroad, however, provides some limited information on the characteristics of production/distribution networks.

The analysis in this section is based on the micro data compiled by the Ministry of Economy, Trade, and Industry (METI), Government of Japan (the former name was the Ministry of International Trade and Industry (MITI)): *The 1993F/Y, 1996F/Y, 1999F/Y,*

and 2002F/Y Survey of Overseas Business Activities of Japanese Companies. This database presents information on the performance of foreign affiliates of Japanese firms. In particular, the extensive surveys conducted every three years, which are used in this section, include detailed information on overseas business activities such as intra-firm and arm's length transactions.[19]

Table 5 presents the number of Japanese affiliates located in East Asia and their performance in terms of total sales/purchases, by-destination sales/by-origin purchases ratios, and intra-firm transaction ratios in 1992, 1995, 1998, and 2001. As Table 5 shows, machinery industries (industry 290 to 320) hold over 30 percent and approximately 40 percent of the total number of Japanese affiliates in East Asia and their total sales/purchases in 2001, respectively. In particular, electric machinery (300) and transport equipment (310) sectors compose of a large portion of Japanese machinery affiliates in East Asia in terms of their number and their activities. To clarify features of their transactions, Tables 6 and 7 focuses on intra-firm and arm's length transactions by Japanese electric machinery affiliates and Japanese transport equipment affiliates in East Asia, NIEs4, ASEAN4, and China, respectively, which are calculated based on Table 5 and corresponding tables to Japanese affiliates located in NIES4, ASEAN4, and China.[20] In the tables, "local" refers to the country in which the affiliate concerned is located,

[19] In this data set, foreign affiliates include both "affiliates abroad" with no less than 10 percent ownership by Japanese parent firms and "affiliates of affiliates abroad" with no less than 50 percent ownership by "affiliates abroad," except those in finance, insurance, or real estate. Note that the effective return ratios are unfortunately as low as 60 percent since the survey is voluntary (i.e., non-compulsory).

[20] The corresponding tables on Japanese affiliates in NIES4, ASEAN4, and China are omitted from the paper and are available upon request.

"third countries" are countries other than Japan and "local," and "East Asia" indicates countries in East Asia other than Japan and "local."

The nature of fragmentation and its changes over time can be observed particularly in the largest sector, electric machinery (300), and patterns of by-destination sales and by-origin purchases vividly present the development of international production/distribution networks. The most salient phenomenon is the large and increasing share of sales/purchases with other East Asian countries, suggesting the extensiveness of networks and their development: shares of other East Asian countries increased from 18 percent (nine percent) in 1992 to 22 percent (20 percent) for sales and 15 percent (eight percent) in 1992 to 28 percent (20 percent) in the electric machinery sector (machinery sectors as a whole). In addition, increasing shares of Japan in sales and decreasing shares of Japan in purchases indicate the expansion of back-and-forth cross-border production sharing as well as the development of local vendors. The declining trend of local sales ratios suggests a shift in weight from import-substituting-type industries to export-oriented, network-forming industries.

Ratios of intra-firm/arm's-length transactions conform to our two-dimensional fragmentation framework. Intra-firm transaction ratios for transactions with Japan, other East Asian countries, and local become smaller in this order (Table 5).[21] In other words, intra-firm transactions are large in transactions with Japan while arm's-length transactions are important in local transactions, and transactions with other East Asian

[21] A similar pattern is observed for the U.S. affiliates in East Asia. See Ando, Arndt, and Kimura (2006) for more detailed discussion on similarities in operations by Japanese and the U.S. firms in East Asia.

countries are categorized in the middle. This observation proves a close link between geographical proximity and disintegration-type fragmentation, indicating the formation of agglomeration of fragmented production blocks, as discussed in Section 2.

The above-mentioned characteristics seem to be reflected most closely in the case of Japanese affiliates in ASEAN4. That is, intra-firm transactions are large in transactions with Japan, while arm's-length transactions are important in local transactions, and transactions with other East Asian countries are categorized in the middle, reflecting a close link between geographical proximity (agglomeration) and arm's length fragmentation (Table 6). In the case of Japanese affiliates in China, we must note that operations by Japanese firms in China seriously started only recently (see values of sales and purchases in Tables 6 and 7).[22] Rapid increases in local purchases ratios from 16 percent in 1992 to 37 percent in 2001, eventually reaching up to the level of ASEAN4, with the rapid expansion of arm's length transactions in the local market, suggest the formation of local vertical links in agglomeration in China.

[22] The performance of Japanese electric machinery affiliates in China drastically expanded from 70 billion JPY in 1992 to 1,298 billion JPY in 2001 for sales and from 47 billion JPY in 1992 to 919 billion JPY in 2001 for purchases. The number of affiliates also confirm the recent expansion of Japanese firms' operations in China: the number of Japanese electric machinery affiliates in China in the dataset is 30 (54) in 1992 and 281 (552) in 2001 in the electric machinery sector (machinery sectors as a whole), which accounts for around seven percent and 27 percent of Japanese electric machinery in East Asia, respectively.

Table 5. Sales and Purchases by Japanese Affiliates in East Asia

Year	Industry	Number of Affiliates	%	Total Sales (billion JPY)	%	By-destination sales ratio (%)						Intra-firm transaction ratio (%)					
						Japan	Local	Third countries				Japan	Local	Third countries			
									East Asia	North America	Europe				East Asia	North America	Europe
(a) Sales																	
	Manufacturing total	1,463	56.3	7,887	50.7	15.8	66.0	18.2	10.0	3.4	1.8	84.2	6.3	42.9	44.6	62.6	47.7
	Machinery total	715	27.5	5,202	33.4	16.8	66.2	17.0	9.4	4.0	1.8	90.5	7.8	57.7	53.9	76.6	65.0
	290	91	3.5	216	1.4	23.6	53.0	23.4	11.3	2.1	9.8	96.7	3.0	71.2	55.6	54.3	93.9
1992	300	416	16.0	2,872	18.5	27.2	45.7	27.1	17.7	4.9	2.1	90.0	8.0	56.2	53.5	82.6	58.0
	310	171	6.6	1,999	12.8	1.7	92.6	5.7	0.8	3.1	0.4	73.9	7.2	60.2	57.9	71.2	28.3
	320	37	1.4	115	0.7	51.8	36.9	11.3	1.6	4.5	3.3	96.5	32.4	46.6	77.9	51.1	50.8
	Total	2,597	100.0	15,556	100.0	21.8	59.4	18.8	9.3	2.4	1.2	64.1	4.7	28.9	33.1	53.5	44.8
	Manufacturing total	2,966	64.5	12,300	50.0	18.8	58.4	22.8	13.3	3.6	1.8	83.2	15.8	45.4	49.1	57.0	60.7
	Machinery total	1,428	31.0	9,080	36.9	20.8	56.6	22.6	12.8	4.0	1.9	90.6	19.9	55.4	60.2	64.8	71.5
	290	234	5.1	541	2.2	28.5	48.5	23.1	13.9	0.7	5.4	97.6	1.5	68.8	66.5	71.4	98.7
1995	300	755	16.4	5,107	20.8	28.7	38.0	33.2	19.6	5.6	2.2	88.9	9.0	52.6	59.5	56.7	58.4
	310	339	7.4	3,095	12.6	2.2	92.8	5.0	0.8	2.3	0.8	85.1	27.3	65.4	30.3	97.2	94.5
	320	100	2.2	337	1.4	51.2	27.7	21.1	15.9	1.9	2.2	98.9	66.6	74.7	76.6	69.3	75.5
	Total	4,600	100.0	24,579	100.0	17.8	54.7	27.5	13.5	2.5	1.4	67.6	10.4	24.3	31.2	49.1	58.3
	Manufacturing total	3,835	61.7	12,325	53.0	25.4	49.2	25.4	16.9	4.5	2.7	73.1	7.6	45.9	47.2	48.3	40.7
	Machinery total	1,809	29.1	8,485	36.5	44.1	38.6	17.3	15.4	1.1	0.4	80.6	15.6	48.7	47.5	50.8	63.7
	290	315	5.1	689	3.0	40.7	32.4	27.0	14.8	5.5	4.6	90.7	6.9	79.7	76.7	91.5	87.4
1998	300	916	14.7	5,192	22.3	32.9	32.3	34.8	24.9	5.3	3.0	73.6	14.5	51.4	55.4	46.0	37.4
	310	478	7.7	2,140	9.2	11.1	81.0	7.9	2.2	3.5	1.5	82.1	2.8	73.0	52.2	98.5	52.6
	320	100	1.6	464	2.0	45.9	27.2	26.9	23.1	1.5	2.0	70.6	26.8	16.3	15.9	11.3	18.6
	Total	6,213	100.0	23,235	100.0	21.9	49.6	28.4	21.2	3.4	2.6	62.7	5.6	32.3	30.1	47.4	34.1
	Manufacturing total	4,247	62.5	20,382	56.6	25.9	46.1	28.0	18.6	4.9	2.6	77.4	10.9	46.1	44.0	58.1	43.8
	Machinery total	2,121	31.2	14,826	41.2	29.1	40.1	30.9	19.9	5.8	2.9	79.3	13.7	52.6	51.6	62.4	47.6
	290	381	5.6	1,084	3.0	40.0	35.1	24.9	17.0	2.4	1.7	93.9	22.8	81.5	75.0	96.5	94.3
2001	300	1,041	15.3	8,539	23.7	34.4	31.2	34.4	22.0	7.4	2.8	77.6	15.6	54.3	55.8	55.7	52.4
	310	582	8.6	4,575	12.7	8.1	66.1	25.8	16.4	2.9	4.0	80.7	9.3	33.0	23.3	94.6	29.4
	320	117	1.7	628	1.7	40.4	42.5	17.2	12.7	2.9	1.3	72.2	14.1	79.7	78.0	91.4	74.4
	Total	6,799	100.0	35,984	100.0	25.0	47.5	27.5	18.8	4.2	2.5	67.2	8.2	39.5	34.6	60.0	40.7

Table 5. Sales and Purchases by Japanese Affiliates in East Asia *(Continued)*

Year	Industry	Number of Affiliates	%	Total Purchases (billions JPY)	%	By-origin purchases ratio (%)						Intra-firm transaction ratio (%)					
						Japan	Local	Third countries				Japan	Local	Third countries			
									East Asia	North America	Europe				East Asia	North America	Europe
(b) Purchases																	
	Manufacturing total	1,463	56.3	3,384	43.3	37.9	48.4	13.7	8.1	1.6	0.0	78.2	4.2	42.7	50.2	47.7	-
	Machinery total	715	27.5	2,466	31.5	46.2	43.4	10.3	8.3	1.3	0.0	84.4	2.0	62.6	58.8	80.8	-
	290	91	3.5	138	1.8	47.8	49.0	3.3	0.7	1.1	0.3	93.9	4.5	49.7	84.8	80.3	23.9
1992	300	416	16.0	1,469	18.8	46.7	36.6	16.7	15.2	1.1	0.1	84.6	1.9	62.5	59.8	86.6	98.1
	310	171	6.6	790	10.1	43.8	52.9	3.2	1.0	1.7	0.4	81.7	0.6	76.7	34.6	76.2	86.2
	320	37	1.4	68	0.9	60.2	34.2	5.6	0.3	0.1	0.0	85.6	17.5	4.9	100.0	0.0	-
	Total	2,597	100.0	7,817	100.0	34.7	38.5	26.8	11.6	1.6	0.0	82.8	5.1	21.2	33.6	36.3	-
	Manufacturing total	2,966	64.5	6,914	47.5	40.3	40.3	19.4	14.4	1.4	0.7	76.5	15.1	40.8	44.9	32.6	50.7
	Machinery total	1,428	31.0	5,479	37.6	29.3	43.3	27.5	18.6	4.7	2.7	76.2	9.3	53.6	54.3	59.1	46.3
	290	234	5.1	380	2.6	44.0	42.9	13.2	12.6	1.1	1.0	82.9	1.6	25.7	35.4	25.1	13.2
1995	300	755	16.4	2,834	19.5	38.9	33.8	27.3	24.8	1.3	0.2	86.0	14.1	46.5	45.9	33.1	48.2
	310	339	7.4	2,008	13.8	51.6	45.6	2.8	1.0	0.8	0.7	73.6	16.1	68.8	39.9	97.2	85.2
	320	100	2.2	257	1.8	44.3	34.9	20.8	20.6	0.1	0.1	85.9	42.4	73.7	74.5	0.0	0.3
	Total	4,600	100.0	14,559	100.0	31.5	36.1	32.4	14.9	1.3	1.4	69.1	14.2	23.2	36.2	44.7	27.5
	Manufacturing total	3,835	61.7	7,502	49.3	35.1	43.3	21.6	18.6	1.5	0.6	58.7	7.1	44.9	47.0	44.7	31.6
	Machinery total	1,809	29.1	5,764	37.9	36.8	41.3	21.8	20.3	1.0	0.4	61.9	6.7	49.3	50.0	51.6	21.8
	290	315	5.1	401	2.6	32.2	57.7	10.1	8.8	0.8	0.4	79.1	3.4	76.1	85.1	21.2	0.0
1998	300	916	14.7	3,711	24.4	37.0	35.8	27.2	26.3	0.4	0.2	64.0	6.5	49.7	50.8	24.0	7.4
	310	478	7.7	1,381	9.1	37.2	53.4	9.4	6.1	2.5	0.7	43.8	5.2	48.4	36.2	89.5	17.0
	320	100	1.6	272	1.8	41.2	40.2	18.6	14.5	2.6	1.5	72.9	20.5	22.6	22.3	0.0	65.3
	Total	6,213	100.0	15,223	100.0	33.4	41.1	25.5	20.7	1.5	1.3	59.3	9.9	35.6	39.4	41.8	15.4
	Manufacturing total	4,247	62.5	13,781	51.5	35.8	43.3	21.0	18.6	1.0	0.6	66.0	9.5	42.0	42.6	43.1	19.2
	Machinery total	2,121	31.2	10,417	38.9	38.0	40.3	21.7	20.2	0.7	0.3	69.9	10.1	46.4	45.4	64.7	41.3
	290	381	5.6	786	2.9	36.2	59.0	4.8	4.3	0.3	0.1	67.1	9.8	48.3	48.7	40.9	56.5
2001	300	1,041	15.3	6,249	23.3	35.3	35.2	29.4	28.0	0.5	0.3	74.4	8.6	44.7	44.4	33.3	39.0
	310	582	8.6	2,945	11.0	46.5	47.3	6.2	3.9	1.6	0.4	59.6	13.7	71.4	65.4	98.2	46.2
	320	117	1.7	437	1.6	42.5	49.9	7.7	7.4	0.0	0.2	68.5	11.4	52.1	52.4	79.0	26.3
	Total	6,799	100.0	26,784	100.0	33.9	42.5	23.6	19.3	1.8	1.2	62.6	12.9	39.6	42.5	38.2	10.4

Data source: Authors' calculation, based on METI database.
Note: Machinery industries are general machinery (290), electric machinery (300), transport equipment (310), and precision machinery (320).

Table 6. Intra-firm and Arm's Length Transactions by Japanese Electric Machinery Affiliates in East Asia

		Japanese affiliates in East Asia				Japanese affiliates in NIEs4				Japanese affiliates in ASEAN4				Japanese affiliates in China			
		1992	1995	1998	2001	1992	1995	1998	2001	1992	1995	1998	2001	1992	1995	1998	2001
(a) Sales																	
Value (billions JPY)		2,872	5,107	5,192	8,539	1,706	2,793	2,161	3,542	1,083	1,984	2,235	3,595	70	311	750	1,298
Share (%)																	
(i)	Japan	**27.2**	**28.7**	**32.9**	**34.4**	**24.7**	**22.6**	**28.1**	**30.3**	**27.7**	**36.2**	**41.9**	**40.0**	**81.2**	**29.7**	**22.5**	**32.2**
	-intra-firm	24.5	25.6	24.2	26.7	23.3	19.9	19.9	18.0	23.1	32.1	31.8	35.7	80.7	28.3	15.8	26.5
	-arm's length	2.7	3.2	8.7	7.7	1.4	2.7	8.2	12.3	4.6	4.1	10.1	4.4	0.4	1.4	6.7	5.8
(ii)	Local	**45.7**	**38.0**	**32.3**	**31.2**	**52.2**	**45.4**	**44.2**	**41.4**	**38.4**	**29.3**	**17.2**	**18.5**	**13.4**	**34.1**	**40.8**	**37.2**
	-intra-firm	3.7	3.4	4.7	4.9	5.0	3.2	5.6	4.1	2.3	3.8	3.7	5.6	0.0	2.5	4.5	5.7
	-arm's length	42.0	34.6	27.6	26.3	47.2	42.2	38.7	37.4	36.2	25.5	13.4	12.9	13.4	31.6	36.3	31.6
(iii)	Other East Asia	**17.7**	**19.6**	**24.9**	**22.0**	**16.3**	**17.4**	**18.8**	**16.4**	**20.6**	**20.3**	**28.4**	**26.8**	**5.1**	**30.8**	**31.7**	**22.0**
	-intra-firm	9.5	11.6	13.8	12.3	5.2	9.2	6.4	7.5	15.1	11.7	15.8	14.2	5.1	27.9	27.2	17.0
	-arm's length	8.2	7.9	11.1	9.7	11.0	8.1	12.3	8.9	5.4	8.6	12.6	12.6	0.0	2.9	4.5	5.0
(i+ii+iii)	East Asia (total)	**90.6**	**86.3**	**90.1**	**87.6**	**93.1**	**85.3**	**91.1**	**88.1**	**86.7**	**85.9**	**87.4**	**85.3**	**99.8**	**94.6**	**95.0**	**91.4**
	-intra-firm	37.6	40.6	42.7	43.9	33.5	32.3	31.9	29.6	40.5	47.6	51.3	55.4	85.9	58.6	47.5	49.1
	-arm's length	53.0	45.7	47.4	43.8	59.6	53.0	59.2	58.6	46.2	38.2	36.1	29.9	13.8	35.9	47.5	42.3
(b)Purchases																	
Value		1,469	2,834	3,711	6,249	757	1,455	1,700	2,653	654	1,157	1,452	2,602	47	209	532	919
Share																	
(i)	Japan	**46.7**	**38.9**	**37.0**	**35.3**	**48.7**	**37.8**	**42.5**	**40.8**	**42.1**	**37.1**	**33.7**	**28.3**	**83.6**	**53.3**	**33.3**	**38.3**
	-intra-firm	39.5	33.5	23.7	26.3	43.2	33.6	27.8	33.1	32.8	30.7	21.7	19.4	78.4	45.1	19.4	24.9
	-arm's length	7.2	5.4	13.3	9.0	5.5	4.2	14.7	7.7	9.4	6.4	12.0	8.9	5.2	8.2	13.9	13.4
(ii)	Local	**36.6**	**33.8**	**35.8**	**35.2**	**34.3**	**38.4**	**36.4**	**31.3**	**39.7**	**31.2**	**36.0**	**38.7**	**16.1**	**18.7**	**33.7**	**37.3**
	-intra-firm	0.7	4.8	2.3	3.0	0.3	7.5	2.6	3.6	0.7	1.8	2.1	2.1	6.3	1.8	2.6	4.1
	-arm's length	35.9	29.0	33.5	32.2	33.9	30.8	33.8	27.7	39.0	29.4	33.9	36.6	9.9	16.9	31.1	33.2
(iii)	Other East Asia	**15.2**	**24.8**	**26.3**	**28.0**	**15.9**	**20.4**	**20.7**	**26.3**	**15.9**	**30.1**	**29.1**	**31.2**	**0.1**	**27.0**	**32.1**	**23.8**
	-intra-firm	9.1	11.4	13.4	12.4	15.0	12.0	11.1	12.8	3.5	7.9	10.1	10.5	0.1	22.4	27.1	16.1
	-arm's length	6.1	13.4	12.9	15.6	1.0	8.4	9.6	13.5	12.5	22.2	19.0	20.7	0.0	4.6	5.0	7.8
(i+ii+iii)	East Asia (total)	**98.5**	**97.5**	**99.1**	**98.5**	**98.9**	**96.6**	**99.5**	**98.4**	**97.8**	**98.4**	**98.8**	**98.2**	**99.8**	**99.0**	**99.1**	**99.5**
	-intra-firm	49.3	49.6	39.4	41.7	58.6	53.1	41.5	49.5	36.9	40.4	33.9	32.0	84.8	69.3	49.1	45.0
	-arm's length	49.2	47.9	59.8	56.8	40.4	43.5	58.1	48.9	60.9	58.0	64.8	66.2	15.0	29.7	50.0	54.4

Data source: Authors' calculation, based on METI database.

Table 7. Intra-firm and Arm's Length Transactions by Japanese Transport Equipment Affiliates in East Asia

		Japanese affiliates in East Asia				Japanese affiliates in NIEs4				Japanese affiliates in ASEAN4				Japanese affiliates in China			
		1992	1995	1998	2001	1992	1995	1998	2001	1992	1995	1998	2001	1992	1995	1998	2001
(a) Sales																	
Value (billions JPY)		1,999	3,095	2,140	4,575	811	758	557	829	974	1,920	843	2,379	35	145	281	696
Share (%)																	
(i)	Japan	**1.7**	**2.2**	**11.1**	**8.1**	**2.3**	**1.9**	**3.1**	**3.1**	**1.8**	**2.5**	**25.3**	**9.4**	**1.5**	**5.5**	**7.9**	**14.0**
	-intra-firm	1.3	1.9	9.1	6.5	1.1	1.6	1.4	2.7	1.7	2.1	21.0	7.1	1.2	5.2	7.0	12.2
	-arm's length	0.5	0.3	2.0	1.6	1.2	0.2	1.7	0.4	0.1	0.5	4.3	2.3	0.2	0.3	0.9	1.8
(ii)	Local	**92.6**	**92.8**	**81.0**	**66.1**	**92.2**	**92.8**	**91.0**	**84.1**	**92.3**	**91.9**	**59.9**	**54.4**	**92.4**	**87.9**	**88.4**	**82.4**
	-intra-firm	6.7	25.3	2.3	6.1	0.6	22.7	5.3	6.3	11.8	34.3	3.2	8.7	0.0	0.3	0.4	0.8
	-arm's length	85.9	67.4	78.8	59.9	91.6	70.1	85.7	77.8	80.5	57.6	56.6	45.7	92.4	87.5	88.0	81.6
(iii)	Other East Asia	**0.8**	**0.8**	**2.2**	**16.4**	**1.6**	**0.7**	**2.9**	**7.0**	**0.5**	**0.9**	**3.6**	**21.8**	**0.0**	**1.9**	**1.4**	**1.4**
	-intra-firm	0.5	0.3	1.1	3.8	0.8	0.3	0.9	3.7	0.4	0.3	2.7	5.6	0.0	0.2	0.1	0.2
	-arm's length	0.3	0.6	1.1	12.6	0.8	0.4	2.1	3.3	0.1	0.7	0.9	16.2	0.0	1.7	1.3	1.2
(i+ii+iii)	East Asia (total)	**95.1**	**95.8**	**94.3**	**90.6**	**96.1**	**95.4**	**97.0**	**94.2**	**94.6**	**95.3**	**88.7**	**85.7**	**93.9**	**95.2**	**97.7**	**97.9**
	-intra-firm	8.4	27.5	12.5	16.5	2.5	24.6	7.5	12.7	13.8	36.6	27.0	21.5	1.2	5.7	7.5	13.2
	-arm's length	86.7	68.3	81.8	74.1	93.6	70.7	89.5	81.5	80.8	58.7	61.8	64.2	92.6	89.5	90.2	84.6
(b)Purchases																	
Value		790	2,008	1,381	2,945	215	389	419	479	512	1,380	520	1,658	6	91	171	394
Share																	
(i)	Japan	**43.8**	**51.6**	**37.2**	**46.5**	**38.3**	**34.6**	**31.7**	**22.6**	**45.0**	**61.1**	**41.0**	**54.8**	**39.3**	**52.9**	**43.0**	**38.4**
	-intra-firm	35.8	38.0	16.3	27.7	16.9	19.0	13.0	18.2	43.5	50.3	25.5	32.5	38.2	45.0	9.8	19.7
	-arm's length	8.0	13.6	20.9	18.8	21.4	15.6	18.7	4.4	1.6	10.8	15.5	22.4	1.0	7.9	33.2	18.6
(ii)	Local	**52.9**	**45.6**	**53.4**	**47.3**	**59.9**	**64.3**	**60.8**	**62.2**	**51.4**	**35.7**	**46.0**	**39.6**	**40.5**	**43.3**	**52.3**	**57.9**
	-intra-firm	0.3	7.3	2.8	6.5	0.0	0.4	5.6	0.5	0.5	9.5	4.9	10.2	0.0	24.1	0.1	0.5
	-arm's length	52.6	38.3	50.6	40.8	59.9	64.0	55.2	61.6	51.0	26.1	41.1	29.4	40.5	19.2	52.2	57.3
(iii)	Other East Asia	**1.0**	**1.0**	**6.1**	**3.9**	**0.4**	**0.2**	**6.1**	**12.2**	**1.1**	**1.1**	**8.0**	**3.0**	**9.9**	**1.0**	**1.8**	**1.1**
	-intra-firm	0.4	0.4	2.2	2.6	0.3	0.1	1.1	9.1	0.3	0.6	4.2	2.0	9.9	0.7	1.7	0.7
	-arm's length	0.7	0.6	3.9	1.4	0.1	0.2	5.0	3.1	0.9	0.5	3.8	1.0	0.0	0.2	0.1	0.4
(i+ii+iii)	East Asia (total)	**97.8**	**98.3**	**96.7**	**97.7**	**98.6**	**99.2**	**98.7**	**97.0**	**97.6**	**97.9**	**95.0**	**97.5**	**89.6**	**97.2**	**97.1**	**97.3**
	-intra-firm	36.5	45.7	21.3	36.8	17.2	19.5	19.7	27.9	44.2	60.4	34.6	44.7	48.1	69.9	11.5	20.9
	-arm's length	61.3	52.6	75.4	61.0	81.4	79.7	79.0	69.1	53.4	37.4	60.4	52.8	41.5	27.3	85.6	76.4

Data source: Authors' calculation, based on METI database.

On the other hand, the declining trend in purchases from Japan, mostly intra-firm purchases, is clearly observed: shares of purchases from Japan (intra-firm purchases from Japan) in total purchases by Japanese electric machinery affiliates in China are 84 percent (78 percent) in 1992 and 38 percent (25 percent) in 2001. In China, purchases from Japan, particularly intra-firm purchases from Japan, seem to be significantly replaced by local arm's length purchases according to the above-mentioned development of agglomeration in the local market, and intra-firm purchases from other East Asian countries, probably mainly ASEAN countries. Although arm's length transaction ratios are large for transactions with other East Asian countries by Japanese electric machinery affiliates in ASEAN4, intra-firm transaction ratios are large by those in China. Such a difference in intra-firm transaction ratios with other East Asian countries may indicate proximity among ASEAN countries and remoteness of China from ASEAN4. Low intra-firm sales ratios in selling to the local market perhaps reflect regulations in the local distribution sector.

In contrast with the electric machinery sector, the transport equipment sector (310) has been heavily affected by import-substitution policies. Extremely high ratios of local sales in total sales in the 1990s reflect trade protection and import-substitution-type operations in most of the East Asian countries. The ratios, however, have been in a declining trend even in this sector, particularly in ASEAN4, reflecting trade liberalization and the removal of local contents requirements, which encourages exports of parts and components as well as built up cars. [23]

[23] Ando (2006) also demonstrates that even in the transportation equipment sector, in which one-way

5. Conclusion

This paper applies the analytical framework of two-dimensional fragmentation to empirically examine the spatial structure and characteristics of international production/distribution networks in East Asia.

The analysis on international trade data, particularly trade in machineries and machinery parts and components, verifies the importance of international production/distribution networks in East Asian economies, and the enhancing relative importance of intra-East Asian markets to other markets outside of the region including the U.S market for East Asian exports. Although production/distribution networks in East Asia have architecture open to other regions and are utilized by firms with various firm nationalities, dense networking is in particular developed within the region. The recent enhancement of transactions among developing countries including ASEAN and China is noteworthy; both markets of intermediate and finished products start being integrated with massive FDI and trade liberalization/facilitation. Together with the rapid expansion of its own market, East Asia seems to be gaining self-contained economic structure with keeping its open setting intact.

The investigation of the data set of affiliates of Japanese firms in East Asia suggests the spatial microstructure of vertical production chains effectively combining intra-firm and arm's-length transactions. The development of arm's-length transactions and the

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trade is still the main pattern of trade in the whole sector largely due to import substitution policies, vigorous vertical transactions of parts and components across borders were observed in 2000, while they were seldom found at the beginning of the 1990s.

formation of agglomeration come into a mutually enhancing causal link. Forces of agglomeration provide opportunities for local firms to penetrate into production/distribution networks that were initially constructed by MNEs, which induces drastic changes in the perception of industrial promotion policy.

The formation of international production/distribution networks at the level of sophistication observed in East Asia is an unprecedented phenomenon. It presents a new form of trade and FDI among countries at different development stages and at the same time suggests the possibility of new development strategies for developing countries. Recognizing the importance of its policy implication, we must continue to analyze the phenomenon more deeply and extensively.

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Table A1. Definition of Machinery Parts and Components

HS classification
840140, 840290, 840390, 840490, 840590, 8406, 8407, 8408, 8409, 8410, 8411, 8412, 8413, 8414, 841520, 841590, 8416, 8417, 841891, 841899, 841990, 842123, 842129, 842131, 842191, 842199, 842290, 842390, 842490, 8431, 843290, 843390, 843490, 843590, 843680, 843691, 843699, 843790, 843890, 843991, 843999, 844090, 844190, 844240, 844250, 844390, 8448, 845090, 845190, 845240, 845290, 845390, 845490, 845590, 8466, 846791, 846792, 846799, 846890, 8473, 847490, 847590, 847690, 847790, 847890, 847990, 8480, 8481, 8482, 8483, 8484, 8485, 8503, 850490, 8505, 850690, 8507, 850890, 850990, 851090, 8511, 8512, 851390, 851490, 851590, 851690, 851790, 8518, 8522, 8529, 853090, 8531, 8532, 8533, 8534, 8535, 8536, 8537, 8538, 8539, 8540, 8541, 8542, 854390, 8544, 8545, 8546, 8547, 8548, 8607, 8706, 8707, 8708, 870990, 8714, 871690, 8803, 8805, 9001, 9002, 9003, 900590, 900691, 900699, 900791, 900792, 900890, 900990, 901090, 901190, 901290, 9013, 9014, 901590, 901790, 902490, 902590, 902690, 902790, 902890, 902990, 903090, 903190, 903290, 9033, 9110, 9111, 9112, 9113, 9114, 9209

Source: Ando and Kimura (2005).

Table A2. Development of Intra-regional Exports in Japan

(a) Intra- and inter-regional exports (millions US$)

	1990		2005	
	Value	%	Value	%
Machinery goods: parts and components				
Intra-East Asia	21,217	27.5	94,328	47.3
Inter-regional	55,921	72.5	105,277	52.7
(U.S.)	(26,401)	(34.2)	(42,085)	(21.1)
Total	77,138	100.0	199,604	100.0
Machinery goods: final goods				
Intra-East Asia	22,861	16.2	45,886	20.9
Inter-regional	118,560	83.8	173,562	79.1
(U.S.)	(49,971)	(35.3)	(67,512)	(30.8)
Total	141,421	100.0	219,448	100.0
Machinery goods: total				
Intra-East Asia	44,078	20.2	140,214	33.5
Inter-regional	174,480	79.8	278,839	66.5
(U.S.)	(76,373)	(34.9)	(109,598)	(26.2)
Total	218,559	100.0	419,052	100.0
All products				
Intra-East Asia	69,431	24.2	234,354	39.4
Inter-regional	217,517	75.8	360,587	60.6
(U.S.)	(90,944)	(31.7)	(135,947)	(22.9)
Total	286,947	100.0	594,941	100.0

(b) Factors of growth in exports (1990-2005)

<Intra-East Asian exports>	
(i) Growth in intra-East Asian exports	
All products	238%
Machinery goods (total)	218%
- Machinery final goods	101%
- Machinery parts and components	345%
(ii) Contribution to the growth (all products)	
Machinery goods (total)	58%
- Machinery final goods	14%
- Machinery parts and components	44%
<Inter-regional exports>	
(i) Growth in inter-regional exports	
All products	66%
Machinery goods (total)	60%
- Machinery final goods	46%
- Machinery parts and components	88%
(ii) Contribution to the growth (all products)	
Machinery goods (total)	73%
- Machinery final goods	38%
- Machinery parts and components	34%

Data source: Authors' calculation, based on UN COMTRADE.

Note: "Intra-East Asia" here includes China, ASEAN4, and NIES3. Due to lack of data available from UN COMTRADE, Taiwan is not included in East Asia. Growth rates are in nominal terms.

Table A3. Development of Intra-regional Exports in NIEs3

(a) Intra- and inter-regional exports (millions US$)

	1990		2005	
	Value	%	Value	%
Machinery goods: parts and components				
Intra-East Asia	23,518	53.6	205,188	68.3
Inter-regional	20,357	46.4	95,351	31.7
(U.S.)	(9,600)	(21.9)	(27,952)	(9.3)
Total	43,875	100.0	300,539	100.0
Machinery goods: final goods				
Intra-East Asia	18,499	30.1	61,747	30.9
Inter-regional	43,033	69.9	137,876	69.1
(U.S.)	(17,336)	(28.2)	(39,429)	(19.8)
Total	61,532	100.0	199,623	100.0
Machinery goods: total				
Intra-East Asia	42,017	39.9	266,935	53.4
Inter-regional	63,390	60.1	233,227	46.6
(U.S.)	(26,936)	(25.6)	(67,381)	(13.5)
Total	105,407	100.0	500,162	100.0
All products				
Intra-East Asia	104,639	41.3	420,707	52.2
Inter-regional	148,478	58.7	385,482	47.8
(U.S.)	(61,841)	(24.4)	(111,862)	(13.9)
Total	253,116	100.0	806,189	100.0

(b) Factors of growth in exports (1990-2005)

<Intra-East Asian exports>	
(i) Growth in intra-East Asian exports	
All products	302%
Machinery goods (total)	535%
- Machinery final goods	234%
- Machinery parts and components	772%
(ii) Contribution to the growth (all products)	
Machinery goods (total)	71%
- Machinery final goods	14%
- Machinery parts and components	57%
<Inter-regional exports>	
(i) Growth in inter-regional exports	
All products	160%
Machinery goods (total)	268%
- Machinery final goods	220%
- Machinery parts and components	368%
(ii) Contribution to the growth (all products)	
Machinery goods (total)	72%
- Machinery final goods	40%
- Machinery parts and components	32%

Data source: Authors' calculation, based on UN COMTRADE.

Note: "Intra-East Asia" here includes China, ASEAN4, and Japan. Due to lack of data available from UN COMTRADE, (i) Taiwan is not included in East Asia, and (ii) data for Hong Kong in 1993 are used in calculating intra-East Asian exports in 1990. Growth rates are in nominal terms.

Table A4. Development of Intra-regional Exports in ASEAN4

(a) Intra- and inter-regional exports (millions US$)

	1990		2005	
	Value	%	Value	%
Machinery goods: parts and components				
Intra-East Asia	5,383	51.0	65,005	61.4
Inter-regional	5,170	49.0	40,853	38.6
(U.S.)	(3,162)	(30.0)	(15,329)	(14.5)
Total	10,553	100.0	105,858	100.0
Machinery goods: final goods				
Intra-East Asia	2,187	34.7	26,563	36.7
Inter-regional	4,107	65.3	45,824	63.3
(U.S.)	(2,004)	(31.8)	(21,065)	(29.1)
Total	6,293	100.0	72,387	100.0
Machinery goods: total				
Intra-East Asia	7,570	44.9	91,568	51.4
Inter-regional	9,276	55.1	86,677	48.6
(U.S.)	(5,166)	(30.7)	(36,394)	(20.4)
Total	16,846	100.0	178,245	100.0
All products				
Intra-East Asia	40,548	51.9	193,097	51.1
Inter-regional	37,649	48.1	184,858	48.9
(U.S.)	(13,594)	(17.4)	(62,104)	(16.4)
Total	78,197	100.0	377,954	100.0

(b) Factors of growth in exports (1990-2005)

<Intra-East Asian exports>	
(i) Growth in intra-East Asian exports	
All products	376%
Machinery goods (total)	1110%
- Machinery final goods	1115%
- Machinery parts and components	1108%
(ii) Contribution to the growth (all products)	
Machinery goods (total)	55%
- Machinery final goods	16%
- Machinery parts and components	39%
<Inter-regional exports>	
(i) Growth in inter-regional exports	
All products	391%
Machinery goods (total)	834%
- Machinery final goods	1016%
- Machinery parts and components	690%
(ii) Contribution to the growth (all products)	
Machinery goods (total)	53%
- Machinery final goods	28%
- Machinery parts and components	24%

Data source: Authors' calculation, based on UN COMTRADE.

Note: "Intra-East Asia" here includes China, NIES3, and Japan. Due to lack of data available from UN COMTRADE, (i) Taiwan is not included in East Asia, and (ii) data for the Philippines are not included in calculating intra-East Asian trade in 1990. Growth rates are in nominal terms.

Table A5. Development of Intra-regional Exports in China

(a) Intra- and inter-regional exports (millions US$)

	1990		2005	
	Value	%	Value	%
Machinery goods: parts and components				
Intra-East Asia	4,218	74.2	35,361	22.9
Inter-regional	1,468	25.8	119,342	77.1
(U.S.)	(460)	(8.1)	(22,846)	(14.8)
Total	5,685	100.0	154,704	100.0
Machinery goods: final goods				
Intra-East Asia	7,385	71.8	120,542	53.8
Inter-regional	2,898	28.2	103,570	46.2
(U.S.)	(872)	(8.5)	(60,905)	(27.2)
Total	10,283	100.0	224,112	100.0
Machinery goods: total				
Intra-East Asia	11,603	72.7	155,904	41.2
Inter-regional	4,366	27.3	222,912	58.8
(U.S.)	(1,332)	(8.3)	(83,751)	(22.1)
Total	15,968	100.0	378,816	100.0
All products				
Intra-East Asia	55,848	65.7	291,663	38.3
Inter-regional	29,092	34.3	470,290	61.7
(U.S.)	(8,599)	(10.1)	(163,180)	(21.4)
Total	84,940	100.0	761,953	100.0

(b) Factors of growth in exports (1990-2005)

<Intra-East Asian exports>	
(i) Growth in intra-East Asian exports	
All products	422%
Machinery goods (total)	1244%
- Machinery final goods	1532%
- Machinery parts and components	738%
(ii) Contribution to the growth (all products)	
Machinery goods (total)	61%
- Machinery final goods	48%
- Machinery parts and components	13%
<Inter-regional exports>	
(i) Growth in inter-regional exports	
All products	1517%
Machinery goods (total)	5006%
- Machinery final goods	3474%
- Machinery parts and components	8031%
(ii) Contribution to the growth (all products)	
Machinery goods (total)	50%
- Machinery final goods	23%
- Machinery parts and components	27%

Data source: Authors' calculation, based on UN COMTRADE.

Note: "Intra-East Asia" here includes ASEAN4, NIES3, and Japan. Due to lack of data available from UN COMTRADE, (i) Taiwan is not included in East Asia, and (ii) data for China in 1992 are used in calculating intra-East Asian trade in 1990. Growth rates are in nominal terms.

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