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Abstract
This paper investigates regional differences within China in the degree of participation in East Asia's production and distribution networks in machinery industries. By employing customs-based export data, large regional disparity in the pattern of machinery exports as well as a hint of catching-up by late-coming regions is demonstrated. China has been regarded as a "lumpy" country in the sense of including a variety of comparative advantage due to regional differences in factor prices. The extended fragmentation theory would suggest positive agglomeration effects and differences in service link costs as additional economic elements to explain regional diversity in the trade pattern.

Keywords: China export; export variety; fragmentation; agglomeration; lumpy country
JEL Categories: F14; F23

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1. Introduction

The growth performance of China has truly been remarkable. With its massive size, China has continuously attained 10% plus growth rates for years. Although some scholars predict a number of risks and challenges that China may face, the existence of vigorous economic dynamism is obvious. Furthermore, the Chinese economy actually becomes increasingly open and international though the splendid growth of China's domestic economy often overshadows it.[1] China's international trade as well as China's exporting sectors has grown much faster than its GDP.

The rise of China as a trading power has stimulated a number of studies on the nature and characteristics of China's export structure and growth as well as its implication for the rest of the world. For example, Amiti and Freund (2008) reveal peculiar features of China's export performance by decomposing its export growth along various dimensions. As for China's stunning export growth, the vital role of foreign-invested firms (Blonigen and Ma, 2007; Koopman et al., 2008) and a heavy dependence on imports of high value-added parts & components for export activities (Lall and Albaladejo, 2004) have been pointed out in the literature. Besides the expansion of China's exports, Rodrik (2006), Schott (2008), and Wang and Wei (2008) highlight the enhancing sophistication of its export structure, demonstrating the fact that China's export structure increasingly resembles that of high-income countries than would be expected given its income level and endowment. This fact would induce anxiety over China's competitive threat not only to developing countries but to advanced countries, in particular, neighbor countries in East Asia. Several studies investigate whether or not exports of other East Asian countries are replaced by exports from China (Lall and Albaladejo, 2004; Eichengreen et al., 2007; Greenaway et al., 2008; Hanson and Robertson, 2008).

In the East Asian economy, we have observed the unprecedented development of

[1] Branstetter and Lardy (2006) comprehensively review China's progressive opening to foreign trade and investment since 1978.

international production and distribution networks since the beginning of the 1990s, particularly in machinery industries (Ando and Kimura, 2005; Kimura, 2006). China has no doubt increasingly become an important player in such networks. If we look into China's penetration into the networks at the regional level, however, the performance of intra-East Asian machinery exports considerably varies across regions within the country. Using the customs- and region-product level trade data obtained from World Trade Atlas, this paper reveals regional variations in export performance along three dimensions: the extensive and intensive margins of export growth, the diversification or specialization of export structure, and the similarity or dissimilarity of export product bundles among regions. It thus seems worthwhile investigating explicitly how export structure and growth vary across regions within China at the product level, in the context of the emerging China in production and distribution networks in East Asia.

As demonstrated in this paper, regional diversity within China in export structure as well as the degree of participation in intra-East Asian machinery trade is obvious at a glance. China is a "lumpy" country (Courant and Deardorff, 1992) in the sense that factor prices widely differ across regions within the country and cater a variety of comparative advantage at the same time.[2] To explain wide regional diversity in the degree of participation in international production and distribution networks, however, we may need to consider other economic elements in addition to imperfect mobility of productive factors. One of the essential elements seems to be positive agglomeration effects in the activities of machinery industries within a certain geographical boundary. Furthermore, high service link costs are also crucial in explaining differences between coastal and inland areas. We also observe that lagged-behind regions are catching up with forerunning regions, which indicates the existence of congestion effects in industrial agglomeration. Such dynamism in production networking exists in China in a more drastic form than we observe in Southeast Asia.

[2] Courant and Deardorff (1992) theoretically demonstrate that uneven distribution of factors across regions within a country, called "lumpiness," can induce exports of the good that intensively uses its unevenly distributed factor, if other determinants of trade are absent.

Because machinery exports, in particular machinery parts & components exports, are powerful indicators for the degree of participation in East Asia's production and distribution networks, most of our analyses deal with machinery exports of each region and customs in China. Although such data do not include transactions between regions within China, the current status of production and distribution networks as well as their over-time dynamism is vividly demonstrated.

The rest of this paper proceeds as follows: the next section outlines the emerging presence of China in East Asia's production and distribution networks. Section 3 reviews the mechanics of international production and distribution networks along the fragmentation theory and extracts some key elements that make the networks viable. Using the customs- and regional-product level trade data, Section 4 examines regional differences in export performance within China as well as providing an overview on regional trends of intra-East Asian machinery exports. Section 5 discusses the interpretation of the regional diversity in export performance within China along the extended fragmentation theory as well as the lumpy country argument. And the last section concludes.

2. Emerging China as an Important Player in Production Networks in East Asia

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 networks are necessarily observed in machinery industries. The proportion of machinery exports in total exports, particularly that of machinery parts & components exports, is a good indicator for judging the degree of participation in international production/distribution networks. In the process of joining in the

networks, although both exports and imports of machineries increase, the export side changes much more drastically.

Table 1 presents the overall pattern of intra-regional machinery exports from East Asian countries in 1993-2006.[3] Countries/economies are grouped into four: Japan, NIEs3 (Korea, Hong Kong, and Singapore), ASEAN4 (Malaysia, Thailand, the Philippines, and Indonesia), and China. The left part of the table reports values of total exports to the world in 1993, 2000, and 2006 for each country/country group. As for intra-East Asian exports, in addition to values of exports for three points in time, intra-East Asia's shares of total exports to the world, commodity composition, shares of each country/country group in intra-East Asian total exports, and annual average growth rates in nominal prices are tabulated. Machineries here include HS84-92, i.e., general machinery, electric machinery, transport equipment, and precision machinery. Machinery products are further classified into machinery parts & components and machinery finished products.[4]

== Table 1 ==

First and foremost, shares of intra-East Asian exports in the total exports to the world already reached a high level as of 1993 particularly in machinery parts & components and increased steadily during the last decade. For Japan's machinery parts & components exports, intra-East Asian exports gained their shares from 42% in 1993 to 52% in 2006, indicating the expansion and deepening of Japan's intra-regional trade relationships. For machinery finished products, on the other hand, inter-regional exports continuously occupied a substantial share around 70-80%. The similar pattern is observed for NIEs3 and ASEAN4; the shares of intra-East Asian exports increased from about 55% in 1993 to about 65% in 2006 for machinery

[3] See Appendix A for the data source.
[4] For the definition of "machinery parts & components" and "machinery finished products" based on the HS classification, see Ando and Kimura (2005).

parts & components while the shares of inter-regional exports remained dominant, around 60-75%, for machinery finished products. China caught up with other East Asian countries during the last decade, in terms of its trade pattern; intra-East Asian exports of machinery parts & components reached around 50% by 2000 and gradually declined afterward, and inter-regional exports of machinery finished products increased its share from 50% in 1993 to 75% in 2006. As of 2006, every country/country group had about 50% or more share of intra-East Asian exports in the total machinery parts & components exports to the world.

Commodity composition figures clearly indicate active participation of respective East Asian countries in international production/distribution networks developed across the region. Japan was already a key country for machinery industries as of 1993 and maintained a very large proportion of machinery exports in the total intra-East Asian exports, about 65%. NIEs3 became significant players in East Asia's production/distribution networks by 2000; machinery parts & components in particular occupied a large share in the total exports.[5] ASEAN4 also grew up as active players in back-and-forth transactions of machinery parts & components. And China is rapidly catching up with other East Asian countries, enhancing the proportion of machinery exports.

As is clear from a figure in Appendix B, as of 2006, more than the half of both intra-East Asian exports and inter-regional exports are accounted for by machineries for every country/country group of the region except China's inter-regional exports.[6] It should be noted, however, that a substantial share of intra-East Asian machinery exports are of parts & components, unlike inter-regional machinery exports. Furthermore, for NIE3, ASEAN4, and

[5] Note that exports of machinery parts & components may be magnified to some extent by multi-layered trade; same parts & components may be traded again and again in production/distribution networks. Yi (2003) points out such a possibility of double- or triple-counting in parts & components trade. Also note that exports from NIEs3 (ASEAN4) include trade among NIEs3 (ASEAN4) countries.

[6] The contrast with other parts of the world is sharp. In Latin America, only Mexico and Costa Rica participate in international production networks in the sense that the proportion of machinery exports in the total exports is fairly large. Eastern Europe countries are also presenting an evolutionary pattern. See Ando and Kimura (2005).

China, increases in the machinery's shares of intra-East Asian exports during the last decade are attributed mainly to rapidly increasing shares of parts & components. These facts confirm the development of East Asia's production/distribution networks with active participation of countries all over the region.

Shares of each country/country group in intra-East Asian total exports have also significantly changed since the beginning of the 1990s (see Table 1 again). Japan's share in intra-East Asian total machinery exports dropped from 55% in 1993 to 26% in 2006. NIEs3's share was kept at around one-fourth. ASEAN4's share reached 22% in 2000 though slowly declined after that. The most drastic changes are found for China; China's share was merely 12% in 1993 and explosively expanded up to 20% in 2000 and 30% in 2006. China no doubt becomes one of the major players in East Asia's production/distribution networks.

These changes are confirmed by annual average real growth rates in 1993-2006. Growth rates of intra-East Asian machinery exports are considerably high in Japan, NIEs3, and ASEAN4, compared with their growth rates of GDP. But most of all, annual average growth rates of intra-East Asian machinery exports from China are truly amazing; 17% for machinery products as a whole and 23% for machinery parts & components.

Table 2 is a more detailed table for China's intra-East Asian exports that are classified by country/country group of destination. Values of intra East-Asian exports by destination and their shares in total exports to the world are reported in the upper and lower parts of the table, respectively.

== Table 2 ==

The proportion of intra-East Asian exports in China's total machinery exports to the world decreased from 58% in 1993 to 35% in 2006; it is striking that the decrease in the share of intra-East Asian exports is wholly attributed to a sharp drop in the share of exports to Hong

Kong. The Hong Kong's share decreased by half for machinery parts & components exports and dropped down to less than one-forth for machinery finished products exports. In contrast, the shares of China's exports to the other countries/country groups in East Asia trend upward, which indicates that China has developed trade relationships with not only Hong Kong but countries all over the region. Despite the decreasing share of China's exports to Hong Kong, the role of Hong Kong as a place for reshipment is still large. Particularly in the case of machinery parts & component exports, however, a considerable portion of exports to Hong Kong is supposed to end up with East Asia.

From the perspective of the diversification of exported products, the emerging presence of China in East Asia's production/distribution networks is also significant. Figure 1 shows the distribution of the number of machinery products exported bilaterally among East Asian countries in 1993 and 2006 as a circle, marking out those exported from China. If we simply count product lines of the machineries of interest according to the HS 1992 classification, the maximal possible number of exported products is 1,124. The ranges of machinery products exported from china to other East Asian countries expanded during the decade and have exceeded most of exporter-importer pairs. The number of machinery products exported from China ranges from 393 for the exports to the Philippines to 899 for those to Hong Kong in 1993, and then, as of 2006, from 862 for those to the Philippines to 1,034 for those to Indonesia.

== Figure 1 ==

3. The Fragmentation Theory and the Evolution of Production Networks

Once we admit that China is an important player in production/distribution networks in East Asia, the understanding of the mechanics of such networks becomes crucial to further examining the rise of China. The fragmentation theory initiated by Jones and Kierzkowski (1990) and its extension well explain the mechanics of fragmentation in East Asia. Figure 2

illustrates the original idea of fragmentation. Suppose that this is an electronics company and the whole production from downstream to upstream are originally located in a developed country. If we closely look at the factory, however, it includes various production processes in terms of technologies, required factor inputs, and others. Hence, if we can separate production processes into production blocks and relocate them to remote places with different location advantages, the total production costs may be reduced. Such fragmentation of production processes becomes viable if (i) production costs per se are saved in fragmented production blocks and (ii) additional cost of connecting remotely located production blocks, i.e., service link costs, is not prohibitively high. Service link costs include transport costs, telecommunication costs, various coordination costs, and others.

== Figure 2 ==

Condition (i) means that the larger differences in location advantages between two countries/regions, the more likely fragmentation is viable. Wage levels of unskilled labor are no doubt one of the important determinants of location choices but do not fully represent multi-dimensional components of location advantages. Firms have a degree of freedom in how to cut off production blocks so that they can take advantage of various niches in local investment climate. Condition (ii) is also crucial when latecomers try to attract economic activities. Geographical positioning is one of the important factors for service link costs. In addition, service link typically has strong economies of scale in both static and dynamic sense. These would adversely affect latecomers. However, service link costs are also controllable in many aspects such as trade facilitation and the development of logistic infrastructure and services.

To accommodate the sophistication of production/distribution networks in East Asia, Kimura and Ando (2005) extend the concept of fragmentation into two dimensions:

fragmentation in terms of geographical distance and fragmentation in terms of the disintegration of corporate activities (see Figure 3). The latter is particularly important in the context of East Asia, which explains the proliferation of arm's length, i.e., inter-firm, transactions including various classes of outsourcing such as subcontracting, OEM (original equipment manufacturing or original equipment manufacturer)/ODM (original design manufacturing or original design manufacturer) contracts, EMS (electronics manufacturing service) firms, foundries, and internet auction. The development of arm's length transactions in production/distribution networks, in addition to intra-firm transactions, is compatible with recent innovative business models in which the concentration of resources to core competences and the choice of business architecture, i.e., modular versus total integration, are crucial.

== Figure 3 ==

Furthermore, the introduction of disintegration-type fragmentation is also essential to explaining the simultaneous advancement of firm-level fragmentation and industry- or macro-level agglomeration. Arm's length transactions, particularly in tight just-in-time (JIT) system, are highly sensitive to geographical distance, which generates geographical concentration of vertical arm's length transactions in order to save transaction costs. This is one of the economic forces that accelerate the formation of industrial agglomeration. In East Asia, we have indeed experienced the simultaneous development of firm-level fragmentation of economic activities and industry-level formation of agglomeration, which has not yet realized in other developing regions in the world. Industrial agglomerations in Bangkok metropolitan area, the Pearl River delta, and Shanghai with its backyard are the examples.

In cases of machinery industries, most of the high-frequency just-in-time system of vertical division of labor are actually conducted with a gate-to-gate lead time of 2.5 hours or less, which roughly corresponds to a geographical boundary of 100km diameter; transactions

with such a short lead time are called the "first-layer" transactions by Kimura (2008).[7] Once industrial agglomeration starts working, it also becomes an important element of location advantages, particularly in counterbalancing wage hikes as economic development proceeds.[8] Industrial agglomeration also provides ample opportunities for local firms and entrepreneurs to penetrate into production/distribution networks developed by multinationals.

Negative agglomeration effects or congestion effects generate dispersion forces with which some of the economic activities in industrial agglomeration, typically labor-intensive activities, start looking for new production sites in peripheries. From the viewpoint of lagging-behind countries or regions, such forces provide good opportunities to invite production blocks if proper improvement in location advantages and the reduction in service link costs are prepared. Investment in lagging-behind countries may be new investment by multinationals or dispatches of satellite plants from neighboring agglomeration. This is a novel channel for latecomers to initiate industrialization by taking advantage of globalizing forces.

4. Regional Disaggregation of Networking Pattern

China has become an important player in international production/distribution networks stretched across East Asia, in terms of not only the increased trade value but also the increasing number of exported products. However, the degree of penetration into the networks varies considerably across regions within the country. This section examines regional diversity in the performance of intra-East Asian machinery exports within China, using the customs- and

[7] For example, Toyota now has four assembly/parts plants in Bangkok Metropolitan area and operates tight just-in-time system in which intermediate inventories of parts and components are equivalent to the amount for less-than-two-hour production. More than 80% parts suppliers for these plants are located within 2.5-hour truck transportation. The frequency of procurement is sometimes extremely high; one of the major suppliers Aisin procures parts and components from their plant in Bangkok area to Toyota assembly plants 50 times a day, most of which are with one-ton pick-up trucks.

[8] The literature of new economic geography also argues positive and negative agglomeration effects. See, for example, Baldwin, Forslid, Martin, Ottaviano, and Robert-Nicoud (2003).

region-product level trade data obtained from World Trade Atlas.[9] After outlining regional trends of intra-East Asian machinery exports, the following subsections look further into regional diversity in export performance along three dimensions: the extensive and intensive margins of export growth, the transformation of export structure, and the overlap of export product bundles between regions.

4.1. Regional Differences in Intra-East Asian Machinery Exports

Table 3 presents the overall pattern of intra-East Asian machinery exports from China in 2006 by regions and by customs. East Asia here includes Taiwan as well as Japan, NIEs3, and ASEAN4. Seven regions of interest and the corresponding 41 customs are listed in Appendix C.[10] As for the customs level data, we focus only on the top 10 major customs in terms of the total value of merchandise exports both in 2002 and 2006. In addition to values of exports, machinery's shares of total exports, shares by regions and by customs, and the composition of machinery exports are tabulated.[11]

== Table 3 ==

Although the proportion of machinery exports in the total intra-East Asian exports from China as a whole has reached 55%, the machinery's share ranges from 6% for the southwest region to 63% for South China. The degree of participation in East Asia's production/distribution networks greatly varies across regions within China. Intra-East Asian machinery exports from China are dominated by South China and East China, which account for 53% and 38% of those, respectively. Meanwhile, the top 10 most major customs are

[9] See Appendix A for data sources.
[10] As for the map of all the ports of entry in China, see the web page of China Customs (http://www.customs.gov.cn/tabid/3173/Default.aspx).
[11] As in the previous section, machinery products including HS84-92 are grouped into parts & components and finished products, along the line of Ando and Kimura (2005).

mostly located in South China and East China. More than 90% of intra-East Asian machinery exports from China are attributed to vigorous export activities of just 10 customs. Even among the top 10 major customs, we can observe variations in the importance of machineries relative to total exports. The machinery's shares are more than 70% for Nanjing and Shenzhen Customs but are less than 30% for Qingdao and Dalian Customs. As for the composition of machinery exports, parts & components make up a larger share than finished products for every part of China except the southwest region as well as for all the top 10 major customs except Xiamen Customs.

It is striking that the larger value of the total intra-East Asian exports from a region, the larger share is accounted for by machineries. Indeed, the proportion of machinery exports in the total exports is 57% for the top 10 major customs, which is obviously larger than 44% for the other 31 customs. As for the three largest customs in terms of the total value of intra-East Asian exports, including Shenzhen, Shanghai, and Huangpu Customs, the machinery's shares are all more than 55%, which is the figure for China as a whole.

Figure 4 presents more detailed composition of intra-East Asian machinery exports for respective regions within China in 2002 and 2006. As observed in Table 3, machinery industries account for a substantial share of intra-East Asian merchandise exports for every part of China, except for the southwest region.

== Figure 4 ==

More importantly, machinery's shares of total exports for South China, East China, and North China steadily increased while those for the northwest and southwest regions declined from 2002 to 2006. This contrasting pattern can be interpreted as indicating inter-industry specialization among regions within China. A region with a larger share as well as a larger value of intra-East Asian machinery exports initially in 2002 has further enhanced its

capacity to export machinery products, leading to the increasing share of machineries in the total intra-East Asian exports. The northwest and southwest regions, on the other hand, have specialized in producing and exporting goods of industries other than machinery industries. In addition, although electric machinery plays an important role for every region, the shares of machinery subsectors in intra-East Asian machinery exports vary by region.

4.2. Extensive versus Intensive Margin of Export Growth

The range of exported products also widely varies across regions within China. Table 4 highlights that, as of 2006, the number of exported products ranges from 113 for the southwest region to 1,084 for South China. At the aggregated country level, compared to the maximal possible number of product lines (1,172 products), a very wide range of products, 1,133 products, is exported. Regional diversity within China in the sense that different regions export different ranges of products may help explain a substantial diversification of exported products at the country level.

== Table 4 ==

In addition to the number of exported products, Table 4 records values and annual average real growth rates of intra-East Asian machinery exports in 2002-2006. Along the line of Evenett and Venables (2002) and others, the intra-East Asian machinery export growth is decomposed into changes in the composition of products as follows:

$$\frac{\sum_j V^i_{j,2006} - \sum_j V^i_{j,2002}}{\sum_j V^i_{j,2002}} = \frac{\sum_{j\in E^i}(V^i_{j,2006} - V^i_{j,2002})}{\sum_j V^i_{j,2002}} - \frac{\sum_{j\in D^i} V^i_{j,2002}}{\sum_j V^i_{j,2002}} + \frac{\sum_{j\in N^i} V^i_{j,2006}}{\sum_j V^i_{j,2002}},$$

where V^i_{jt} is country/region i's exports of product j in year t, and E^i, D^i, and N^i are the sets of existing, disappearing, and new products exported from country/region i, respectively. The most right three columns of the table record the share of contribution of products in each

category to the intra-East Asian machinery export growth.

Intra-East Asian machinery exports from China as a whole expanded three times from 2002 to 2006, with an annual average real growth rate of 31%. Even those from the northeast region with the lowest growth rate among regions almost doubled during the period; those from East China rapidly increased four-fold in just four years.

An increase in intra-East Asian machinery exports has been almost entirely driven by the larger volume of existing products; the export contribution of existing products, i.e., intensive margin, is 99.9% for China as a whole.[12] It should be noted, however, that the export growth contribution of newly exported products, i.e., extensive margin, is overwhelmingly large, 93%, for the southwest region with a limited number of exported products as well as the smallest value of exports as of 2002. Newly exported products also play a considerable role in the export growth for the northwest and northeast regions. Although unambiguously large regional disparities exist in the value of intra-East Asian machinery exports within China, "latecomer" regions are gradually catching up with "forerunner" regions to some extent through the birth of newly exported products or the wider range of exported products.

4.3. Diversification versus Specialization of Export Product Composition

Next, whether or not export shares are equally distributed across products is examined, regardless of the birth and death of products. The degree of the specialization of product composition of intra-East Asian machinery exports is measured by calculating Gini coefficients as follows:

$$Gini_t^i = 1 - 1/n \sum_k (cumshare_{k-1,t}^i + cumshare_{kt}^i),$$

[12] Amiti and Freund (2008) also find that most of China's export growth occurred in the intensive margin, for both its exports to the U.S. and to the world, by decomposing its export growth into the extensive margin and the intensive margin. On the other hand, Hummels and Klenow (2005) find that the extensive margin accounts for 60 percent of the greater exports of larger economies relative to smaller economies in their sample of 126 exporting countries, which is suggestive of the importance of the extensive margin growth for emerging countries such as China.

where there are n products with a product's rank k in the ascending order in terms of export shares, and $cumshare^{i}_{kt}$ is the cumulative share of exports of the k-th product in the total value of intra-East Asian machinery exports from country/region i in year t. A Gini coefficient of zero indicates that export shares are equally distributed across products. A larger coefficient corresponds to a higher degree of the specialization of export product composition, and an increase in the coefficient indicates an increase in the degree of specialization. Table 5 reports Gini coefficients not only for the whole sample of machinery products actually exported but also for top 75% and bottom 75% of the sample in terms of export shares.

== Table 5 ==

For intra-East Asian machinery exports from China as a whole, the Gini coefficient remained unchanged for the whole sample. If we focus on the top 75% of the sample, the coefficient slightly increased from 2002 to 2006, indicating enhanced specialization. A smaller number of products have occupied a larger portion of intra-East Asian machinery exports from China.[13] However, the specialization of export product composition is not uniformly observed for every part of China. The coefficients decreased for the northeast and southwest regions, indicating the diversified range of non-negligible exported products; in addition, if focusing only on the top 75% of the sample, the coefficients also decreased for the northwest region and South China. The diversification pattern of export product composition observed for the northeast, southwest, and northwest regions is consistent with the considerable contribution of newly exported products to the intra-East Asian machinery export growth revealed in the last subsection.

Even when the top one-fourth products in terms of export share are excluded, the

[13] Amiti and Freund (2008) also highlight enhanced specialization in China's exports to the U.S. and to the world, by calculating the Gini coefficient for their product compositions.

regional variations in specialization/diversification pattern of export product composition do not substantially differ from the whole sample. Furthermore, the coefficients still remain at a high level for respective regions as well as for China as a whole, which means that the major products occupying large shares do not pull up the degree of the specialization of export product composition.

4.4. Similarity versus Dissimilarity of Export Product Bundle

To directly measure the extent to which export product bundles are overlapping between regions and between customs, the Export Similarity Index (ESI) proposed by Finger and Kreinin (1979) is utilized. ESI is defined as

$$ESI_t^i = 100\sum_j \min(s_{jt}^i, s_{jt}^*),$$

where s_{jt}^i is the share of product j in the total value of intra-East Asian machinery exports from region/customs i in year t, and * denotes a reference region/customs.[14] Export product bundles of South China and Shenzhen Customs are used as reference, since they have been a leading player in intra-East Asian machinery exports from China, as seen in the last couple of subsections. The index is bounded by zero when region/customs i and a reference region/customs export no products in common, i.e., no overlap, and 100 when their exports are identically distributed across products. Note that the index incorporates information on both product penetration and its market share.

Table 6 reports each region's export similarity with South China as a reference region for intra-East Asian machinery trade in 2002 and 2006. The ESI figures greatly vary across regions within China, which indicates large regional differences in the product bundle of

[14] Schott (2006) compares China's exports to the US to those of OECD countries and highlights that China more exports products in common with OECD countries than would be expected, by calculating ESI. Wang and Wei (2008) investigate the factors behind cross-city differences in sophistication of export product structure in China. While Wang and Wei measure China's export sophistication at the highly-detailed city level, using G-3 (Japan, the US, and EU) as a reference, this paper directly analyzes the diversity of export product bundles among regions/customs within China, using its leading region/customs as a reference.

intra-East Asian machinery exports. As of 2006, the index ranges from 6.4 for the northwest region to 61.8 for East China. Not to be overlooked, however, is that the index increased from 2002 to 2006 for every region, which indicates that, despite regional differences in export performance, the export product bundles of respective regions are catching up with South China, the leading exporting region in China. From the standpoint of what they export with an overlap, regional trends of intra-East Asian machinery exports within China become similar with each other rather than becoming more skewed toward different products.

== Table 6 ==

The index slightly decreases if we focus only on top 90% or 75% major exported products in terms of export share since exports of products negligible in amount are excluded. In addition, the index is uniformly higher for the export product bundle of machinery parts & components than for that of all the machinery products. Compared to finished products, the same product of machinery parts & components is more likely to be exported simultaneously from different regions within China to other East Asian countries.

As is clear from Table 7, ESI calculated using Shenzhen Customs as a reference customs also varies among the top 10 most major customs in China. As of 2006, the index ranges from 31.8 for Dalian Customs to 61.6 for Nanjing Customs. The index increased over time for most of the customs but decreased for Guangzhou and Gongbei Customs. As for the export product bundle of machinery parts & components, the index decreased for Guangzhou and Dalian Customs. Unlike with the regional comparison in Table 6, some customs have become exporting different products with reference to the leading customs, Shenzhen customs. Given the fact that Guangzhou and Gongbei Customs are located near Shenzhen customs, the decreasing index figures appear to reflect enhanced specialization within South China as the regional economy grows. This result is consistent with the decreasing Gini coefficient for the

composition of major products exported from South China observed in Table 5, which indicates the increase in the degree of diversification of export product composition at the regional level.

== Table 7 ==

5. Interpretation of Regional Diversity along the Extended Fragmentation Theory

As demonstrated in the last section, the degree of participation in intra-East Asian machinery trade considerably varies across regions within China in terms of the proportion of machinery exports in the total intra-East Asian exports and the number of exported products of machineries. In particular, the contrasting pattern of changes in machinery's shares between coastal areas and inland areas implies inter-industry specialization among regions within China. There are also large regional variations within China in the export product bundle of intra-East Asian machinery trade.

Such regional diversity in export performance partially reflects the uneven internal distribution of productive factors which causes different factor prices across regions. Particularly in case of China, the government's control on labor movements from inland areas to coastal areas, though it has recently been loosened, has caused imperfect factor mobility across regions, leading to an entrenched situation of the factor lumpiness within the country. Because factor prices widely differ across regions within the country, different regions would produce and export different ranges of products at the same time according to different comparative advantage.

In addition to the interpretation along the lumpy country argument, the extended fragmentation theory provides a couple of reinforcing economic logics. First, positive agglomeration effects seem to enhance the location advantages of coastal area, particularly South China and East China. As mentioned in Section 3, geographical concentration of vertical arm's length transactions along the disintegration-type fragmentation accelerates the

formation of industrial agglomeration. Once industrial agglomeration starts working, it also becomes an important source of location advantages, which in turn attracts more fragmented production blocks and boosts more arm's length transactions within the industrial cluster. In this process, as arm's length transactions are sensitive to geographical distance, the geographical boundary of industrial cluster would become finely defined, leading to the development of industrial agglomeration in different parts of the country and entrenched regional variations in location advantages. China is a large country. As a figure in Appendix D presents, 100km-diameter circles for customs in China are barely overlapped. It indicates that single industrial agglomeration with tight just-in-time system cannot cover the whole China. Industrial clusters developed separately in South China, East China, and some of other regions to a lesser extent appear to have been providing economic environment desirable for arm's length transactions, which at least partially offset congestion effects such as wage hikes, shortage of human capital, traffic jam, pollution, and others.

Second, differences between coastal and inland areas are partially due to different service link costs in the formation and functioning of international production and distribution networks. Even if inland areas have location advantages such as the availability of inexpensive labor, high service link costs to access international production and distribution networks may make fragmentation unviable. Service link costs are of course a function of geographical distance. In that sense, inland areas may be located in somewhat disadvantageous position. However, they also depend on other factors such as trade facilitation measures and the development of logistic infrastructure and services, which may at least partially be taken care of.

Although regional diversity in export performance within China is clearly evident, more importantly, latecomers in inland areas are gradually catching up with forerunners in coastal areas in some respects. First, the enormous contribution of the intensive margin of the intra-East Asian machinery export growth, which is obvious at the aggregated country level, is

not uniformly observed for every part of China. In inland areas that initially exported a limited range of products, the export growth is largely attributed to the birth of newly exported products or the wider range of products. Second, the enhanced specialization of export product composition is observed at the country level, but not for all the regions within China. The Gini coefficients have decreased in inland areas, indicating the diversifying range of exported products that are non-negligible in amount. Third, as indicated by the increases in the ESI figures, the export product bundles of respective regions have become similar to that of the leading exporting region in China, i.e., South China.

These regional trends for the last several years can be interpreted as indicating that not only coastal areas but also inland areas of China have steadily embraced the opportunities offered by production/distribution networks in East Asia. A sort of trickle-down effect within China is surely observed.

6. Further Research Agenda

Our findings on the regional diversity within China in terms of the degree of penetration into East Asian production and distribution networks as well as a hint of catching-up process by relatively retarded regions suggest similarities to and differences from the experience of Southeast Asia. China is a large country, and its geographical boundary has a size similar to the whole Southeast Asia. Both China and Southeast Asia have benefited from international production and distribution networks though both have included substantial regional/international diversity in the involvement in the networks. We can say that static as well as dynamic pattern of fragmentation and agglomeration looks very similar. Further investigation on similarities and differences would provide useful insights for both academic and non-academic interests.

The first checkpoint is the implication of differences in initial or first-nature conditions. Although the geographical extension may be similar, China is a unified country,

people speak common language, the mobility of resources is probably freer, and policies could be consistent across regions, compared with Southeast Asia. The size of population in late-coming regions in China is also substantially large, compared with latecomers in Southeast Asia. Such differences in initial conditions may affect, either positively or negatively, the penetration of production and distribution networks as well as the formation of industrial agglomeration.

Second, the composition of actors in production and distribution networks may differ between China and Southeast Asia. In the case of Southeast Asia, such networks have been created, coordinated, and managed primarily by traditional multinationals such as Japanese, the US, and European firms, with some limited role by NIEs firms. Local firms have often been premature, and their penetration into the networks has been limited. In the case of China, indigenous firms as well as Chinese ethnic multinationals have played a much larger role as both network creators/coordinators and participants. The implication of such differences should be investigated much more in details.

Third, the applicability of standard policy prescription by the extended fragmentation theory in China is another important topic. The theory suggests that the "local" improvement of location advantages and the reduction in service link costs are the key for latecomers to invite the first wave of economic activities from congested industrial agglomeration. Late-coming regions in China seem to have good potentials for utilizing the mechanics of fragmentation and agglomeration in order to narrow development gaps. It is extremely important to pinpoint bottlenecks from the viewpoint of penetration into production and distribution networks.

The relationship among regions inside China should be investigated more carefully. Compared with "international" relationship in Southeast Asia, "inter-regional" relationship inside China may be qualitatively different in the mobility of productive factors and goods, players in production/distribution networks, and effects of national policies. While we find some signs of convergence across regions, new economic geography literature suggests

complicated implication of the reduction of transport cost in whether agglomeration or dispersion of economic activities would occur. Further examination on intra-China transactions as well as the pattern of within-China industrial location may explore new frontiers of the fragmentation theory and new economic geography.

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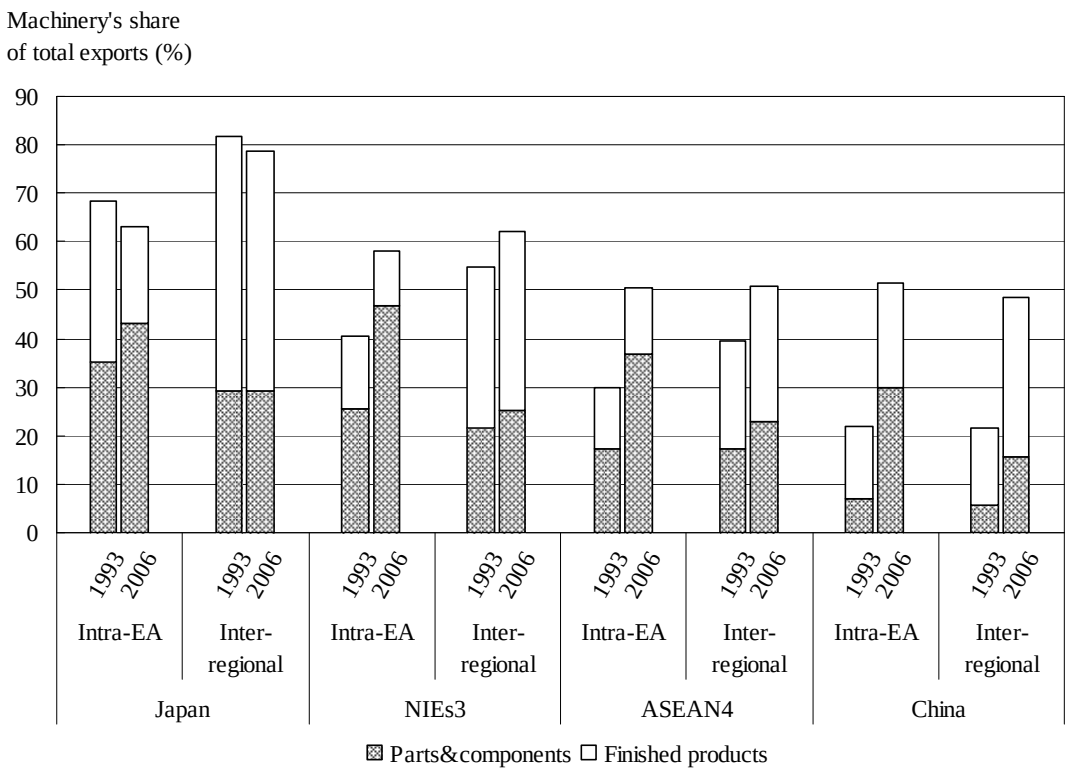
Appendix A. Trade Data

As for the trade data obtained from UN Comtrade, this paper basically uses bilateral import data from the standpoint of reliability, because country of origin is more closely verified due to tariff regulations although final destination may not be known at time of export. To utilize intra-East Asian trade data for as long as possible (from 1993 to 2006), HS 1992 classification is employed. Note that (i) data for Singapore's imports from Indonesia, which only have been officially reported since 2003, are not included, and (ii) Taiwan is not included in East Asia. We modified data as follows: First, data for the Philippines' imports, which only have been reported according to the HS classification since 1996, are replaced by data for exports to the Philippines. The export data are adjusted by the c.i.f. / f.o.b. ratio specific to the machinery industry sub-sector and exporter-importer pair, which is calculated using the corresponding data reported according to the SITC Rev.3. Second, since the annual data at the HS six-digit level below $500 (current US$) are not reported before 2000, trade flows below $500 are treated as if there was no trade at all for all the years in the sample.

As for the trade data obtained from World Trade Atlas, this paper uses the customs level data of China's intra-East Asian exports. Note that East Asia here includes Taiwan as well as Japan, NIEs3, and ASEAN4.

Appendix B. Commodity Composition of Intra-East Asian Exports and Inter-regional Exports: By Country/Country Group



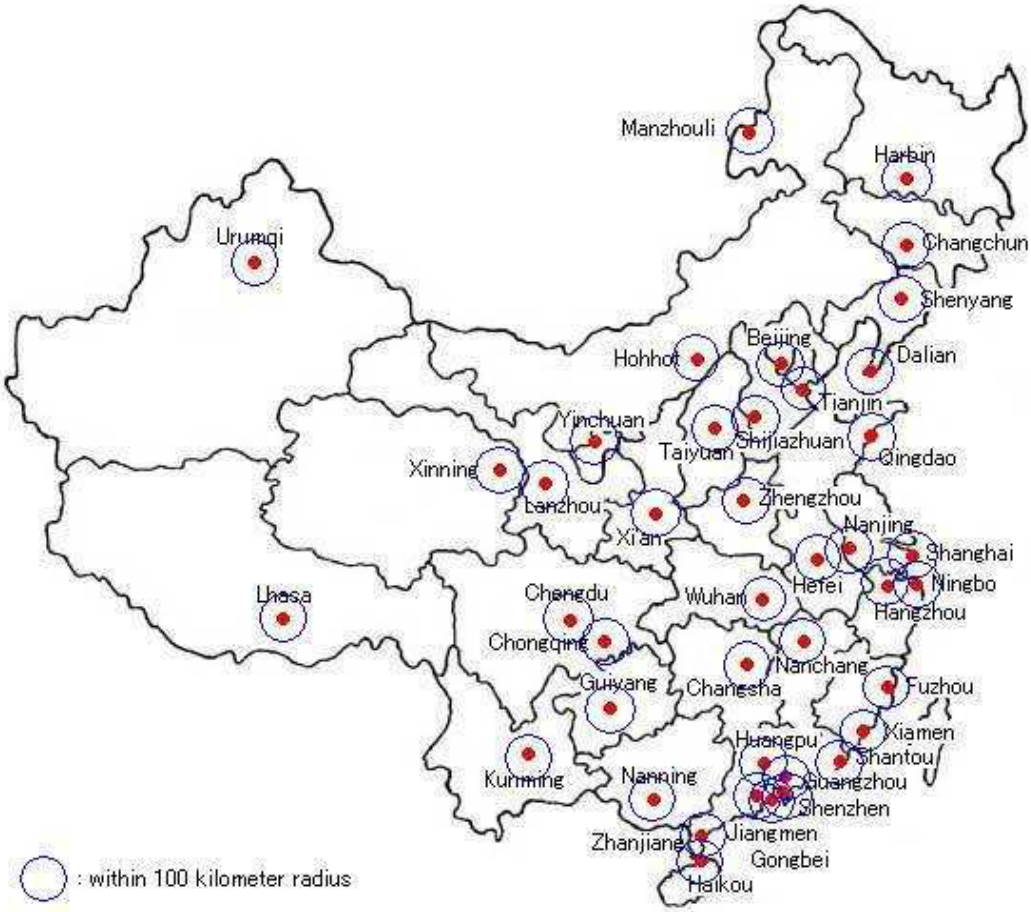
Source: Authors' calculation based on the data from UN Comtrade (HS 1992, six-digit).

Appendix C. Regional Classification of Customs

Region		Customs
Northeast region	(6 customs)	Changchun; **Dalian**; Harbin; Hohhot; Manzhouli; Shenyang
North China	(4 customs)	Beijing; Shijiazhuang; Taiyuan; **Tianjin**
Northwest region	(5 customs)	Lanzhou; Urumqi; Xi'an; Xining; Yinchuan
East China	(7 customs)	Hangzhou; Hefei; Nanchang; **Nanjing**; Ningbo; **Qingdao**; **Shanghai**
Central China	(5 customs)	Changsha; Chengdu; Chongqing; Wuhan; Zhengzhou
South China	(11 customs)	Fuzhou; **Gongbei**; **Guangzhou**; Haikou; **Huangpu**; Jiangmen; Nanning; Shantou; **Shenzhen**; **Xiamen**; Zhanjiang
Southwest region	(3 customs)	Guiyang; Kunming; Lhasa

Notes: Top 10 most major customs (out of 41 customs) in terms of the total value of merchandise exports both in 2002 and 2006 are indicated by boldface.

Appendix D. Locations of Customs in China



Notes: The locations of customs marked with dots and surrounded by circles with 100-kilometer radius are added by the authors.

Table 1. Intra-East Asian exports: by country/country group.

	Total exports to the world			Intra-East Asian exports												
	Export value (millions US$)			Export value (millions US$)			Share of total exports to the world (%)			Commodity composition (%)			Share in intra-East Asian total exports (%)			Annual average export growth 1993-2006 (%)
	1993	2000	2006	1993	2000	2006	1993	2000	2006	1993	2000	2006	1993	2000	2006	
Japan																
Machinery products	279,343	358,357	381,540	93,416	112,958	141,588	33.4	31.5	37.1	68.3	67.7	63.1	54.5	35.3	26.0	3.3
Parts&components	114,365	178,389	185,658	48,152	77,791	96,755	42.1	43.6	52.1	35.2	46.6	43.1	53.4	36.9	25.7	5.5
Finished products	164,978	179,968	195,882	45,264	35,167	44,833	27.4	19.5	22.9	33.1	21.1	20.0	55.7	32.1	26.7	-0.1
All commodities	364,156	469,806	528,846	136,790	166,953	224,468	37.6	35.5	42.4	100.0	100.0	100.0	35.0	26.9	22.8	3.9
NIEs3																
Machinery products	87,288	184,832	272,472	35,490	71,740	129,238	40.7	38.8	47.4	40.4	52.4	58.3	20.7	22.4	23.7	10.5
Parts&components	42,845	101,932	161,912	22,535	50,628	104,077	52.6	49.7	64.3	25.7	37.0	46.9	25.0	24.0	27.6	12.5
Finished products	44,443	82,900	110,559	12,955	21,112	25,161	29.1	25.5	22.8	14.8	15.4	11.3	15.9	19.2	15.0	5.2
All commodities	182,450	307,097	452,314	87,763	136,969	221,785	48.1	44.6	49.0	100.0	100.0	100.0	22.4	22.0	22.6	7.4
ASEAN4																
Machinery products	47,484	149,627	210,016	22,326	71,445	113,504	47.0	47.7	54.0	29.7	50.6	50.6	13.0	22.3	20.8	13.3
Parts&components	23,924	89,149	126,305	12,982	50,768	82,399	54.3	56.9	65.2	17.3	35.9	36.7	14.4	24.1	21.9	15.3
Finished products	23,560	60,478	83,711	9,344	20,677	31,105	39.7	34.2	37.2	12.4	14.6	13.9	11.5	18.8	18.5	9.7
All commodities	138,851	286,378	414,554	75,105	141,237	224,244	54.1	49.3	54.1	100.0	100.0	100.0	19.2	22.7	22.8	8.8
China																
Machinery products	34,676	146,154	465,227	20,220	64,139	160,818	58.3	43.9	34.6	22.0	36.4	51.5	11.8	20.0	29.5	17.3
Parts&components	10,350	59,822	192,720	6,529	31,392	93,748	63.1	52.5	48.6	7.1	17.8	30.0	7.2	14.9	24.9	22.7
Finished products	24,326	86,332	272,507	13,691	32,747	67,070	56.3	37.9	24.6	14.9	18.6	21.5	16.9	29.9	39.9	13.0
All commodities	158,212	395,289	942,454	91,723	176,288	312,546	58.0	44.6	33.2	100.0	100.0	100.0	23.4	28.4	31.8	9.9

Notes: All values are calculated at constant prices (constant 2000 US$; deflated by the US's WPI obtained from World Development Indicator Online).
Source: Authors' calculation based on the data from UN Comtrade (HS 1992, six-digit).

Table 2. Intra-East Asian exports from China: by destination.

	All commodities			Machinery products								
				All machinery products			Parts&components			Finished products		
	1993	2000	2006	1993	2000	2006	1993	2000	2006	1993	2000	2006
Export value (millions US$)												
Intra-East Asia	91,723	176,288	312,546	20,220	64,139	160,818	6,529	31,392	93,748	13,691	32,747	67,070
Japan	22,812	55,100	95,486	2,065	14,733	39,408	903	7,486	19,139	1,162	7,247	20,269
NIEs3	65,112	111,680	184,830	17,287	45,322	102,670	5,306	21,307	62,476	11,981	24,015	40,194
Hong Kong	58,046	91,765	123,790	16,266	36,526	70,116	4,846	15,838	42,466	11,420	20,688	27,650
ASEAN4	3,799	9,509	32,230	868	4,084	18,740	319	2,599	12,133	548	1,485	6,607
World total	158,212	395,289	942,454	34,676	146,154	465,227	10,350	59,822	192,720	24,326	86,332	272,507
Share by destination (%)												
Intra-East Asia	58.0	44.6	33.2	58.3	43.9	34.6	63.1	52.5	48.6	56.3	37.9	24.6
Japan	14.4	13.9	10.1	6.0	10.1	8.5	8.7	12.5	9.9	4.8	8.4	7.4
NIEs3	41.2	28.3	19.6	49.9	31.0	22.1	51.3	35.6	32.4	49.3	27.8	14.7
Hong Kong	36.7	23.2	13.1	46.9	25.0	15.1	46.8	26.5	22.0	46.9	24.0	10.1
ASEAN4	2.4	2.4	3.4	2.5	2.8	4.0	3.1	4.3	6.3	2.3	1.7	2.4
World total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Notes: All values are calculated at constant prices (constant 2000 US$; deflated by the US's WPI obtained from World Development Indicator Online).
Source: Authors' calculation based on the data from UN Comtrade (HS 1992, six-digit).

Table 3. Intra-East Asian exports from China in 2006: by region/customs.

	All commodities	Machinery products				
	Export value (millions US$)	Export value (millions US$)	Share of total exports (%)	Share by region/ customs (%)	Composition of machinery exports (%)	
					Parts& components	Finished products
Total	374,187	206,693	55.2	100.0	63.5	36.5
Northeast region	16,753	4,751	28.4	2.3	58.2	41.8
North China	30,056	14,196	47.2	6.9	60.4	39.6
Northwest region	668	121	18.1	0.1	52.0	48.0
East China	151,118	77,686	51.4	37.6	71.8	28.2
Central China	2,968	894	30.1	0.4	80.1	19.9
South China	171,896	109,000	63.4	52.7	58.1	41.9
Southwest region	729	46	6.3	0.0	47.1	52.9
Top 10 major customs	335,668	189,949	56.6	91.9	64.1	35.9
Shenzhen	92,878	66,248	71.3	32.1	58.4	41.6
Shanghai	88,697	49,074	55.3	23.7	74.8	25.2
Nanjing	25,361	18,320	72.2	8.9	69.1	30.9
Huangpu	27,415	17,523	63.9	8.5	66.8	33.2
Gongbei	13,662	8,548	62.6	4.1	52.3	47.7
Guangzhou	16,760	7,661	45.7	3.7	52.1	47.9
Tianjin	18,670	6,801	36.4	3.3	71.1	28.9
Qingdao	25,946	5,796	22.3	2.8	71.1	28.9
Xiamen	10,387	5,622	54.1	2.7	37.4	62.6
Dalian	15,892	4,356	27.4	2.1	56.5	43.5
Other 31 customs	38,519	16,744	43.5	8.1	56.5	43.5

Notes: All values are at current prices. In the lower part of the table, top 10 most major customs (out of 41 customs) in terms of the total value of merchandise exports both in 2002 and 2006 are listed. Customs are ranked in decreasing order of machinery export value in 2006.
Source: Authors' calculation based on the data from World Trade Atlas (HS 2002; six-digit).

Table 4. Export growth decomposition for intra-East Asian machinery exports from China: by region.

	Export value (millions US$)		Annual average export growth 2002-06 (%)	The number of exported products (max: 1172)		Export growth contribution (%)		
	2002	2006		2002	2006	Existing	Disappear	New
Total	70,738	206,693	30.7	1,110	1,133	99.9	0.0	0.1
Northeast region	2,615	4,751	16.1	648	748	87.7	-0.5	12.9
North China	4,651	14,196	32.2	850	917	97.4	-0.1	2.7
Northwest region	61	121	18.4	129	167	84.4	-9.3	24.9
East China	19,537	77,686	41.2	1,044	1,082	99.9	0.0	0.1
Central China	320	894	29.3	424	524	94.4	-1.5	7.1
South China	37,955	109,000	30.2	1,041	1,084	99.9	0.0	0.1
Southwest region	17	46	27.5	108	113	17.1	-9.8	92.6

Notes: All values are calculated at constant prices (constant 2006 US$; deflated by China's CPI obtained from International Financial Statistics Online).
Source: Authors' calculation based on the data from World Trade Atlas (HS 2002; six-digit).

Table 5. Gini coefficient for the product composition of intra-East Asian machinery exports from China: by region.

	All machinery products		Top 75%		Bottom 75%	
	2002	2006	2002	2006	2002	2006
Total	0.90	0.91	0.54	0.57	0.87	0.88
Northeast region	0.93	0.89	0.54	0.43	0.91	0.87
North China	0.93	0.94	0.61	0.67	0.90	0.90
Northwest region	0.91	0.94	0.57	0.49	0.88	0.93
East China	0.88	0.91	0.54	0.64	0.85	0.87
Central China	0.93	0.92	0.62	0.64	0.90	0.88
South China	0.92	0.93	0.54	0.48	0.90	0.92
Southwest region	0.92	0.90	0.51	0.36	0.90	0.90

Source: Authors' calculation based on the data from World Trade Atlas (HS 2002; six-digit).

Table 6. Export Similarity Index for the product composition of intra-East Asian machinery exports from China: by region (South China as a reference).

	All machinery products						Machinery parts&components					
	All		Top 90%		Top 75%		All		Top 90%		Top 75%	
	2002	2006	2002	2006	2002	2006	2002	2006	2002	2006	2002	2006
Northeast region	35.6	38.6	34.2	37.1	33.9	34.9	48.2	47.6	46.7	45.7	47.0	45.6
North China	32.5	38.2	29.7	35.6	23.8	30.3	33.2	43.6	29.2	39.8	21.1	35.8
Northwest region	5.7	6.4	2.9	3.3	2.0	0.8	6.5	7.3	2.8	3.8	1.7	0.0
East China	56.8	61.8	54.8	60.2	52.6	59.2	58.7	63.2	56.6	61.4	51.4	60.0
Central China	13.2	21.4	8.9	18.6	4.5	15.1	13.5	25.9	8.6	22.9	3.1	21.5
Southwest region	6.4	24.5	3.4	24.0	0.0	22.2	11.4	33.2	9.2	34.3	0.0	27.9

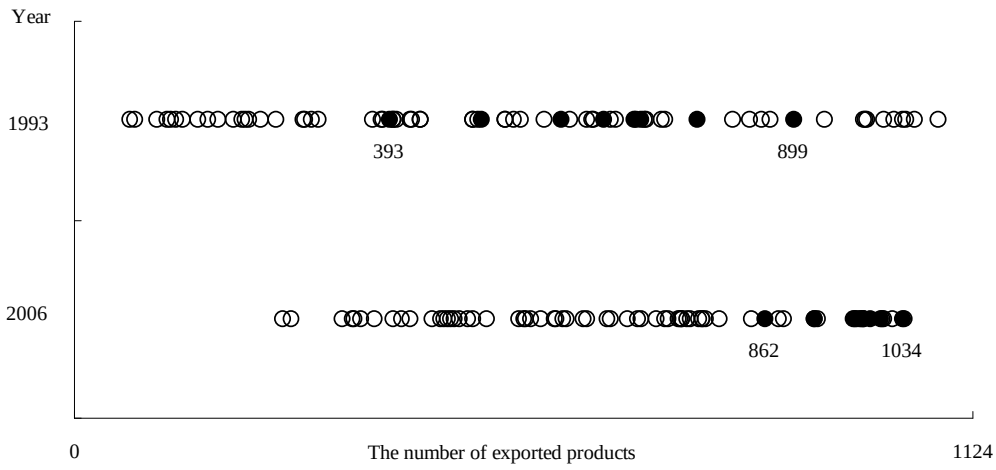
Notes: Export Similarity Index is calculated using South China as a reference region.
Source: Authors' calculation based on the data from World Trade Atlas (HS 2002; six-digit).

Table 7. Export Similarity Index for the product composition of intra-East Asian machinery exports from China: by customs (Shenzhen Customs as a reference).

	All machinery products						Machinery parts&components					
	All		Top 90%		Top 75%		All		Top 90%		Top 75%	
	2002	2006	2002	2006	2002	2006	2002	2006	2002	2006	2002	2006
Shanghai	44.2	52.5	42.2	49.8	39.4	49.3	46.6	53.2	44.0	50.6	38.5	49.0
Nanjing	54.2	61.6	54.7	62.0	53.2	63.5	57.8	67.3	57.5	67.0	57.9	67.9
Huangpu	54.1	65.2	51.7	63.6	48.6	62.7	57.3	74.8	54.6	73.6	54.3	75.8
Gongbei	49.8	47.5	48.3	45.2	45.8	45.8	53.0	58.6	51.2	56.6	52.5	56.5
Guangzhou	46.7	40.5	44.0	36.7	40.6	32.7	53.4	43.8	50.5	39.5	51.8	33.7
Tianjin	30.9	39.7	29.0	37.3	24.5	35.1	31.0	45.7	26.2	42.8	23.5	40.3
Qingdao	32.2	40.2	30.5	38.3	28.7	37.6	37.5	45.7	34.4	43.3	34.1	43.4
Xiamen	28.2	31.9	24.8	29.0	20.5	26.0	35.3	37.1	30.9	34.1	31.0	30.5
Dalian	28.7	31.8	26.7	30.0	27.2	26.0	40.1	39.8	37.8	37.0	40.4	35.7

Notes: Only top 10 most major customs (out of 41 customs) in terms of the total value of merchandise exports both in 2002 and 2006 are listed. Customs are ranked in decreasing order of machinery export value in 2006. Export Similarity Index is calculated using Shenzhen Customs as a reference customs.
Source: Authors' calculation based on the data from World Trade Atlas (HS 2002; six-digit).

Figure 1. The number of machinery products exported bilaterally within East Asia.



Notes: This figure shows the distribution of the number of machinery product lines exported across exporter-importer pairs within East Asia in 1993 and 2006 as a circle, marking out those exported from China.
Source: Authors' calculation based on the data from UN Comtrade (HS 1992, six-digit).

Figure 2. Fragmentation of production processes: an illustration.

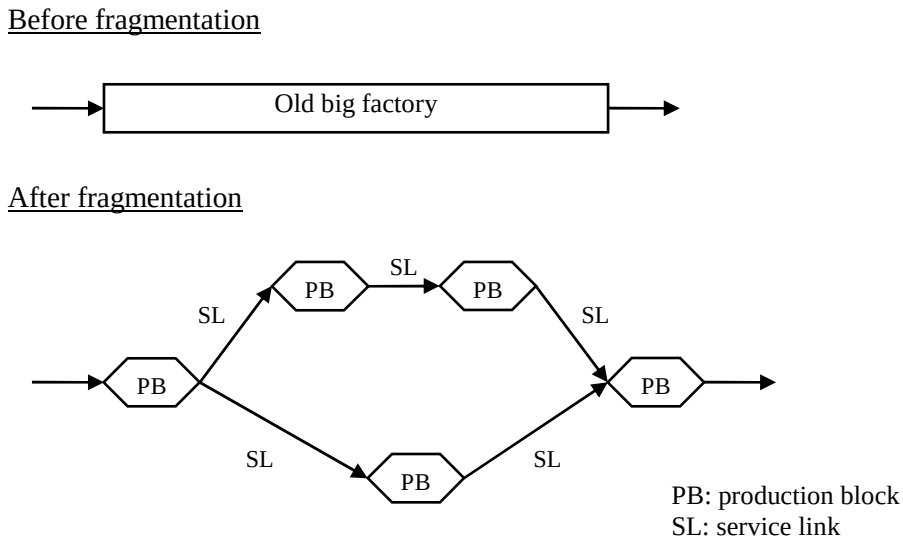
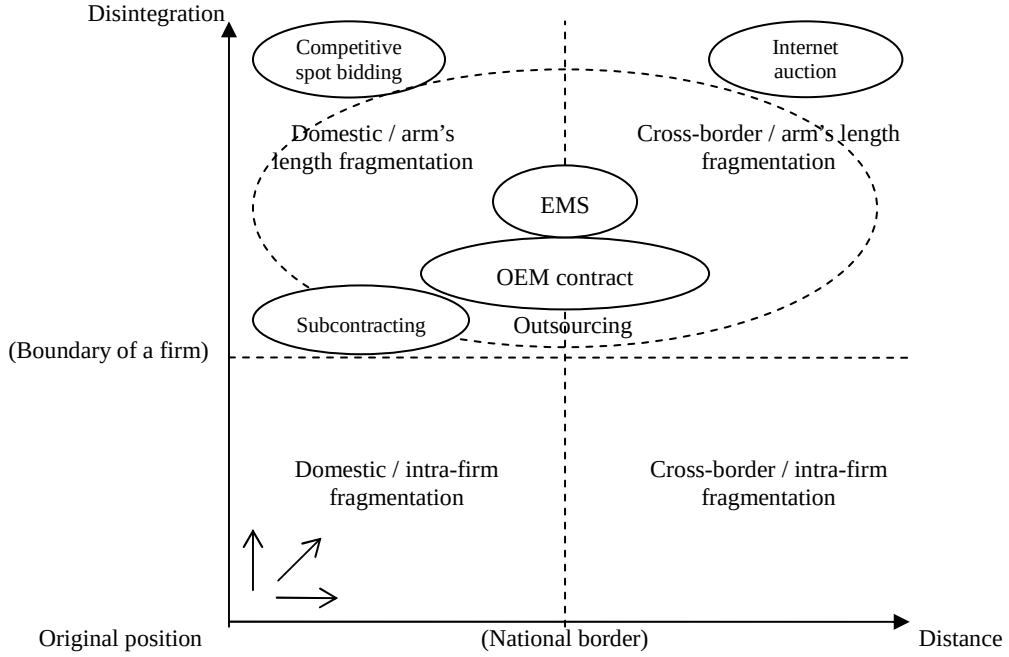
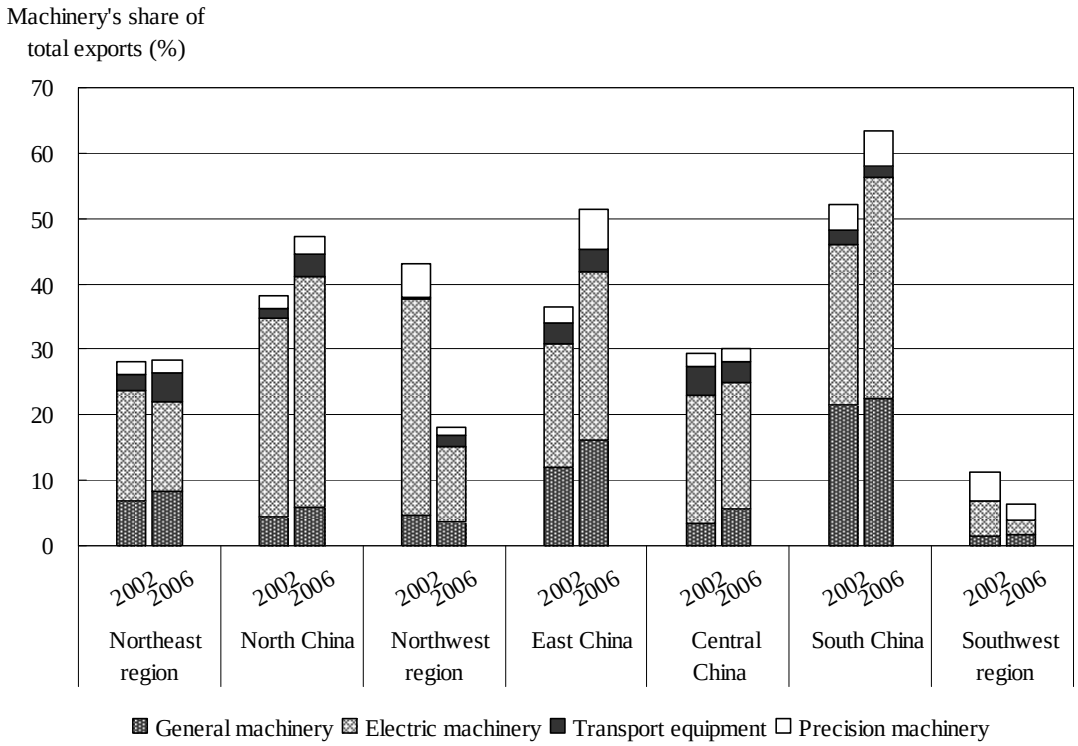


Figure 3. Two-dimensional fragmentation.



Source: Kimura and Ando (2005).

Figure 4. Composition of intra-East Asian machinery exports from China: by region.



Source: Authors' calculation based on the data from World Trade Atlas.