

**Research Unit for Statistical
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**The Nature and Characteristics of
Production Networks in East Asia:
Evidences from Micro/Panel Data Analyses**

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Abstract

Production networks in East Asia, particularly being extended by machinery industries, have presented unprecedented development with their significance in economies in the region, their geographical extension, and their sophistication in combining intra-firm and arm's length transactions. In particular, the fragmentation of production activities together with the formation of industrial agglomerations in developing countries is a novel phenomenon that would lead to an East Asian model of economic development. Starting from a brief review of our conceptual framework based on the fragmentation theory as well as an empirical overview with international trade statistics and others, the paper presents a survey on empirical evidences that have been established by previous micro-data analyses in East Asia and discusses a list of empirical issues that future studies should explore. Topics include (i) the selection of exporters and investors, (ii) organizational structure and spatial design of production networks, (iii) location choice, (iv) impacts of outward FDI on developed countries, and (v) learning and impacts of inward FDI on LDCs.

1. Distinctive development of production networks and micro data analyses in East Asia

Production networks in East Asia, particularly being extended by machinery industries, have presented unprecedented development with their significance in economies in the region, their geographical extension, and their sophistication in combining intra-firm and arm's length transactions. In particular, the fragmentation of production activities together with the formation of industrial agglomerations in developing countries is a novel phenomenon that would lead to an East Asian model of economic development.

A full set of rigorous empirical analyses on production networks in East Asia, however, is yet to come. Although the existing statistics at the aggregated level including international trade statistics is useful in observing the nature and characteristics of international production networks, the detailed structure and mechanics as well as the sophisticated combination of intra-firm and arm's length (i.e., inter-firm) transactions are captured only at the micro level. The impacts of globalizing corporate activities can also be investigated only at the micro level. There is certainly ample room for exploring micro/panel data of manufacturing census or tailor-made micro data sets to deepen our understanding on international production networks.

The existing literature of micro data analysis has its own academic agenda, which is not necessarily served directly for deepening our understanding on international production networks in East Asia. However, once we review the existing literature with great interest in production networks, we can find a number of subtle empirical findings in the related papers. Furthermore, if we slightly redirect the focus of empirical studies, we can surely learn more about production networks. The paper is a sort of "subjective" literature survey on micro data analysis by a production-networks lover.

Starting from a brief review of our conceptual framework based on the fragmentation theory and new economic geography as well as an empirical overview with international trade statistics, the paper presents a

survey on empirical evidences that have been established by previous micro-data analyses and discusses empirical issues that future studies could pursue.

2. Mechanics of production networks: conceptual framework

Although international production/distribution networks in East Asia began forming from the beginning of the 1990s, Jones and Kierzkowski (1990) made an early start in developing the theory of fragmentation. The theory pointed out fundamental differences between industry-wise division of labor and production-process-wise division of labor or between finished-products trade and intermediate-goods trade, particularly in the flexibility of a firm's decision-making in cutting out production blocks and the existence of service link costs.

Figure 1 illustrates the original idea of fragmentation. Suppose that a large factory initially exists in the electronics industry that takes care of all upstream and downstream production processes. Such a factory is capital and human capital intensive as a whole and thus is likely to be located in a developed country. However, a closer look at the factory may find a variety of production processes. Some processes are human-capital intensive and require close monitoring by researchers and technicians. On the other hand, some are purely labor-intensive, and a mass of unskilled labor may suffice. Alternately, some processes need 24-hour operations to accelerate capital depreciation. Hence, if we can fragment production processes into several production blocks and locate them in appropriate places with different location advantages, total production costs may be reduced. This is fragmentation.

== Figure 1 ==

Fragmentation of production processes makes sense when: (i) the saving in production costs *per se* in production blocks is large; and (ii)

incurred service link costs to connect remotely located production blocks are small. Firms can cut out production blocks so as to exploit differences in location advantages in remote areas. On the other hand, service link costs, including not only transport costs but also various coordination costs, should not be too high. Transactions between production blocks tend to be relation-specific rather than those in spot markets.

Kimura and Ando (2005) propose an expanded version of the framework called two-dimensional fragmentation. Figure 2 illustrates the basic concept. The horizontal axis depicts fragmentation along the axis of geographical distance, which is the traditional fragmentation, while the vertical axis represents fragmentation along the axis of disintegration or uncontrollability. The sophisticated nature of international production/distribution networks arises from a sophisticated combination of two kinds of fragmentation.

== Figure 2 ==

An important aspect of two-dimensional fragmentation is the spatial implication of disintegration-type fragmentation. Service link costs in arm's-length transactions, in other words "transaction cost" in Oliver Williamson's sense, are highly sensitive to geographical distance. Geographical proximity reduces search costs for new business partners, monitoring costs for quality and delivery timing, and trouble-shooting costs when an unexpected event occurs. The intimacy between disintegration-type fragmentation and geographical proximity is one of the major sources of agglomeration forces. In East Asia, fragmentation and agglomeration have proceeded together.

Although it is very difficult to comprehend intra-firm and arm's-length transactions in official statistics, the data of foreign affiliates of Japanese firms collected by METI (*Kaiji Chosa*) provide useful information. By-destination sales and by-origin purchases of affiliates of Japanese firms in East Asia, particularly in machinery industries, present a clear-cut

pattern of intra-firm and arm's-length transactions. Transactions with Japan are predominantly intra-firm while those in the host country's market are mostly arm's-length. Transactions with other East Asia countries fall in between (Ando and Kimura (2009a)). This is important evidence that confirm the intimacy between disintegration-type fragmentation and geographical proximity.

We observe a wide variety of disintegration-type fragmentation in production/distribution networks. East Asia has a number of prototypes for arm's-length transactions. The *Shitauke* system in Japan, subcontracting in Taiwan, and Hong Kong – Guangdong operations are examples of these. Some of the arm's-length transactions in East Asia are a direct extension of these prototypes in the international setting. Furthermore, the abundance of opportunities for exploiting differences in location advantages and firm-specific assets in East Asia results in the proliferation of outsourcing. Examples include original equipment manufacturers (OEM), original design manufacturers (ODM), electronics manufacturing services (EMS), and foundries. The designers or managers of networks are also varied, not necessarily downstream assemblers; vendor-managed inventory (VMI) services are examples in which logistic companies play a crucial role.

The recent technological and managerial innovation in corporate management is clearly supporting the proliferation of various business models in East Asia. As mentioned above, the evolution of business models, particularly in the computer industry, from vertically-integrated giants to firms concentrating on core competences is one of the crucial changes in the mindset of corporate managers. Another significant trend is the development of a lean production method, a just-in-time system, value (supply) chain management, and cash flow management. Furthermore, the deepening of the product architecture argument, namely modular versus integral, is also crucial to the development of various business models.

The next task for research for the conceptual framework is to investigate the spatial structure of production/distribution networks. Currently, machinery industries are dominant players in East Asian

networking, both in quantity and quality. An assembly plant in the machinery industry uses a large number of parts and components, and the procurement of parts and components and the sales of products are typically stratified into four layers primarily in terms of gate-to-gate lead time (Table 1). For convenience, let us call these “the first layer (local),” “the second layer (sub-regional),” “the third layer (regional),” and “the fourth layer (world).”¹

== Table 1 ==

3. Some key evidences from international trade data and others

Production fragmentation is observed in various industries such as textiles and garment, chemical industry, and software. However, machinery industries are by far the most important sector, both quantitatively and qualitatively, in formulating production/distribution networks. Machines typically consist of a large number of parts & components, and production processes are multi-layered. Various production processes require a wide range of resource inputs and different technologies, and thus the most sophisticated, quick, and high-frequency networks are necessarily observed in machinery industries. The proportion of machinery exports in total exports, particularly that of machinery parts and components exports, is a good indicator for judging the degree of participation in international production/distribution networks.

Figure 3 presents 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 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. We can see active back-and-forth

¹ More detailed explanation on the four layers of transactions, see Kimura (2009).

parts and components trade among East Asian countries while some countries do not simply participate in quick high-frequency production networks yet.

== Figure 3 ==

Figure 4 compares seven regions in China as well as ASEAN member countries with respect to the ratio of intra-East-Asian machinery exports to total intra-East-Asian exports. We can again observe a sharp contrast between countries/regions that actively conduct international production networks while others that do not.

== Figure 4 ==

The IDE-JETRO GSM Team together with ERIA is now developing a simulation model called the Geographical Simulation Model. The model is based on a setting of new economic geography and currently covers ASEAN and a part of surrounding East Asia. From its base data set, Figure 5 presents the location of industries across the disaggregated regions. White color indicates that manufacturing GDP is less than 10% of total GDP. For other regions, we pick up the largest one among five manufacturing subsectors: automotive (red), electric and electronic (yellow), textiles and garment (blue), food processing (green), and others (grey). Red and yellow areas correspond to regions actively conducting quick and high-frequency production networks. Blue and a part of green areas are conducting production networks at a slower pace. The rest has not yet participated in production networks.

== Figure 5 ==

One of the important exercises conducted with international trade data is a bunch of empirical studies based on the gravity equation. Among those, Kimura, Takahashi, and Hayakawa (2007) find consistently low

penalty from geographical distance in machinery parts and components trade compared with that in Europe. Hayakawa and Kimura (2009) find that exchange rate volatility deters a country to participate in international production networks. These suggest the importance of service links in the operation of international production networks.

Obashi (2009) applies survival analysis on the disaggregate trade data and finds the stability and long-lasting nature of machinery parts and components trade compared with other traded goods. This suggests the existence of sunk cost in the set-up of international production networks.

4. Microdata analyses on the mechanics of production networks

With existing empirical evidences as well as conjecture from casual observation in our mind, we will review the literature of micro data analyses in East Asia, try to reinterpret the results in the context of international production networks, and suggest prospective direction of future research.² This section covers studies related to the mechanics of production networks; namely the literature on (i) selection, (ii) corporate organizational structure and spatial design of production networks, and (iii) location choice.

(1) Selection

Melitz (2003), Helpman, Melitz, and Yeaple (2004), and other related theoretical papers ignited a numerous number of empirical papers on the selection of exporters and investors in both developed and developing countries. An important step forward is the introduction of firm heterogeneity. Although firm heterogeneity has for long been well known as a fact by empirical researchers, particularly in studies on small and medium enterprises, theorists could not cross their psychological threshold for discarding their obsession on market clearance even in the short run. Melitz introduces the setting in which firms are not homogeneous in terms of

² In the following, a number of papers are drawn from Hayakawa, Kimura, and Machikita (2009).

the initial productivity by lottery and is successful in making a major breakthrough in the literature.

In the context of East Asia, selection in exports has been studied by a number of papers including Hallward-Driemeier, Iarossi, and Sokoloff (2002) for Indonesia, Korea, Malaysia, the Philippines, and Thailand; Aw and Hwang (1995), Liu, Tsou, and Hammitt (1999), Aw, Chung, and Roberts (2000), and Aw, Roberts, and Winston (2007) for Taiwan; Aw, et al. (2000) and Hahn (2004) for Korea; and Kimura and Kiyota (2006) and Murakami (2005) for Japan. Most of these studies find evidence that a more productive producer tends to self-select into the export market.³ As for selection in FDI, Murakami (2005) and Kimura and Kiyota (2006) conduct analyses for Japan.

Do these studies indicate any important findings on international production networks in East Asia? Relatively strong results particularly on selection in exports may reflect dynamism of East Asian economies. However, the results are not in general interpreted closely to the existence of production networks.

At least in two directions, we can expand the scope of selection studies in the context of East Asia, subject to the existence of statistical information. First, in addition to exporting and investing, participating in local or international production networks is an important threshold for firms. In particular for local firms in less developed countries (LDCs), whether they can have production links with multinationals in industrial agglomeration is crucially important. This aspect can be and should be incorporated in selection studies.

Second, the current theoretical setting does not properly capture firm heterogeneity in terms of their activities or “what to make” in their inter-firm production links. Products and activities can be heterogeneous depending on the positioning of the firm in production networks. Exogenous productivity differences and fixed cost setting do not seem to capture such heterogeneity properly.

³ Wagner (2007) provides an excellent literature survey.

(2) Organizational structure and spatial design of production networks

Antras and Helpman (2004) and Grossman, Helpman, and Szeidl (2006) incorporate intra-firm and arm's length (inter-firm) transactions in the firm heterogeneity setting with FDI. The basic story is due to heterogeneity in exogenous productivity and a fixed cost story. The higher the productivity, the wider internalization occurs.

Tomiura (2007) attempts empirical verification of their story and finds that investing firms are more productive than exporting firms and that the firms trading with overseas intra-firm group are more productive than those trading with overseas inter-firm group firms in Japan. Murakami (2005) however finds the opposite. One issue may be the definition of "outsourcing."

More fundamental issue in the context of East Asia would be to incorporate an informational setting or a transaction cost story behind intra-firm and arm's length transactions. As I mentioned earlier, Ando and Kimura (2009a) find that long-distance transactions tend to be intra-firm while short-distance transactions, particularly within industrial agglomeration, are predominantly arm's length. Simple setting of differences in exogenous productivity and fixed cost does not seem to capture some of the important aspects of international production networks in East Asia.

(3) Location choice

A huge number of empirical papers have been devoted to analyses on location choice in FDI, and some of them have tried to capture the implication of agglomeration with various indicators. It has been rare, however, to interpret the empirical results carefully in the context of production networks. We observe at the aggregated level extremely uneven distribution of networking activities. I believe that it is worthwhile reinterpreting or redoing location choice analyses with the extension of production networks explicitly in our mind.

5. Microdata analyses on the consequences of production networks

This section reviews studies related to the consequences of production networks; in particular, (i) resource reallocation or expansion in developed countries and (ii) learning and technology spillovers/transfers in LDCs.

(1) Impacts of outward FDI on developed countries

Outsourcing and off-shoring in LDCs by MNEs raise concerns about activities in high-income countries. A popular argument claims that domestic employment and operations may shrink due to the relocation of economic activities taking advantage of a large wage gap between developed and developing countries. However, even in the case when FDI is pursuing inexpensive labor in developing countries, the effect of FDI on domestic operations is not necessarily negative; it depends on to what extent the cost reduction through FDI allows the firm to strengthen its competitiveness and whether the firm maintains activities at home that are complementary to operations abroad, sometimes further shifting their activities to the procurement of specialized parts and components, headquarters functions, and the development of new products.

Hijzen, Inui, and Todo (2007) apply the propensity score matching method and the difference-in-difference approach and find positive impacts of becoming MNEs on output and employment though not on productivity.⁴ This is an important result because most of the empirical results are ambiguous in other parts of the world. Our conjecture claims that firms are more likely to retain or even expand domestic operations in fragmenting production processes compared with one-for-all relocation of production sites.

Ando and Kimura (2009b) conduct a more focused study. They analyze the impact of expanding operations in East Asia on domestic operations for Japanese firms; domestic operations here include domestic

⁴ Also see Ito (2007). Hijzen, Inui, and Todo (2009) find positive impacts of international outsourcing on corporate performance.

employment, the number of domestic establishments/affiliates, exports and imports. While domestic employment in manufacturing sector as a whole has a slow declining trend, firms expanding operations in East Asia tend to reduce domestic employment less or even increase it in case of small and medium enterprises. Differences across industries are distinctive; industries that conduct international production networks present stronger results.

Skill shift is another topic to be explored in the literature. However, skill composition at the firm level is not directly available in the Japanese data. Ito and Fukao (2005) work at the industry level and find that vertical intra-industry trade with Asia raises the share of professional and technical or managerial and administrative workers. Head and Ries (2002) employ Toyo Keizai's data and find that additional foreign affiliate employment in low-income countries raises non-production share of the wage bill at home. It would be interesting to dig into differences across industries in order to pick up the nature of international production networks.

How a firm allocates economic activities at home and abroad is not formally checked yet. Ando and Kimura (2005) find that firms pretty often switch its activities at home and abroad; i.e., industrial classification of major activities at home and that of affiliates abroad are occasionally different. Hayakawa, Kimura, and Matsuura (2009) start from the implication of the fragmentation theory and test a theoretical prediction that a firm that successfully makes a larger difference in factor intensity between home and abroad performs better. The result is affirmative.

(2) Learning and impacts of inward FDI on LDCs

There is another literature that explores learning from exporting. Hahn and Park (2009) find positive for Korea. Other studies in East Asia often seem to present positive results, which contrasts from studies in other parts of the world reviewed by Wagner (2007). In the case of local firms in East Asia, learning from participation in domestic/international production networks must be assessed if such statistical data are available.

Impacts of cross-border M&A have also been investigated by

checking domestic firm's productivity before and after cross-border M&A. Arnold and Javorcik (2005) and Petkova (2008) for Indonesia and Fukao, Ito, Kwon, and Takizawa (2006) for Japan are examples; they consistently find significantly positive impacts. Some also find larger impacts with cross-border M&A than local M&A.

The literature of spillover, i.e., technology leakage from MNEs to local firms, has been grown for long. Four channels of spillover effects are perceived in the literature: imitation, skill acquisition and proliferation, competition, and exports. Competition may actually work negatively, too. Statistical tests typically check whether the presence of MNEs enhances productivity of local firms or not. Chuan and Lin (1999) obtain positive impacts in Taiwan. However, most of the studies in the rest of the world fail to find positive association.

The literature further scrutinizes mixed results among heterogeneous combination of MNEs and local firms. As for the heterogeneity on the MNEs side, Todo and Miyamoto (2002, 2006) work with Indonesian data and find that MNEs conducting human resource development on site provide positive influence on local firms' productivity. As for the heterogeneity of local firms, absorption capacity, geographical proximity, and input-output relationship are tested. Particularly on input-output relationship, the implication of international production networks may be detected. Unfortunately, however, studies exploring input-output relationship cannot utilize information on actual production links at the firm level but employ input-output tables to infer the input-output relationship between MNEs and local firms.

ERIA (2009) conducts an extensive questionnaire survey in Bangkok, Manila, Jakarta, and Hanoi and tries to identify and quantitatively assess channels of innovative information. They find that production linkage with MNEs is crucial and daily communication is important.

6. Concluding remarks

Studies on international production networks in East Asia bear a very important mission for actual policy making. The formation of international production networks in East Asia is an unprecedented event, which is presenting a new model of economic development with aggressively utilizing globalizing forces. There may also be important implication for investing countries.

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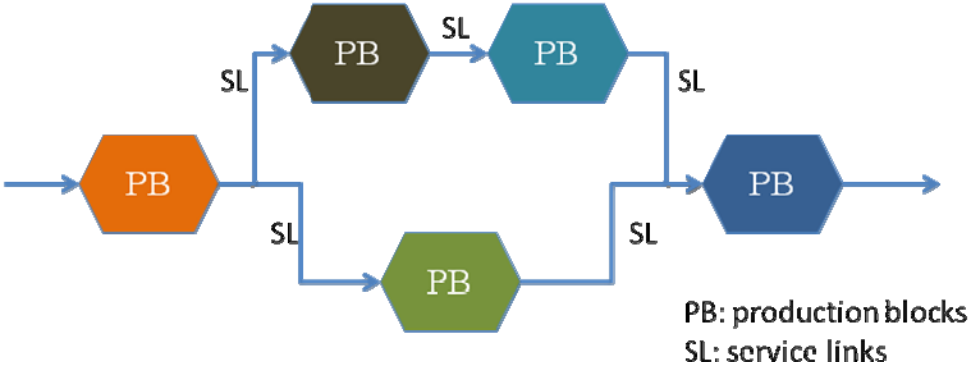
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Figure 1. The Original Idea of Fragmentation: An Illustration

Before fragmentation

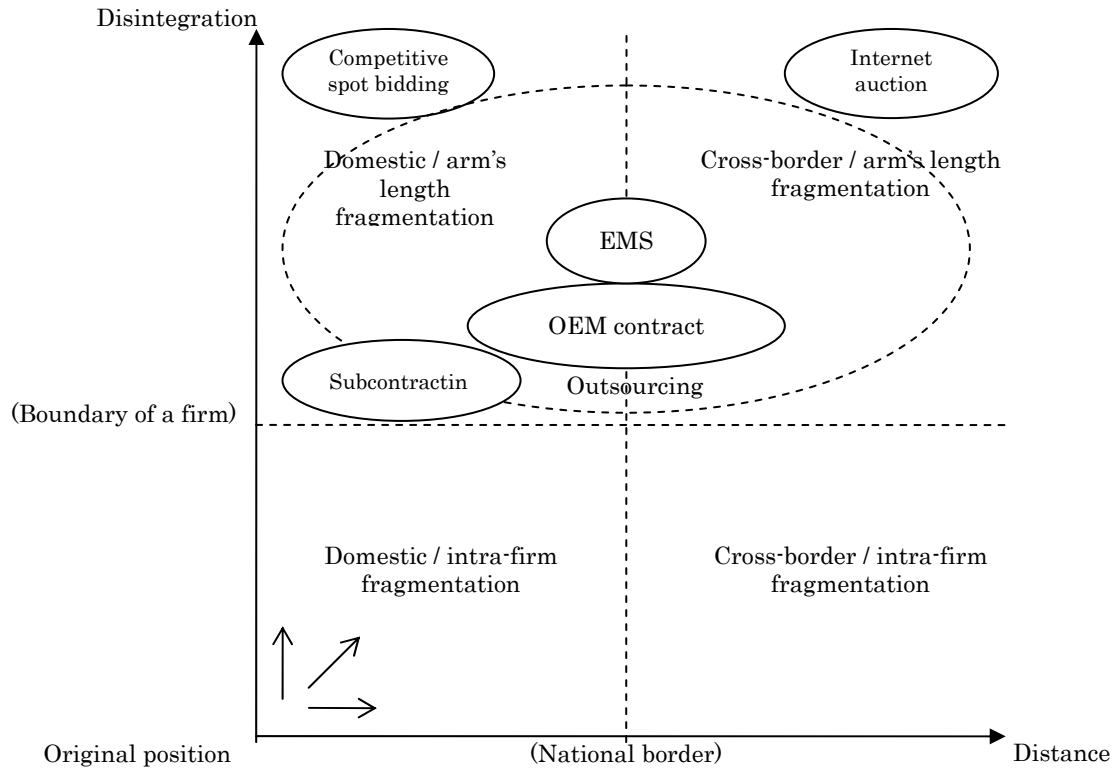


After fragmentation



Source: Author.

Figure 2. Two-dimensional Fragmentation: An Illustration



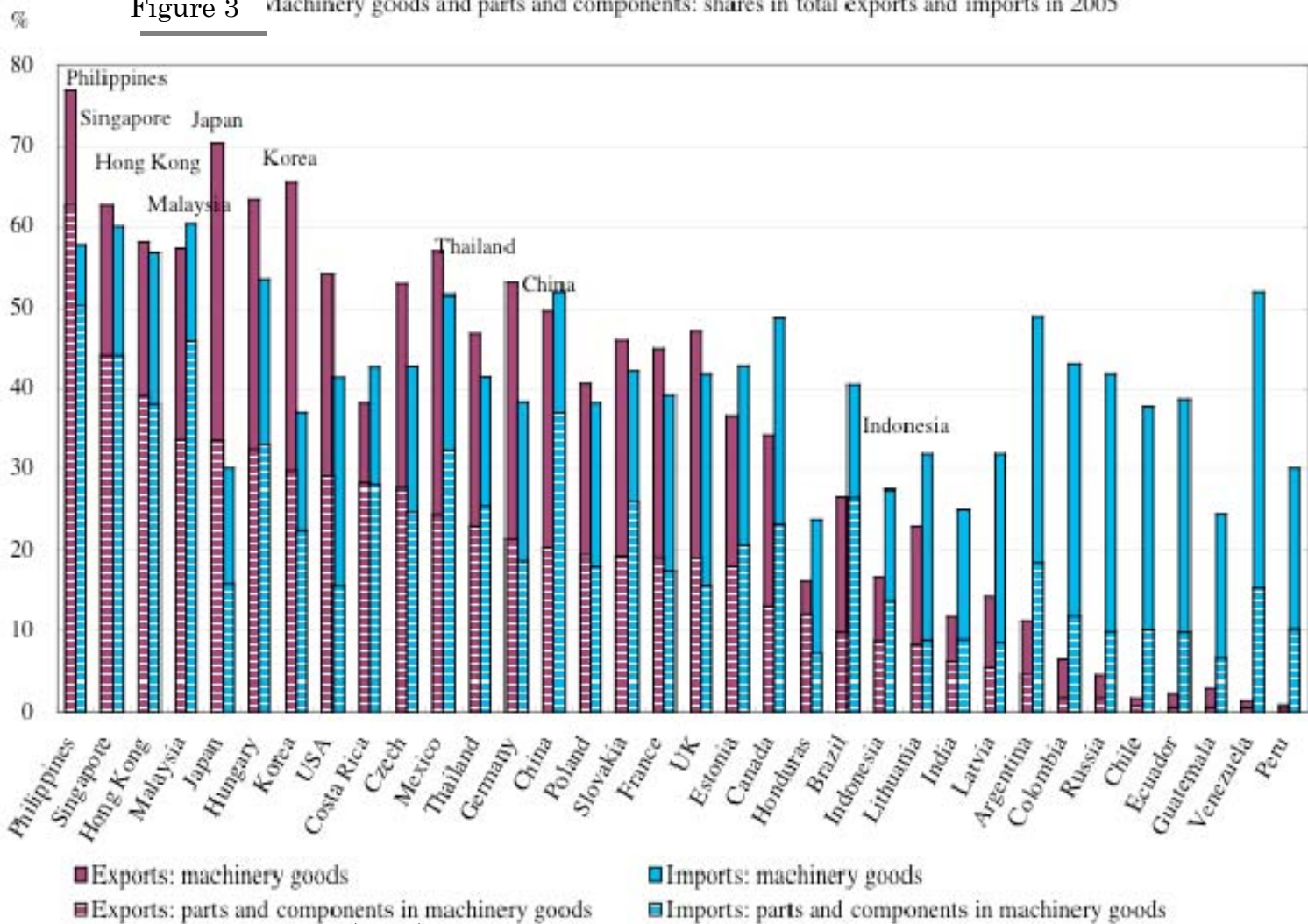
Source: Kimura and Ando (2005).

Table 1. Four Layers of Transactions in Production/Distribution Networks

	1st layer (local)	2nd layer (sub-regional)	3rd layer (regional)	4th layer (world)
Lead time	Less than 2.5 hours	1 to 7 days	1 to 2 weeks	2 weeks to 2 months
Frequency	Once or more in a day	Once or more in a week	Once a week	Once a week
Transport mode	Trucks	Trucks/ships/ airplanes	Ships	Ships
Trip length	Less than 100km	Less than 1,500km	Less than 6,000km	Longer

Source: Kimura (2009).

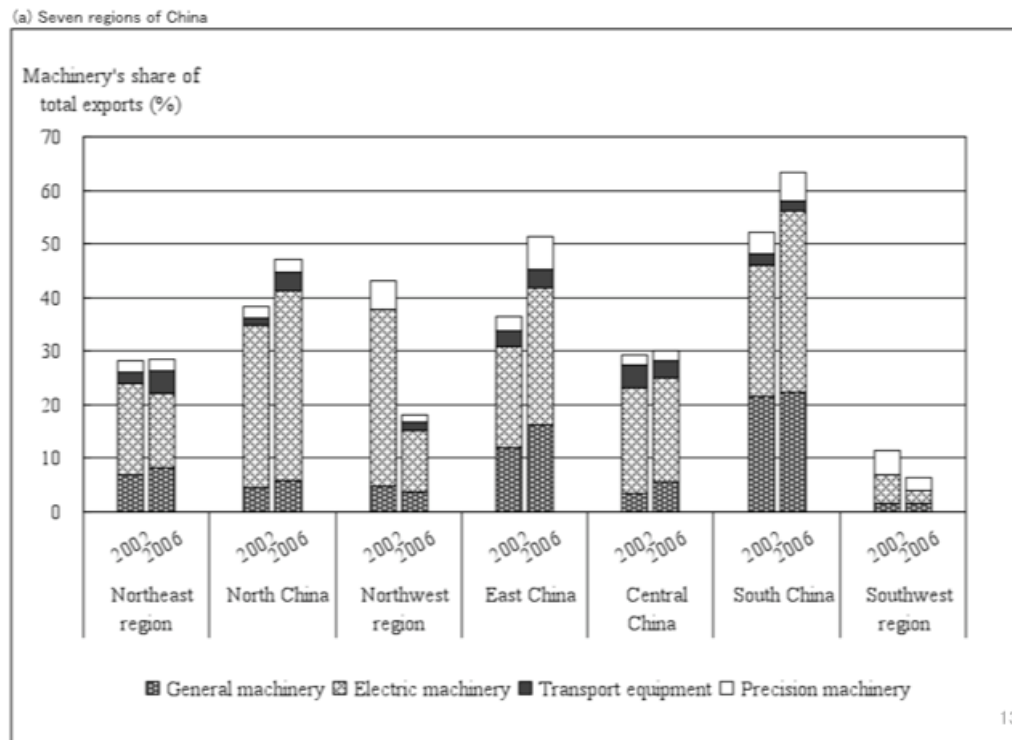
Figure 3 Machinery goods and parts and components: shares in total exports and imports in 2005



Source: Ando and Kimura (2009).

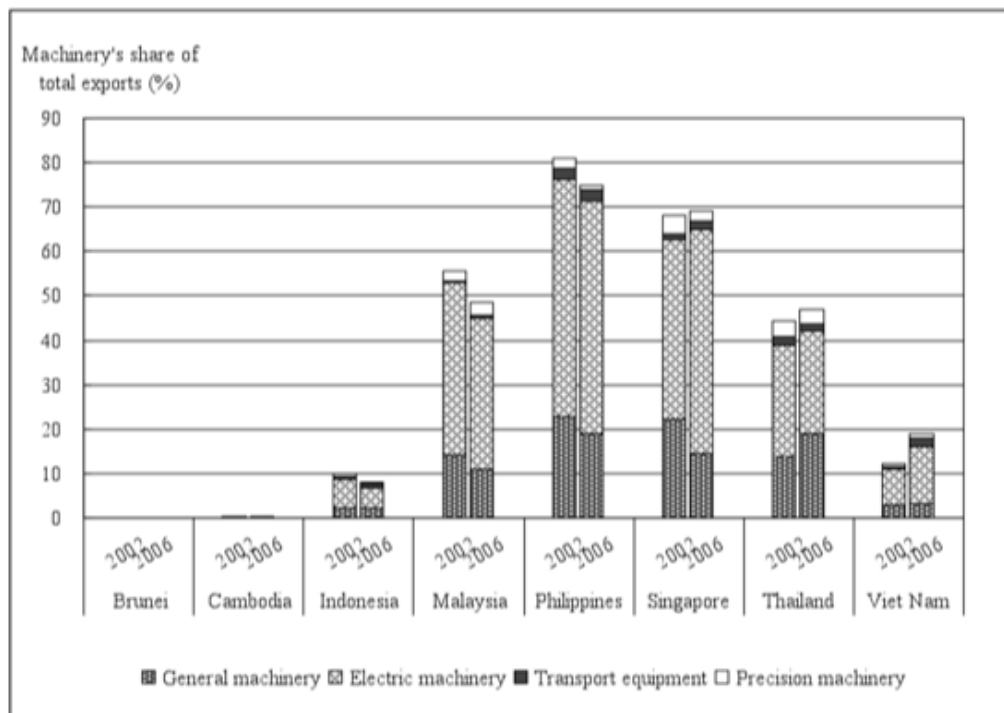
Data source: Authors' calculation, based on UN COMTRADE.

Figure 4
Shares of machinery products in intra-East-Asian exports in 2002 and 2006



13

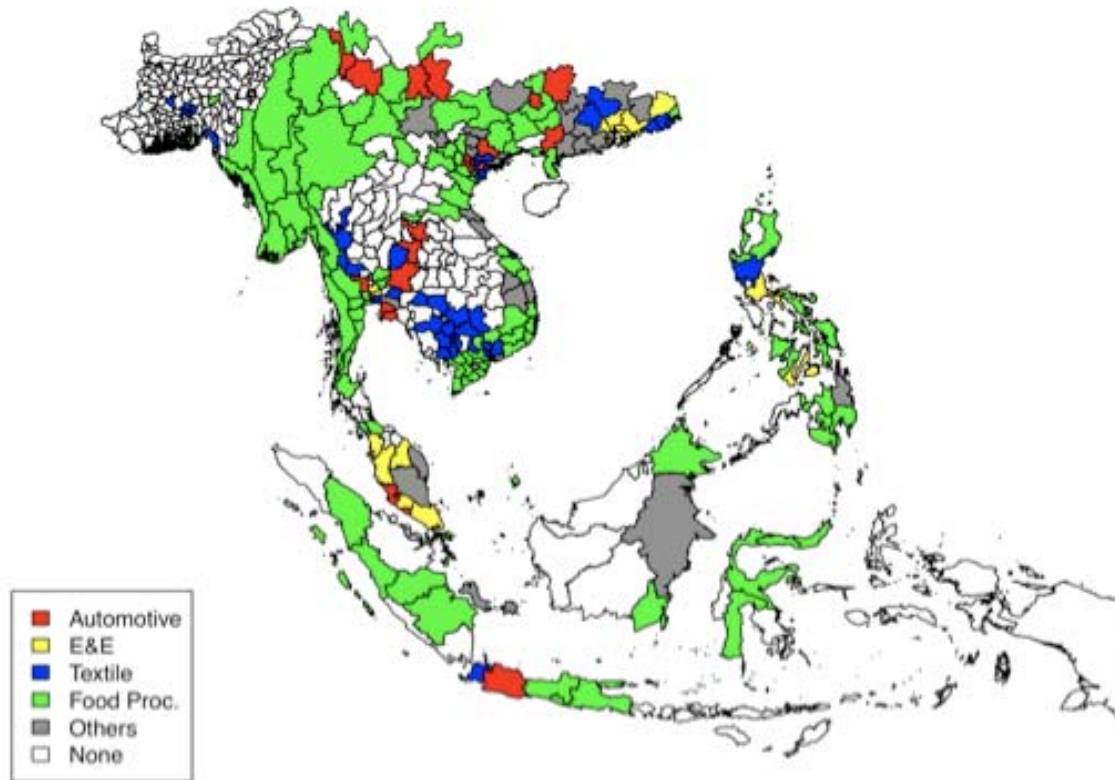
(b) ASEAN



Source: Kimura and Obashi (2009).

Figure 5

Comparative Advantage in Manufacturing Sector(2005)



Source: IDE-JETRO GSM Team.