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Why Has the Border Effect in the Japanese Market Declined? The Role of Business Networks in East Asia

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Abstract

This paper analyzes the causes of the decline in Japan's border effect by estimating gravity equations for Japan's international and interregional trade in four machinery industries (electrical, general, precision, and transportation machinery). In the estimation, we explicitly take account of firms' networks. We find that ownership relations usually enhance trade between two regions (countries), and also find that we can explain 35% of the decline in Japan's border effect from 1980 to 1995 in the electrical machinery industry by the increase of international networks.

JEL Classification numbers: F14; F17; F21;L14
Keywords: Gravity Model; Border Effect; Networks

1. Introduction

As global trade barriers are being steadily dismantled and economies are becoming increasingly integrated, one would expect international borders to have a diminishing effect on international trade flows. Nevertheless, economists estimating gravity models to examine trade flows find that international borders continue to matter. (McCallum (1995), for example, found that trade between Canada's different provinces was 22 times as large as trade between the provinces and different states of the United States.) McCallum's findings were surprising to those who believed that trade barriers between Canada and the US did not matter much anymore.

Given that Japan has often been regarded as one of the most closed markets among developed economies, one would expect to find a large national border effect in the case of Japan.[1] Using data on Japan's international trade and trade between Japan's regions, Okubo (2004) found that Japan's border effect was smaller than the one estimated for Canada in preceding studies.[2] Table 1.1 compares Okubo's result with Helliwell's (1998) results on Canada. This table also shows that in both countries the border effect is declining rapidly. Okubo's finding is consistent with the casual observation that Japan has experienced a substantial increase in her import penetration in the 1980s and 1990s.

INSERT Table 1.1

Probably we can explain the decline in Canadian border effects as the result of trade creation

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[1] On Japanese trade impediments, see Lawrence (1987), Sazanami, Urata and Kawai (1995), and Fukao, Kataoka, and Kuno (2003).

[2] See McCallum (1995), Helliwell (1996; 1998) and Evans (2000). Using a theoretical model, Anderson and van Wincoop (2003) recently showed that small-sized countries tend to have smaller McCallum's border parameter than large countries. It seems that we can partly explain Okubo's result by the relatively large size of the Japanese economy.

effects following the launch of NAFTA.[3] But what factors caused the decline in Japan's border effects? As we shall show later, Japan's international division of labor with other East Asian countries has deepened significantly through the fragmentation of production processes and vertical intra-industry trade. A driving factor behind this trend has been the substantial increase in Japan's outward foreign direct investment (FDI) during the 1980s and 1990s, spurring Japan's international trade and contributing to the decline in the border effect.[4]

A number of studies have analyzed the relationship between Japan's FDI and the increase in her international trade. Using industry level data on Japan's international trade and on exports and imports by Japanese firms' foreign affiliates, Fukao and Chung (1997) showed that since around 1986 Japan's FDI in Asia has contributed to re-imports[5] and intermediate goods trade.[6] Fukao, Ishido and Ito (2003) examined the influence of Japan's FDI on its VIIT more rigorously: they developed a model to capture the main determinants of VIIT that explicitly includes the role of FDI then tested this model empirically, using data from the electrical machinery industry. Their findings show that FDI does play a significant role in the rapid increase in VIIT in East Asia seen in recent years. But few empirical studies on this issue have measured how Japan's FDI has reduced national border effects.[7]

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[3] On the Canadian case, see Fairfield (2003).

[4] Another possible explanation for the decline of the border effect is that reductions in Japan's tariff rates and non-tariff barriers have increased Japan's foreign trade. But reductions in Japan's tariff rates mainly occurred in the period of 1960-1980; Japan's average tariff rate was already very low in the 1980s (Okubo 2004). In the case of Japan's machinery industry, it seems that, by the 1980s, non-tariff barriers were also not particularly high (Sazanami, Urata, and Kawai 1995 and Fukao, Kataoka, and Kuno 2003).

[5] Re-imports are defined as Japanese foreign affiliates' exports to Japan.

[6] On this issue, also see Lipsey, Ramstetter, and Blomström (1999).

[7] One study examining the relationship between Japan's outward FDI and imports using a gravity type equation is the one by Eaton and Tamura (1994), which, however, does so only at the macro

The aim of this paper is to study the causes of the decline in Japan's border effect by estimating gravity equations for Japan's interregional trade and trade between Japan's regions. In the estimation, we explicitly take account of interfirm networks. We conduct separate gravity model estimations for four machinery industries (electrical, general, precision, and transportation machinery). Our reasons for focusing on these four sectors are as follows: (a) most of Japan's FDI in the manufacturing sector has been concentrated in the machinery industry; and (b) even within the machinery industry, there are large differences in the patterns of VIIT and outsourcing in the electrical machinery and the transportation machinery sector, as we will show in the next section. In order to analyze the effects of interfirm networks on international trade, it is necessary to look at trade flows at a relatively disaggregated level.

It is important to note the that national border effects estimated in a gravity equation will depend not only on outward FDI, but also on inward FDI and firms' networks linking Japan's regions. Using inward FDI statistics and data from the *Establishment and Enterprise Census*, we will take these factors into account.

The remainder of the paper is organized as follows. Section 2 provides an overview of Japan's trade and FDI patterns; Section 3 presents an econometric analysis of Japan's border effects; and. Section 4 summarizes the main findings of this paper.

2. Overview of Japan's International Trade

In this section, we take a general look at the pattern of Japan's trade and FDI in the last two decades.

2.1 Rapid Increase in the Import Penetration of Manufactured Products

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level.

Although Japan's overall import-GDP ratio gradually declined over the last two decades, imports of manufactured products have actually grown faster than the economy as a whole (Table 2.1).[8] As Figure 2.1.B shows, the increase in imports is mainly concentrated in electrical machinery and labor intensive goods, such as apparel and wooden products, which in this figure are classified as "other manufacturing products." Since the share of the manufacturing sector in GDP declined during this period, the ratio of imports of manufactured products to gross value added in the manufacturing sector increased rapidly: by 11.5 percentage-points from 15.2% in 1985 to 26.7% in 2000 (Table 2.1).[9]

INSERT Table 2.1 and Figure 2.1

In contrast with the rapid changes in the commodity composition of Japan's imports, the commodity composition of Japan's exports has remained relatively stable over the last fifteen years (Figure 2.1.A).

Japan's increased imports of electrical machinery and labor intensive products are mainly provided by East Asian economies. Figure 2.2 shows that nine East Asian economies (China, Hong Kong, Taiwan, Korea, Singapore, Indonesia, Thailand, the Philippines, and Malaysia) provided 64.2% of Japan's electrical machinery imports and 49.2% of Japan's imports of "other manufacturing products" in 2000. The East Asian economies' share in Japan's total imports of machinery and intermediate products such as metal products and chemical products has also

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[8] Comparing export shares and import penetration in the US, Canada, the UK and Japan during the period 1974–93, Campa and Goldberg (1997) found import penetration to be extremely stable and significantly lower in Japan than in the other countries. However, Japan has experienced a substantial change in her import penetration in the 1990s. If we were to conduct a similar analysis using more recent data, it seems probable that Campa and Goldberg's conclusion no longer holds.

[9] The United States experienced a similar trend during the 1980s, when this ratio jumped by 12.4 percentage-points from 18.3% in 1978 to 30.7% in 1990 (Sachs and Shatz 1994).

increased rapidly.

INSERT Figure 2.2

As a result of these trends, East Asia during the 1990s became the most important destination for and origin of Japan's international trade. As Figure 2.3 shows, trade with the nine East Asian economies accounted for 48.5% of Japan's total manufactured imports and 41.0% of total manufactured exports in 2000.

INSERT Figure 2.3

2.2 Fragmentation and Vertical Intra-industry Trade

This rise in Japan's imports of labor intensive products and exports of capital and technology intensive products (such as machinery and advanced intermediate products) can be easily recognized as a deepening of the international division of labor with the relatively unskilled-labor abundant East Asian economies. But how can we interpret the rapid increase in the two-way trade in electrical machinery? Table 2.2, presenting Japan's bilateral trade in electrical machinery with China and Hong Kong in 1999 at the 3-digit level, provides a clue.

INSERT Table 2.2

This table shows two important facts. First, there is a huge trade in electrical machinery equipment and related parts and components between Japan and China plus Hong Kong. According to MITI (1999), the share of machine parts in Japan's total exports to East Asia increased from 31.7% in 1990 to 40.2% in 1998. It seems that the international division of labor through the fragmentation of production processes has contributed to the increase of Japan's trade with East Asia.

The second important fact that this table shows is the existence of huge intra-industry trade between Japan and China plus Hong Kong. For example, in the case of television receivers, the total trade value is 37 times greater than the trade balance.

Using Japan's custom statistics on electrical machinery trade at the HS 9-digit commodity classification (Harmonized Commodity Description and Coding System), Fukao, Ishido and Ito (2003) found that in the case of Japan's trade with East Asian economies, the unit prices of Japan's exports tends to be substantially higher than those of her imports. 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, their findings indicate that there has been a rapid increase in Japan's intra-industry trade with a vertical division of labor, i.e. vertical intra-industry trade (VIIT), with her East Asian neighbors.[10] Figure 2.4 shows the share of the trade types for Japan's trade in the electrical machinery industry by partner region or economy in 1988, 1994 and 2000. This figure is a simplex diagram, where 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 one way trade (OWT). Similarly, the distance to the line OWT-VIIT denotes the share of horizontal intra-industry trade (HIIT), while the distance to HIIT-OWT denotes the share of vertical intra-industry trade (VVIT). For the definition of the three trade types see Appendix A. The starting point of each arrow corresponds to the value for the year 1988 and the end of the arrow corresponds to the value for 2000. This figure reveals a dramatic increase of VIIT in Japan's trade with China and the ASEAN countries during 1988 to 2000.

INSERT Figure 2.4

The contribution of VIIT to the rapid increase in intra-regional trade in East Asia is shown by a comparison of intra-regional trade pattern in East Asia and the EU.

The simplex diagrams in Figures 2.5 and 2.6 show the shares of the three trade types in

[10] Major preceding studies on vertical intra-industry trade using this gap between unit export and import prices to distinguish vertical and horizontal IIT are Greenaway, Hine, and Milner (1995), Fontagné, Freudenberg, and Péridy (1997), and Aturupane, Djankov, and Hoekman (1999).

intra-EU and intra-East Asian trade for each commodity category.[11] 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 regions, OWT dominates in agricultural and mining products. The share of VIIT is relatively high in the trade in machinery.

INSERT Figure 2.5 and 2.6

There also exist some differences between trade in the EU and in East Asia. In East Asia, the share of VIIT is exceptionally high in electrical machinery and general and precision machinery. We should note that in East Asia, export oriented FDI is concentrated in these sectors. 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.

It is important to note that the commodity composition of intra-East Asian trade is very different from that of intra-EU trade, which as is shown in Figures 2.7 and 2.8. In East Asian trade, 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. IIT has been a crucial factor underlying the overall

[11] For the analysis of trade patterns in the EU and East Asia, Fukao, Ishido and Ito (2003) used the PC-TAS (Personal Computer Trade Analysis System) published by the United Nations Statistical Division. The dataset is based on the 6-digit HS88 commodity classification.

increase in trade.

INSERT Figure 2.7 and 2.8

Ito and Fukao (2003) showed that, Japan's transportation machinery industry is lagging behind other machinery industries not only in VIIT but also in outsourcing. Figure 2.9 shows the share of VIIT and outsourcing measures derived by Ito and Fukao (2003). Their measures of broad and narrow outsourcing are constructed following Feenstra and Hanson (1999).[12] The broad outsourcing measure expresses imported intermediate inputs relative to total expenditure on non-energy intermediate inputs in each industry.[13] The narrow outsourcing measure represents the imported intermediate inputs from the same industry as the good being produced (based on the Japan Industrial Productivity [JIP] database) divided by the total expenditure on non-energy intermediate inputs in each industry.[14] Ito and Fukao's (2003) finding that Japan's transportation machinery industry is behind in VIIT and outsourcing is consistent with our previous finding that the trade share of transportation machinery in East Asian total trade is much smaller than in the EU.

INSERT Figures 2.9 and 2.10

Figure 2.10 presents the growth rate of the VIIT share and the growth rates of the broad and narrow outsourcing measures for the period 1988–2000 for each industry. This shows that all three measures have increased in all the machinery industries except in the ship building industry. The broad and narrow outsourcing measures have grown more rapidly than the VIIT share in almost all the industries.

2.3 The Role of Foreign Direct Investment

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[12] For the definition of broad and narrow outsourcing measures, see Appendix A.

[13] Ito and Fukao's (2003) industry classification is based on the basic industry classification of the Japan Input-Output Tables 1990 by the Management and Coordination Agency. Their classification lists 246 manufacturing industries

[14] The JIP database classifies the manufacturing sector into 35 industries.

It is important to note that Japan's foreign direct investment (FDI) plays a key role in the rapid growth of Japan's trade in manufactured products with the rest of East Asia. Table 2.3 shows the share of Japan's trade with Japanese affiliates abroad in Japan's total trade with East Asia in 1999. Both imports of intermediate products from Japan by Japanese manufacturing affiliates in East Asia and exports of their output to Japan occupy a large share in Japan's total trade with this region. Though in the case of general machinery, the share of procurements by Japanese manufacturing affiliates' located in East Asia in Japan's total exports to East Asia does not seem to be large, it is important to note that this share does not include Japanese affiliates' purchases of investment goods from Japan. Japanese affiliates in East Asia imported 400 billion yen worth of capital equipment for investment from Japan in 1999. Probably a substantial part of the equipment imports consists of general machinery.[15]

Figure 2.11 shows the trade and FDI patterns for Japan's machinery industry. In the case of the two leading export industries, electrical machinery and transportation machinery, production by Japanese affiliates abroad surpassed exports from Japan. Especially in the case of electrical machinery, Japan's imports have increased rapidly. As we have seen in Table 2.3, one half of Japan's imports from East Asia are produced by Japanese affiliates there.

INSERT Table 2.3 and Figure 2.11

Fukao, Ishido and Ito (2003) examined the influence of Japan's FDI on its VIIT more rigorously: they developed a theoretical model to capture the main determinants of VIIT that explicitly includes the role of FDI and then tested this model empirically, using data from the

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[15] Japan's total exports of general machinery to East Asia amounted to 1,200 billion yen in 1999. Okubo (2003b) analyzed Japan's IIT in recent years, finding that not only a similarity of GDP levels but also technological similarity across nations enhance IIT, and that Japanese FDI toward Asian countries greatly contributes to such technological similarity.

electrical machinery industry. The findings show that FDI does indeed play a significant role in the rapid increase in VIIT in East Asia seen in recent years.

3 Econometric Analysis

In this section we conduct a statistical analysis of border effects for Japan's international trade and trade among Japan's regions and study how Japanese firms' networks across countries and regions have influenced Japan's trade pattern.

3. 1 Data and Methodology

The majority of studies on border effects so far has been based on the estimation of gravity equations at the macro level (McCallum 1995, Helliwell 1996, 1998, Evans 2000, Anderson and van Wincoop 2003, and Okubo 2003a). In this paper, we conduct estimations of a gravity model for four machinery industries (electrical, general, precision, and transportation machinery).[16]

Studies estimating gravity equations at the macro level have used the GDP of the exporting country (or region) as the measure of production and the GDP of the importing country (or region) as the measure of the size of demand. For our industry-level analysis, we use domestic production and domestic demand in each industry in place of GDP.[17] We obtain regional domestic demand and production data from the *Input-Output Tables of Interregional Relations* (Chiiki-kan Sangyo Renkan Hyo) published by the Ministry of Economy Trade and Industry (MITI), which are published every

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[16] It is also important to note that machinery products are usually well differentiated and this characteristic is consistent with basic assumptions in the standard gravity model.

[17] Helliwell (1998, Ch. 2) estimated gravity equations at the industry level. He used the GDP of exporting and importing provinces (or states). He observed positive and significant border effects at an industrial level between Canada and the United States. We think that his approach is problematic because the regional distribution of production of certain industries is usually quite different from the distribution of GDP and, similarly, the distribution of domestic demand for a certain industry is not identical with the distribution of GDP.

five years and cover all the industries at the 2-digit level divided into nine Japanese regions: Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, Kyushu, and Okinawa. Since Okinawa's economy is very small in comparison with the other regions and the production of machinery in Okinawa is negligible, we excluded Okinawa from our data and analyzed eight regions.

We obtain cross country data of domestic demand and production from the *Industrial Demand Supply Balance Database* of the United Nations Industrial Development Organization (UNIDO). The UNIDO data are available from 1981; based on the five-year intervals dictated by the regional I-O tables, our econometric analysis therefore begins in 1980 (where we use 1981 data for 1980).

The drawback of our source for data on interregional trade in Japan is that the international trade data in the I–O table are available only at the national level. There are no statistics on each region's bilateral trade with other countries. Therefore, we had to estimate this data, using the following methodology: first, we calculated each region's share in Japan's total imports and exports for each industry in I-O table. Next, we multiplied Japan's bilateral international trade in each industry with each region's trade share. We obtain data on Japan's international trade from the *World Trade Flows 1980–1997* of the Center for International Data, University of California, Davis. Figure 3.1 shows the share of international trade in the total trade of the eight Japanese regions for each industry. The denominator of each value is the sum of the eight regions' imports from (exports to) all foreign countries and all the other regions. The numerator is the sum of the eight regions' imports from (exports to) all the foreign countries. The share of international imports in total imports of the eight regions increased in all the four industries in 1980–1995 and was especially large in the electrical and the precision machinery industries. In contrast, the share of international exports in total exports of the eight regions declined slightly in the transportation and the precision machinery industries.

INSERT Figure 3.1

Foreign countries' GDP was taken from the World Bank's *World Development Indicators*, while the GDP of the eight Japanese regions is from the *Prefectural Income Statistics* (Kenmin Shotoku Tokei) by the Ministry of Public Management, Home Affairs, Posts and Telecommunications.

We measure the size of Japanese firms' networks in a certain industry, which connect Japan with the same industry in a foreign country, by the number of Japanese affiliates in the same industry in that country. We measure the extent of Japan's international links in a particular industry by using the number of Japanese affiliates in that industry in a particular country. Similarly, we measure foreign countries' network links with Japan in a particular industry by using the number of those countries' affiliates in Japan in the same industry.

We obtain these data from various issues of the following MITI publications: the *Basic Survey of Overseas Business Activities* (Kaigai Jigyo Katsudo Kihon Chosa), the *Survey on Trends of Japan's Business Activities Abroad* (Kaigai Jigyo Katsudo Doko Chosa) and the *Report on Trends of Business Activities by Japanese Subsidiaries of Foreign Firms* (Gaishi-kei Kigyo no Doko). No statistics on Japan's region's bilateral inward and outward direct investment relationship with other foreign countries at the industry level are available. We assume that Japan's inward and outward FDI affects all Japanese regions in a similar way and use national data on FDI for each region. Figure 3.2 shows firms' network linkages between Japan and foreign countries. The number of foreign affiliates owned by Japanese firms increased very rapidly in 1980–1995. In contrast, the number of foreign firms' affiliates in Japan stagnated.

We measure the size of firms' networks in a certain industry in region *i*, which connect this region with the same industry in region *j*, by the number of establishments owned by firms in region *i* and located in region *j*. We take this data from the *Special Aggregation Tables of the Establishment* *and Enterprise Census* (Jigyosho Kigyo Tokei Chosa, Tokubetsu Shukei Hyo) of the Ministry of Public Management, Home Affairs, Posts and Telecommunications. Unfortunately, the data are available only for 1991. We assume that firms' interregional networks in Japan remained unchanged during the period 1980–1995 and use the same data for this period.[18]

3.2 The Empirical Model

First we estimate a McCallum-type gravity equation for each industry (McCallum 1995):

$$\log(TRADE_{i,j,t}^{k}) = \alpha_0 + \alpha_1\log(GDP_{i,t}) + \alpha_2\log(GDP_{j,t}) + \alpha_3\log(DIS_{i,j}) + \alpha_4 GAP_{i,j,t} + \sum_{\tau=80}^{95} \alpha_{5\tau} BORDUM_{i,j} * YEARDUM_{t,\tau} + \varepsilon_{i,j,t}^{k} \quad (3.1)$$

where $TRADE_{i,j,t}^{k}$ denotes the nominal exports (in million yen) of industry k products from country (or region) i to country (or region) j in year t. We use data of cross-regional trade within Japan ($i \in R$ and $j \in R$, where R denotes the set of the eight Japanese regions) and data of Japan's international trade ($i \in R$ and $j \in C$, or $i \in C$ and $j \in R$, where C denotes the set of Japan's trade partner countries) for the years 1980, 1985, 1990, and 1995. $GDP_{i,t}$ and $GDP_{j,t}$ are the gross domestic products in country (or region) i and country (or region) j in year t. $DIS_{i,j}$ is the distance (in km) between the capital (or the seat of government of the prefecture with the largest GDP in the region) of country (region) i and the capital (or the seat of government) of country (region) j.[19] $GAP_{i,j,t}$ denotes the absolute value of the difference of the logarithm of the per-capita GDP of i and the logarithm of the per-capita GDP of j in year t. $BORDUM_{i,j}$ is a dummy variable for domestic trade. $BORDUM_{i,j}=1$, if $i \in R$ and $j \in R$.

[18] According to various issues of the *Establishment and Enterprise Census*, the number of manufacturing establishments in the years 1981, 1986, 1991, and 1996 was 873,000, 875,000, 857,000, and 772,000 respectively. Therefore, it seems that the number of firms' interregional linkages in Japan have stagnated or slightly declined in the period. On this issue, see Tomiura (2003).

[19] To calculate the distance between a region in Japan and a foreign country, we used the distance between Tokyo and the capital of the foreign country.

Otherwise $BORDUM_{i,j}$ =0. $YEARDUM_{t,\tau}$ is a year dummy. $YEARDUM_{t,\tau}$=1 if $\tau=t$. Otherwise $YEARDUM_{t,\tau}$=0. $\varepsilon_{i,j,t}{}^{k}$ is an ordinary error term. In order to take account of the possibility of heteroscedasticity among different groups, we estimate this and the following equations by the feasible generalized least square (FGLS) method.

Next, we estimate an equation in which we replace the GDP of exporting country (region) i with $SUPEX_{i,t}{}^{k}$ – representing the total domestic supply of industry k output in country (region) i – and the GDP of the importing country (region) j with $DEMIM_{j,t}{}^{k}$ – which stands for the total domestic demand for industry k output in country (or region) j:

$$\log(TRADE_{i,j,t}{}^{k}) = \alpha_0 + \alpha_1\log(SUPEX_{i,t}{}^{k}) + \alpha_2\log(DEMIM_{j,t}{}^{k}) + \alpha_3\log(DIS_{i,j})$$
$$+\alpha_4 GAP_{i,j,t} + \sum_{\tau=80}^{95} \alpha_{5\tau} BORDUM_{i,j} * YEARDUM_{t,\tau} + \sum_{\tau=80}^{95} \alpha_{6\tau}\, EXDUM_{i,j} * YEARDUM_{t,\tau} + \varepsilon_{i,j,t}{}^{k} \quad (3.2)$$

The border effect on imports might be different from the border effect on exports. In order to control for this difference, we add an export dummy $EXDUM_{i,j}$ on the right hand side. $EXDUM_{i,j}$=1, if $i\in R$ and $j\in C$. Otherwise $EXDUM_{i,j}$=0.

In the third equation, we add network variables:

$$\log(TRADE_{i,j,t}{}^{k}) = \alpha_0 + \alpha_1\log(SUPEX_{i,j,t}{}^{k}) + \alpha_2\log(DEMIM_{i,j,t}{}^{k}) + \alpha_3\log(DIS_{i,j})$$
$$+\alpha_4 GAP_{i,j,t} + \sum_{\tau=80}^{95} \alpha_{5\tau} BORDUM_{i,j} * YEARDUM_{t,\tau} + \sum_{\tau=80}^{95} \alpha_{6\tau}\, EXDUM_{i,j} * YEARDUM_{t,\tau}$$
$$+\alpha_7\log(NPAAFWO_{i,j,t}{}^{k}) + \alpha_8\log(NAFPAWO_{i,j,t}{}^{k}) + \alpha_9\log(NPAAFJA_{i,j}{}^{k}) + \alpha_{10}\log(NPAAFJA_{i,j}{}^{k})$$
$$+ \varepsilon_{i,j,t}{}^{k} \quad (3.3)$$

where $NPAAFWO_{i,j,t}{}^{k}$ and $NAFPAWO_{i,j,t}{}^{k}$ denote variables for networks between Japan and the foreign country. $NPAAFWO_{i,j,t}{}^{k}$ denotes the number of cross-border ownership relations in year t in industry k where the parent firm is located in exporting country (region) i and the affiliate is located in importing country (region) j. Conversely, $NAFPAWO_{i,j,t}{}^{k}$ denotes the number of cross-border ownership relations in year t in industry k where the parent firm is located in the importing country (region) i and the affiliate is located in the exporting country (region) j. Similarly, $NPAAFJA_{i,j}^{k}$ and $NPAAFJA_{i,j}^{k}$ denote variables for networks among regions in Japan. The rigorous definitions of the four variables are as follows:[20]

$NPAAFWO_{i,j,t}^{k}$: the number of affiliates in country j owned by Japanese firms, if $i \in R$ and $j \in C$.

$NPAAFWO_{i,j,t}^{k}$: the number of affiliates in Japan owned by country i firms, if $i \in C$ and $j \in R$.

$NPAAFWO_{i,j,t}^{k} = 0$, if $i \in R$ and $j \in R$.

$NAFPAWO_{i,j,t}^{k} = NPAAFWO_{j,i,t}^{k}$

$NPAAFJA_{i,j,t}^{k}$: the number of establishments in region j owned by firms in region i, if $i \in R$ and $j \in R$.

$NPAAFJA_{i,j,t}^{k} = 0$, if $i \in R$ and $j \in C$ or if $i \in C$ and $j \in R$.

$NAFPAJA_{i,j,t}^{k} = NPAAFJA_{j,i,t}^{k}$

In order to check the robustness of our results we also estimate the following equation using a dataset of interregional trade alone ($i \in R$ and $j \in R$).

$$\log(TRADE_{i,j,t}^{k}) = \alpha_0 + \alpha_1\log(SUPEX_{i,j,t}^{k}) + \alpha_2\log(DEMIM_{i,j,t}^{k}) + \alpha_3\log(DIS_{i,j})$$
$$+\alpha_4 GAP_{i,j,t} + \sum_{\tau=80}^{95} \alpha_{5\tau} YEARDUM_{t,\tau} + \alpha_6\log(NPAAFJA_{i,j}^{k}) + \alpha_7\log(NPAAFJA_{i,j}^{k}) + \varepsilon_{i,j,t}^{k} \quad (3.4)$$

Similarly, we estimate the following equation using a data set of international trade alone ($i \in R$ and $j \in C$, or $i \in C$ and $j \in R$).

$$\log(TRADE_{i,j,t}^{k}) = \alpha_0 + \alpha_1\log(SUPEX_{i,j,t}^{k}) + \alpha_2\log(DEMIM_{i,j,t}^{k}) + \alpha_3\log(DIS_{i,j})$$
$$+\alpha_4 GAP_{i,j,t} + \sum_{\tau=80}^{95} \alpha_{5\tau} YEARDUM_{t,\tau} + \sum_{\tau=80}^{95} \alpha_{6\tau} EXDUM_{i,j} * YEARDUM_{t,\tau}$$
$$+\alpha_7\log(NPAAFWO_{i,j,t}^{k}) + \alpha_8\log(NAFPAWO_{i,j,t}^{k}) + \varepsilon_{i,j,t}^{k} \quad (3.5)$$

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[20] In order to take logarithmic values, we added one to each variable.

3.3 Estimation Results

Tables 3.1, 3.2, 3.3, and 3.4 show the estimation result for the four machinery industries.

INSERT Tables 3.1, 3.2, 3.3, and 3.4

In all the estimations, the coefficients on the distance variable are negative and significant. We also obtain positive estimates for the coefficients on GDP and the coefficients on *SUPEX* and *MEMIM*.

In the case of the estimation of the standard McCallum-type equation (equation 1 in each table), we find that the border effect declined in all four industries over the period 1980–1995. Another interesting finding is that the magnitude of the border effects is very small when compared with the results found in previous studies on border effects in the Canadian case. For example, Helliwell's (1998) estimation at the industry level in 1990, based on data for the US and Canada, found that interregional trade in Canada is 7.14 times greater than Canada–US trade in the case of machinery and equipment and 27.27 times greater in the case of electrical and communications equipment. In contrast, our results on border effects in 1990 imply that interregional trade in Japan is only 2.79 times greater than Japan's international trade in the case of general machinery and 4.60 times greater in the case of transportation equipment. In the case of electrical machinery and precision machinery we get negative values for the estimated border effects for recent years. This suggests that international trade is more active than interregional trade.

In contrast with Helliwell's data on Canada and the US, our data covers Japan's trade with many poor countries. If trade springs mainly from factor price gaps, then our data should be able to explain why international trade is more active than interregional trade. In order to test this hypothesis, we add the per-capita GDP gap to our explanatory variables (equation 2). But contrary to our expectations, the estimated coefficient on the per-capita GDP gap took a negative and significant value in all the four industries and the inclusion of the per-capita GDP gap variable reduced the estimated border effects in all four industries. The negative coefficient on the per-capita GDP gap implies that trade is more active between regions (countries) of a similar per-capita GDP level. It seems that the horizontal division of labor plays an important role in Japan's interregional and international trade of machinery.

Next we replace the GDP of the exporting and importing region (country) with the domestic supply of each industry in the exporting region (country) and the domestic demand for each industry's output in the importing country (equation 3 and equation 4). Our main results on the low and declining border effects and the negative coefficient on the per-capita GDP gap, however, remain unchanged.

It may be possible that border effects on imports and on exports are different. In order to examine this, we add an export dummy, which takes the value one in the case of Japan's exports to foreign countries (equation 5). The estimated coefficient on the export dummy is positive and significant in all four industries in all years, except in the electrical and the precision machinery industries in 1995. This implies that the border effect for Japan's imports is larger than for Japan's exports. But even after taking this difference into account, the estimated border effect (for Japan's imports) is still very small in the case of all the industries except transportation equipment.

Next, we add network variables (equations 6 and 7). In many cases, the estimated coefficients on the four network variables take positive and significant values. This finding implies that cross-border ownership relations usually enhance trade between the two regions (countries). In all four industries, the coefficients on *NPAAFWO* are greater than the coefficients on *NAFPAWO*, implying that the creation of cross-border ownership relations increases the exports from the location of the parent firm to the location of the affiliate more than vice versa. (delete: the exports from the location of the affiliate to the location of the parent firm.)

On the other hand, in the cases of transportation equipment, general machinery and precision machinery, *NAFPAJA* is greater than *NPAAFJA*. This implies that active domestic transaction of parts and components enhances "exports" from the location of the establishment to parent firms within Japan.

Because the definition of the interregional network variable, which is based on the relationship between the head office and the other establishments, and the definition of the international network variable, which is based on the relationship between the parent firm and its foreign affiliates, the inter-temporal average of the border dummies no longer contains useful information in the case of equation 5. But the inter-temporal changes of border dummies still show how Japan's border effect changed over time. If we obtain a smaller decline in border effects from 1980 to 1995 by adding network variables, we can infer that the inter-temporal decline in Japan's border effect is caused by the spread of Japan's international networks. Comparing the estimation results of equations 5 and 7, we find that we get this type of result only in the case of the electrical machinery industry, where the decline in the border effect from 1980 to 1995 in equation 7 is 35% smaller than the corresponding decline in equation 5 (exp((0.75+0.199)-(0.512+0.871))-1=-0.434). Therefore, we can infer that we can explain 35% of the decline in Japan's border effect from 1980 to 1995 in the electrical machinery industry by the spread of international networks.

In order to check the robustness of our results we estimate the gravity equation using a data set of interregional trade alone. The result is reported as equation 8. Similarly, we estimate the gravity equation using a data set of international trade alone. The results are shown as equations 9 and 10. Our main results remain same in these regressions. We obtain positive estimates for the coefficients on SUPEX and MEMIM. The estimated coefficients on the network variables take positive and significant values in many equations. The values of NAFPAWO are negative or insignificantly positive except for electrical machinery sector. This suggests that in the electrical machinery industry, Japan's outward FDI clearly encouraged re-imports from Asian countries. Another important finding from this sensitivity analysis concerns the absolute value of the coefficient on the distance variable: this is smaller in the estimation with the data set of interregional trade alone than in the estimation with the data set of international trade alone. It therefore seems that distance plays a different role in interregional than in international trade. This is a finding that it would be desirable to examine more carefully in the future.

4. Conclusions

In this paper we analyze the causes of the decline in Japan's border effect by estimating gravity equations for Japan's international and interregional trade in four machinery industries (electrical, general, precision, and transportation machinery). In the estimation, we explicitly take account of firms' networks. We obtain data on firms' networks from outward and inward FDI statistics and data from the *Establishment and Enterprise Census*.

In the case of the estimation of the standard McCallum-type equation, we find that the border effect declined in all four industries over the period 1980–1995. Another interesting finding is that the magnitude of the border effects is very small when compared with the results found in previous studies on border effects in the Canadian case. When we add network variables, we find that ownership relations usually enhance trade between two regions (countries). This result implies that the creation of ownership increases the exports from the location of the parent firm to the location of the affiliate more than vice versa. Conversely, in the cases of transportation equipment, general machinery and precision machinery, the creation of domestic ownership increases the "exports" from the location of the establishment to the location of the parent firm more. Further, in the case of electrical machinery, the creation of cross border ownership linkages increases the exports from the location of the affiliate to the location of the parent firm. This result is consistent with our finding that in the case of this industry, Japan’s outward FDI encourages re-imports from Asian countries. We also find that we can explain 35% of the decline in Japan’s border effect from 1980 to 1995 in the electrical machinery industry by the increase of international networks.

Appendix A: Measurement Methods and Data Sources for Vertical Intra-industry Trade and Outsourcing

Measures of Vertical Intra-Industry Trade

In order to identify vertical and horizontal IIT we adopt the methodology used in major preceding studies on vertical IIT such as Greenaway, Hine, and Milner (1995) and Fontagné, Freudenberg, and Péridy (1997). This 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 in the products exported and imported between two economies.

We break down the bilateral trade flows of each detailed commodity category into the following 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). Then the share of each trade type is defined as:

$$\frac{\sum_j (M^Z_{kk'j} + M^Z_{k'kj})}{\sum_j (M_{kk'j} + M_{k'kj})} \qquad \text{(A1)}$$

where the variables are defined as

$M_{kk'j}$: 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;

$UV_{kk'j}$: 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.

The upper-suffix 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 shown in Appendix Table 1.

For our analysis, we chose to identify horizontal IIT by using the range of relative export/import unit values of 1/1.25 (i.e., 0.8) to 1.25.

Appendix Table 1. 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 $1.25 < \frac{UV_{kk'j}}{UV_{k'kj}}$

We used Japan's customs data provided by the Ministry of Finance (MOF). Japan's customs data are recorded at the 9-digit HS88 level and the data classified by HS88 are available from the year 1988. 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 the statistics consistent with the original HS88 code. In Japan's customs statistics, export data are recorded on an f.o.b. basis while import data are on a c.i.f. basis. We should note that our estimate of the VIIT share is biased upward because of this difference.

Outsourcing Measures

Following Feenstra and Hanson (1999) and other previous studies, Ito and Fukao (2003) constructed outsourcing measures as follows:

For each industry *i*, we measure imported intermediate inputs as

Σ_j [input purchases of good *j* by industry *i*]*[(imports of good *j*)/(consumption of good *j*)]

(A2)

where consumption of good j is measured as (shipments + imports - exports). The *broad* measure of foreign outsourcing is obtained by dividing imported intermediate inputs by total expenditure on non-energy intermediate inputs in each industry. The *narrow* measure of outsourcing is obtained by restricting attention to those inputs that are purchased from the same JIP industry as the good being produced. Using Japan's customs data, Hiromi Nosaka, Tomohiko Inui, Keiko Ito, and Kyoji Fukao compiled trade data at the basic industry classification of the I-O tables in 1990 prices as part of the Japan Industrial Productivity (JIP) database project at the Economic and Social Research Institute, Cabinet Office, Government of Japan (Fukao et. al 2003).

The correspondence between the Fukao-Ito industry classification and the 1980-85-90 Japan Linked Input-Output standard classification for manufacturing industries and the correspondence between the JIP classification and the Fukao-Ito classification for manufacturing industries is presented in Ito and Fukao (2003).

When calculating the outsourcing measures, Ito and Fukao first calculated the input coefficients by Fukao-Ito industry and aggregated the imported intermediate inputs in each Fukao-Ito industry into the corresponding JIP industry. As for the narrow outsourcing measure, we restricted the Fukao-Ito industry subscripts i and j in equation (A2) to be within the same JIP industry. We should note that Ito and Fukao (2003) only took account of intermediate inputs from manufacturing industries.

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Table 1.1 Estimation Results on Border Effects: A Comparison between Canada and Japan

Canadian Border Effects

		1988	1989	1990	1991	1992	1993	1994	1995	1996
Helliwell (1998)	(OLS)	20.7	19.0	25.3	17.0	15.2	12.3	11.4	14.0	11.9

Japan's Border Effects

			1960	1965	1970	1975	1980	1985	1990
Okubo (2004)	(OLS)	Tradable goods	8.57	8.85	10.38	6.42	3.6	4.58	3.41
	(OLS)	Manufactured goods	60.76	97.51	46.45	16.8	12.96	16.17	7.46

Border effect (times)=exp(the estimated coefficient of the border dummy)

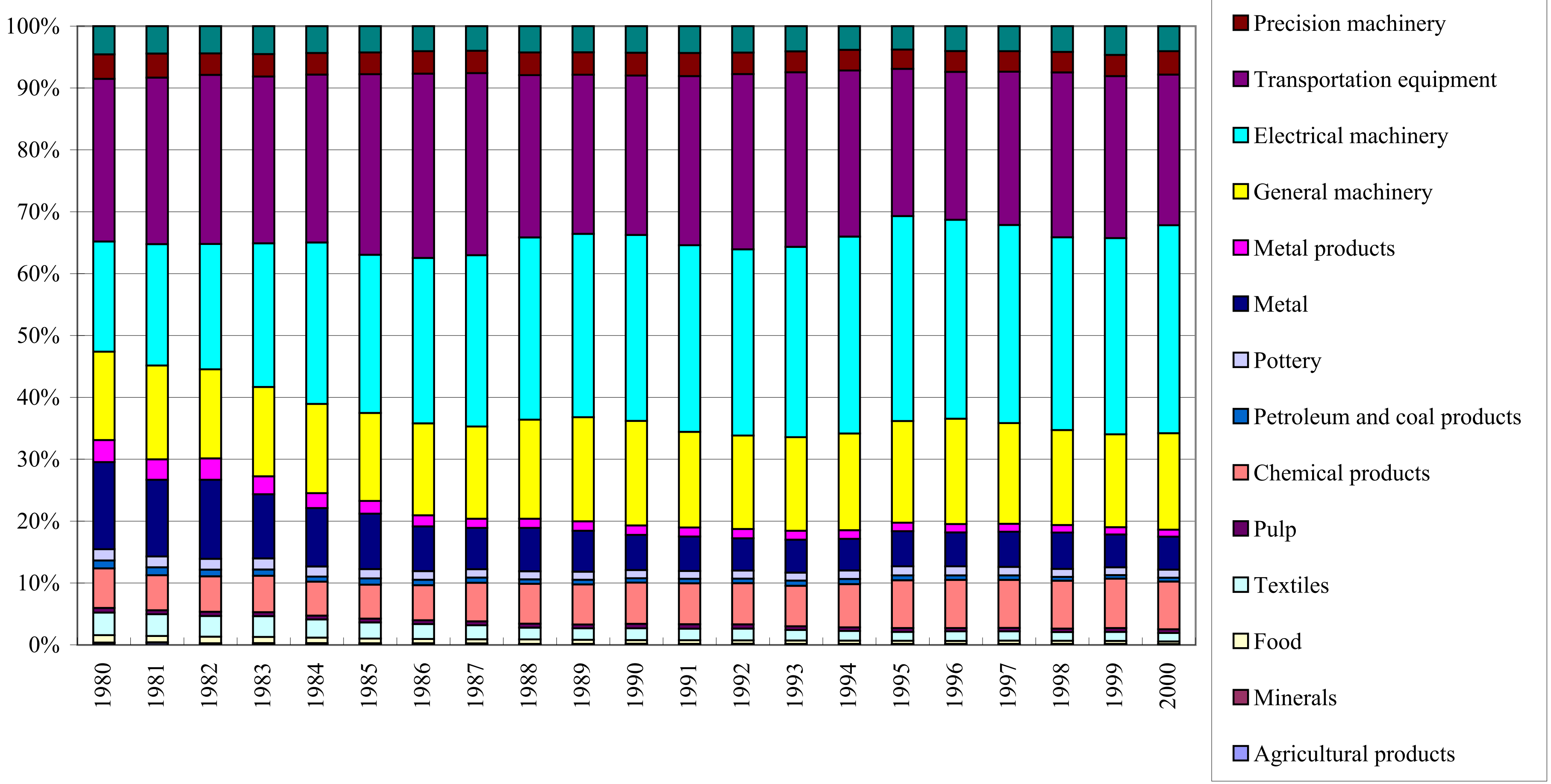
Table 2.1 Japan's Share of Imports and Manufacturing Sector in GDP, Employment, and Gross Value Added

	Imports of goods and services/GDP	Imports of manufactured products (CIF)/GDP	Imports of services/GDP	Share of manufacturing sector in total GDP	Share of manufacturing sector in total employed persons	Imports of manufactured products (CIF)/gross value added by manufacturing sector
1980	15.1%	5.1%	1.7%	29.2%	26.2%	17.4%
1985	11.3%	4.5%	1.6%	29.5%	26.5%	15.2%
1990	9.4%	5.3%	1.6%	28.2%	26.2%	18.7%
1995	7.8%	5.0%	1.3%	24.7%	24.7%	20.3%
2000	9.5%	6.3%	1.3%	23.4%	22.3%	26.7%

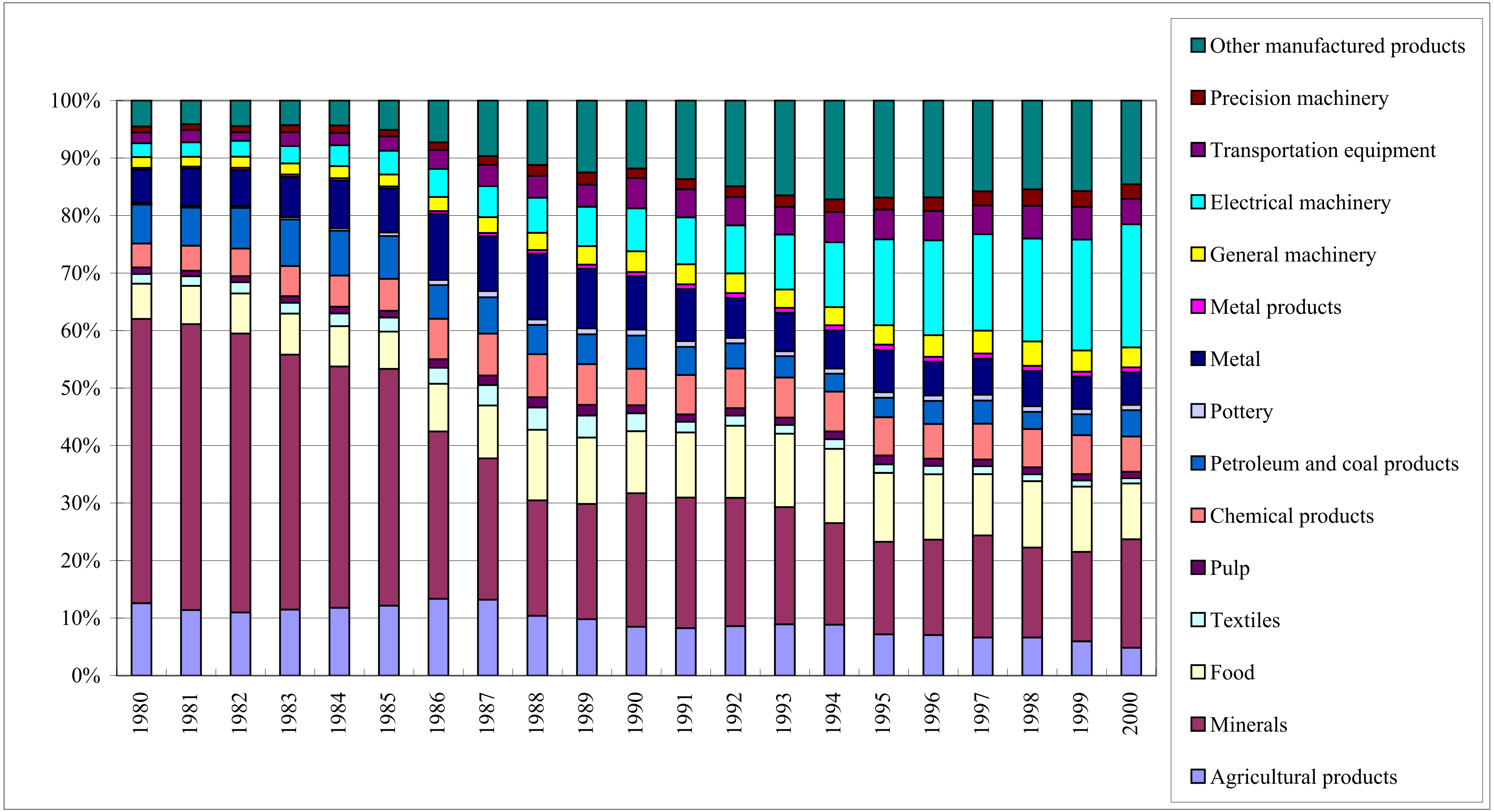
Notes: Official SNA statistics for the year 20(
In order to make long-term comparisons we derived values for 2000 by an extrapolation based on values of 1995 and the 1995–2000 growth rate of each variable reported in SNA statistics based on 1993 SNA.

Sources: Ito and Fukao (2003). Original data is taken from Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on National Accounts 2002* , Economic Planning Agency, Government of Japan, *Annual Report on National Accounts 2000* .

Figure 2.1.A Commodity Composition of Japan's Exports: 1980-2000

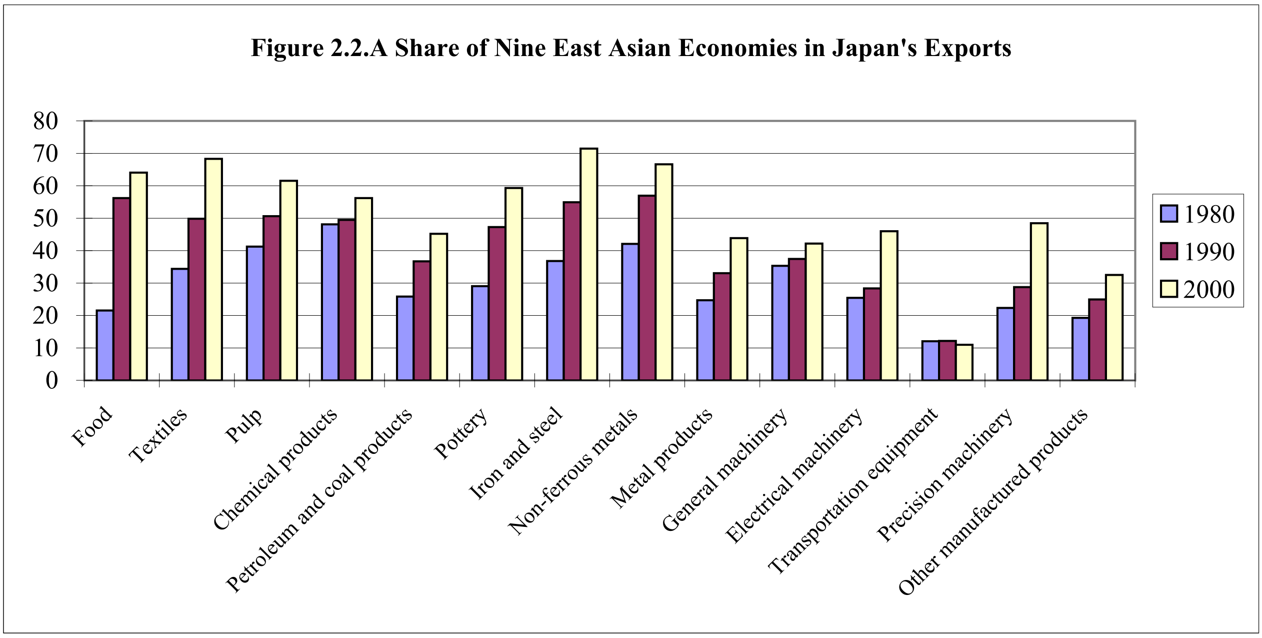


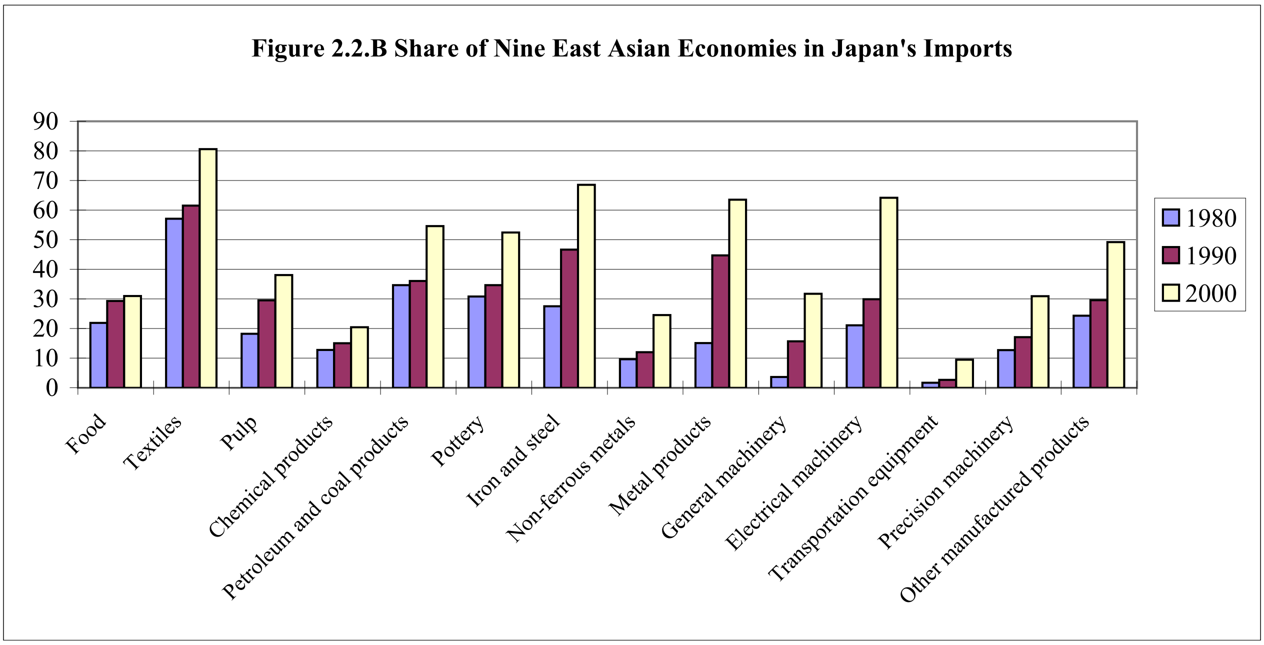
Sources: Ito and Fukao (2003). Original data is taken from Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on National Accounts 2002*, Economic Planning Agency, Government of Japan, *Annual Report on National Accounts 2000*.



Sources: Ito and Fukao (2003). Original data is taken from Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on National Accounts 2002*, Economic Planning Agency, Government of Japan, *Annual Report on National Accounts 2000*.

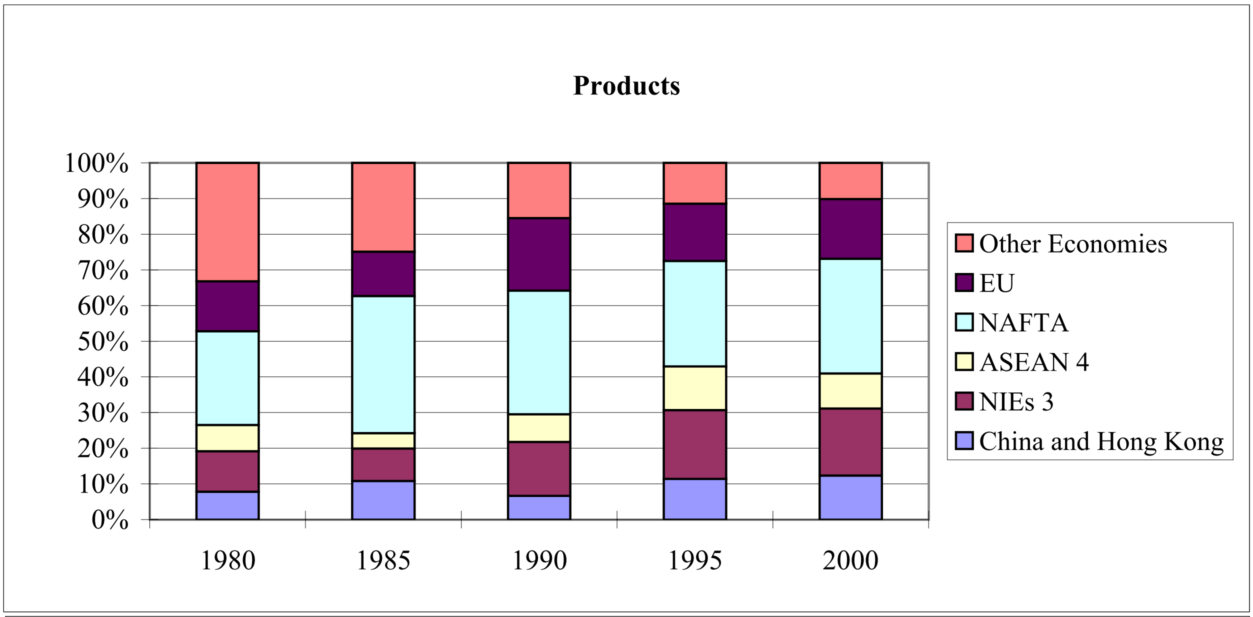
Figure 2.2 Share of Nine East Asian Economies in Japan's Trade in Manufacturing Products: 1980–2000, by Commodity

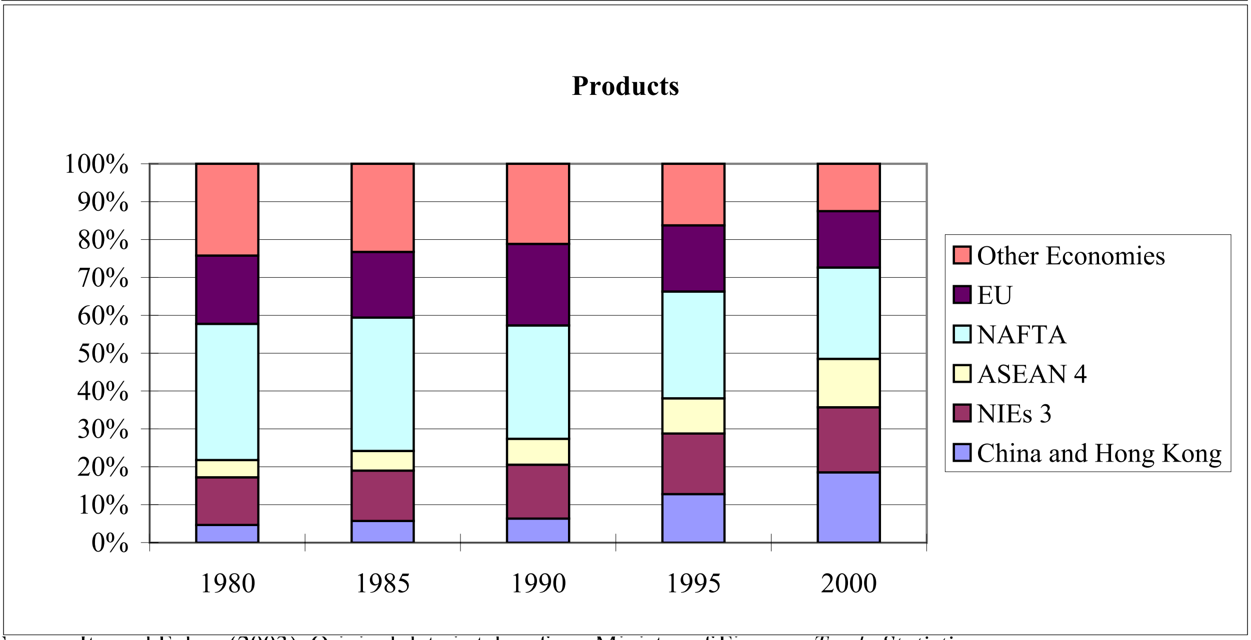




Source: Ito and Fukao (2003). Original data is taken from Ministry of Finance, *Trade Statistics*

Figure 2.3 Japan's Major Trade Partners: Manufacturing Products, 1980-2000





Source: Ito and Fukao (2003). Original data is taken from Ministry of Finance, *Trade Statistics*

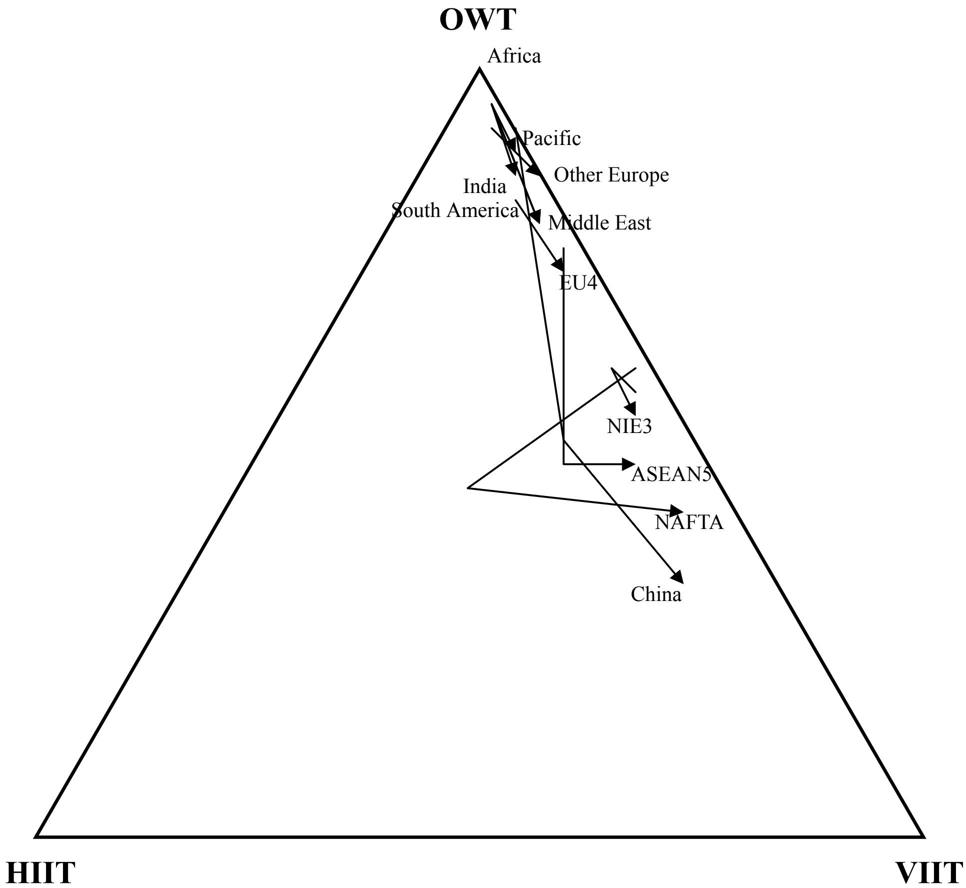
Table 2.2 Japan's Trade in Electrical Machinery and Office Machines with China and Hong Kong in 1999

(billion yen)

Commodity classification, SITC R3	Japan's exports to China and Hong Kong (f.o.b. base)	Japan's imports from China and Hong Kong (f.o.b. base)	Japan's net-exports to China and Hong Kong
75-Office machines & automatic data processing machines	275.3	231.0	44.2
751-Office machines	173.5	117.2	56.3
752-Automatic data processing machines & units	59.0	83.7	-24.8
759-Parts of and accessories suitable for 751-752	42.8	30.1	12.7
76-Telecommunications & sound recording apparatus	316.7	302.5	14.1
761-Television receivers	37.5	39.5	-2.1
762-Radio-broadcast receivers	6.8	41.2	-34.4
763-Gramophones, dictating, sound recorders etc	n.a.	n.a.	n.a.
764-Telecommunications equipment and parts	272.4	221.8	50.6
77-Electrical machinery, apparatus & appliance	1377.9	454.2	923.7
771-Electric power machinery and parts thereof	65.7	122.7	-57.0
772-Elect.app.such as switches, relays, fuses, pl	235.2	65.9	169.4
773-Equipment for distributing electricity	48.7	63.9	-15.2
774-Electric apparatus for medical purposes	12.9	1.2	11.7
775-Household type, elect. & non-electrical equipment	14.1	52.3	-38.3
776-Thermionic, cold & photo-cathode valves, tubes	724.0	85.7	638.3
778-Electrical machinery and apparatus, n.e.s.	277.3	62.6	214.8
Total	1969.8	987.7	982.1

Source: Statistics Canada, *World Trade Analyzer 2001* .

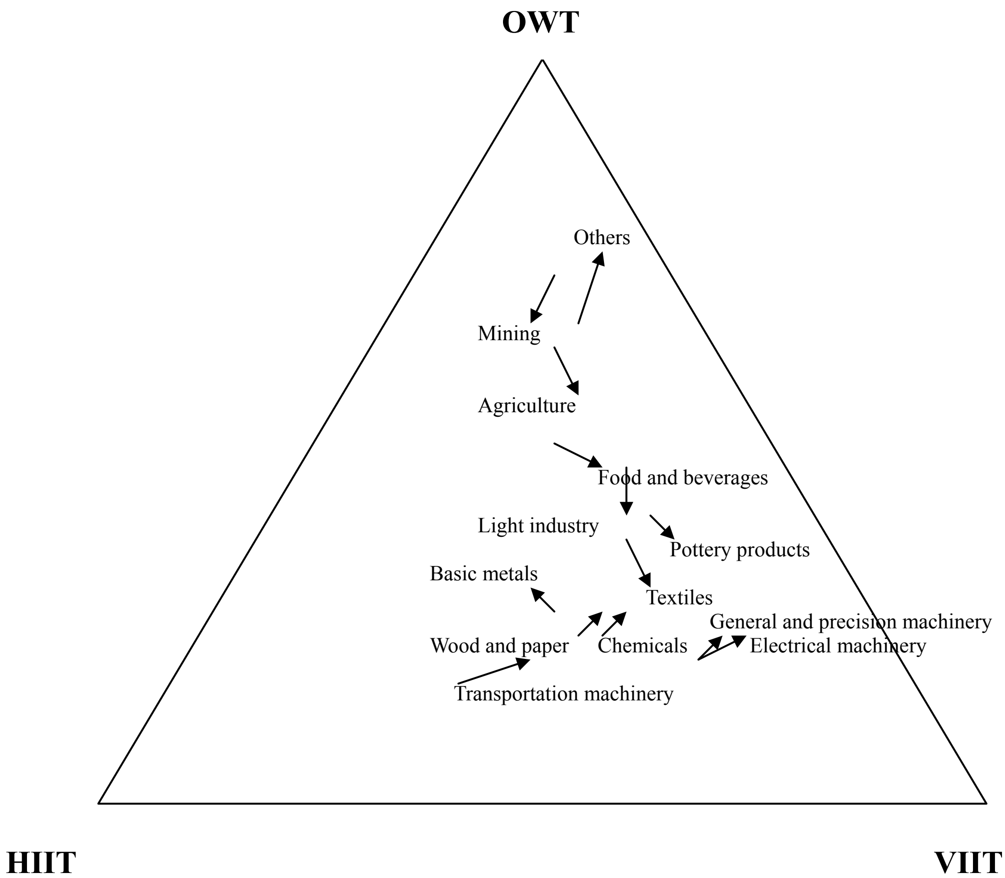
Figure 2.4 The Share of Each Trade Type in Japan's Bilateral Trade in Electrical Machinery: by Partner Region or Economy, 1988, 1994, 2000



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), South America (Argentina, Brazil, Columbia, Costa Rica, Panama, Peru, Venezuela).

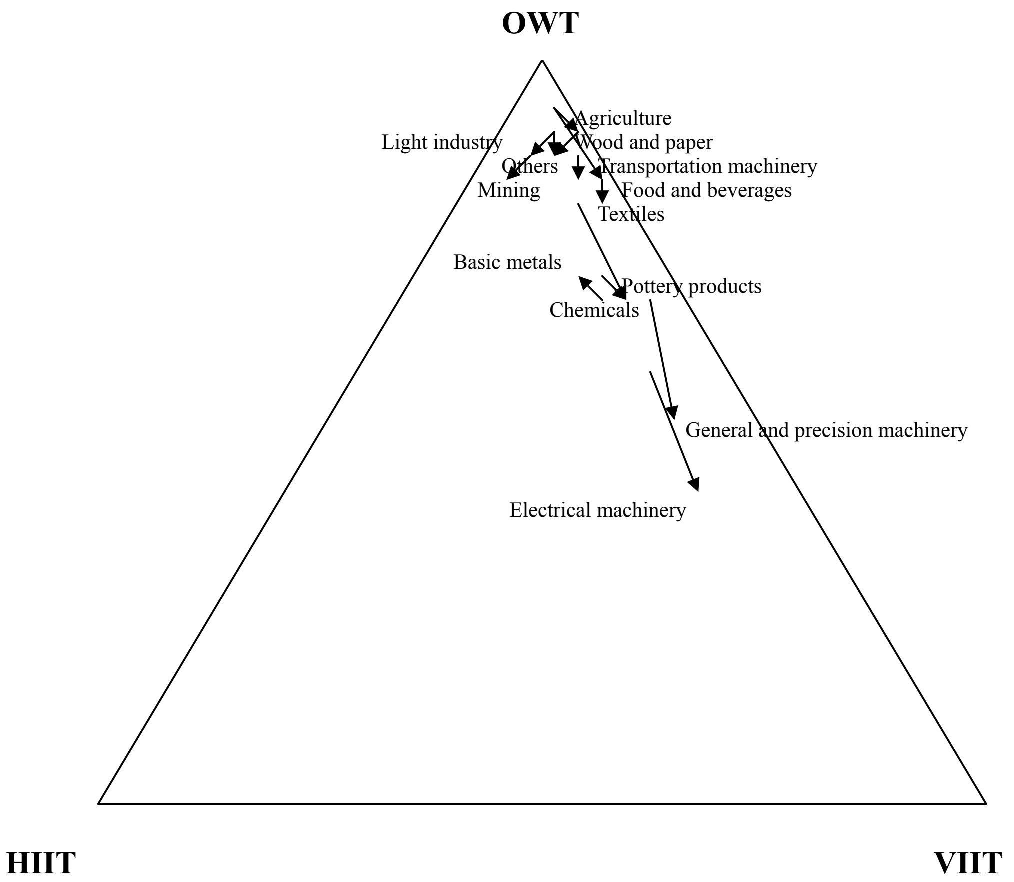
Source: Authors' calculation based on Japan's trade statistics which are taken from http://www.customs.go.jp/toukei/download/index_d012_e.htm.

Figure 2.7 The Share of the Three Trade Types in Intra-EU Trade: by Industry, 1996 and 2000



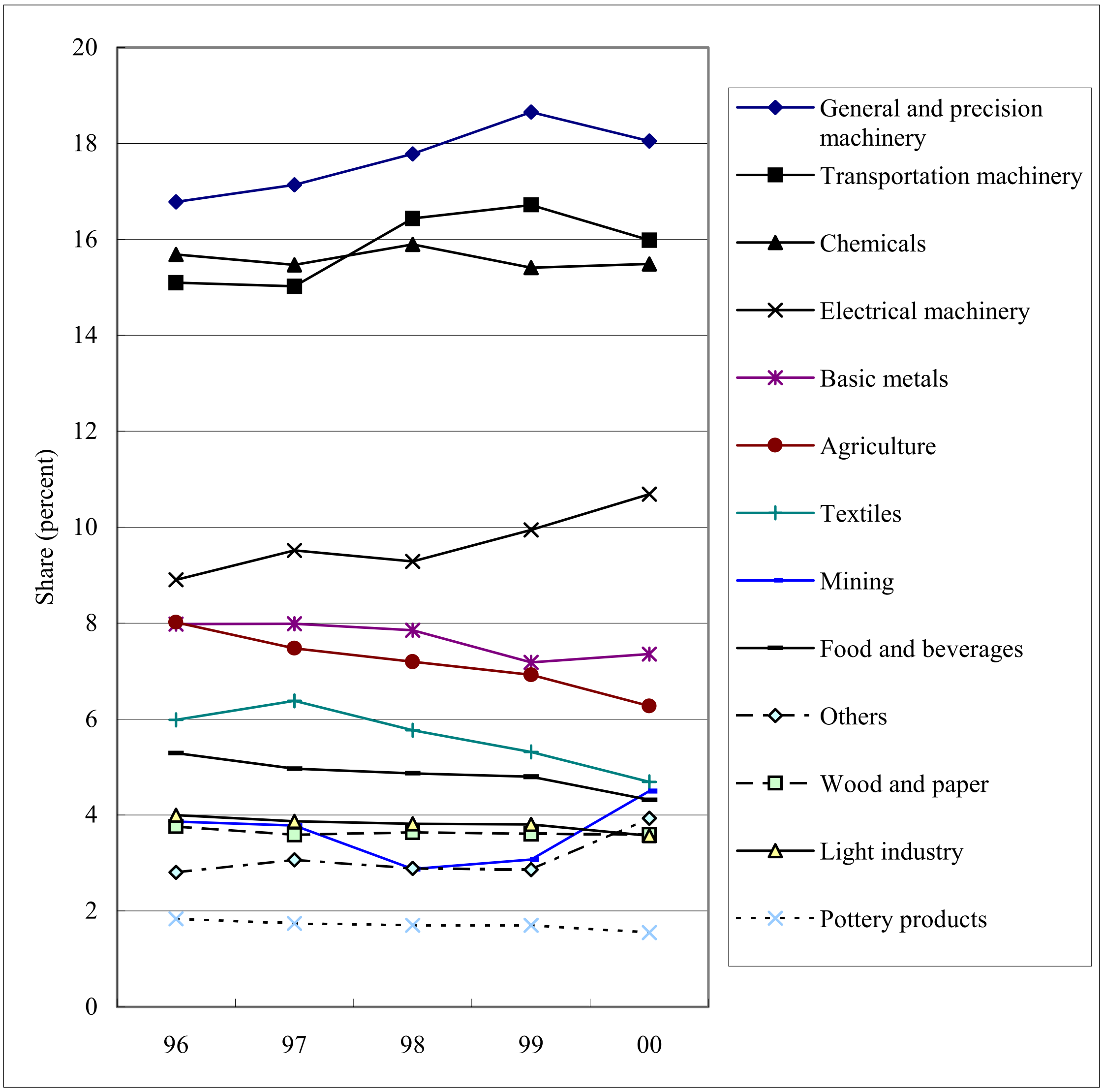
Source: Fukao, Ishido and Ito (2003). Original data is taken from PC-TAS.

Figure 2.8 The Share of the Three Trade Types in Intra-East Asian Trade: by Industry, 1996 and 2000



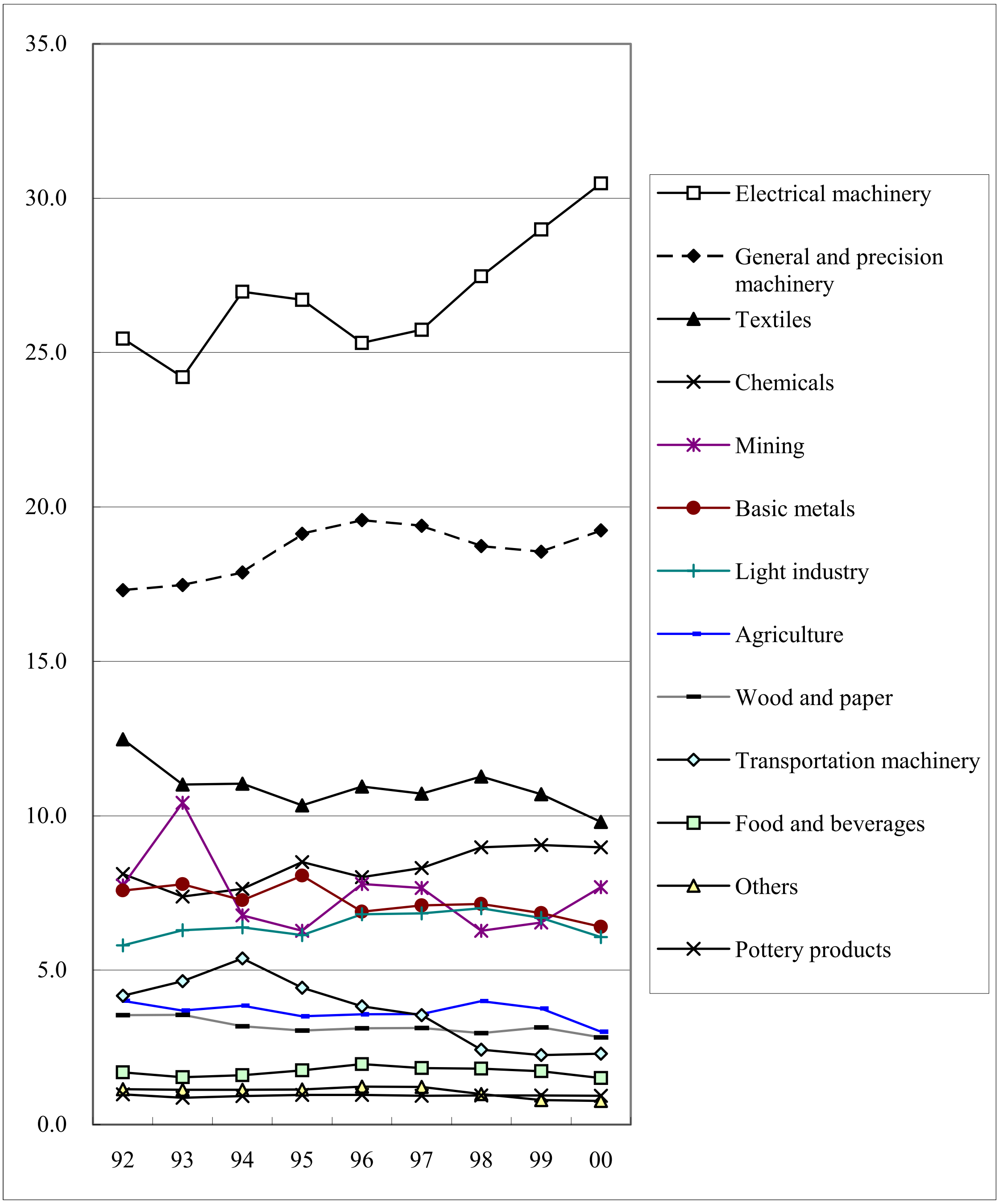
Source: Fukao, Ishido and Ito (2003). Original data is taken from PC-TAS.

Figure 2.9 The Commodity Composition of Intra-EU trade, 1996-2000



Source: Fukao, Ishido and Ito (2003). Original data is taken from PC-TAS.

Figure 2.10 The Commodity Composition of Intra-East Asian trade, 1992-2000



Note: Since the industry classification used for 1992-1995 (based on SITC-R3) is different from that used for 1996-2000 (based on HS88), each industry's figures for 1992-1995 have been multiplied by a ratio which make the two sets of figures for 1996 (the one based on SITC-R3 and the other based on HS88) equal.

Source: Fukao, Ishido and Ito (2003). Original data is taken from PC-TAS.

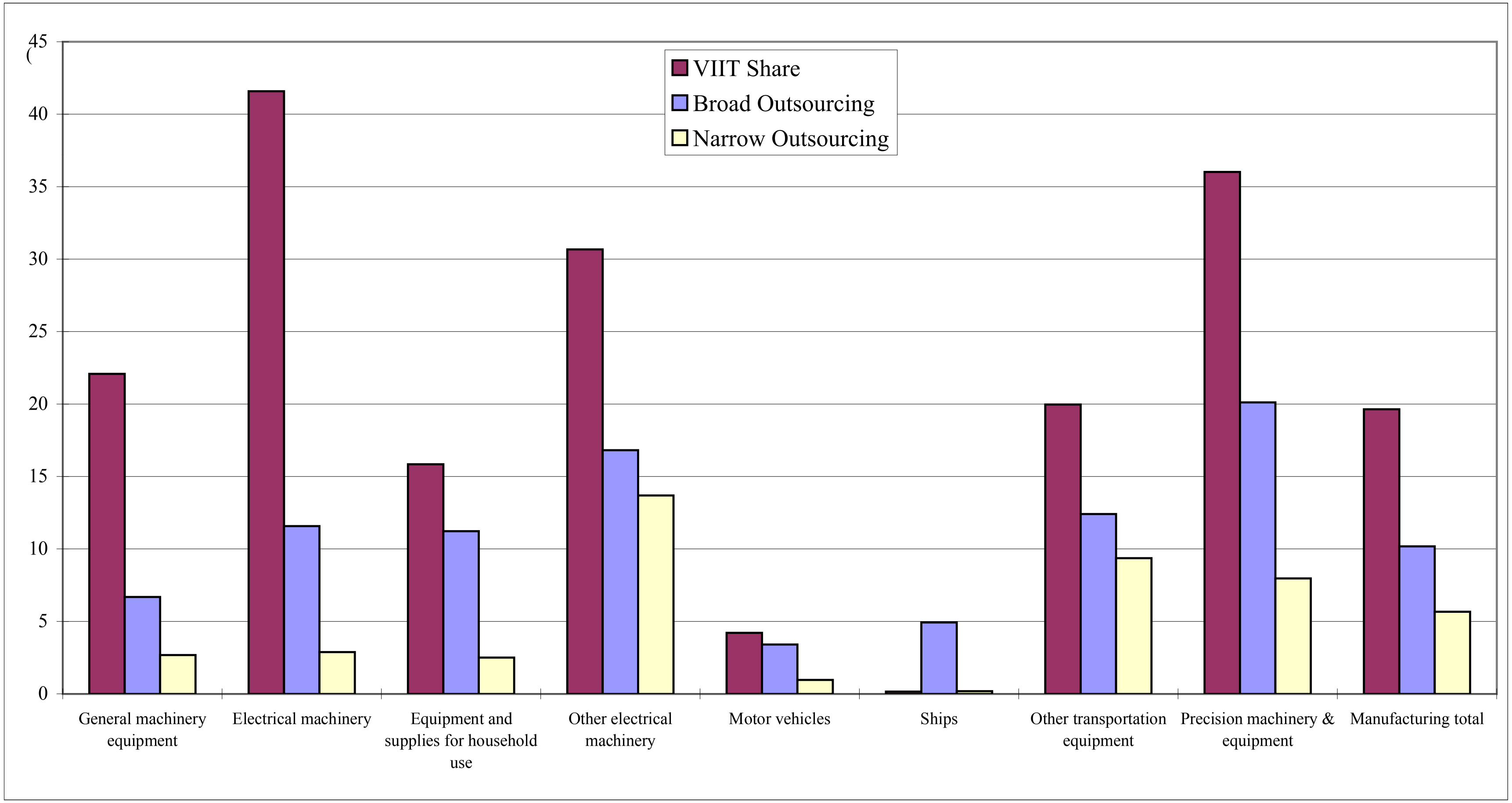
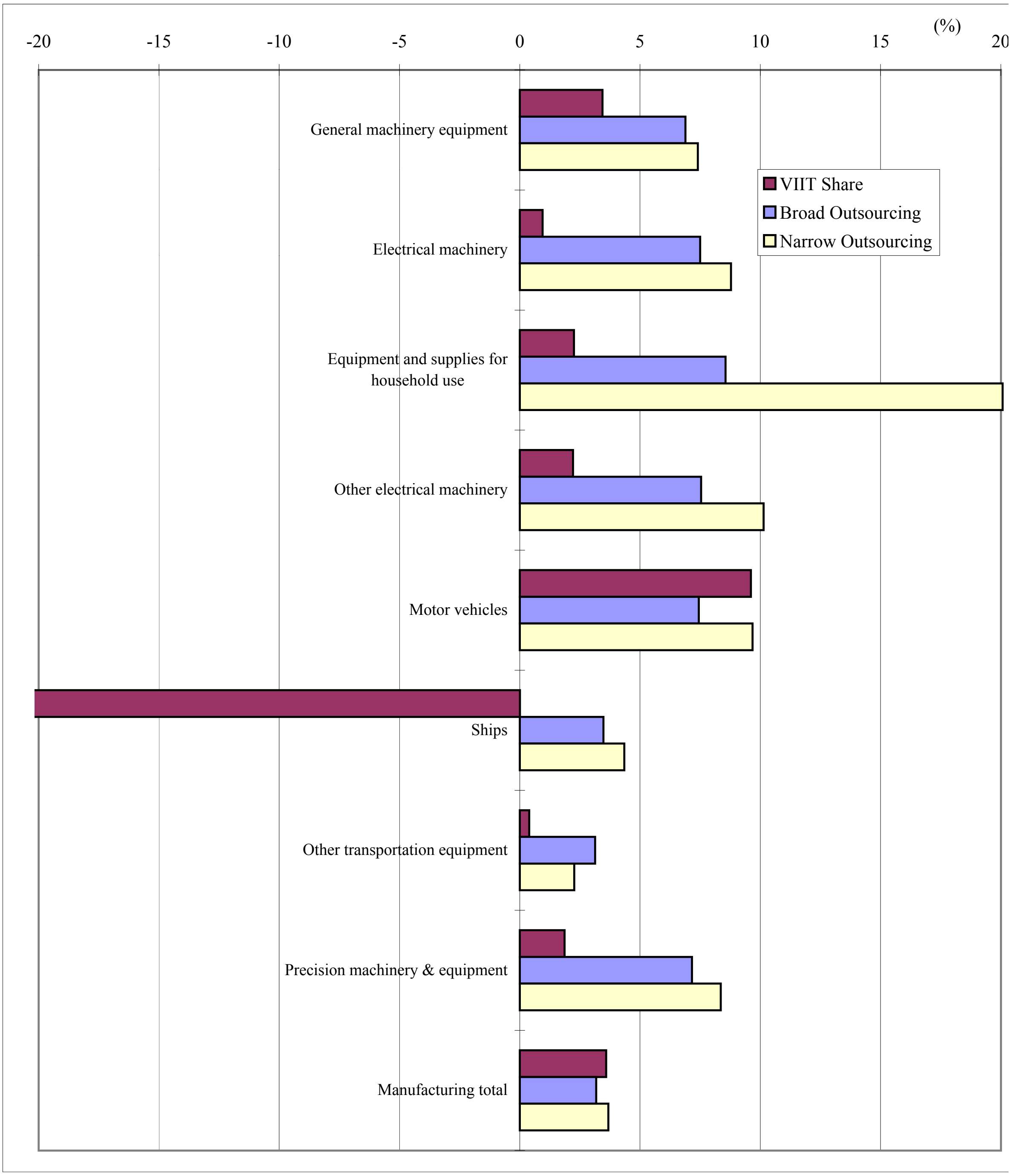


Figure 2.9 Vertical Intra-Industry Trade Share and Outsourcing Share by Industry: 2000

Source: Ito and Fukao (2003).



Growth rate of VIIT share: Δln (VIIT/Total trade)
Growth rate of broad outsourcing share: Δln (Broad outsourcing/Total intermediate inputs)
Growth rate of narrow outsourcing share: Δln (Narrow outsourcing/Total intermediate inputs)

Figure 2.10 Annual Growth Rate of Vertical Intra-Industry Trade Share and Outsourcing Share by Indust

Source: Ito and Fukao (2003).

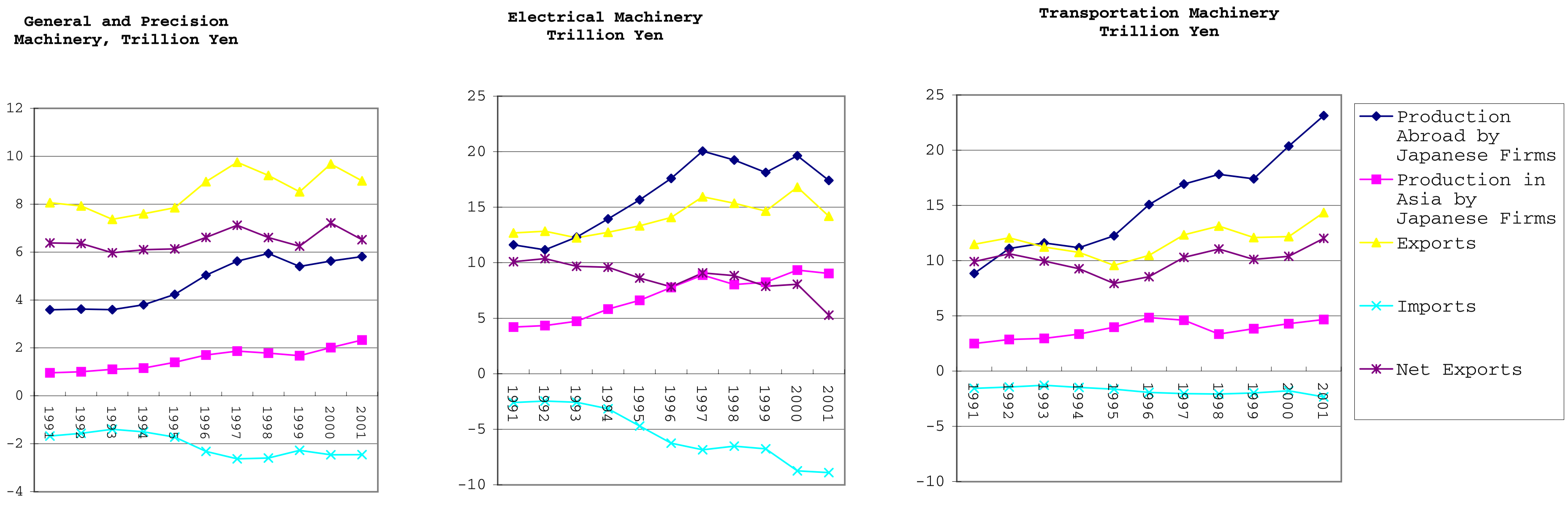
Table 2.3 The Shares of the Trade with Japanese Affiliates in Japan's Total Trade with East Asia: by Industry, 1999

	Exports of intermediate products to Japanese manufacturing affiliates in East Asia/total exports to East Asia	Imports of intermediate products from Japanese manufacturing affiliates in East Asia/total imports from East Asia
General machinery	6.1%	77.7%
Electrical machinery	27.8%	50.0%
Transportation equipment	44.7%	30.8%
Precision machinery	21.5%	73.1%

Source: METI (2001) and Ministry of Finance, *Trade Statistics* .

Note: Because a large share of machinery exports from Japanese parents are to their sales affiliates abroad, exports of intermediate products to manufacturing affiliates in East Asia were calculated using manufacturing affiliates' imports from Japan. Similarly, Japanese imports of intermediate products from overseas affiliates were calculated using overseas affiliates' exports to Japan.

Figure 2.11 Japan's Trade and Foreign Direct Investment: Machinery Industry, 1991-2000.



Sources: Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on National Accounts 2002*, Economic Planning Agency, Government of Japan, *Annual Report on National Accounts 2000*.

Figure 3.1. Share of International Trade in Total Trade of Japanese Regions: By Industry

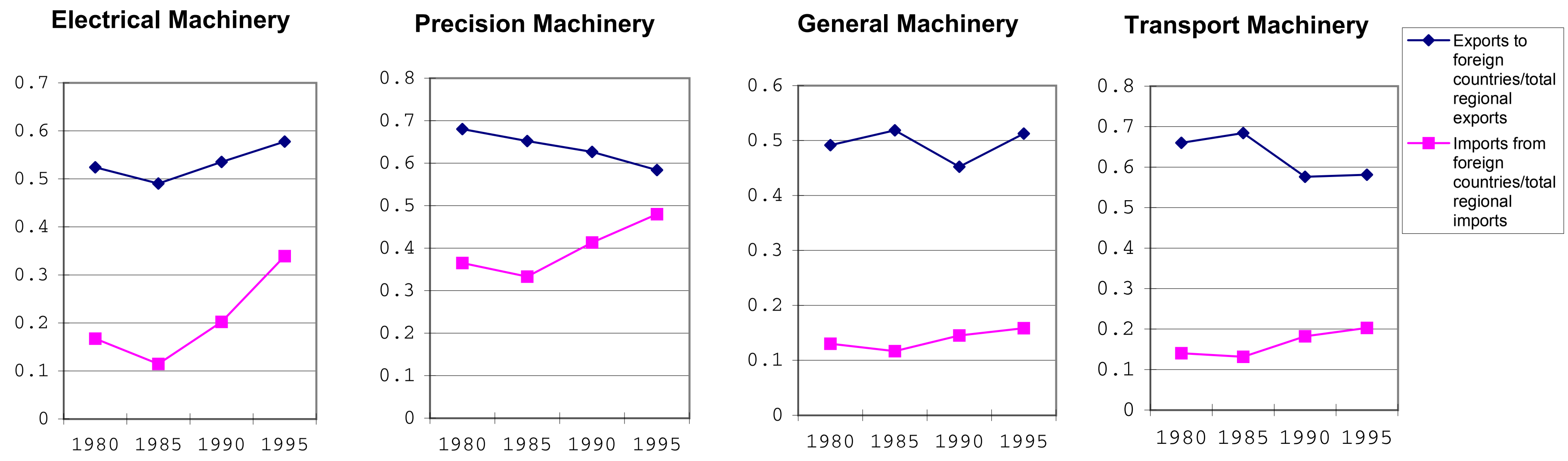
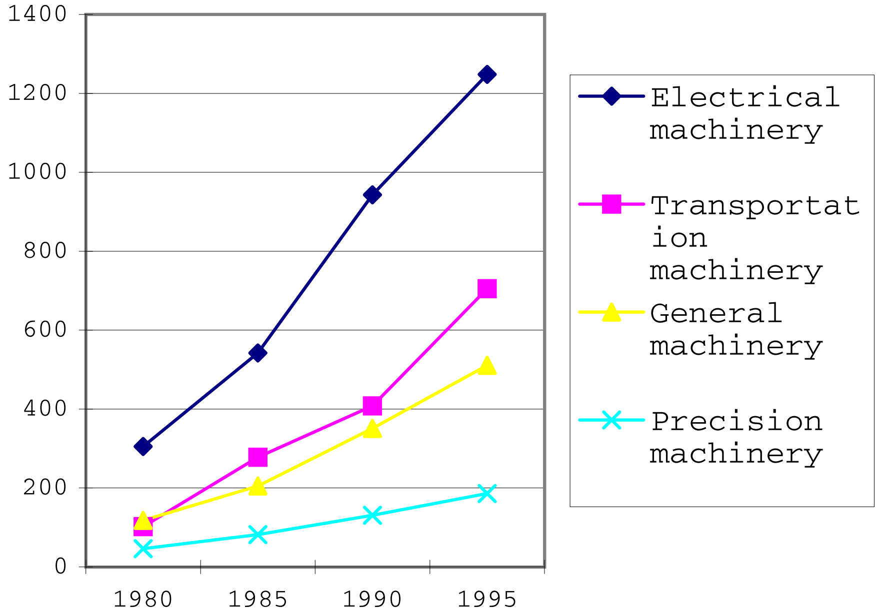


Figure 3.2 Firms' Network Linkages between Japan and Foreign Countries: By Industry

Number of Foreign Affiliates Owned by Japanese Firms: By Industry



Number of Japanese Affiliates Owned by Foreign Firms: By Industry

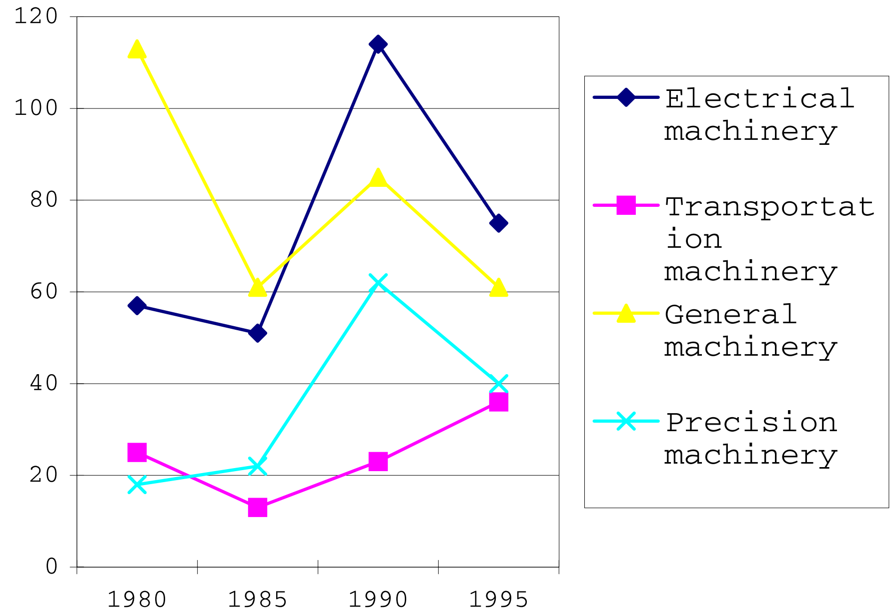


Table 3.1 Feasible GLS Estimation Results: Electrical Machinery

	Eq 1	Eq 2	Eq 3	Eq 4	Eq 5	Eq 6	Eq 7	Eq 8	Eq 9	Eq 10
GDPI	0.55	0.469								
	[77.63]**	[61.82]**								
GDPE	1.551	1.518								
	[257.00]**	[175.72]**								
SUPEX			1.366	1.333	1.309	1.244	1.235	1.065	1.272	1.186
			[270.5]**	[175.44]**	[225.16]**	[129.28]**	[142.26]**	[17.96]**	[146.69]**	[135.23]**
DEMIM			0.534	0.438	0.54	0.312	0.387	0.536	0.36	0.494
			[144.75]**	[56.01]**	[67.40]**	[33.63]**	[45.28]**	[9.59]**	[37.03]**	[66.11]**
DIS	-1.83	-1.827	-1.176	-1.307	-1.263	-1.237	-1.216	-0.133	-1.451	-1.524
	[-71.65]**	[-60.55]**	[-53.1]**	[-49.15]**	[-36.93]**	[-36.53]**	[-38.23]**	[-2.76]**	[-54.79]**	[-45.94]**
BOR Dummy*year1980	0.029	-0.795	0.954	0.094	0.512	0.335	0.75			
	[0.24]	[-6.12]**	[10.31]**	[0.87]	[4.30]**	[3.27]**	[7.31]**			
BOR Dummy*year1985	0.335	-0.408	0.6	-0.191	0.213	0.158	0.542			
	[2.85]**	[-3.16]**	[6.41]**	[-1.79]*	[1.80]*	[1.58]*	[5.36]**			
BOR Dummy*year1990	-0.7	-1.413	-0.094	-0.812	-0.454	-0.299	0.036			
	[-5.89]**	[-11.15]**	[-0.99]	[-7.67]**	[-3.88]**	[-3.05]**	[0.36]			
BOR Dummy*year1995	-1.246	-1.935	-0.453	-1.183	-0.871	-0.505	-0.199			
	[-10.38]**	[-15.38]**	[-4.7]**	[-11.11]**	[-7.43]**	[-5.14]**	[-1.98]**			
EX Dummy*year1985					1.441		1.134			2.785
					[35.56]**		[20.19]**			[27.95]**
EX Dummy*year1990					0.607		0.378			1.232
					[19.69]**		[8.11]**			[23.56]**
EX Dummy*year1995					-0.004		-0.283			1.046
					[-0.06]		[-3.85]**			[10.54]**
GAP		-0.512		-0.403	-0.367	-0.335	-0.289	0.209	-0.264	-0.239
		[-46.51]**		[-31.00]**	[-26.25]**	[-21.31]**	[-23.21]**	[0.94]	[-21.59]**	[-19.63]**
Year 1985								-0.234	-0.532	-2.332
								[-2.57]**	[-12.19]**	[-23.24]**
Year 1990								-0.68	-0.741	-1.619
								[-4.99]**	[-17.84]**	[-25.27]**
Year 1995								-0.953	-1.206	-2.053
								[-5.14]**	[-21.52]**	[-21.58]**
NPAAFJA						0.435	0.38	0.299		
						[19.47]**	[17.13]**	[6.89]**		
NPAAFWO						0.557	0.505		0.536	0.36
						[50.76]**	[46.83]**		[57.12]**	[26.55]**
NAFPAJA						-0.173	-0.152	0.046		
						[-7.64]**	[-6.69]**	[1.02]		
NAFPAWO						0.09	0.128		0.094	0.27
						[4.01]**	[6.38]**		[4.15]**	[15.82]**
constant	-29.86	-26.099	-11.373	-7.571	-9.535	-5.466	-6.979	-12.942	-4.202	-4.162
	[-82.48]**	[-52.59]**	[-52.46]**	[-20.34]**	[-25.07]**	[-12.01]**	[-16.91]**	[-10.26]**	[-10.12]**	[-10.90]**
Number of obs	2366	2342	2008	1928	1928	1928	1928	224	1704	1704
Number of groups	840	832	792	760	760	760	760	56	704	704
Wald Chi-2	112282.82	103699.39	139091.25	75280.97	487744.89	77656.74	219015.66	3964.85	90020.32	490685.29
Loglikelihood	-4553.145	-4533.466	-3391.302	-3209.434	-3125.529	-3089.922	-3036.675	-169.3102	-2728.152	-2631.962

The numbers in parentheses are z-values.
** Significance at 5% level
* Significance at 10% level

Table 3.2 Feasible GLS Estimation Results: General Machinery

	Eq 1	Eq 2	Eq 3	Eq 4	Eq 5	Eq 6	Eq 7	Eq 8	Eq 9	Eq 10
GDPI	0.492	0.411								
	[70.57]**	[54.78]**								
GDPE	1.687	1.662								
	[205.28]**	[487.35]**								
SUPEX			1.304	1.277	1.222	1.184	1.168	0.831	1.235	1.173
			[248.86]**	[203.05]**	[189.58]**	[199.89]**	[131.49]**	[21.46]**	[191.39]**	[138.80]**
DEMIM			0.556	0.53	0.583	0.395	0.439	0.566	0.437	0.543
			[171.74]**	[99.87]**	[74.62]**	[88.21]**	[49.67]**	[16.62]**	[71.32]**	[63.50]**
DIS	-1.307	-1.423	-0.905	-0.87	-0.956	-1.046	-1.039	-0.212	-1.188	-1.139
	[-40.68]**	[-42.28]**	[-36.58]**	[-28.22]**	[-28.31]**	[-40.19]**	[-32.80]**	[-9.56]**	[-43.16]**	[-38.70]**
BOR Dummy*year1980	2.311	1.429	1.7	1.665	1.779	2.039	2.141			
	[23.88]**	[14.26]**	[20.53]**	[16.37]**	[15.43]**	[23.68]**	[21.89]**			
BOR Dummy*year1985	1.933	1.075	1.722	1.685	1.81	2.041	2.142			
	[19.91]**	[10.75]**	[20.73]**	[16.55]**	[15.71]**	[23.70]**	[21.94]**			
BOR Dummy*year1990	1.027	0.274	1.323	1.282	1.403	1.781	1.869			
	[10.38]**	[14.26]**	[15.51]**	[12.46]**	[12.27]**	[20.72]**	[19.45]**			
BOR Dummy*year1995	0.174	-0.57	1.015	0.998	1.111	1.555	1.616			
	[1.73]*	[-5.77]**	[11.72]**	[9.63]**	[9.71]**	[17.90]**	[16.79]**			
EX Dummy*year1985					0.982		0.453			1.083
					[26.89]**		[10.93]**			[17.31]**
EX Dummy*year1990					0.857		0.518			0.991
					[29.71]**		[13.87]**			[24.11]**
EX Dummy*year1995					0.74		0.241			2.028
					[17.01]**		[4.48]**			[17.31]**
GAP		-0.383		-0.14	-0.182	-0.04	-0.067	-0.055	0.013	0.039
		[-53.2]**		[-16.57]**	[-16.30]**	[-4.18]**	[-5.82]**	[-0.51]	[1.14]	[3.44]**
Year 1985								0.042	-0.278	-2.313
								[1.06]	[-8.86]**	[17.31]**
Year 1990								-0.068	-0.28	-0.967
								[-1.14]	[-7.24]**	[24.11]**
Year 1995								-0.225	-0.934	-0.974
								[-2.94]**	[-19.80]**	[27.29]**
NPAAFJA						-0.21	-0.185	0.155		
						[-12.29]**	[-10.01]**	[5.48]**		
NPAAFWO						0.75	0.719		0.71	0.55
						[68.56]**	[42.08]**		[60.50]**	[32.90]**
NAFPAJA						0.169	0.138	0.08		
						[11.12]**	[8.35]**	[3.74]**		
NAFPAWO						-0.09	-0.095		-0.083	0.017
						[-8.27]**	[-4.57]**		[-5.00]**	[0.94]
constant	-36.895	-32.527	-13.022	-12.314	-11.863	-7.854	-8.44	-8.823	-7.716	-8.725
	[-89.56]**	[-87.92]**	[-63.77]**	[-41.12]**	[-31.09]**	[-28.46]**	[-21.56]**	[-10.05]**	[-23.86]**	[-21.27]**
Number of obs	2310	2270	1880	1816	1816	1816	1816	224	1592	1592
Number of groups	842	834	768	744	744	744	744	56	688	688
Wald Chi-2	101997.46	4763149	234279.51	157080.22	264160.51	414477.91	123592.44	10405.03	130537.55	86202.89
Loglikelihood	-4074.199	-3960.944	-2600.152	-2526.946	-2539.912	-2298.278	-2326.647	-48.8076	-2107.083	-2031.849

The numbers in parentheses are z-values.
** Significance at 5% level
* Significance at 10% level

Table 3.3 Feasible GLS Estimation Results: Precision Machinery

	Eq 1	Eq 2	Eq 3	Eq 4	Eq 5	Eq 6	Eq 7	Eq 8	Eq 9	Eq 10
GDPI	0.769	0.648								
	[165.18]**	[63.58]**								
GDPE	1.749	1.68								
	[366.44]**	[249.83]**								
SUPEX			0.887	0.904	1.077	0.836	1.082	0.827	1.308	1.282
			[166.20]**	[148.80]**	[120.66]**	[61.41]**	[112.98]**	[14.63]**	[138.45]**	[124.49]**
DEMIM			0.431	0.294	0.457	0.209	0.447	0.129	0.699	0.736
			[87.23]**	[76.80]**	[48.26]**	[19.66]**	[48.91]**	[1.94]*	[79.32]**	[53.14]**
DIS	-1.524	-1.522	-1.088	-1.188	-1.104	-1.209	-1.063	-0.278	-1.005	-1.031
	[-42.55]**	[-35.39]**	[-30.21]**	[-24.46]**	[-21.77]**	[-20.02]**	[-21.76]**	[-2.97]**	[-24.72]**	[-23.00]**
BOR Dummy*year1980	0.672	-0.041	0.961	-0.366	-0.034	-0.675	-0.058			
	[4.08]**	[-0.22]**	[5.64]**	[-1.87]*	[-0.17]	[-2.87]**	[-0.28]			
BOR Dummy*year1985	0.63	-0.06	1.135	-0.239	0.125	-0.408	0.099			
	[3.84]**	[-0.32]	[6.65]**	[-1.22]	[0.62]	[-1.74]*	[0.49]			
BOR Dummy*year1990	-1.416	-1.943	0.263	-1.029	-0.921	-1.127	-0.929			
	[-8.8]**	[-10.50]**	[1.55]	[-5.26]**	[-4.59]**	[-4.84]**	[-4.56]**			
BOR Dummy*year1995	-1.726	-2.256	-2.407	-3.485	-4.229	-3.511	-4.318			
	[-10.85]**	[-12.18]**	[-13.87]**	[-17.59]**	[-21.09]**	[-14.40]**	[-19.65]**			
EX Dummy*year1985					0.726		0.529			1.225
					[20.04]**		[16.65]**			[9.41]**
EX Dummy*year1990					0.68		0.492			0.465
					[14.44]**		[10.62]**			[4.37]**
EX Dummy*year1995					-3.969		-4.54			-0.568
					[-51.29]**		[-56.28]**			[-5.37]**
GAP		-0.492		-0.858		-0.823	-0.582	0.033	-0.251	-0.284
		[-45.54]**		[-58.32]**		[-38.35]**	[-36.25]**	[0.07]	[-19.06]**	[-13.99]**
Year 1985								0.297	-6.116	-1.038
								[1.77]*	[-1.83]*	[-7.88]**
Year 1990								-0.278	-0.496	-0.868
								[-1.58]*	[-7.63]**	[-7.94]**
Year 1995								-2.381	-0.115	-5.79
								[-7.26]**	[-77.19]**	[-52.45]**
NPAAFJA						0.192	-0.072	0.239		
						[3.24]**	[-1.36]	[2.99]**		
NPAAFWO						0.219	0.528		0.14	0.117
						[5.49]**	[18.32]**		[4.44]**	[3.04]**
NAFPAJA						0.267	0.23	0.35		
						[4.62]**	[4.14]**	[5.28]**		
NAFPAWO						0.319	-0.357		-0.066	-0.14
						[6.86]**	[-10.15]**		[-1.62]*	[-3.10]**
constant	-45.562	-39.861	-2.282	1.605	-3.963	3.548	-4.218	-1.975	-10.809	-10.582
	[-94.63]**	[-70.92]**	[-6.22]**	[3.62]**	[-7.33]**	[5.35]**	[-8.22]**	[-1.53]	[-22.76]**	[-19.86]**
Number of obs	1880	1864	1492	1420	1420	1420	1420	214	1206	1206
Number of groups	783	775	599	575	575	575	575	56	519	519
Wald Chi-2	282250.31	188735.64	45276.88	565155.52	82941.53	23826.06	107099.85	1197.81	72258.79	31808.55
Loglikelihood	-3607.522	-3557.062	-2954.443	-2685.008	-2478.24	-2687.619	-2432.595	-287.2879	-1939.531	-1927.852

The numbers in parentheses are z-values.
** Significance at 5% level
* Significance at 10% level

Table 3.4 Feasible GLS Estimation Results: Transportation Equipment

	Eq 1	Eq 2	Eq 3	Eq 4	Eq 5	Eq 6	Eq 7	Eq 8	Eq 9	Eq 10
GDPI	0.318	0.243								
	[28.15]**	[26.50]**								
GDPE	1.637	1.663								
	[193.39]**	[285.50]**								
SUPEX			1.214	1.192	1.081	1.139	1.059	1.098	1.118	1.01
			[268.04]**	[278.62]**	[352.56]**	[302.56]**	[149.35]**	[26.02]**	[164.78]**	[284.07]**
DEMIM			0.329	0.266	0.358	0.212	0.297	0.486	0.143	0.294
			[64.66]**	[53.68]**	[168.70]**	[46.03]**	[33.80]**	[9.74]**	[15.12]**	[38.96]**
DIS	-0.843	-0.897	-0.42	-0.533	-0.637	-0.519	-0.569	-0.074	-0.768	-0.696
	[-29.70]**	[-24.84]**	[-18.98]**	[-19.40]**	[-28.16]**	[-14.58]**	[-16.28]**	[-1.19]	[-16.17]**	[-18.50]**
BOR Dummy*year1980	2.4	1.788	2.446	1.943	2.283	1.812	2.13			
	[21.99]**	[13.02]**	[30.52]**	[20.47]**	[23.87]**	[14.00]**	[15.92]**			
BOR Dummy*year1985	2.323	1.689	2.32	1.806	2.159	1.798	2.083			
	[21.25]**	[12.38]	[29.24]**	[19.33]**	[22.59]**	[13.91]**	[15.63]**			
BOR Dummy*year1990	1.527	0.943	2.34	1.894	2.244	1.9	2.185			
	[13.82]**	[7.04]**	[30.15]**	[20.96]**	[23.47]**	[14.71]**	[16.46]**			
BOR Dummy*year1995	0.851	0.245	2.104	1.644	2.001	1.655	1.945			
	[7.62]**	[1.84]*	[27.28]**	[18.42]**	[20.95]**	[12.83]**	[14.66]**			
EX Dummy*year1985					1.852		1.577			2.763
					[127.93]**		[31.80]**			[26.87]**
EX Dummy*year1990					1.775		1.615			1.35
					[69.92]**		[30.77]**			[80.92]**
EX Dummy*year1995					2.13		1.812			2.106
					[60.45]**		[25.38]**			[16.13]**
GAP		-0.352		-0.246	-0.375	-0.219	-0.357	0.132	-0.296	-0.368
		[-30.27]**		[-59.26]**	[-137.10]**	[-24.89]**	[-30.97]**	[0.51]	[-20.10]**	[-29.87]**
Year 1985								-0.154	0.168	-1.298
								[-1.54]	[10.26]**	[-12.96]**
Year 1990								-0.167	0.723	0.078
								[-1.42]	[15.87]**	[1.95]*
Year 1995								-0.345	0.65	-0.384
								[-2.62]**	[10.26]**	[-3.15]**
NPAAFJA						0.009	0.07	0.052		
						[0.37]	[2.95]**	[1.37]		
NPAAFWO						0.635	0.422		0.687	0.405
						[23.76]**	[15.67]**		[37.66]**	[15.74]**
NAFPAJA						0.266	0.212	0.175		
						[10.40]**	[8.72]**	[4.60]**		
NAFPAWO						-0.287	-0.047		-0.261	0.04
						[-15.04]**	[-2.12]**		[-19.91]**	[1.56]
constant	-34.933	-32.65	-12.439	-9.78	-9.114	-8.47	-8.544	-13.063	-5.081	-6.384
	[-87.39]**	[-62.42]**	[-42.15]**	[-26.27]**	[-40.45]**	[-25.45]**	[-20.64]**	[-11.49]**	[-10.29]**	[-15.74]**
Number of obs	2200	2192	1839	1775	1775	1775	1775	223	1552	1552
Number of groups	816	816	744	728	728	728	728	56	672	672
Wald Chi-2	53290	145368.43	146251.3	242837.88	4921072	173275.37	533201.8	2569.04	56220.98	1575181
Loglikelihood	-4198.64	-4195.121	-3046.347	-2930.562	-2837.199	-2897.142	-2823.906	-206.2076	-2646.685	-2561.401

The numbers in parentheses are z-values.
** Significance at 5% level
* Significance at 10% level