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## Abstract

As economic integration in East Asia progresses, trade patterns within the region are displaying an ever-greater complexity: Though *inter*-industry trade still accounts for the majority, its share in overall trade is declining. Instead, *intra*-industry trade (IIT), which can be further divided into horizontal IIT (HIIT) and vertical IIT (VIIT), is growing in importance.

In this paper, we set out to measure and examine vertical intra-industry trade patterns in the East Asian region and compare these with the results of previous studies focusing on the EU, to which such analyses so far have been confined. Based on the supposition that VIIT is closely related to offshore production by multinational enterprises, we then develop a model to capture the main determinants of VIIT that explicitly includes the role of FDI. The model is tested empirically using data from the electrical machinery industry. The findings support our hypothesis, showing that FDI plays a significant role in the rapid increase in VIIT in East Asia seen in recent years.

JEL Classification: F14, F23

Key Words: Vertical Intra-Industry Trade, Vertical Foreign Direct Investment, East Asia, European Union

## 1. Introduction

Recent studies on intra-industry trade (IIT) have brought to light rapid increases in vertical IIT, i.e. intra-industry trade where goods are differentiated by quality.<sup>1</sup> As Falvey (1981) pointed out in his seminal theoretical paper, commodities of the same statistical group but of different quality may be produced using different mixes of factor inputs. Moreover, developed economies may export physical and human capital-intensive products of high-quality and import unskilled labor-intensive products of low-quality from developing economies. Through this mechanism, an increase in vertical IIT may have a large impact on factor demands and factor prices in Japan and elsewhere.<sup>2</sup>

Vertical IIT is likely to be driven by differences in factor endowments. Consequently, we expect vertical IIT to be more pronounced between developing and developed economies. At the same time, however, developing economies rarely possess the technology to produce commodities that belong to the same statistical categories as the commodities exported by the developed economies, such as telecommunications equipment and advanced office machinery.

Developing economies' main source of advanced technology in recent years probably has been inward direct investment. A major part of vertical IIT may be conducted by multinational enterprises in the context of the international division of labor. In East Asia, efficiency-seeking and export-oriented foreign direct investments (FDI) mainly from Japan and the United States have increased rapidly over the last decade. As a result, we would expect active vertical IIT between developing economies in East Asia and Japan and the United States.

Despite the potential importance of this issue and the fact that theory suggests that the determinants of vertical and horizontal IIT differ, most of previous empirical studies on IIT in East Asia have focused on total IIT without distinguishing between vertical and horizontal

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<sup>1</sup> Several studies on vertical IIT have been conducted for European countries and the United States. Based on trade statistics for the United Kingdom, Greenaway, Hine and Milner (1994), and Greenaway, Hine, and Milner (1995) studied how country- or industry-specific factors affect the relative importance of vertical and horizontal IIT. Aturupane, Djankov and Hoekman (1999) studied the same type of issues in the case of IIT between Eastern Europe and the European Union. Differentiating between vertical and horizontal IIT, Fontagné, Freudenberg, and Péridy (1997) carried out a detailed investigation of trade patterns within the European Union.

<sup>2</sup> The "fragmentation" of production processes, that is, the international division of labor in production processes and the increase in the trade in intermediate inputs of different factor contents, may have the same kind of impact. Feenstra and Hanson (2001) provide a survey of studies on this issue. Several studies have found that multinational enterprises play a key role in the "fragmentation" (see Feenstra and Hanson 1996, Slaughter 2000, Head and Ries 2002, Kimura and Fukasaku 2001, and Kimura 2001). Since there already exist many theoretical and empirical studies on this issue, we do not focus on "fragmentation" in this paper.

IIT.<sup>3</sup> In this paper, we review vertical and horizontal IIT in East Asia and compare it with trade patterns in other regions, particularly the European Union. We will also construct a theoretical model to understand the relationship between vertical IIT and FDI. Based on the model we will conduct an econometric analysis in order to determine what country specific factors determine the size of vertical IIT. For the econometric analysis we will use statistics of Japan's electrical machinery trade at the HS (Harmonized Commodity Description and Coding System) 9-digit level.

The remainder of the paper is organized as follows. In Section 2 we provide an overview of trade and FDI patterns in East Asia and present a descriptive analysis. In Section 3 we review existing theories of IIT and propose a theoretical model which explains the relationship between FDI and vertical IIT. In section 4 we conduct an econometric analysis of the determinants of vertical IIT. Section 5 summarizes the main findings of this paper.

## **2. Descriptive Analysis**

### **2.1. Major Characteristics of Economic Development and Integration in East Asia**

As a first step of our descriptive analysis we present an overview of the trade patterns of the East Asian economies.

In the last two decades, the countries of East Asia accomplished rapid economic growth based on trade expansion. Table 2-1 shows the export-GDP and import-GDP ratios of East Asia and other regions. In the 1980s and 90s, the dependence on international trade increased at an amazing speed in the case of the ASEAN-4, China and Hong Kong. Compared with this, the ratio has not increased substantially for the EU or MERCOSUR. The East Asian countries increased not only their exports of labor-intensive products, such as apparels and leather products, but also of technology-intensive products, such as electrical machinery and telecommunications equipment. Economic development of the "leapfrogging" type has occurred in the East Asian countries. A good example for this is China, which is competitive not only in the export of labor-intensive but also of high-tech products such as office machines and telecommunication apparatuses. The share of China's exports in world total imports is rapidly catching up with Japan's in many high-tech product categories. The share of China's and Hong Kong's combined exports in world total imports

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<sup>3</sup> Abe (1997) and Murshed (2001) studied IIT of the East Asian countries without distinguishing between vertical and horizontal IIT. Based on Japan's trade statistics at the HS 9-digit level, Yoshiike (2002) and Ishida (2002) found that Japan has substantially increased its vertical IIT with the East Asian countries during the last decade. Using relatively aggregated trade data (SITC 3-digit level), Hu and Ma (1999) have studied the vertical IIT of China.

in 1999 was 9.3% in the case of telecommunications and sound recording apparatus (SITC R3 #76) and 6.5% in the case of office machines and automatic data processing machines (SITC R3 #75), whereas Japan's shares in these categories were 11.2% and 9.7% respectively.<sup>4</sup>

#### INSERT TABLE 2-1

In the case of technology-intensive products, we also observe very active IIT among the East Asian countries. In 1999, Japan exported 272.4 billion yen worth of telecommunications equipment and parts (SITC R3 #764) to China and Hong Kong and imported 221.8 billion yen worth of the same products from these two economies. Similarly, in the case of television receivers (SITC R3 #761), Japan exported to and imported from China and Hong Kong 37.5 billion yen and 39.5 billion yen worth of merchandise respectively in 1999.

The East Asian countries' export-led growth has depended not only on regional trade, but also on trade with other regions. Table 2-2 shows the trade matrix of IT-related products for trade among Japan, Asia (excluding Japan), the US and the EU. Compared with the EU countries, which depend more on the regional market, the Asian countries depend on the US and the EU markets.<sup>5</sup> The reason for this is that East Asia is a major supplier of IT products for the world market, not only for the regional market.

#### INSERT TABLES 2-2 and 2-3

A very important role in East Asian development was also played by inward FDI. Table 2-3 shows the inward FDI stock as a percentage of GDP by region. In the case of the East and Southeast Asian countries, excluding Japan, the inward FDI/GDP ratio is very high compared with the EU, North America, or Latin America. It seems that this is the most important characteristic, and that the other characteristics such as export-led growth and leapfrogging-type development pointed out above have mainly been created by active inward FDI. For example, FDI in this region is very export-oriented. Table 2-4 compares the sales destinations of foreign manufacturing affiliates of Japanese and US firms by host region. This table shows that affiliates in East Asia owned by Japanese and US firms are more export oriented than affiliates in other regions. Japanese and US direct investments in East Asia seem to be "vertical" in the sense that manufacturing affiliates are established in order to take

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<sup>4</sup> These data are taken from Statistics Canada, *World Trade Analyzer 1980-99*.

<sup>5</sup> For details on this issue, see Urata (2002).

advantage of cheap labor, and the majority of the output is exported to their home countries or other countries. According to the standard theory of FDI, multinational enterprises tend to conduct FDI of the “vertical type” when there is a huge gap in factor prices between their home and the host country, and when the market of the host country is relatively small and trade costs are not large.<sup>6</sup> Developing economies in East Asia seem to satisfy these conditions and attract “vertical” FDI.<sup>7</sup>

Export-led growth and leapfrogging development is caused by FDI. We can confirm this if we look at the statistics on the production share of affiliates owned by foreign firms in China. In industries which experienced export-led growth, for example garments, leather, and electric and telecommunications equipment, the share of foreign affiliates in value-added is close to or greater than 50%.<sup>8</sup> Thus, it is fair to say that China’s amazing export-led growth in fact has been brought about by foreign firms.

INSERT TABLE 2-4

## 2.2. Measurement of Intra-Industry Trade: Threshold-Based Indices

In order to identify vertical and horizontal IIT we adopt a methodology used by major preceding studies on vertical IIT, such as Greenaway, Hine, and Milner (1995), Fontagné, Freudenberg, and Péridy (1997), and Aturupane, Djankov, and Hoekman (1999). The methodology is based on the assumption that the gap between the unit value of imports and the unit value of exports for each commodity reveals the qualitative differences of the products exported and imported between the two economies.

We break down the bilateral trade flows of each detailed commodity category into the three patterns: (a) *inter*-industry trade (one-way trade), (b) *intra*-industry trade (IIT) in horizontally differentiated products (products differentiated by attributes), and (c) IIT in vertically differentiated products (products differentiated by quality).

$M_{kk'j}$ : value of economy  $k$ 's imports of product  $j$  from economy  $k'$

$M_{k'kj}$ : value of economy  $k'$ 's imports of product  $j$  from economy  $k$

<sup>6</sup> For more details on this issue, see Markusen (1995), Markusen, Venables, Konan and Zhang (1996), and Carr, Markusen and Maskus (2001).

<sup>7</sup> For East Asian manufacturing affiliates owned by foreign firms, trade costs depend on their location and the category of commodities they import and export. These affiliates are located mainly in coastal areas and the infrastructure of East Asian ports is relatively efficient. Additionally, export oriented affiliates can usually get special tariff-reductions for their imports of intermediate inputs. Because of these factors, the affiliates seem to face relatively small trade costs.

<sup>8</sup> For more details, see *China Statistical Yearbook 2001*, National Bureau of Statistics of China, China Statistics Press, Beijing, China 2001. We should note that in China’s statistics affiliates owned by Hong Kong and Taiwanese firms are included under foreign-owned affiliates.

$UV_{kk'j}$ : average unit value of economy k's imports of product j from economy k'

$UV_{k'kj}$ : average unit value of economy k's imports of product j from economy k.

Then the *share* of each trade type is defined as:

$$\frac{\sum_j (M_{kk'j}^Z + M_{k'kj}^Z)}{\sum_j (M_{kk'j} + M_{k'kj})} \quad (2.1)$$

where  $Z$  denotes one of the three intra-industry trade types, i.e., “One-Way Trade” (OWT) “Horizontal Intra-Industry Trade” (HIIT) and “Vertical Intra-Industry Trade” (VIIT) as in Table 2-5.

For our analysis, we chose to identify horizontal IIT mainly by using the range of relative export/import unit values of 1/1.25 (i.e., 0.8) to 1.25. Although most previous studies, such as Abd-el-Rahman (1991), Greenaway, Hine, and Milner (1994), and Fontagné, Freudenberg, and Péridy (1997), mainly use a 15% threshold to distinguish between horizontally and vertically differentiated products, we employ a 25% threshold for the following reasons. First, the value recorded in trade statistics is often affected by exchange rate fluctuations. Second, as we rely on import statistics at the HS88 (Harmonized Commodity Description and Coding System Revised in 1988) 6-digit level in our descriptive comparison between trade in EU and in East Asia, our measurements of unit values are likely to include more noise, caused by the aggregation of different commodities, than the measurements by Fontagné, Freudenberg, and Péridy (1997) who used the classification of the 8-digit “Combined Nomenclature (CN).” In order to test the sensitivity of our results to the range of relative export/import unit values chosen, we also calculate the measures using a 1/1.15 (approx. 0.87) to 1.15 range (a 15% threshold).

**Table 2-5. Categorization of trade types**

Type	Degree of trade overlap	Disparity of unit value
“One-Way Trade” (OWT)	$\frac{\min(M_{kk'j}, M_{k'kj})}{\max(M_{kk'j}, M_{k'kj})} \leq 0.1$	Not applicable
“Horizontal Intra-Industry Trade” (HIIT)	$\frac{\min(M_{kk'j}, M_{k'kj})}{\max(M_{kk'j}, M_{k'kj})} > 0.1$	$\frac{1}{1.25} \leq \frac{UV_{kk'j}}{UV_{k'kj}} \leq 1.25$
“Vertical Intra-Industry Trade” (VIIT)	$\frac{\min(M_{kk'j}, M_{k'kj})}{\max(M_{kk'j}, M_{k'kj})} > 0.1$	$\frac{UV_{kk'j}}{UV_{k'kj}} < \frac{1}{1.25}$ or $1.25 < \frac{UV_{kk'j}}{UV_{k'kj}}$



### 2.3. Data for the Analysis of IIT

We used two sets of trade statistics in this paper. For the analysis of trade patterns in East Asia and the EU we used the PC-TAS (Personal Computer Trade Analysis System) published by the United Nations Statistical Division. This dataset provides us with bilateral trade data of almost all the countries at the 6-digit HS88 commodity classification for the years 1996 to 2000.<sup>9</sup> For the calculation of the IIT measures, we used the importing countries' data. For the analysis of Japan's trade patterns for electrical machinery products (HS88 2-digit code: 85) we used Japan's Custom data provided by the Ministry of Finance (MOF). Japan's Custom data are recorded at the 9-digit HS88 level and the data classified by HS88 are available from the year 1988.<sup>10</sup>

We should note several drawbacks of the PC-TAS data. First, because of the lack of data on trade volumes, we were unable to decide the trade patterns (OWT, VIIT, and HIIT) for many commodities. Therefore the coverage of commodities used for our analysis is not high.<sup>11</sup> Second, in the compilation process of the PC-TAS, trade data of less than 50,000 US dollars are excluded.<sup>12</sup> If we do not make adjustment for this cut-off procedure, our estimation of OWT shares will be biased upwards. For this reason, we did not use trade data of commodities where the import value was not recorded for one of the pair countries in the PC-TAS.<sup>13</sup> Third, trade data for Taiwan are not included in the PC-TAS.

Compared with the PC-TAS data, Japan's Custom statistics are much better. The data cover a longer period (1988-2000), and the unit values based on HS 9-digit level data are more reliable than those based on 6-digit level data.<sup>14</sup>

In the case of Japan's Custom statistics, export data are recorded on an f.o.b. basis while import data are on a c.i.f. basis. We adjusted the discrepancy between the export and

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<sup>9</sup> Other versions of the PC-TAS exist for earlier periods which, however, are based on other commodity classifications. We tried to combine the PC-TAS for 1992-1996, which is based on the SITC R3 5-digit standard with the PC-TAS for 1996-2000, which is based on the HS88 6-digit standard, but could not get stable results.

<sup>10</sup> The 9-digit HS88 code has been changed several times for some items, and the HS code was revised in 1996. Using the code correspondence tables published by the Japan Tariff Association for code changes, we made adjustments to make statistics consistent with the original HS88 code.

<sup>11</sup> In the case of Japan's trade with China in 2000, the coverage was 57.1 percent.

<sup>12</sup> When there is at least one year (during 1996-2000) in which the trade value of a certain commodity exceeds the cut-off level of 50,000 US dollars, the trade values of this commodity for the other years are reported in PC-TAS, even if the trade values of the other years are less than this cut-off level. In this sense, the cut-off threshold is applied in an irregular manner.

<sup>13</sup> As a result, our estimations of IIT shares are biased upwards. When the import value of one of the pair countries is not recorded, that is, less than 50,000 US dollars, then the other country's imports of this commodity are usually not very large either. Therefore, we presume the biases are not serious.

<sup>14</sup> At the 9-digit level, the commodity classifications for imports are usually different from the classifications for exports. Based on the definition of each classification, we adjusted for these differences.

import data in the following way. First, using the PC-TAS data, we calculated the sum of Japan's import value (c.i.f. basis) of electrical machinery (HS88 2-digit code: 85) from all the trading partners for 1996-2000. Next, using the PC-TAS data, we also calculated the sum of the trading partners' export value (f.o.b. basis) of electrical machinery to Japan for 1996-2000. Then, we calculated the ratio of Japan's total imports (c.i.f. basis) to the trading partners' total exports to Japan (f.o.b. basis), which was 1.1235. In order to convert the export data of Japan's Custom statistics to a c.i.f. basis, we multiplied all the export value data by 1.1235.<sup>15</sup>

Appendix Table B shows details of our Custom data on electrical machinery for the case of Japan's trade with China for the year 2000. Commodities are listed in a descending order of trade values (sum of exports plus imports) between Japan and China. The table contains information on the top 10 commodities. These 10 commodities cover 33 percent (594 billion yen) of all the electrical machinery trade between the two countries, which consists of 309 commodities in our adjusted classification.<sup>16</sup> We could identify trade patterns for all the top 10 commodities. Two commodities were classified as OWT. Two commodities were classified as HIIT. The remaining six commodities were classified as VIIT. In the case of these six commodities, the unit values of Japan's exports were greater than China's. In vertical IIT with China, Japan mainly exports products of higher unit value.

#### **2.4. Comparison Between Trade Patterns in East Asia and the EU**

In this section, using the data of the PC-TAS we will compare IIT in East Asia with that in the EU. For the purpose of this study, East Asia includes China, the ASEAN-4 (Indonesia, Malaysia Thailand, Philippines), the NIE3 (Hong Kong, Korea, Singapore), and Japan. We will use the EU as a benchmark case for our analysis of East Asia. In East Asia, there exist much higher barriers against intra-regional trade and FDI than in the EU. These barriers are likely to reduce IIT within East Asia. On the other hand, there is a huge income gap among countries in East Asia. Probably this gap enhances vertical IIT because of the differences in labor costs and other factor prices. At the same time, this gap is likely to reduce horizontal IIT because of the differences in industrial structure and preferences (Helpman and Krugman 1985).

Table 2-6 shows the shares of the three trade types (OWT, VIIT, and HIIT) and the Grubel-Lloyd index in intra-EU and intra-East Asian trade for all the commodities. Consistent with our above arguments, the share of IIT and the Grubel-Lloyd index are much

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<sup>15</sup> The gap between c.i.f. and f.o.b. might be a function of the distance between Japan and its trade partners. By calculating the c.i.f. and f.o.b. ratio for each of Japan's trade partners we tested this hypothesis but did not find a significant effect.

<sup>16</sup> In our descriptive and econometric analysis we used data of all the commodities.

higher in the EU. The share of HIIT in East Asia is very low. We should also note that the share of VIIT in East Asia has increased substantially (by 7.1 percentage points) over the past five years.

INSERT TABLE 2-6

Figures 2-1 and 2-2 show the shares of the three trade types in intra-EU and intra-East Asian trade for each commodity category. The commodity classification we used is explained in Appendix A. These figures are simplex diagrams. A set of shares of the three trade types is expressed as one point in the diagram. The distance between this point and the horizontal line HIIT-VIIT denotes the share of OWT. Similarly, the distance between this point and the line OWT-VIIT denotes the share of HIIT. The starting point of each arrow corresponds to the value for the year 1996 and the end of the arrow corresponds to the value for 2000. Although the figures for East Asia are located towards the upper right in comparison with those for the EU, there is a similar pattern in terms of the differences between commodity groups. In both the regions, OWT dominates the trade in agricultural and mining products. The share of VIIT is relatively high in the trade in machinery.

There also exist some differences between the EU and East Asia. In East Asia, the share of VIIT is exceptionally high in the trade in electrical machinery and general and precision machinery. We should note that in East Asia, export oriented FDI is most active in the production of these goods. In the EU, the shares of VIIT and HIIT are very high not only in the trade in this type of machinery but also in the trade in many other manufacturing products, such as chemical products, transportation machinery, and wood and paper products.

INSERT FIGURES 2-1 and 2-2

It is important to note that the commodity composition of intra-East Asian trade is very different from that of intra-EU trade. In the trade of East Asia, the shares of electrical machinery and general and precision machinery are very high (30.5% and 19.2% respectively versus 10.7% and 18.1% for the EU), while the shares of transportation machinery and chemical products are very low in comparison with the EU (2.3% and 9.0% versus 16.0% and 15.5%). These differences and the fact that the IIT shares are very high in the EU trade in transportation machinery and chemical products seem to imply that IIT has contributed to the increase in trade volumes in both regions.

To finish off the comparison between East Asia and the EU, let us examine differences in

IIT patterns among countries. Figures 2-3 and 2-4 show the shares of three trade types for each country. In the case of the EU, the most developed and large economies, such as Germany and France, have the highest shares of VIIT and HIIT. In the case of East Asia, there seems to be no simple country factor by which we can explain differences in IIT patterns among the countries. Although Japan and Korea are relatively advanced and large, the VIIT shares of these countries are lower than those of Singapore, the Philippines, and Malaysia. We should also note that in East Asia, the share of IIT is rapidly increasing for many developing countries. In the EU, with the exception of Ireland and Portugal, the share of IIT has remained almost constant for most countries.

INSERT FIGURES 2-3 and 2-4

### **2.5 Japan's Foreign Direct Investment and Intra-Industry Trade with East Asia: The Case of the Electrical Machinery Industry**

As has been shown, vertical IIT has been increasing rapidly in East Asia in recent years, particularly in the electrical machinery industry. Although the share of vertical IIT in total trade in East Asia is still much lower than that in EU, it has grown remarkably from 31% in 1996 to 43% in 2000 in the electrical machinery industry while during the same period the corresponding share in EU increased only slightly from 52% to 58%. In this subsection, using Japan's bilateral trade data provided by the Ministry of Finance (MOF) of Japan, we further investigate the intra-industry trade of electrical machinery between Japan and other East Asian countries. The MOF trade data are recorded at the 9-digit HS88 level and the data classified by HS88 are available from the year 1988.

Figure 2-5 shows the share of the trade types for Japan's trade in electrical machinery industry by partner region or economy in 1988, 1994 and 2000. This figure reveals a dramatic increase of VIIT in Japan's trade with China and the ASEAN countries from 1988 to 2000. Now let us look at the trends of the VIIT share in Japan's trade with each East Asian country. Figure 2-6 confirms that the share of VIIT in the bilateral trade between Japan and China grew remarkably from less than 10% in 1988 to nearly 60% in 2000. As for the ASEAN countries, the VIIT share increased during the period for all the countries except Malaysia (though in the trade with the Philippines the share largely fluctuated while in the trade with Thailand, it remained relatively stable during the 1990s).

INSERT FIGURES 2-5 and 2-6

What factors have contributed to the recent increase of VIIT in East Asia? As widely perceived, Japanese MNEs in the electrical machinery industry have been actively expanding their overseas production since the late 1980s. According to METI (2001), the ratio of overseas production for the Japanese electrical machinery industry rose from 11.4% in 1990 to 20.8% in 1998, which is much higher than the average overseas production ratio for overall manufacturing, which stood at 13.1% in 1998. Moreover, 8.5% out of the 20.8% is attributed to the Asian region, while 7.0% accrues to North America and 4.6% to Europe. Table 2-7 presents the estimated sales amount by Japanese-affiliated firms in the electrical machinery industry in 1988, 1994, and 2000. Looking at the share of each region or country in total sales by Japanese-affiliated firms, China and the ASEAN countries increased their shares remarkably from 1988 to 2000. It would seem, therefore, that the boost in overseas production by Japanese MNEs in China and the ASEAN countries has been promoting VIIT between Japan and these countries.

INSERT TABLE 2-7

### 3. Theoretical Analysis of Vertical Intra-Industry Trade

Although many empirical studies on VIIT expected that FDI would have a positive impact on VIIT, they did not provide a formal model to explain this relationship.<sup>17</sup> In this section, we present a simple theoretical model to understand this relationship. Basically, we introduce FDI into the partial equilibrium and continuum of commodities version of Falvey's (1981) model.

#### 3.1. A Model of Vertical Intra-Industry Trade and Foreign Direct Investment

We assume the existence of two countries ( $h$  and  $f$ ) and two factors, labor ( $L$ ) and capital ( $K$ ). We study a partial equilibrium in one manufacturing industry, such as electrical or general machinery. Suppose that a continuum of commodities  $[\underline{n}, \underline{n}+1]$  is produced in this industry. For each commodity, there is a continuum of different qualities  $[0, 1]$ . We assume that each "commodity" in our model corresponds to one product item in the most detailed commodity classification of trade statistics and the difference in "quality" is not recorded as a difference in products in the statistics.

Each commodity is produced subject to a Leontief-type production function. There is no technology gap between the two countries. The production function for product  $(n, q)$ , that is, commodity  $n$  of quality  $q$ , is defined by

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<sup>17</sup> For example, see Greenway, Hine, and Milner (1995), Fontagné, Freudenberg, and Péridy (1997), Hu and Ma (1999), and Aturupane, Djankov, and Hoekman (1999).

$$y_{n,q} = \min\left[\frac{1+k_{n,q}}{k_{n,q}}K_{n,q}, (1+k_{n,q})L_{n,q}\right] \quad (3.1)$$

where  $K_{n,q}$  and  $L_{n,q}$  denote the capital and labor input.  $k_{n,q}$  denotes the capital-labor ratio in this production.  $k_{n,q}$  is assumed to be the following function of  $n$  and  $q$ :

$$k_{n,q} = an + b(q - 0.5) \quad (3.2)$$

Parameters  $a$  and  $b$  are constant positive values. As  $n$  approaches  $\underline{n}+1$  and  $q$  approaches 1, the commodity becomes more capital intensive.

It is assumed that the factor endowment pattern is different between the two countries and the factor price equalization mechanism is limited, so that there remains a factor price gap between the two countries in trade equilibrium. The home country is assumed to be more abundant in capital and the two countries' factor prices satisfy

$$w_f < w_h < r_h < r_f \quad (3.3)$$

where  $r_i$  and  $w_i$  denote the real rental price of capital and the real wage rates in country  $i$ . Since we analyze the partial equilibrium of one industry, we treat these factor prices as constant. The marginal production cost of product  $(n, q)$  in country  $i$  is given by

$$MC_{n,q}^i = w_i + \frac{k_{n,q}}{1+k_{n,q}}(r_i - w_i) \quad (3.4)$$

INSERT FIGURE 3-1

Figure 3-1 shows the marginal cost of this industry's product in the two countries. The horizontal axis denotes the commodity index  $n$  and the vertical axis denotes the marginal production cost of product  $(n, q)$ . The curve  $MC_{n,0}^i$  denotes the relationship between the commodity index  $n$  and the marginal production cost of the lowest-quality product ( $q=0$ ) of each commodity  $n$  in country  $i$ . Similarly, the curve  $MC_{n,1}^i$  denotes the relationship between the commodity index  $n$  and the marginal production cost of the highest-quality product ( $q=1$ ) of each commodity  $n$  in country  $i$ . For each quality of products  $q$ , the curve of the foreign country is steeper than that of the home country. For each country, the horizontal distance between the two curves is constant and equal to  $b/a$ . Since country  $h$  is abundant in capital, the marginal production cost of capital intensive products in country  $h$  is lower than that in country  $f$ . Equation 3.4 implies that the critical value of the capital-labor ratio  $k^*$  is given by

$$k^* = \frac{W_h - W_f}{r_f - r_h} \quad (3.5)$$

In the case of products with a capital-labor ratio smaller than  $k^*$ , the marginal production cost in the foreign country is lower than that in the home country. From Equation 3.2 we can show that country  $h$  has the lower production cost for the capital intensive commodities  $[(k^*+0.5b)/a, \underline{n}+1]$  of all the qualities  $[0, 1]$  and country  $f$  has the lower production cost for the labor intensive commodities  $[\underline{n}, (k^*-0.5b)/a]$  of all the qualities  $[0, 1]$ .<sup>18</sup> In the case of the intermediate commodities  $[(k^*-0.5b)/a, (k^*+0.5b)/a]$ , county  $h$  has the lower production cost for the high-quality products, of which the capital-labor ratio is greater than  $k^*$  and country  $f$  has the lower production cost for the low-quality products, of which the capital-labor ratio is smaller than  $k^*$  (Figure 3-1).

Next we explain the product markets of our model. Each product  $(n, q)$  is produced by many firms in monopolistic competition. It is assumed that each firm needs to conduct a fixed amount of R&D activity in order to obtain the production technology for each commodity. To simplify our analysis we assume that the fixed cost ( $R$ ) is identical in the two countries. The production technology for commodity  $n$  is applicable for products  $(n, q)$  with any quality  $q$ . That is, a firm can produce commodity  $n$  of any quality once it obtains the necessary technology. This assumption will play a key role in our model.

Let  $[0, j(n)]$  denote the set of firms that produce commodity  $n$ . We assume that the elasticity of substitution between different kinds of commodity ( $n$ ) is one. And within each type of commodity, the elasticity of substitution between different levels of quality and different firms' output is  $1/(1-\sigma)$ . We assume  $0 < \sigma < 1$ . For the time being, we also assume that trade costs are zero. Later we will introduce trade costs into our model. The world demand for firm  $j$ 's product  $(n, q)$  is given by

$$\left( \frac{P_{n,q,j}}{P_n} \right)^{\frac{1}{1-\sigma}} \frac{E}{P_n j(n)} \quad (3.6)$$

where  $E$  denotes the world total real expenditure on commodity  $n$ . We treat  $E$  as constant and identical for all  $n$  and  $q$ .  $P_n$  is defined by

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<sup>18</sup> We assume that the parameters satisfy  $\underline{n} < (k^*-0.5b)/a$  and  $(k^*+0.5b)/a < \underline{n}+1$ .

$$P_n = \left( \frac{1}{j(n)} \int_0^1 \int_0^{j(n)} p_{n,q,j}^{-\frac{\sigma}{1-\sigma}} djdq \right)^{\frac{1-\sigma}{\sigma}} \quad (3.7)$$

We assume free market entry. The number of suppliers of commodity  $n$ ,  $j(n)$  is determined by the zero profit condition, which will be presented later.

We define a multinational firm as one that conducts manufacturing activities in both the countries. We assume that firms incur a fixed cost ( $M$ ) to become a multinational.<sup>19</sup> It is also assumed that firms in the developed economy (country  $h$ ) become multinationals more easily than firms in the developing economy (country  $f$ ). That is, the fixed cost for country  $h$  firm ( $M_h$ ) is lower than that for country  $f$  firm ( $M_f$ ). Under this assumption all the multinationals are country  $h$  firms in our model.

In the remainder of this section, we will study how trade patterns are influenced by FDI costs, trade costs, and the factor price gap between the two countries. In particular, we will study the following three situations: first, zero trade costs coupled with prohibitively high FDI costs; second, zero trade and FDI costs; and third, substantial trade costs and zero FDI costs.

### 3.2. Trade Patterns Under High FDI Costs and Low Trade Costs

Let us first study a situation in which the fixed cost of FDI,  $M_h$  is so large that no multinational firms exist. However, the trade costs are assumed to be negligible. Under these conditions, if a firm in country  $h$  produces commodity  $n$  of all levels of quality  $[0, 1]$ , its profit will be<sup>20</sup>

$$\pi_n^h = \frac{1-\sigma}{\sigma} \frac{E}{P_n j(n)} (\sigma P_n)^{\frac{1}{1-\sigma}} \int_0^1 \left( w_h + \frac{k_{n,q}}{1+k_{n,q}} (r_h - w_h) \right)^{-\frac{\sigma}{1-\sigma}} dq - R \quad (3.8)$$

If a firm in country  $f$  produces this commodity of all the levels of quality  $[0, 1]$ , its profit will be

<sup>19</sup> See, e.g., Horstmann and Markusen (1992) for a similar incorporation of fixed costs associated with the establishment of foreign subsidiaries.

<sup>20</sup> Since the price elasticity of the demand function (3.6) is a constant value, i.e.  $1/(1-\sigma)$ , the mark-up rate also takes the constant value  $1/\sigma-1$ . By producing product  $(n, q)$ , this firm will obtain

$$\frac{1-\sigma}{\sigma} \frac{E}{P_n j(n)} (\sigma P_n)^{\frac{1}{1-\sigma}} (MC_{n,q}^h)^{-\frac{1}{1-\sigma}}$$

By integrating the above value for all the levels of quality  $[0, 1]$  and subtracting the fixed cost  $R$ , we get equation (3.8).



$$\pi_n^f = \frac{1-\sigma}{\sigma} \frac{E}{P_n j(n)} (\sigma P_n)^{\frac{1}{1-\sigma}} \int_0^1 \left( w_f + \frac{k_{n,q}}{1+k_{n,q}} (r_f - w_f) \right)^{\frac{\sigma}{1-\sigma}} dq - R \quad (3.9)$$

Because of the assumption of free market entry, firms in only one of the two countries will survive to produce each commodity  $n$  in equilibrium. From the above two equations we can easily show that there exists a critical value of the commodity index,  $n^*$ , and that country  $f$  specializes in the production of commodities  $[\underline{n}, n^*]$  and country  $h$  specializes in the production of commodities  $[n^*, \underline{n}+1]$ . The critical value  $n^*$  is determined by the following equation.<sup>21</sup>

$$\int_0^1 \left( w_h + \frac{k_{n^*,q}}{1+k_{n^*,q}} (r_h - w_h) \right)^{\frac{\sigma}{1-\sigma}} dq = \int_0^1 \left( w_f + \frac{k_{n^*,q}}{1+k_{n^*,q}} (r_f - w_f) \right)^{\frac{\sigma}{1-\sigma}} dq \quad (3.10)$$

In this equilibrium, the number of suppliers of commodity  $n$ ,  $j(n)$  is determined by the zero-profit condition. Using the definition of the price index (3.7) and equations (3.8) and (3.9), we can express the zero-profit condition as

$$R = \left( \frac{1}{\sigma} - 1 \right) \frac{E}{j(n)} \quad (3.11)$$

The left-hand side denotes R&D expenditure and the right-hand side denotes a representative firm's total profit from the production of commodity  $n$ . The above equation implies that the number of suppliers will be identical for all the commodities.

Figure 3-2 shows the production pattern in a trade equilibrium under prohibitively high FDI costs coupled with zero trade costs. The horizontal axis denotes the index of commodity  $n$ . The vertical axis denotes the capital-labor ratio. The parallelogram denotes the set of all products  $(n, q)$ . The set of products which is expressed by the shaded part of the parallelogram is produced in country  $h$ . In this case, there is no intra-industry trade.

INSERT FIGURE 3-2

### 3.3. Trade Patterns Under Low Costs of FDI and Trade

Next we study the case in which the fixed cost of FDI for home country firms,  $M_h$ , is very small. We still assume that trade costs are negligible. Firms in the home country will choose to become multinationals, if the benefit from the international division of labor within

<sup>21</sup> We assume that there exists  $n^*$  which satisfies  $\underline{n} < n^* < \underline{n}+1$ .

the firm is greater than the fixed cost of the FDI. They will produce high-quality products, of which the capital-labor ratio is greater than  $k^*$  in country  $h$ , and produce low-quality products, of which the capital-labor ratio is smaller than  $k^*$ , in country  $f$ . This FDI is “vertical” in the sense that manufacturing affiliates are established in order to take advantage of cheap labor and a large part of the output is exported to the multinational’s home country.

If a firm of country  $h$  that produces commodity  $n$  becomes a multinational, its profit will be

$$\begin{aligned} \pi_n^M &= \frac{1-\sigma}{\sigma} \frac{E}{P_n j(n)} (\sigma P_n)^{\frac{1}{1-\sigma}} \left[ \int_0^{0.5+\frac{k^*-an}{b}} \left( w_f + \frac{k_{n,q}}{1+k_{n,q}} (r_f - w_f) \right)^{\frac{\sigma}{1-\sigma}} dq \right. \\ &+ \left. \int_{0.5+\frac{k^*-an}{b}}^1 \left( w_h + \frac{k_{n,q}}{1+k_{n,q}} (r_h - w_h) \right)^{\frac{\sigma}{1-\sigma}} dq \right] - M_h - R \end{aligned} \quad (3.12)$$

If this firm produces commodity  $n$  of all the levels of quality  $[0, 1]$  in country  $h$ , its profit will be given by equation (3.8). By comparing equations (3.8) and (3.12) we can easily show that commodities  $[(k^*-0.5b)/a, (k^*+0.5b)/a]$  will be produced by multinationals.

In the case of these commodities, the number of firms  $j(n)$  is determined by the following zero-profit condition.

$$\pi_n^M = 0$$

Using the definition of the price index (3.7) and (3.12), we can easily show that the above zero-profit condition becomes identical with equation (3.11), which is the zero-profit condition under high FDI costs and low trade costs.

We can show that the capital intensive commodities  $[(k^*+0.5b)/a, \underline{n}+1]$  of all qualities  $[0, 1]$  are produced by country  $h$  firms in country  $h$  and the labor intensive commodities  $[\underline{n}, (k^*-0.5b)/a]$  are produced by country  $f$  firms in country  $f$ . Again, the number of firms  $j(n)$  is determined by the zero-profit condition (3.11). In the case of these commodities, only inter-industry trade occurs.

In the case of commodities  $[(k^*-0.5b)/a, (k^*+0.5b)/a]$ , two-way trade is conducted. Since we have assumed that each “commodity” in our model corresponds to one product item in the most detailed commodity classification of trade statistics and the difference in “quality” is not recorded as a difference in products in the statistics, international trade in commodities  $[(k^*-0.5b)/a, (k^*+0.5b)/a]$  will be regarded as IIT. Using Figure 3-1 we can easily show that for each commodity  $n$ , which satisfies  $(k^*-0.5b)/a < n < (k^*+0.5b)/a$ , the average unit value of

developed country  $h$ 's exports is higher than the average unit value of developing country  $f$ 's exports. Intra-industry trade with a vertical division of labor occurs for these commodities. Figure 3-3 shows the production pattern when the costs of FDI and trade are very small. Under these circumstances, the share of vertical IIT in total trade is large. The products expressed by the parallelogram  $efgh$  are subject to vertical IIT while the products expressed by the two parallelograms,  $abfe$  and  $hgcd$  are subject to inter-industry trade.

Under very low costs of FDI and trade, country  $h$  specializes more in the production of the capital-intensive products than would be the case with high FDI costs (Figure 3-2). What is more, VIIT caused by FDI reduces the demand for labor in country  $h$  and the demand for capital in country  $f$ .

INSERT FIGURE 3-3

If the fixed cost of FDI,  $M_h$ , is not negligible, the set of commodities that are produced by multinationals will be smaller. In the case of commodities that are included in the set  $[(k^*-0.5b)/a, (k^*+0.5b)/a]$  but close to the border values  $(k^*-0.5b)/a$  or  $(k^*+0.5b)/a$ , gains from the international division of labor within a firm are surpassed by FDI costs and firms do choose not to become a multinational. If there exist substantial costs of FDI, the set of commodities subject to VIIT will be narrower than the corresponding set in the case of negligible FDI costs.<sup>22</sup> And the share of vertical IIT in total trade will become smaller than that in the case of negligible FDI costs.

It is important to note that if the factor-price gap between the two countries is small, then firms will have limited incentive to engage in the international division of labor through FDI and the set of commodities subject to VIIT will become narrower. For example, if the two countries have almost identical factor prices, even relatively small FDI costs will stifle vertical FDI and vertical IIT.

### 3.4. Trade Patterns Under Low FDI Costs and High Trade Costs

Next, let us study the effects of trade costs. In order to keep our analysis tractable, we assume again that FDI costs for firms in country  $h$ ,  $M_h$ , are negligible. Let  $T_{h,f}$  denote one plus the cost factor of trading products from country  $h$  to country  $f$ . Moreover, for the time being, we assume that  $T_{f,h}$ , the cost factor of trading products in the reverse direction from country  $f$  to country  $h$ , is zero. Under these assumptions, firms from country  $h$  will have an

<sup>22</sup> More rigorously, we should note that the increase of the number of multinational firms will cause a decline in  $P_n$  and reduce the incentive for firms to become a multinational. Therefore, at a certain value of  $n$  multinational firms and non-multinational firms co-exist.

incentive to conduct local market oriented FDI in country  $f$ . At home in country  $h$  they will then produce relatively capital-intensive products. Let  $E_f$  denote country  $f$ 's total expenditure on commodity  $n$ . And let  $P_{n,f}$  denote the average price (including trade costs) of commodity  $n$  in country  $f$ . If a firm, in order to serve the market in country  $f$  with product  $(n, q)$ , decides to replace its exports from country  $h$  with local production in country  $f$ , its profits will be changed by

$$\frac{1-\sigma}{\sigma} \frac{E}{P_n j(n)} (\sigma P_n)^{\frac{1}{1-\sigma}} \left[ \left( w_f + \frac{k_{n,q}}{1+k_{n,q}} (r_f - w_f) \right)^{\frac{\sigma}{1-\sigma}} - T_{h,f} \frac{\sigma}{1-\sigma} \left( w_h + \frac{k_{n,q}}{1+k_{n,q}} (r_h - w_h) \right)^{\frac{\sigma}{1-\sigma}} \right]$$

The sign of the above value is positive for  $k_{n,q}$  that satisfies

$$k_{n,q} < \frac{T_{h,f} w_h - w_f}{r_f - T_{h,f} r_h} \quad (3.13)$$

Figure 3-4 shows the production pattern under high trade costs.  $k_1$  on the vertical axis denotes the right-hand-side of the inequality (3.13). In the case of products where the capital-labor ratio takes a value between  $k^*$  and  $k_1$ , firms in country  $h$  will replace their exports from country  $h$  with local production in country  $f$ . Under these circumstances, country  $f$  affiliates owned by firms in country  $h$  will produce a large amount. They will produce products expressed by the parallelogram  $abcd$  for the country  $f$  market plus the triangle  $aeb$  for the two countries as a form of international division of labor. In contrast with these large activities of multinationals, vertical IIT is very small. Only the products expressed by the two shaded triangles are subject to vertical IIT.<sup>23,24</sup> The multinational firms' production of products  $abcd$  can be regarded as "horizontal" type of FDI in the sense that their manufacturing affiliates in country  $f$  are established in order to avoid trade costs and all the output is supplied to the local market.

If  $T_{f,h}$ , the cost factor on trading products from country  $f$  to country  $h$ , is large, then the firms will start to produce labor-intensive products in country  $h$ . Again, trade costs reduce

<sup>23</sup> Using a general equilibrium model with no FDI, Falvey (1981) has already shown that import tariffs serve to widen the range of non-traded qualities.

<sup>24</sup> If we introduce scale economies at the plant level then the effects of trade costs on FDI and trade patterns will depend on the market size of the two countries.

vertical IIT substantially.

#### INSERT FIGURE 3-4

The main results of our theoretical analysis can be summarized as follows.

- (1) Vertical intra-industry trade is a fragile flower, which flourishes only when both FDI costs and trade costs are small. If there exist substantial FDI costs, gains from the international division of labor within firms will be surpassed by FDI costs; firms in the developed country will not conduct “vertical” FDI which, in our model, is indispensable for vertical IIT. If it is very costly to trade products from the developed country to the developing country, then firms in the developed country will replace their exports from their home country with local production in the developing country. Because of this “horizontal” FDI, vertical IIT becomes very small.
- (2) If there exist substantial costs of FDI, the share of vertical IIT in total trade will depend on the factor price gap between the two countries. If the factor price gap is small, then firms will have limited incentive to engage in the international division of labor through FDI, and vertical IIT will become small.

#### **4. An Econometric Analysis of the Determinants of Japan’s Intra-Industry Trade**

##### **4.1. The Method of Estimation**

So far we have seen that vertical IIT has been rapidly growing in importance in the East Asian countries. As described in the previous section, perhaps FDI is an important determinant of vertical IIT.

In the past twenty years, a number of studies have empirically tested for country- and industry-specific influences on intra-industry trade (for example, Balassa 1986, Balassa and Bauwens 1987, Bergstrand 1990, Stone and Lee 1995, etc.). However, most of the previous results, using Grubel-Lloyd intra-industry trade indexes, do not distinguish between horizontal and vertical IIT even though theory suggests their determinants will differ. More recently, Greenaway, Hine and Milner (1994, 1995), Fontagné, Freudenberg and Périddy (1997), Durkin and Krygier (2000), and others did make such a distinction in their data and tested for the determinants of horizontal and vertical IIT separately, employing a methodology which builds on the work of Abd-el-Rahman (1991).<sup>25</sup> Examining the trade of the UK with

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<sup>25</sup> In addition to the studies listed above, Aturupane, Djankov and Hoekman (1999) analyze the determinants of vertical and horizontal IIT between the EU and Central and Eastern European transition economies, while Hu and Ma (1999) focus on China, making a distinction between vertical and horizontal IIT.

62 countries in the year 1988, Greenaway, Hine and Milner (1994) focus on whether the pattern of IIT was related to country-specific factors and find that both market size and membership of a customs union are relevant to the explanation of the pattern of vertical IIT. In their results, however, relative factor endowments do not seem to support the neo-factor proportions model. Their results seemed to accord with Linder-type trade. That is, their results suggest that much vertical IIT arises from similarities in tastes among consumers across different countries rather than from differential endowments of capital and labor. On the other hand, Durkin and Krygier (2000), examining US bilateral IIT with 20 OECD trading partners for the years 1989-92, find evidence of a positive and significant relationship between differences in GDP per capita and the share of vertical IIT. Contrary to the results of Greenaway, Hine and Milner (1994), the findings of Durkin and Krygier (2000) support the view that IIT may be positively related to differences in relative wages and, to the extent that differences in GDP per capita and relative wages are correlated, differences in per capita GDP.<sup>26</sup>

Fontagné, Freudenberg and Péridy (1997) construct a four-dimensional panel data set (i.e. time, industry, reference countries and partner countries) on intra-EC vertical and horizontal IIT for the period from 1980 to 1994, and conduct an econometric analysis of the determinants of IIT. They find that the difference in factor endowments between countries, proxied by the difference in per capita income, reduces horizontal IIT but increases vertical IIT. Moreover, they include an indicator of bilateral FDI, a proxy for the in-depth integration of economies, as an explanatory variable, and find that FDI leads to greater trade in both vertical and horizontal IIT.

Although some of these studies mentioned the importance of FDI and mostly found a positive relationship between FDI and IIT, the mechanism of how FDI has enhanced the international division of labor and consequently increased IIT has not been well explained and adequately examined. Moreover, as for vertical and horizontal IIT in Asia, hardly any comprehensive empirical studies have been conducted although many researchers have been investigating total IIT (not making a distinction between vertical and horizontal IIT). A rare exception is Hu and Ma's (1999) study on China, in which the dependent variable, the bilateral vertical/horizontal IIT index, is aggregated over industrial groups of SITC 3, 6, 7, and 8. By examining bilateral trade with 45 countries, the study finds a significant positive

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<sup>26</sup> Durkin and Krygier (2000) explain that their regression results differ from those in Greenaway, Hine and Milner (1994) because: 1) the sample in Greenaway, Hine and Milner (1994) includes some developing as well as developed countries; 2) the absolute levels of GDP enter slightly differently as regressors; and 3) Greenaway, Hine and Milner (1994) do not run fixed-effects regressions.

relationship between FDI and vertical IIT. However, the FDI variable used in their study is the total amount of China's inward FDI from the partner countries, not inward FDI data by industry.<sup>27</sup> Analyses using industry-level FDI data have been extremely difficult because of the limited data availability for Asian countries.

In this section, we test for the determinants of bilateral vertical IIT between Japan and her 43 major trading partners for the period from 1988 to 2000, taking the electrical machinery industry as a case.<sup>28</sup> Because of the limitations of the PC-TAS data mentioned in Section 2, Japan's bilateral trade data at the 9-digit HS88 level provided by the Ministry of Finance (MOF) are used for the econometric analysis, which allows us to cover a much longer period and more partner countries.<sup>29</sup> As argued in Section 2.5, vertical IIT in Japan's trade with China and the ASEAN economies in electrical and machinery products has been growing rapidly in recent years. At the same time, the Japanese electrical machinery industry has been vigorously pursuing FDI and is characterized by an active international division of labor. Given that China and the ASEAN countries are among the largest recipients of Japanese FDI, we would expect FDI to be a major driving force behind the increase in vertical IIT as shown in the theoretical analysis in the previous section. Thus, the hypotheses formulated in Section 3 are tested using the following equations:

$$Y_{kk't} = \alpha_0 + \alpha_1 FDI_{kk't} + \alpha_2 DGDPPC_{kk't} + \alpha_3 DIST_{kk'} + \alpha_4 INDSIZE_{kk't} + \alpha_5 DREG_k + \alpha_6 D_t + \varepsilon_{kk't} \quad (4.1)$$

where

$y_{kk't}$  = SHVIIT, LTSHVIIT

$FDI_{kk't}$  : foreign direct investment

$DGDPPC_{kk't}$  : comparative advantage (and human capital)

$DIST_{kk'}$ : geographic distance

$INDSIZE_{kk't}$ : size of the industry

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<sup>27</sup> The total amount of FDI includes investment in natural resource seeking and/or in sales establishments, etc. Although it is certainly more appropriate to use industry-level FDI data to capture the size of activities in each industry, there are no comprehensive FDI data by industry and by country for Asian countries.

<sup>28</sup> The list of the forty-three countries used in the regression analysis is presented in Appendix Table C1. Japan's trading partners included in the econometric analysis are limited to these forty-three countries based on the availability of data for constructing explanatory and instrumental variables.

<sup>29</sup> As the Japanese trade data provided by MOF include quantity data for most HS 9-digit products, the coverage of products used for the calculation of IIT indexes becomes much wider than with the PC-TAS data. However, an important deficiency of the MOF trade data is that exports are recorded on an f.o.b. basis while imports are on a c.i.f. basis. For details on our methodology of adjusting for the discrepancy between f.o.b. and c.i.f., see Section 2.

$DREG_k$ : region dummies

$D_t$ : year dummies

Subscript  $t$  denotes year  $t$ .

The variables used in this estimation are defined in Table 4-1. Further details on the definitions and sources of the variables are provided in Appendix C. As dependent variables we use the shares of vertical intra-industry trade (SHVIIT) between countries  $k$  and  $k'$  (Japan), which are defined in Section 2. Since our dependent variable SHVIIT is limited in range between zero and one, we will mainly use the logistic transformations of SHVIIT, denoted by LTSHVIIT, as our dependent variable. In line with our procedure so far, the regression analysis in this section is mainly conducted using a 25% threshold to distinguish between vertically and horizontally differentiated products.<sup>30</sup>

We mainly consider the following four factors as determinants of SHVIIT:

- (1)  $\underline{FDI}_{kk't}$ . This measures the activity of Japanese-affiliated firms in the electrical machinery industry in country  $k$ . As shown in Section 3, we expect that the expansion of the activities by Japanese-affiliated firms might be associated with an increase in vertical IIT. We employ the variable  $FDISALE_{kk't}$  as a proxy for the extent of the activity of Japanese-affiliated firms. The variable is defined as the ratio of the sales by Japanese-affiliated firms in country  $k$  to domestic output in Japan for the electrical machinery industry. We also include an interaction term of  $FDISALE_{kk't}$  and a variable representing the degree of trade friction between the two countries (TRFRC) in order to distinguish FDI for the purpose of avoiding trade friction from FDI aimed at the international division of labor.
- (2) The difference in per capita GDP ( $DGDPPC_{kk't}$ ), which is defined as the absolute value of the difference in per capita GDP between country  $k$  and  $k'$  (Japan). In our theoretical model presented in Section 3, vertical differentiation is explicitly modeled as differences in quality between similar products. In the case where two countries have differential endowments of capital and labor, it is assumed that the higher quality variety of the differentiated good is produced using relatively capital-intensive techniques. As a result, the higher income, relatively capital-abundant country specializes in relatively high-quality manufactures, while the lower income, relatively labor-abundant country specializes in low-quality manufactures. Therefore, we predict that the share of vertical IIT in the bilateral trade of a pair of countries will be greater the greater the difference in

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<sup>30</sup> To test the sensitivity of our results, the regression analysis was also repeated using a 15% threshold. The regression result is presented in Appendix Table C2.



the capital-labor endowment of the two countries and, accordingly, the greater the difference in per capita GDP. In addition to our basic model, we estimate some additional models which include  $DGDPPC_{kk't}$  squared as an explanatory variable, taking non-linearity into account. Moreover, differences in human capital accumulation between country k and Japan,  $DEDUYR_{kk'}$ , is also included as an explanatory variable.  $DEDUYR_{kk'}$  is defined as the absolute value of the gap in average years of schooling between country k and Japan. Since vertical IIT is determined by quality factors, we believe that the human capital intensity would be one of the most important factors influencing this type of intra-industry trade. A larger difference in human capital intensity would result in a larger difference in the price (quality) of the product. Therefore, vertical IIT will increase.

- (3) The geographical distance between the capital city of country k and Tokyo,  $DIST_{kk'}$ . The distance between producers should lead to a reduction in two-way trade for goods subject to transportation costs. In the case of vertical FDI, the distance between the parent firm and its subsidiaries should hinder them from creating an efficient production network and from communicating smoothly. Therefore, the distance should reduce vertical FDI, resulting in a reduction of vertical IIT. Consequently, it is to be expected that this variable will have a negative impact.
- (4) The size of the electrical machinery industry in country k,  $INDSIZE_{kk'}$ . It may be presumed that with the size of the industry in country k, the volume of trade will increase. Therefore, we expect a positive coefficient for this variable.

As FDI variables are endogenously determined, equation (4.1) is estimated by instrumental variables (IV) regression with linear specifications.

INSERT TABLE 4-1

## 4.2 Regression Results

The main results of the regression analysis for the determinants of vertical IIT between Japan and her major trading partners are presented in Table 4-2.<sup>31</sup> In general, they strongly support the hypothesis that FDI measured by the sales amount is a major determinant of

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<sup>31</sup> We also estimated the model by IV regression with samples for which outliers are excluded (we define outliers as observations which exceed the range of mean  $\pm 2.5$ \*standard deviation) and the model by the ordinary least squares (OLS) method. Moreover, we conducted a three-stage least squares estimation for a system of simultaneous equations. These results are reported in Appendix Tables C2 and C3, respectively; we obtain very similar results to those in Table 4.2.

vertical IIT. The coefficient on FDISALE is positive and strongly significant in all the equations in Table 4-2. Moreover, the interaction term of trade friction and FDI (TRFRC\*FDISALE) has, as expected, a significant negative coefficient in all cases. The geographical distance (DIST) also has a significant negative coefficient in all the equations as expected, which suggests that geographical distance raises the transportation and transaction costs between the countries and should lead to a reduction in IIT. The size of the electrical machinery industry (INDSIZE) has the expected positive sign in most cases but is not statistically significant. As for the difference in factor endowments, contrary to our prediction, the difference in per capita GDP (DGDPPC) has a negative coefficient in most of the equations, implying that the share of VIIT will be smaller the greater difference in factor endowments. This result is similar to that in Greenaway, Hine and Milner (1994), although it is inconsistent with the results of the study by Durkin and Krygier (2000) on US IIT with OECD countries and the study by Fontagné, Freudenberg and Péridy (1997) on the EC countries. However, looking at the coefficients on DGDPPC squared in equations (4) and (5) in Table 4-2, we can see that the greater the difference in per capita GDP the greater will be the share of VIIT in the case of bilateral trade with countries of which per capita GDP differs from Japan's per capita GDP by more than approximately 10,000 international dollars. Therefore, in the case of Japan's bilateral vertical IIT in the electrical machinery industry with lower income countries (where the difference in per capita GDP with Japan is more than 10,000 international dollars), this result may imply that relative factor endowments support the Heckscher-Ohlin-type neo-factor proportions hypothesis rather than the Linder-type demand-similarity hypothesis after controlling for the level of FDI and for region-specific effects. In addition to these results, the difference in human capital accumulation (DEDUYR) does not have a significant impact on vertical IIT.

INSERT TABLE 4-2

## 5. Conclusions

In this paper, we investigated the recent change in trade patterns in East Asia and compared these patterns with those in EU, using the HS 6-digit level data published by the United Nations and the HS 9-digit level data provided by the Ministry of Finance of Japan. Specifically, we aimed to establish whether the intra-regional trade in East Asia is of an “inter-industry,” “vertical intra-industry,” or “horizontal intra-industry” nature. We also analyzed the role of FDI in the change of trade patterns. Our analysis reveals that, although still much lower than in the EU, intra-industry trade, and particularly vertical IIT, in East Asia

has grown rapidly in importance in overall intra-regional trade. This is especially the case in the electrical machinery industry and the general and precision machinery industry. Moreover, while for most EU countries, the share of IIT remained almost constant during the period from 1996 to 2000, it expanded quickly for East Asian countries. According to our calculations, the share of vertical IIT in total intra-East Asian trade grew from 16.6% in 1996 to 23.7% in 2000, while that in total intra-EU trade increased only slightly from 37.5% to 40.0% during the same period.

Taking into account that the share of vertical IIT in the electrical machinery industry has increased dramatically in East Asia, we also conducted a more detailed analysis of this industry, using Japan's bilateral trade data at the HS 9-digit level. Most interestingly, vertical IIT has risen dramatically in Japan's trade with China and many of the ASEAN countries. This increase in vertical IIT with these countries seems to have a strong positive correlation with the extent of the activities by Japanese electrical machinery MNEs.

Our theoretical examination suggests that if the fixed cost of FDI is relatively small, firms choose to become multinational and exploit the factor price gap between the home base and foreign countries. As a result, MNE's home country specializes more in the production of capital-intensive high-quality products, while the host country specializes more in the production of labor-intensive low-quality products. Similarly, the lower the trade costs, the more vertical IIT will occur between the home and the host countries. Therefore, our theoretical analysis implies that lower costs of FDI and trade enable firms to benefit from the international vertical division of labor, resulting in an increase in vertical IIT.

Taking the descriptive and theoretical analyses as a cue, we then conducted an econometric investigation to test for the determinants of IIT, taking Japan's bilateral trade in the electrical machinery industry as a case. We found that FDI has a strongly positive impact on vertical IIT. Moreover, we also found a significantly negative impact of the geographical distance on vertical IIT, suggesting that the higher the trade costs, the less vertical IIT is there likely to occur. As for differences in factor endowments, contrary to our prediction, the results suggest that VIIT will be lower the greater the differences in factor endowments are. However, we also found that the difference in factor endowments increases VIIT when the gap in per capita GDP with Japan exceeds 10,000 international dollars (many Asian countries fall into this category) after controlling for the level of FDI and for region-specific effects. In other words, in the case of trade with lower income countries, including many Asian countries, the results support a Heckscher-Ohlin-type neo-factor proportions hypothesis.

Overall, the results imply that in the East Asian region FDI played a significant role in

the rapid increase of vertical IIT in recent years. Moreover, we found that the largest part of total IIT growth in the region is attributable to the growth of vertical and not of horizontal IIT. Many economists have studied the impact of Japan's direct investment abroad on Japan's industrial structure and factor markets as a consequence of the resulting imports from the rest of East Asia.<sup>32</sup> However, there is almost no empirical study on how the increase in vertical IIT has changed the industrial structure and factor prices in Japan. We would like to study this issue in near future.

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<sup>32</sup> For example, see Head and Ries (2002), Tomiura (2001), Kimura (2001), Kimura and Fukasaku (2001), and Kwan (2002).

#### **Appendix A: Definition of Our Commodity Classification for Simplex Figures**

<b>Commodity</b>	<b>SITC-R3 2 digit code</b>	<b>HS88 2 digit code</b>
Agricultural products	00-05, 07, 08, 22, 29, 41-43	01-15
Food and beverages	06, 09, 11, 12	16-24
Mining products	27, 28, 32-35	25-27
Chemicals	23, 51-59, 62	28-40
Light industry products	21, 61, 81-83, 85	41-43, 64-67, 94-96
Wood and paper	24, 25, 63, 64	44-49
Textiles	26, 65, 84	50-63
Pottery products	66	68-70
Basic metals	67-69	72-83
General and precision machinery	72-75, 87, 88	84, 90-92
Electrical machinery	71, 76, 77	85
Transportation machinery	78, 79	86-89
Others	89, 96, 97	71, 93, 97-99

#### **Appendix B: HS 9-Digit Level Data of Japan's Trade with China: Electrical Machinery, 2000**

INSERT APPENDIX TABLE B

#### **Appendix C: Definition of Variables Used in the Regression Analysis and Data Sources**

##### **SHVIIT25**

The variable SHVIIT25 is defined as the share of vertical intra-industry trade in total trade between Japan and each trading partner. The trade in vertically differentiated products is identified following the method described in Section 2.2. As written in the section, we mainly use a 25% threshold. For our econometric analysis, we used Japan's bilateral trade data at the 9-digit HS88 level instead of PC-TAS data.

##### **SHFDISALE**

The variable represents the ratio of sales by Japanese-affiliated firms in a partner country to domestic output in Japan for the electrical machinery industry. The data on sales by Japanese-affiliated firms are taken from the data underlying Fukao and Yuan (2001). As the data on sales by Japanese-affiliated firms are only available up to March 1999, we use the fiscal 1998 data as a proxy for the size of the activity of Japanese-affiliated firms for the calendar years 1999 and 2000. Data on domestic output for the Japanese electrical

machinery industry are taken from Elsevier Advanced Technology/Reed Electronics Research (various years), *Yearbook of World Electronics Data*.

#### DGDPPC

The variable DGDPPC is defined as the absolute difference in per capita GDP between country k and Japan (k'). The per capita GDP data (in current thousands of international dollars) are taken from World Bank (2002b), *World Development Indicators 2002*, CD-ROM. For countries for which data on GDP per capita in current international dollars are not available in World Bank (2002b), we estimated the data using other data sources as follows: first, we multiplied the ratio of the country's GDP to Japan's GDP calculated in current international dollars from International Monetary Fund (various years) by estimates of Japan's GDP in current international dollars from World Bank (2002b). Then, we divided it by population estimates from World Bank (2002b).

#### DEDUYR

The variable DEDUYR is the absolute difference in average years of total schooling of the total population as of 1990 between country k and Japan, which is a proxy for the difference in human capital endowment between country k and Japan. The data are taken from World Bank (2002a), *Barro-Lee Dataset: International Schooling Years and Schooling Quality*, (downloaded from [www.worldbank.org](http://www.worldbank.org) on 18 September, 2002). For Nigeria and Saudi Arabia, where data on average years of total schooling were not available, we estimated the value of this variable as follows: first, for all the countries where the schooling data are available, we regressed the average years of total schooling on GDPPC (per capita GDP), GDP, and regional dummies. Then, using the estimated equation, we estimated the theoretical value of average years of schooling for those countries.

#### DIST

The variable DIST is the logarithm of the geographical distance expressed in 1,000 kilometers between the capital city of country k and Tokyo.

#### INDSIZE

The variable INDSIZE is the size of the electrical machinery industry in country k normalized by the size of the industry in Japan. The data are taken from Elsevier Advanced Technology/Reed Electronics Research (various years), *Yearbook of World Electronics Data*.

## GDP

GDP is an indicator of the size of the economies under study. The data on GDP in current international dollars are taken from World Bank (2002b), *World Development Indicators 2002*, CD-ROM. For countries for which data on GDP in current international dollars are not available in World Bank (2002b), we estimated the data multiplying the ratio of the country's GDP to Japan's GDP calculated in current international dollars from International Monetary Fund (various years) by estimates of Japan's GDP in current international dollars from World Bank (2002b).

## RISK

The variable RISK is a proxy for country k's risk of default. The data are taken from Institutional Investor Systems, *Institutional Investor*, various years.

## COTAX

COTAX is the effective corporate tax rate for country k for the year 1993. The data are taken from Fukao and Yue (1997). For Denmark, Finland, Hungary, and Poland, where the effective corporate tax rate was not available, the legal corporate tax rate is used.

## OPERATE1

The variable OPERATE1 is the first principal component of the conditions for obtaining an operation permission. The data are taken from Fukao and Chung (1996). For Denmark, Finland, Hungary, and Poland, where OPERATE1 data were not available, we estimated the value of this variable as follows: first, for all the countries where OPERATE1 data are available, we regressed the first principal component of the conditions for obtaining an operation permission on GDPPC (per capita GDP), GDP, EDUYR (average years of total schooling of the total population), and regional dummies. Then, using the estimated equation, we estimated the theoretical value of OPERATE1 for those countries.

## OPERATE2

The variable OPERATE2 is the second principal component of the conditions for obtaining an operation permission. The data are taken from Fukao and Chung (1996). For Denmark, Finland, Hungary, and Poland, where OPERATE2 data were not available, we estimated the value of this variable as follows: first, for all the countries where OPERATE2

data are available, we regressed the second principal component of the conditions for obtaining an operation permission on GDPPC (per capita GDP), GDP, EDUYR (average years of total schooling of the total population), and regional dummies. Then, using the estimated equation, we estimated the theoretical value of OPERATE2 for those countries.

#### TRFRC

The variable TRFRC is a measure of the extent of FDI undertaken to avoid trade friction with country k defined as:

(Number of Japanese-affiliated firms who answered that trade friction was one of the motivations behind establishing an affiliate in country k) / (total number of Japanese-affiliated firms in country k)

The data are taken from Fukao and Chung (1996).

INSERT APPENDIX TABLES C1, C2, and C3



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**Table 2-1. Dependence on International Trade**

	Exports/GDP		Imports/GDP	
	1985-87 average	1995-98 average	1985-87 average	1995-98 average
US	5.6	9.8	9.1	11.5
EU	18.0	17.0	17.4	16.7
Japan	11.4	9.5	7.1	7.0
East Asia excl. Japan	28.3	33.9	27.0	36.7
NIEs 3	45.8	41.1	42.1	45.5
ASEAN 4	28.3	41.6	21.1	40.3
China+Hong Kong	18.9	32.4	23.3	35.1
MERCOSUR	10.2	7.6	5.8	8.0

Source: Isogai and Shibamura (2000)

**Table 2-2. Trade Matrix of IT Related Products**

Panel A. 1992-95 Annual Average

(billion US dollars)

		Importer			
		Japan	Asia excl. Japan	US	EU
Exporter	Japan	-	32.7	32.7	19.9
	Asia excl. Japan	11.4	53.4	51.9	29.3
	US	7.7	29.8	-	19.7
	EU	1.3	12.1	8.7	78.7

Panel B. 1996-98 Annual Average

		Importer			
		Japan	Asia excl. Japan	US	EU
Exporter	Japan	-	36.8	30.7	18.9
	Asia excl. Japan	22.4	79.0	82.2	50.0
	US	11.7	46.1	-	25.6
	EU	3.3	19.7	12.9	124.9

Source: Isogai and Shibamura (2000)

**Table 2-3. Inward FDI Stocks as a Percentage of GDP, by Region: 1999**  
(%)

Regions	Inward FDI stock/GDP
EU	22.2
Developing Europe	18.8
North America	12.2
Latin America	25.6
South, East and Southeast Asia excl. Japan	34.4
Japan	1.0

Source: UNCTAD (2001), *World Investment Report 2001* .

**Table 2-4. Share of Sales to Each Destination in Total Sales: Foreign Manufacturing Subsidiaries of Japanese and US Firms, by Location, 1999**

(%)

Destination	Location of Operation						
	East Asia (excl. Japan)	China	Japan	Europe	US	Latin America	All the Economies
<i>U.S. subsidiaries</i>							
Local Market	39.6	50.4	90.1	56.7	-	65.1	57.7
Exports to other countries	32.8	29.6	7.1	37.5	-	13.1	27.2
Exports to the US	27.6	20.0	2.8	5.8	-	21.8	15.1
<i>Japanese subsidiaries</i>							
Local Market	48.2	47.0	-	60.1	90.4	77.3	70.0
Exports to other countries	25.8	21.8	-	36.3	7.3	17.7	20.4
Exports to Japan	26.0	31.2	-	3.6	2.3	5.0	9.6

Source: Authors' calculation based on Department of Commerce (U.S.), *U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and Their Foreign Affiliates*, available on the Internet, <http://www.bea.doc.gov/bea/ai/iidguide.htm#link12b>; and METI (2001).

**Table 2-6. The Shares of the Three Trade Types and the Grubel-Lloyd Index in Intra-Regional Trade: EU-East Asia Comparison, All Industries, 1996-2000**

**Panel A. Intra-EU Trade**

	OWT	VIIT	HIIT	Grubel-Lloyd Index
1996	34.0	37.5	28.5	38.8
1997	35.0	38.9	26.1	38.4
1998	33.5	40.0	26.5	39.5
1999	33.2	40.6	26.2	39.4
2000	34.1	40.0	25.8	38.4

**Panel B. Intra-East Asia Trade**

	OWT	VIIT	HIIT	Grubel-Lloyd Index
1996	78.7	16.6	4.7	17.5
1997	76.1	17.8	6.1	18.1
1998	75.0	20.0	5.1	18.5
1999	70.3	24.6	5.1	19.9
2000	68.7	23.7	7.6	20.5

Note: EU refers to the following economies: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and the United Kingdom.

East Asia refers to the following economies: China, ASEAN4 (Indonesia, Malaysia, Thailand, Philippines), NIE3 (Hong Kong, Korea, Singapore) and Japan.

Source: Authors' calculation based on PC-TAS.



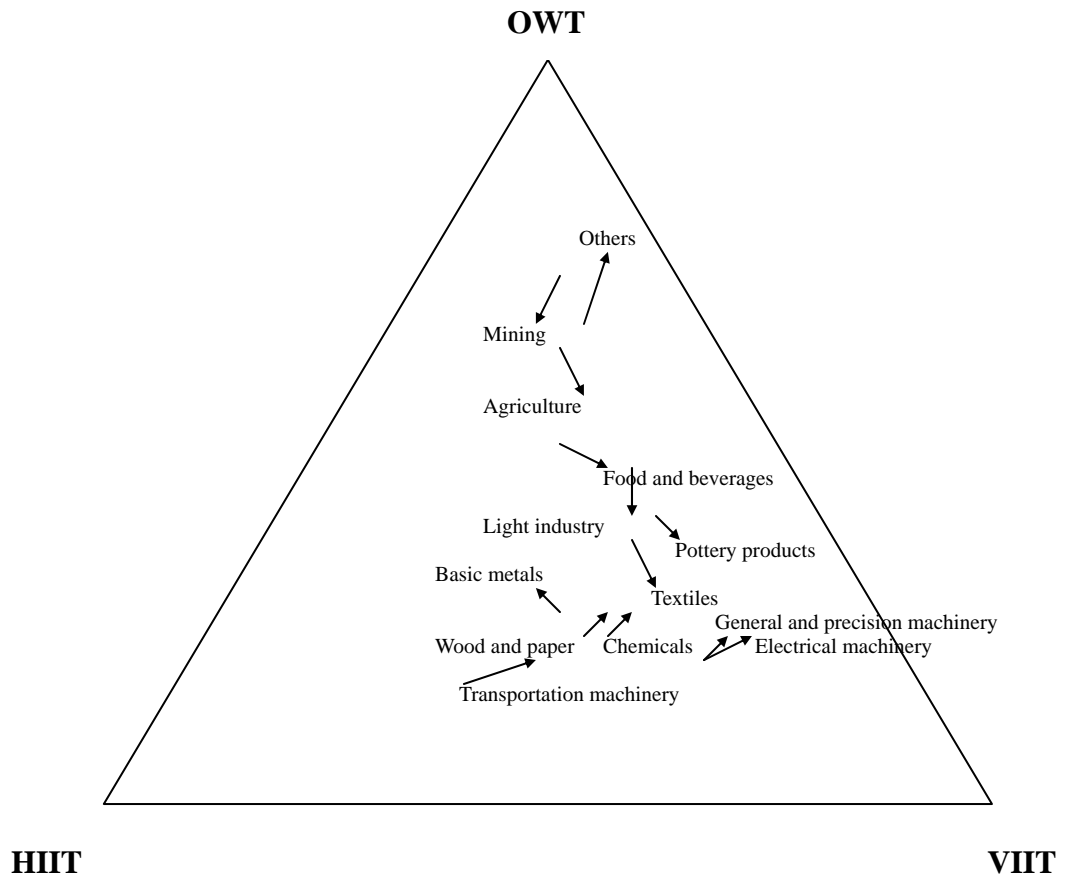
**Table 2-7. Sales by Japanese-Affiliated Firms in the Electrical Machinery Industry**

	(Mil. Yen)					
	1988		1994		1998	
	Value	Share	Value	Share	Value	Share
<b>Total</b>	<b>8,058,566</b>	<b>(100.00%)</b>	<b>13,840,134</b>	<b>(100.00%)</b>	<b>19,144,498</b>	<b>(100.00%)</b>
<b>China</b>	<b>55,533</b>	<b>(0.69%)</b>	<b>289,766</b>	<b>(2.09%)</b>	<b>955,363</b>	<b>(4.99%)</b>
<b>NIE3</b>	<b>1,504,339</b>	<b>(18.67%)</b>	<b>1,875,137</b>	<b>(13.55%)</b>	<b>2,418,761</b>	<b>(12.63%)</b>
<b>ASEAN5</b>	<b>1,001,102</b>	<b>(12.42%)</b>	<b>3,614,067</b>	<b>(26.11%)</b>	<b>4,604,113</b>	<b>(24.05%)</b>
<b>EU</b>	<b>1,664,455</b>	<b>(20.65%)</b>	<b>3,313,790</b>	<b>(23.94%)</b>	<b>4,180,557</b>	<b>(21.84%)</b>
<b>NAFTA</b>	<b>3,485,630</b>	<b>(43.25%)</b>	<b>4,360,695</b>	<b>(31.51%)</b>	<b>6,445,859</b>	<b>(33.67%)</b>
<b>Others</b>	<b>1,907,379</b>	<b>(23.67%)</b>	<b>2,551,581</b>	<b>(18.44%)</b>	<b>3,913,970</b>	<b>(20.44%)</b>

All figures are in nominal terms.

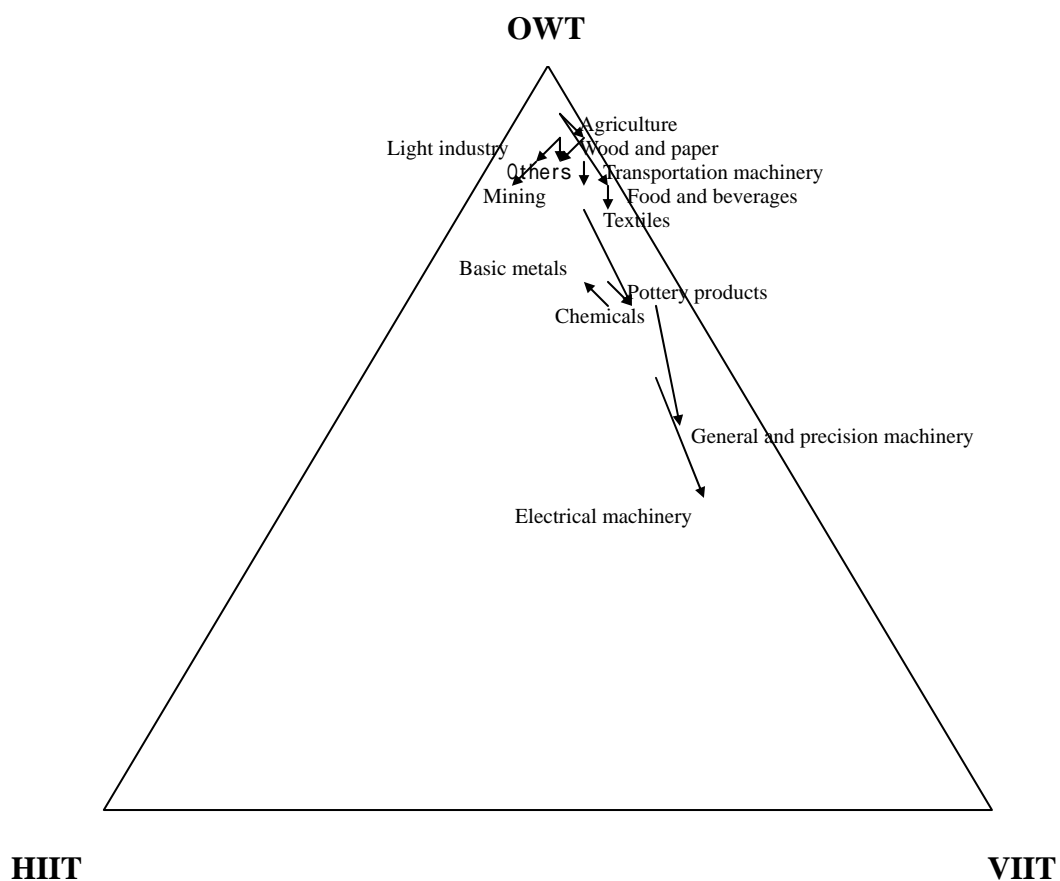
Source: Compiled from the data underlying Fukao and Yuan (2001).

**Figure 2-1. The Share of the Three Trade Types in Intra-EU Trade: by Industry, 1996 and 2000**



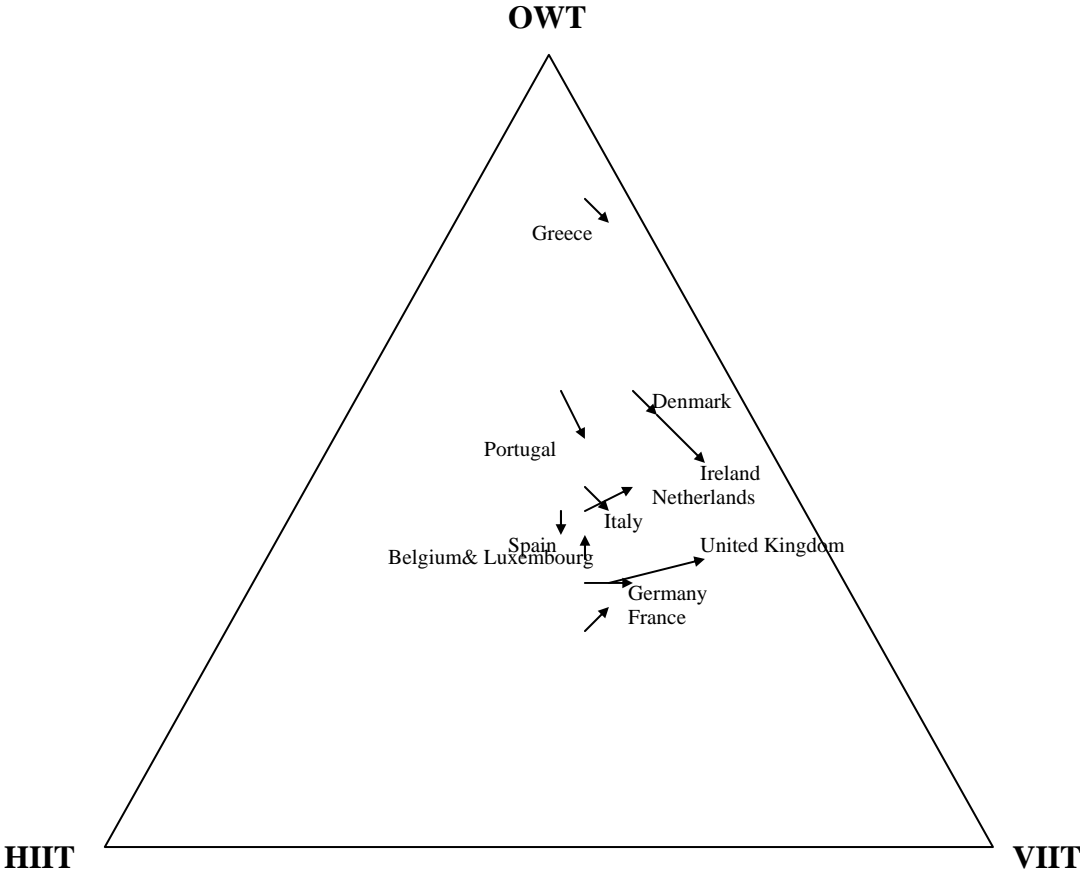
Source: Authors' calculation based on PC-TAS.

**Figure 2-2. The Share of the Three Trade Types in Intra-East Asian Trade: by Industry, 1996 and 2000**



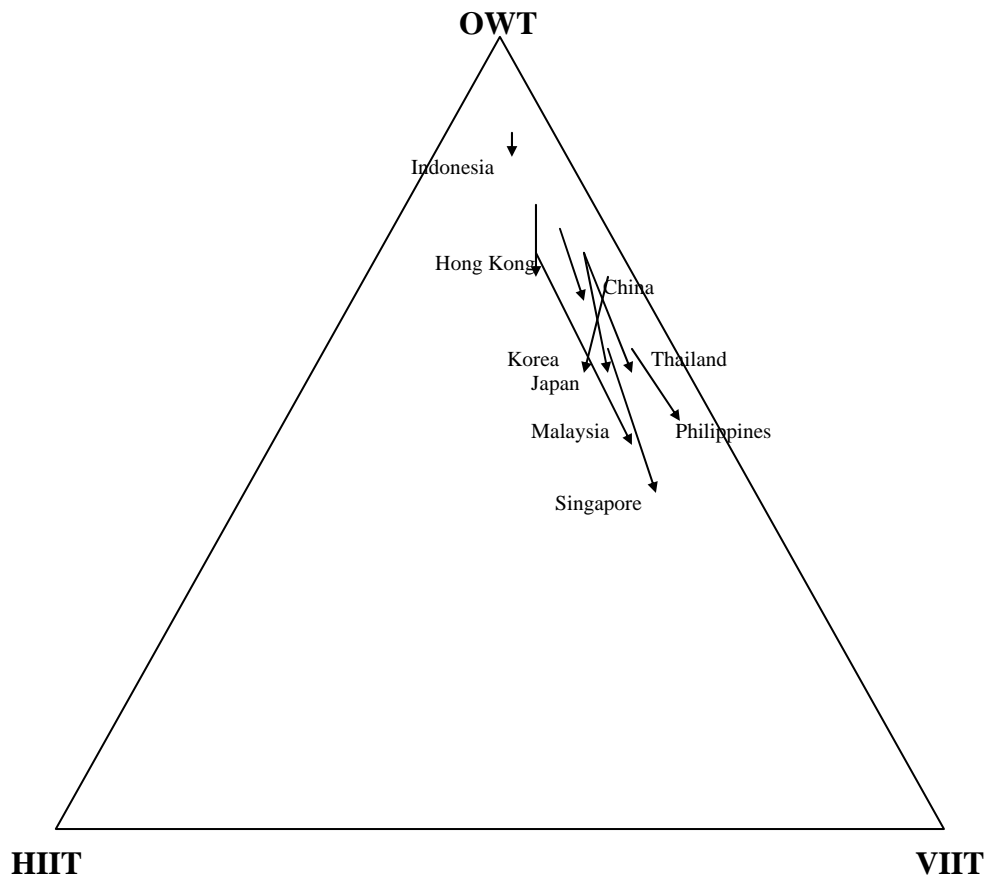
Source: Authors' calculation based on PC-TAS.

Figure 2-3. The Share of the Three Trade Types in Intra-EU Trade: by Country, 1996 and 2000



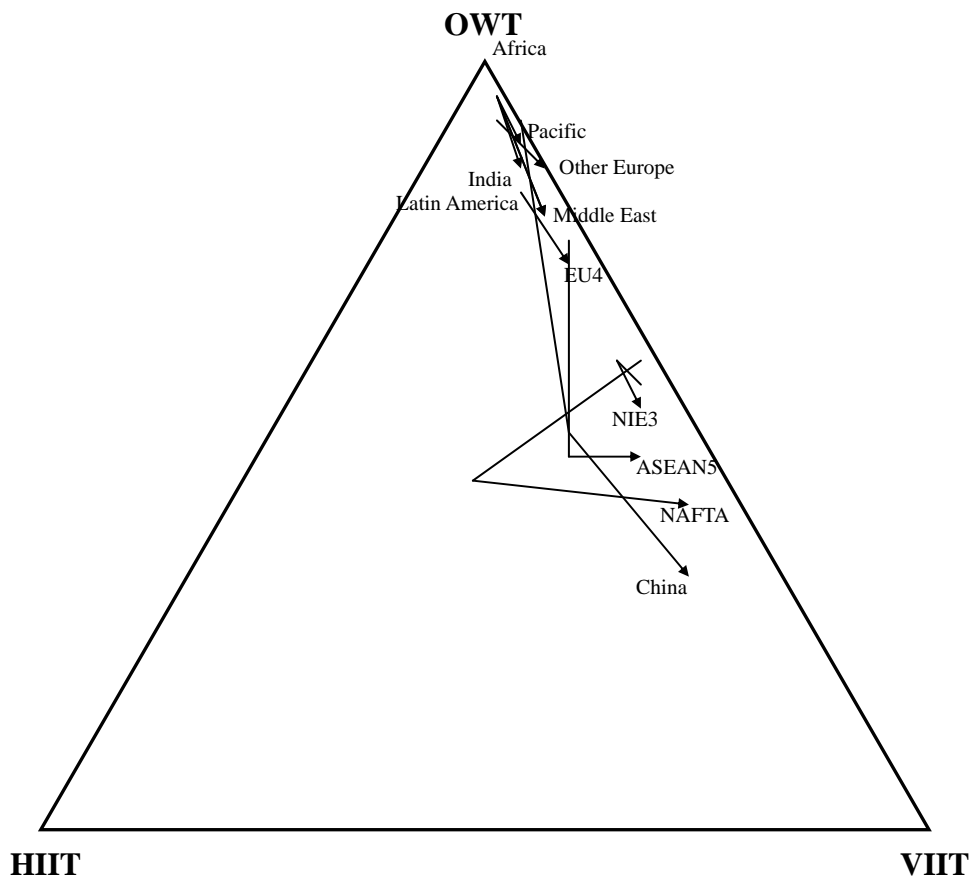
Source: Authors' calculation based on PC-TAS.

**Figure 2-4. The Share of the Three Trade Types in Intra-East Asian Trade: by Country, 1996 and 2000**



Source: Authors' calculation based on PC-TAS.

**Figure 2-5. The Share of the Three Trade Types in Japan's Bilateral Trade in Electrical Machinery: by Partner Region or Economy, 1988, 1994 and 2000**

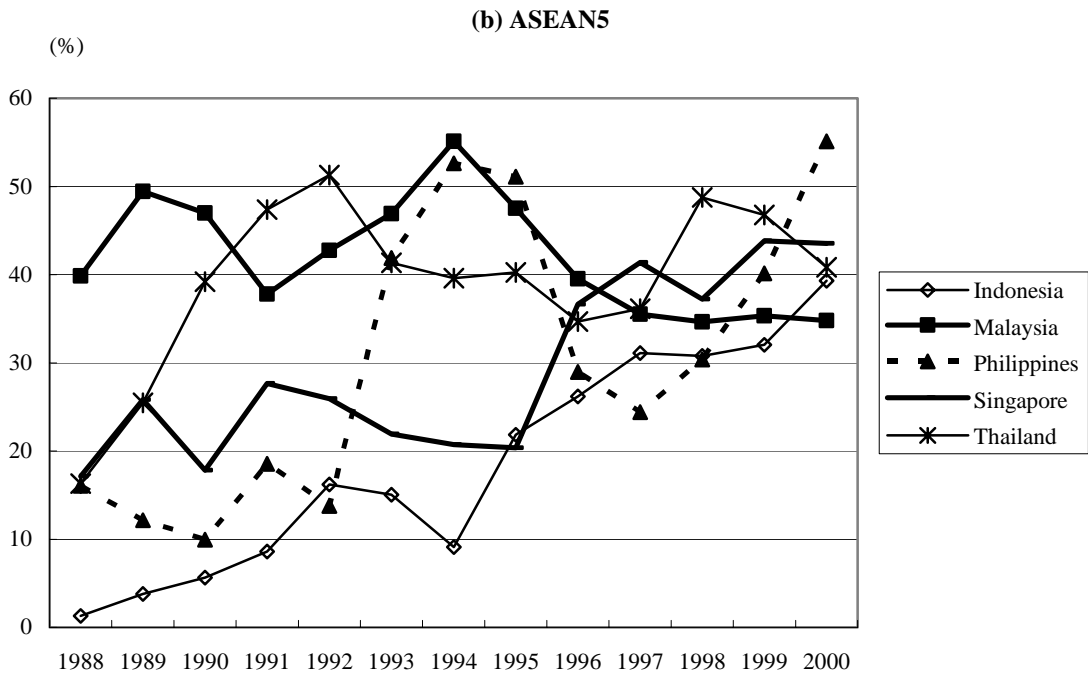
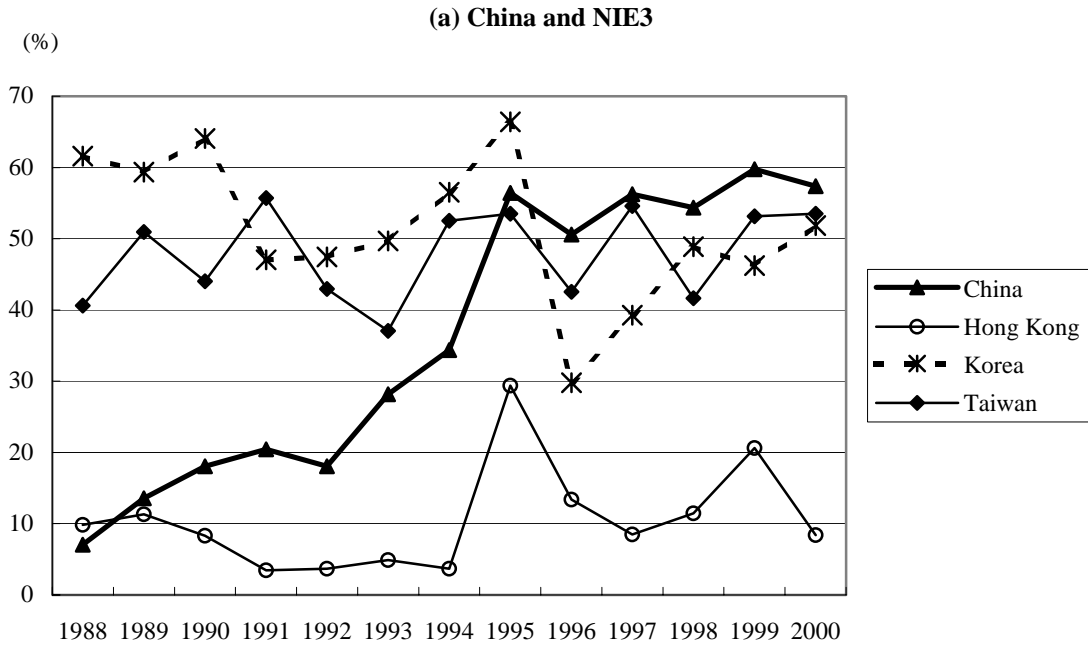


Note: The labels denote the following economies: Africa (Nigeria), ASEAN5 (Indonesia Malaysia, Philippines, Singapore, Thailand), EU4 (France, Germany, Italy, UK), Middle East (Israel, Saudi Arabia), NAFTA (Canada, Mexico, USA), NIE3 (Hong Kong, Korea, Taiwan), Other Europe (Austria, Belgium, Denmark, Finland, Hungary, Ireland, Luxembourg, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland), Pacific (Australia, New Zealand), Latin America (Argentina, Brazil, Columbia, Costa Rica, Panama, Peru, Venezuela).

Source: Authors' calculation based on Japan's trade statistics which are taken from [http://www.customs.go.jp/toukei/download/index\\_d012\\_e.htm](http://www.customs.go.jp/toukei/download/index_d012_e.htm).

**Figure 2-6. Share of Vertical Intra-Industry Trade in Japan's Trade with East Asian Countries:**

*--- Electrical Machinery Industry ---*



Note: Vertical IIT is identified using a 25% threshold as explained in Section 2.  
 Source: Authors' calculation based on Japan's trade statistics taken from [http://www.customs.go.jp/tokei/download/index\\_d012\\_e.htm](http://www.customs.go.jp/tokei/download/index_d012_e.htm).

**Figure 3-1. Marginal-Cost Curves**

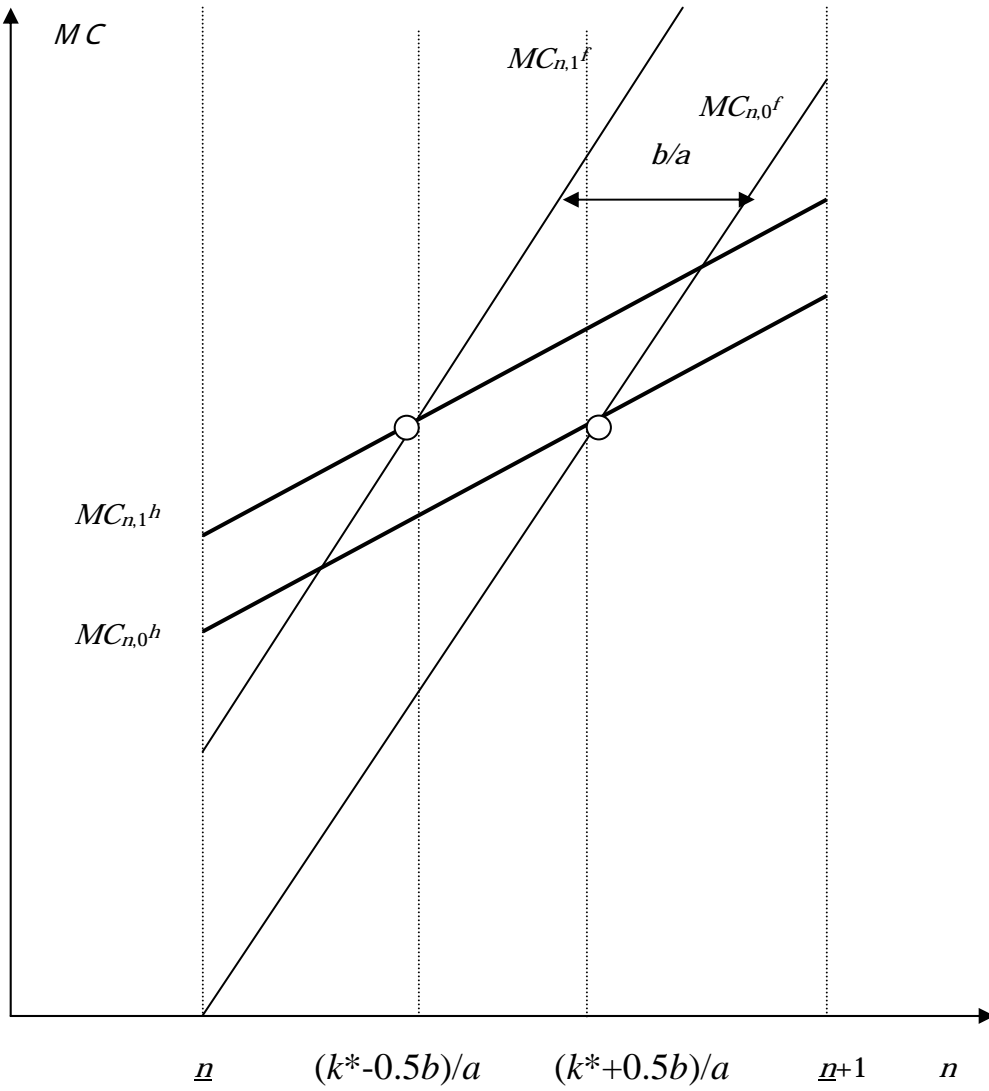
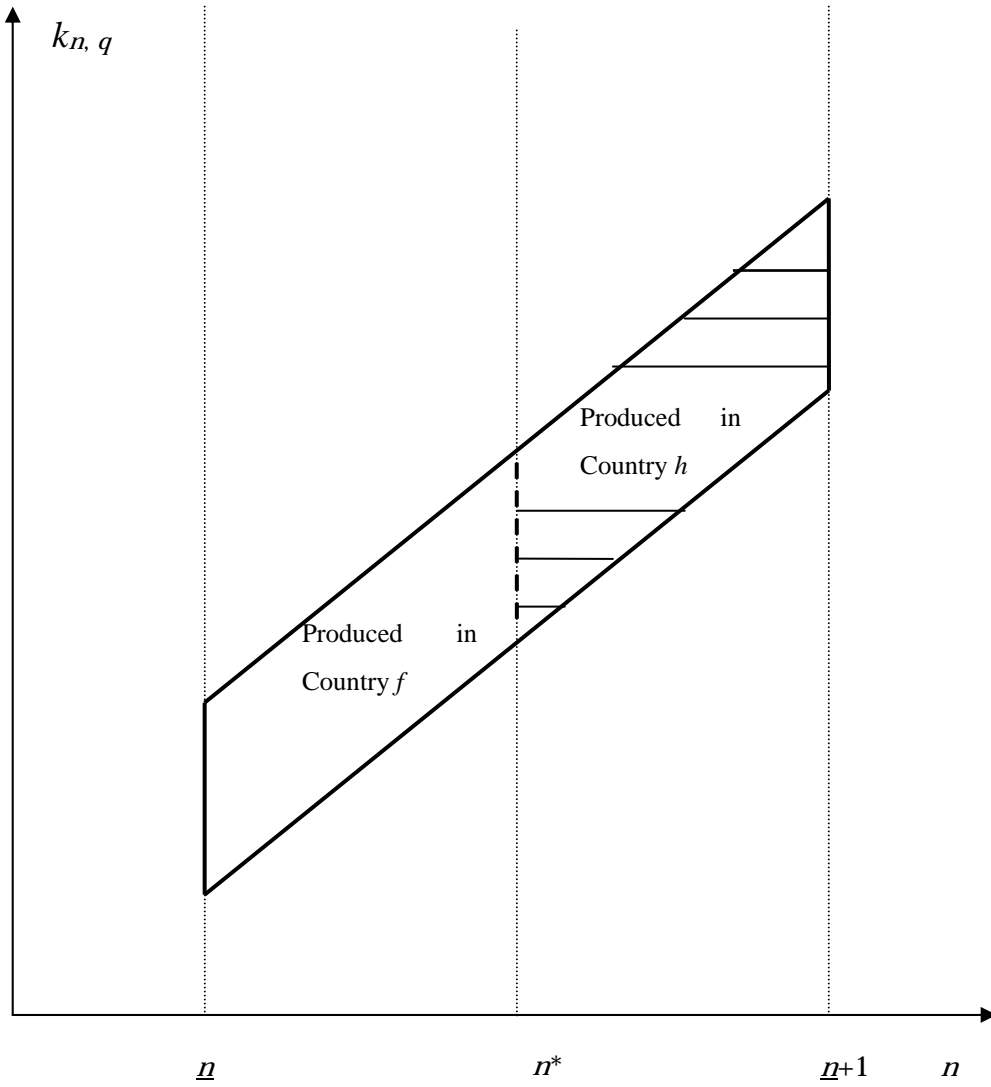
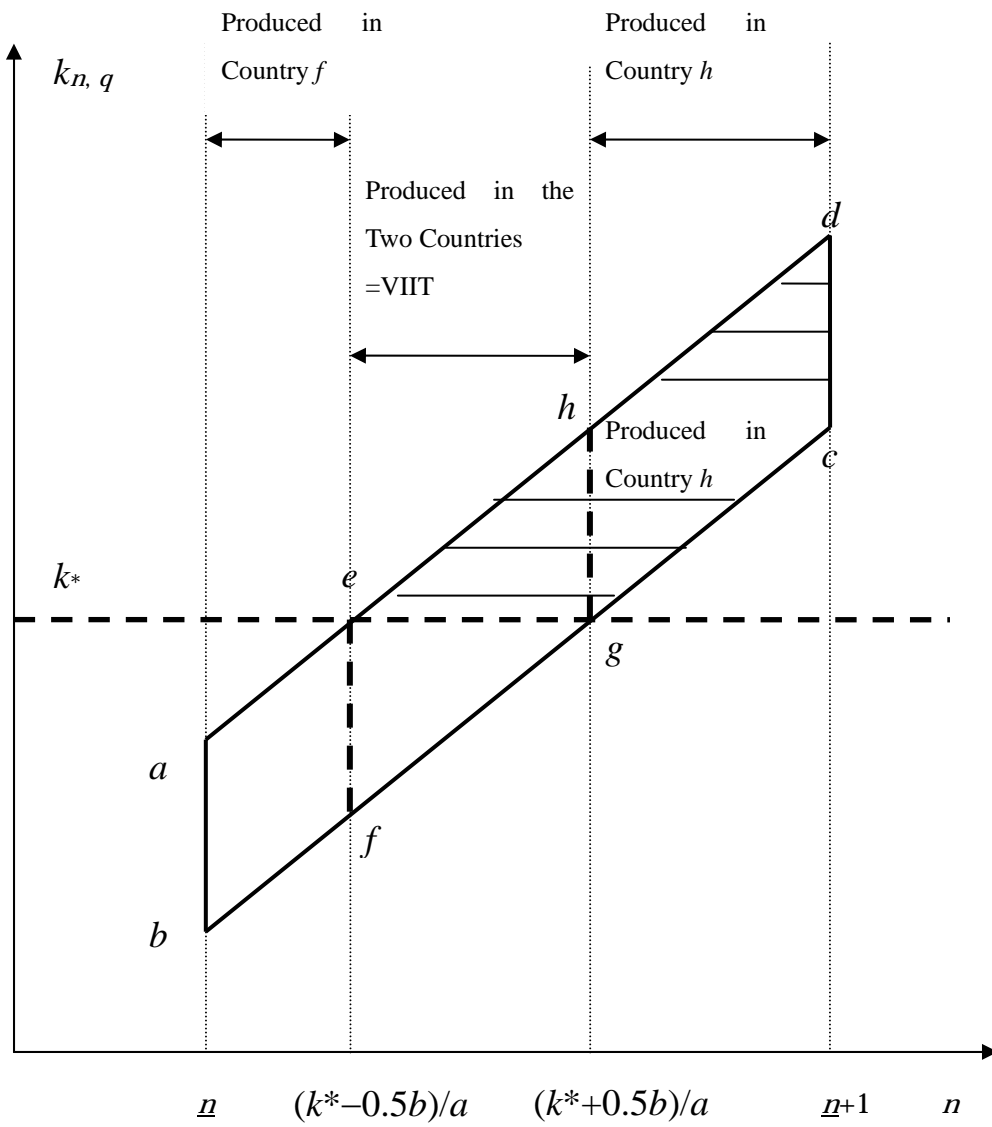




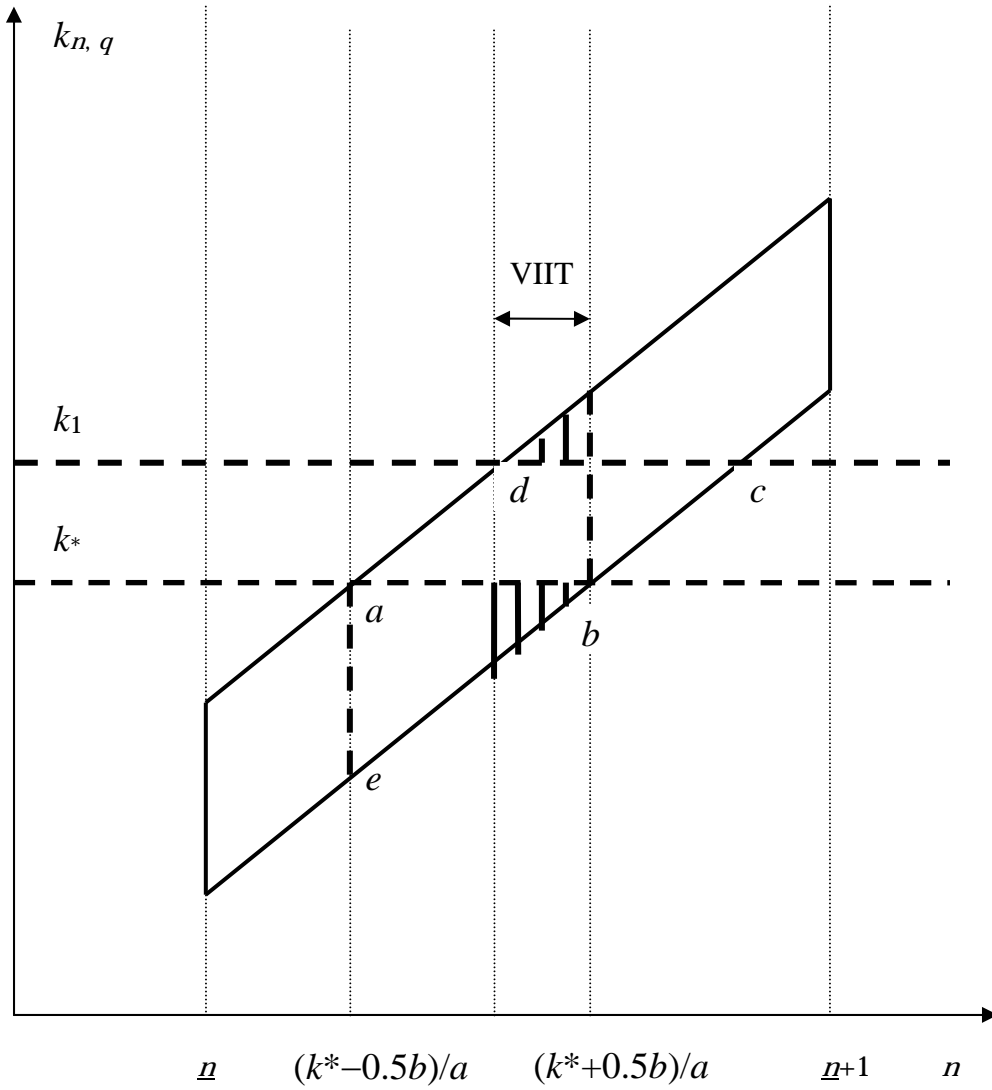
Figure 3-2. Production Pattern under High FDI Costs and Low Trade Costs



**Figure 3-3. Production Pattern under Low FDI and Trade Costs**



**Figure 3-4. Production Pattern under Low FDI Costs and High Trade Costs**



**Table 4-1. Definition of Variables**

<b>Dependent variables</b>		
<b>&lt;25% threshold&gt;</b>		
SHVIIT25		Share of vertical intra-industry trade in total trade
LTSHVIIT25		Logistic transformation of SHVIIT25
<b>&lt;15% threshold&gt;</b>		
SHVIIT15		Share of vertical intra-industry trade in total trade
LTSHVIIT15		Logistic transformation of SHVIIT15
<b>Independent variables</b>		
	expected signs	
FDISALE	+	Ratio of sales by Japanese-affiliated firms in country k to domestic output in Japan for electrical machinery industry
TRFRC*FDISALE	-	Interaction term of TRFRC and FDISALE
DGDPPC	+	Difference in GDP per capita (comparative advantage, factor endowment)
DGDPPC^2	+/-	DGDPPC squared
DEDUYR	+	Difference in human capital accumulation
DIST	-	Logarithm of geographic distance (1,000 km)
INDSIZE	+	Industry size; Output in electrical machinery industry in country k / output electrical machinery industry in Japan
DEU		Region dummy for EU countries
DASIA		Region dummy for Asian countries
DLATIN		Region dummy for Latin American countries
DNAFTA		Region dummy for NAFTA countries
<b>Instrument variables</b>		
GDP		Market size (GDP of country k / Japan's GDP)
RISK		Country risk
COTAX		Corporate tax rate
OPERATE1		The first principal component of the conditions for obtaining an operation permission
OPERATE2		The second principal component of the conditions for obtaining an operation permission
TRFRC		Trade friction

**Table 4-2. Regression Results: Vertical IIT (Instrumental variables regressions, IV)**

	<i>Dependent Variables</i>							
	LTSHVIIT25	LTSHVIIT25	LTSHVIIT25	LTSHVIIT25	LTSHVIIT25	SHVIIT25	SHVIIT25	SHVIIT25
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FDISALE	8.3020 *	89.8104 ***	94.3265 ***	129.3474 ***	135.4249 ***	10.3980 ***	11.8195 ***	12.4178 ***
	(1.73)	(3.74)	(3.92)	(3.76)	(4.00)	(4.94)	(4.59)	(4.72)
TRFRC*FDISALE		-481.1219 ***	-503.7128 ***	-692.6810 ***	-723.3210 ***	-51.4795 ***	-58.9423 ***	-62.3562 ***
		(-3.63)	(-3.78)	(-3.68)	(-3.90)	(-4.41)	(-4.16)	(-4.30)
DGDPPC	-0.0628 ***	-0.0126	-0.0151	-0.2288 ***	-0.2395 ***	0.0042 ***	-0.0040	-0.0038
	(-3.99)	(-0.53)	(-0.57)	(-5.16)	(-5.15)	(2.09)	(-1.45)	(-1.33)
DGDPPC^2				0.0113 ***	0.0117 ***		0.0004 **	0.0004 ***
				(4.00)	(4.16)		(2.57)	(2.68)
DEDUYR			0.0501		0.0583	-0.0048		-0.0039
			(0.73)		(0.86)	(-1.44)		(-1.15)
DIST	-0.8054 ***	-1.0039 ***	-1.1441 ***	-1.2973 ***	-1.4689 ***	-0.1564 ***	-0.1813 ***	-0.1739 ***
	(-4.95)	(-5.05)	(-4.75)	(-5.00)	(-5.00)	(-7.58)	(-8.24)	(-7.27)
INDSIZE	0.5881	0.4135	0.2911	0.1707	0.0259	0.0074	-0.0094	-0.0098
	(1.11)	(1.33)	(0.84)	(0.36)	(0.05)	(0.29)	(-0.33)	(-0.34)
DEU	1.1242 ***	1.4229 ***	1.3870 ***	1.2180 ***	1.1672 ***	0.1079 ***	0.0983 ***	0.1048 ***
	(4.78)	(4.97)	(4.61)	(4.15)	(3.75)	(5.17)	(4.77)	(4.91)
DNAFTA	1.6456 ***	1.9466 ***	1.9058 ***	1.6802 ***	1.6220 ***	0.1353 ***	0.1260 ***	0.1325 ***
	(7.53)	(7.24)	(6.80)	(6.29)	(5.83)	(5.67)	(5.48)	(5.60)
DASIA	2.0883 ***	0.1118	-0.2041	-1.3773	-1.7829 *	-0.0962 *	-0.1639 **	-0.1618 **
	(6.40)	(0.17)	(-0.29)	(-1.39)	(-1.82)	(-1.78)	(-2.46)	(-2.30)
DLATIN	-0.6836 **	-1.0065 ***	-1.0521 ***	-1.1447 ***	-1.2006 ***	0.0236 *	0.0228	0.0253 *
	(-2.14)	(-3.02)	(-3.19)	(-3.16)	(-3.35)	(1.73)	(1.55)	(1.67)
_cons	3.1668 ***	4.8216 ***	6.0826 ***	8.4713 ***	10.0503 ***	1.4139 ***	1.6720 ***	1.6052 ***
	(2.17)	(2.76)	(2.82)	(3.56)	(3.71)	(7.76)	(8.46)	(7.46)
Number of obs	486	486	486	486	486	555	555	555
F	32.46 ***	38.84 ***	37.65 ***	34.14 ***	32.02 ***	69.57 ***	59.13 ***	55.88 ***
R-squared	0.5912	0.5490	0.5422	0.5070	0.4943	0.6239	0.6030	0.5911
Root MSE	1.2487	1.3130	1.3242	1.3742	1.3933	0.1011	0.1038	0.1055

Notes: The numbers in parentheses are t-statistics based on White's robust standard errors (White 1980). All equations include year dummies which are suppressed here.

Instrument variables: GDP, RISK, COTAX, OPERATE1, OPERATE2, TRFRC.

\*significant at 10% level, \*\* significant at 5% level, \*\*\*significant at 1% level (two-tailed test)

In estimation of equations (1) to (5), observations with a) SHVIIT25=0 and therefore unable to be logistic transformed and b) LTSHVIIT25<mean-2.5\*standard deviation or LTSHVIIT25>mean+2.5\*standard deviation are excluded as outliers. As a result, Nigeria is not included in these estimations.

In estimation of equations (6) to (8), observations with SHVIIT25<mean-2.5\*standard deviation or SHVIIT25>mean+2.5\*standard deviation are excluded as outliers

Source: Authors' calculations.

**Appendix Table B: Detail of Japan's Trade of Electrical Machinery with China: The 10 Most Important Commodities, 2000**

Commodity Classification Name	HS for EX	HS for IM	EX+IM	Exports to CHINA				Imports from CHINA				uvEX /uvIM	trade overlap	price similarity	trade type
			TOTAL VALUE (1,000 yen)	unit name	quantity	value (1,000 yen)	unit value	unit name	quantity	value (1000 yen)	unit value				
1 Tuners for television receivers FM tuners for radio-broadcast receivers Parts suitable for use solely or principally with the apparatus of headings Nos.85.25 to 85.28, other than those of subdivisions Nos.8529.10-100 to 8529.90-200	852990100 852990200 852990300 852990900	852990000	118,342,672	KG	4,846,555	65,179,123	13.45	KG	5,064,898	53,163,549	10.50	1.28	yes	no	VIIT
2 Silicon rectifiers Rectifiers, other than silicon rectifiers Static converters, other than rectifiers	850440110 850440190 850440900	850440011 850440019 850440090	76,829,971	KG	1,785,459	9,688,881	5.43	KG	24,710,383	67,141,090	2.72	2.00	yes	no	VIIT
3 Printed circuits	853400000	853400000	59,700,115	KG	2,401,327	40,333,249	16.80	KG	1,336,073	19,366,866	14.50	1.16	yes	yes	HIIT
4 Parts and accessories of machines of subheadings Nos.8519.10 to 8519.39, other than pick-up cartridges Parts and accessories of machines of subheadings Nos.8519.40 to 8521.90, other than pick-up cartridges	852290100 852290900	852290000	59,083,094	KG	4,147,673	32,268,583	7.78	KG	4,176,498	26,814,511	6.42	1.21	yes	yes	HIIT
5 Apparatuses for switching electrical circuits, for a voltage not exceeding 1,000 volts, other than those of subheadings Nos.8536.10 to 8536.69 Connector for a voltage not exceeding 1,000 volts Apparatus formaking connections of electrical circuits, for a voltage not exceeding 1,000 volts, other than those of subheadings Nos.8536.10 to 8536.69, other than connector	853690100 853690200 853690210 853690290	853690000	53,476,413	KG	4,675,039	28,819,014	6.16	KG	5,033,696	24,657,399	4.90	1.26	yes	no	VIIT
6 Reception apparatus for television of color incorporating cathode-ray television picture tubes, for broadcasting Reception apparatus for television of color for broadcasting, not incorporating cathode-ray television picture tubes Reception apparatus for television of color, other than those for broadcasting	852812110 852812111 852812119 852812190 852812900	852812000 852812010 852812090	48,983,835	NO	133,784	2,619,041	19.58	NO	2,453,767	46,364,794	18.90	1.04	no	yes	OWT
7 Cased micro-computers of MOS type, monolithic digital	854213900	854213090	48,429,771	NO	340,000,000	37,973,922	0.11	NO	134,900,000	10,455,849	0.08	1.44	yes	no	VIIT
8 Motors of an output not exceeding 37.5 W: DC motors: Electric motors, of an output not exceeding 10 W	850110110 850110191	850110011	44,101,093	KG	571,696	4,907,953	8.58	KG	10,602,695	39,193,140	3.70	2.32	yes	no	VIIT
9 Chassis and kits of radio-broadcast receivers, combined with sound recording or reproducing apparatus, other than those of subhedings Nos.8527.11 to 8527.29 Radio-broadcast receivers, incorporating digital audio disk players, combined with sound recording or reproducing apparatus, other than those of subheadings Nos.8527.11 to 8527.29 Radio-broadcast receivers, combined with sound recording or reproducing apparatus, other those of subheadings Nos.8527.11 to 8527.29 and those incorporating digital audio disk players	852731100 852731910 852731990	852731000	42,755,915	NO	5,542	49,018	8.84	KG	22760253	42706897	1.88	4.71	no	error	OWT
10 Parts of apparatus for switching electrical circuits Parts of apparatus for making connections electrical circuits Parts suitable for use solely or principally with the apparatus of heading No. 85.35, 85.36 or 85.37, other than those of subdivisions Nos.8538.10-000 to 8538.90-200	853890100 853890200 853890900	853890000	41,859,800	KG	6,680,248	37,705,557	5.64	KG	1,615,926	4,154,243	2.57	2.20	yes	no	VIIT
Subtotal a Sub-total of top 10 commodities			593,562,680			259,544,342				334,018,338					
Subtotal b Other commodities (from the 11th commodity to the 309th Commodity)			1,222,779,585			659,984,336				562,795,249					
Total a+b Total value of Japan's trade of electrical machinery with China			1,816,342,265			919,528,678				896,813,587					

Note: All the export and unit value data are multiplied by 1.123488827 for fob-cif adjustment.

Sources: Japan's trade data are taken from [http://www.customs.go.jp/tokei/download/index\\_d012\\_e.htm](http://www.customs.go.jp/tokei/download/index_d012_e.htm).

Commodity classification names are based on Japan Tariff Classification 'Zeiron 2001 for Windows.'

**Appendix Table C1. List of the 43 Countries Used in the Regression Analysis**

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<b>North and Latin America</b>				
United States	Canada	Mexico	Brazil	Costa Rica
Panama	Columbia	Venezuela	Peru	Argentina
<b>Europe</b>				
United Kingdom	France	Germany	Belgium	Spain
Portugal	Italy	Netherlands	Ireland	Switzerland
Austria	Denmark	Sweden	Norway	Finland
Hungary	Poland	Luxembourg		
<b>Asia</b>				
China	Hong Kong	Singapore	Republic of Korea	Taiwan
Malaysia	Thailand	Philippines	Indonesia	
India	Saudi Arabia	Israel		
<b>Oceania &amp; Others</b>				
Australia	New Zealand	Nigeria		

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**Appendix Table C2. Regression Results**  
**--- Instrumental variables regressions (IV) and OLS ---**

	<i>Dependent Variables</i>		
	LTSHVIIT15	SHVIIT25	LTSHVIIT25
	IV	IV	OLS
	(1)	(2)	(3)
FDISALE	127.7083 *** (3.70)	10.9876 *** (5.86)	35.2495 *** (4.36)
TRFRC*FDISALE	-678.0115 *** (-3.59)	-55.0053 *** (-5.25)	-182.9500 *** (-4.03)
DGDPPC	-0.2343 *** (-5.28)	-0.0045 (-1.64)	-0.1536 *** (-4.02)
DGDPPC^2	0.0114 *** (4.05)	0.0004 *** (2.66)	0.0051 *** (2.99)
LDIST	-1.2960 *** (-5.16)	-0.1491 *** (-6.87)	-0.9246 *** (-5.44)
INDSIZE	0.1634 *** (0.35)	-0.0032 (-0.15)	1.1117 *** (3.51)
DEU	1.2259 *** (4.20)	0.0921 *** (4.96)	1.0359 *** (4.22)
DNAFTA	1.7103 *** (6.40)	0.1186 *** (5.62)	1.6305 *** (7.28)
DASIA	-1.2510 (-1.26)	-0.1235 ** (-2.51)	1.2023 *** (2.85)
DLATIN	-1.1108 *** (-3.04)	0.0128 (0.91)	-0.8416 *** (-2.65)
_cons	8.4812 *** (3.67)	1.3814 *** (7.09)	4.5921 *** (2.91)
Number of obs	486	541	489
F	37.68 ***	46.68 ***	38.24 ***
R-squared	0.5295	0.5472	0.6008
Root MSE	1.3630	0.1011	1.2418
Instruments	GDP RISK COTAX OPERATE1 OPERATE2 TRFRC	GDP RISK COTAX OPERATE1 OPERATE2 TRFRC	

Notes: The numbers in parentheses are t-statistics based on White's robust standard errors (White 1980)

\*significant at 10% level, \*\* significant at 5% level, \*\*\*significant at 1% level (two-tailed test).

All equations include year dummies which are suppressed here.

In estimation of equations (1) and (3), observations with a) SHVIIT15 or SHVIIT25=0 and therefore unable to be logistic transformed and b) LTSHVIIT15 or LTSHVIIT25<mean-2.5\*standard deviation or LTSHVIIT15 or LTSHVIIT25>mean+2.5\*standard deviation are excluded as outliers. As a result, Nigeria is not included in these estimations.

In estimation of equation (2), samples with SHVIIT25<mean-2.5\*standard deviation or SHVIIT25>mean+2.5\*standard deviation are excluded as outliers.

Source: Authors' calculations.



**Appendix Table C3. Regression Results**

--- Three-stage least squares estimation for system of simultaneous equations, 3SLS ---

	<i>Dependent Variables</i>			
	(1)		(2)	
	LTSHVIT25	FDISALE	SHVIT25	FDISALE
FDISALE	124.8659 *** (4.50)		12.0356 *** (4.56)	
TRFRC*FDISALE	-695.3995 *** (-4.62)		-59.5863 *** (-4.28)	
DGDPPC	-0.2256 *** (-5.18)	0.0028 *** (6.78)	-0.0041 (-1.38)	0.0021 *** (5.33)
DGDPPC^2	0.0110 *** (4.51)	-0.0002 *** (-9.43)	0.0004 ** (2.41)	-0.0001 *** (-7.48)
DIST	-1.2456 *** (-4.89)	0.0138 *** (6.49)	-0.1828 *** (-8.71)	0.0127 *** (6.25)
INDSIZE	0.7124 (0.91)	0.0464 *** (10.15)	-0.0213 (-0.31)	0.0534 *** (12.11)
GDP		1.36E-05 *** (16.00)		1.23E-05 *** (15.04)
RISK		-0.0003 *** (-3.92)		-0.0002 *** (-3.05)
TRFRC		-0.0116 (-1.42)		-0.0053 (-0.86)
COTAX		0.0031 (0.81)		0.0031 (0.91)
OPERATE1		-0.0021 *** (-2.90)		-0.0026 *** (-4.70)
OPERATE2		-0.0003 (-0.31)		-0.0002 (-0.33)
DEU	1.2150 *** (5.64)	-0.0045 * (-1.86)	0.0989 *** (5.77)	-0.0064 *** (-2.90)
DNAFTA	1.7405 *** (5.43)	0.0022 (0.71)	0.1253 *** (5.18)	-0.0005 (-0.17)
DASIA	-1.2388 (-1.50)	0.0342 *** (11.10)	-0.1695 ** (-2.41)	0.0284 *** (10.01)
DLATIN	-1.1707 *** (-3.85)	-0.0003 (-0.13)	0.0230 (1.30)	-0.0021 (-1.02)
_cons	7.9808 *** (3.35)	-0.1306 *** (-6.69)	1.6862 *** (8.69)	-0.1189 *** (-6.34)
Number of obs	486	486	555	555
Chi2	615.11 ***	3087.41 ***	874.75 ***	3131.55 ***
R-squared	0.5153	0.8635	0.5985	0.8492
Root MSE	1.3300	0.0119	0.1022	0.0118

Instrumented      LTSHVIT25 FDISALE  
                          FDISALE  
                          TRFRC\*FDISALE

Notes: The numbers in parentheses are z-statistics.

\*significant at 10% level, \*\* significant at 5% level, \*\*\*significant at 1% level (two-tailed test).

All equations include year dummies which are suppressed here.

In estimation of system (1), observations with a) SHVIT25=0 and therefore unable to be logistic transformed and b) LTSHVIT25<mean-2.5\*standard deviation or LTSHVIT25>mean+2.5\*standard deviation are excluded as outliers. As a result, Nigeria is not included in these estimations.

Source: Authors' calculations.