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Why Has the Border Effect in the Japanese Machinery Sectors Declined? The Role of Business Networks in East Asian-Machinery Trade

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Why Has the Border Effect in the Japanese Machinery Sectors Declined?

The Role of Business Networks in East Asian Machinery Trade

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This paper analyzes the causes of the decline in Japan's border effect in four machinery industries (electrical, general, precision, and transportation machinery) by estimating gravity equations for Japan's international and interregional trade. In the estimation, we explicitly take account of firms' networks. We find that ownership relations usually enhance trade between two regions (countries); moreover, we 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; Fragmentation

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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 twenty-two 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 United States did not matter much anymore. Several subsequent studies have re-estimated the U.S.–Canadian border effect and concluded that McCallum may have overestimated the border effect (see, e.g., Anderson and Wincoop, 2003), while others have applied the idea to many other countries and discuss the presence of the national border effect.[1]

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.[2] Using data on Japan's international trade and trade between Japan's regions, Okubo (2004) found that Japan's border effect was

[1] See McCallum (1995), Helliwell (1996; 1998), Chen (2004) and Evans (2003). However, more recent research suggests that these studies overestimated the border effect. Anderson and Wincoop (2003), for example, developed a theoretical trade model with a multilateral resistance term and then estimated this term using price data sets. Their results suggest that small countries tend to have a smaller McCallum border parameter than large countries. However, note that this does not directly link to the preceding sentence which says that the earlier studies *overestimated* the border effect.

[2] On Japanese trade impediments, see Lawrence (1987), Sazanami, Urata and Kawai (1995), and Fukao, Kataoka and Kuno (2005).

smaller than the one estimated for Canada in preceding studies. Table 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

Probably we can explain the decline in the border effect in the case of Canada as the result of trade creation effects following the launch of NAFTA. But what factors caused the decline in Japan's border effects? As Fukao, Ishido and Ito (2003) and Ahn, Fukao and Ito (2007) have shown, 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, particularly in the machinery sectors. A driving factor behind this trend has been the substantial increase in Japan's outward foreign direct investment (FDI) in the machinery sectors during the 1980s and 1990s, spurring Japan's international trade and contributing to the decline in the border effect.[3]

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

[3] 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. However, reductions in Japan's tariff rates occurred mainly between 1960 and 1980 so that by the 1980s, Japan's tariff rates were already very low (Okubo 2004). Moreover, at least in the machinery industry, *non*-tariff barriers also seem to have been not particularly high by the 1980s (Sazanami, Urata and Kawai 1995, Fukao, Kataoka and Kuno 2003).

Japanese firms' foreign affiliates, Fukao and Chung (1997) showed that since around 1986 Japan's FDI in Asia has contributed to re-imports and intermediate goods trade.[4] A more rigorous examination of the influence of Japan's FDI on its vertical intra-industry trade (VIIT) is provided by Fukao, Ishido and Ito (2003) and Okubo (2007a), with the former developing a model to capture the main determinants of VIIT that explicitly includes the role of FDI. Testing this model empirically using data from the electrical machinery industry, they show that FDI in the electrical machinery sector does play a significant role in the rapid increase in VIIT in East Asia seen in recent years. However, few empirical studies on this issue have measured how Japan's FDI has reduced national border effects.[5]

The aim of this paper is to study the causes of the decline in Japan's border effect in the machinery sector by estimating gravity equations for Japan's interregional trade and trade between Japan's regions. In the estimation, we explicitly take account of inter-firm networks. We conduct separate gravity model estimations for four machinery industries (electrical, general, precision, and transportation machinery). Our reasons for focusing on these four machinery industries are as follows:

(a) Most of Japan's FDI activities in the manufacturing sector have been concentrated in the machinery industry. According to the JIP Database 2006, Japanese affiliates abroad in the machinery industry

[4] Re-imports are defined as imports from Japanese affiliates abroad. See Lipsey, Ramstetter and Blomström (2000) for more details about Japan's re-imports.

[5] 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 level.

employed 2.1 million workers, which accounted for 54% of all the workers employed by Japanese affiliates abroad in 2002.[6]

(b) The machinery industry is Japan's most important export sector, accounting for 76% of Japan's total goods exports in 2004. At the same time, the share of machinery imports in Japan's total imports has increased dramatically in recent years from 10% in 1985 to 32% in 2004 (JIP Database 2006).

(c) Theoretical studies in the field of organizational economics as well as a number of empirical studies have shown that firms tend to choose intra-firm transactions in the case of high-tech and R&D-intensive products.[7] The machinery industry is one of the most R&D-intensive industries, accounting for a full 65% of all R&D expenditure in the manufacturing sector in Japan in 1995 (JIP Database 2003).[8] Therefore, we can expect that business networks play an important role in this sector.

(d) Even within the machinery sector, there are large differences in the patterns of VIIT and outsourcing between different industries, such as the electrical and the transportation machinery industry. The trade and FDI patterns of Japan's machinery sector are presented in Figure 1, which shows that in the case of the two leading export industries – the electrical and the transportation machinery industries –

[6] The JIP Database 2006 is downloadable at: <http://www.rieti.go.jp/en/database/d05.html>.

[7] For a comprehensive survey of this issue, see Itoh (2006).

[8] The JIP Database 2003 is downloadable at:
<http://www.esri.go.jp/en/archive/bun/abstract/bun170index-e.html>.
Machinery sectors account for 64.9% (63.4%) of the total R&D expenditure in manufacturing in 1995 (1985).

production by Japanese affiliates abroad has surpassed exports from Japan. Especially in electrical machinery, Japan's imports have rapidly increased and half of Japanese imports from East Asia are produced by Japanese affiliates there (Ahn, Fukao and Ito 2007). In order to analyze the effect of inter-firm networks on international trade in machinery industries, it is therefore necessary to look at trade flows at a relatively disaggregated level.

It is important to note that in machinery industries business networks seem to play important role not only in international trade but also in Japan's intra-national trade. Intermediate input trade between different regions of Japan is fairly high in the machinery sector. Here, we measure this using an interregional outsourcing index which is defined as the ratio of the intermediate input imports in a certain sector from the same sector from all other Japanese regions relative to final goods production of that sector in that region.[9] The data are taken from the *Input-Output (I-O) Tables of Interregional Relations* (Chiiki-kan Sangyo Renkan Hyo). The averages across the nine regions of Japan of the outsourcing index for each manufacturing sector for 1995 are shown in Figure 2. As can be seen, the outsourcing index is relatively high in textiles and in the machinery sectors, indicating active interregional intermediate input trade. Among machinery sectors, the index is particularly high at more than 0.12 in electrical and transport machinery. The high degree of

[9] The index used here is an index of "narrow" outsourcing and is an application to interregional outsourcing of the type of index discussed in the literature on international outsourcing. See, e.g., Feenstra and Hanson (1999) and Ekholm and Hakkala (2006).

interregional intermediate input trade in the machinery industries reflects the fact that these are parts-and-component-intensive industries.

As shown by Fukao and Yue (1997) in their study focusing on firm location in the electrical machinery sector across Japanese regions, these industries tend to divide production processes into discrete steps, relocating labor-intensive processes to rural areas and maintain their headquarters and high-tech process in big cities in the 1980s and 1990s. The fragmentation of production ("the unbundling of tasks") within Japan has led to increased interregional trade, in particular increased intermediate goods and intra-firm trade ("task trade"). In this paper we compare impacts of business networks on international trade with impacts of business networks on intra-national trade.

INSERT Figure 1

INSERT Figure 2

It is also important to note 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 presents an empirical strategy and then Section 3 shows empirical results. Finally, Section 4 summarizes the main findings of this paper.

2 Econometric Analyses

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

2. 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 (see, e.g., McCallum 1995; Helliwell 1996, 1998; Evans 2003; Anderson and Wincoop 2003; and Okubo 2004, 2007b). Accordingly, such studies 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. By contrast, this paper conducts estimations at the sector level, i.e., for four machinery industries (electrical, general, precision, and transportation machinery). Consequently, our industry-level analysis uses domestic production and domestic demand in each industry as well as GDP.[10] The regional domestic demand and production data are taken from the *Input-Output (I-O) Tables of Interregional Relations* (Chiiki-kan Sangyo Renkan Hyo).[11] The cross-country data of domestic demand and production are taken from the *Industrial Demand Supply Balance Database* of the United Nations Industrial Development Organization

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

[11] The interregional I-O tables are published by the Ministry of Economy, Trade and Industry (MITI) every five years and cover all 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.

(UNIDO).[12]

The drawback of our source for data on interregional trade in Japan is that the international trade data in the I–O tables 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 the I-O tables. 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* (the Center for International Data, University of California, Davis). Figure 3 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 foreign countries. The share of international imports in total imports of the eight regions increased in all 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

The other drawback of our data is that price indexes are not available in the interregional I-O table and for many Asian countries that are major trade partners for the Japanese machinery industries. Price indexes

[12] The UNIDO data are available from 1981. Based on the five-year intervals dictated by the regional data I-O tables, our econometric analysis therefore begins in 1980 (where we use 1981 data for 1980).

have been used in recent studies employing gravity equations to estimate multilateral resistance (see, e.g., Anderson and Wincoop 2003). However, because of the lack of price data, we have to rely on the traditional gravity model framework to estimate border effects.

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 (international firm networks). 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* (Gaishikei Kigyo no Doko). No statistics on Japanese regions' bilateral inward and outward direct investment relationships with foreign countries at the industry level are available. Thus, 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 4 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 more or less stagnated.

INSERT Figure 4

Turning to domestic network linkages, 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 (interregional networks). The data are taken 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. However, 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.[13]

2.2 Empirical Models

Now, we turn to empirical models for econometric analysis in order to measure the border effect. The first estimation is a McCallum-type gravity equation for each industry (McCallum, 1995):

$$\log(TRADE_{i,j,t}^{k}) = \alpha_0 + \alpha_1\log(GDP_{i,t}) + \alpha_2\log(GDP_{j,t}) + \alpha_3\log(DIS_{i,j})$$
$$+\alpha_4 GAP_{i,j,t} + \sum_{\tau=80}^{95} \alpha_{5\tau} BORDUM_{i,j} * YEARDUM_{t,\tau} + \varepsilon_{i,j,t}^{k} \qquad (1)$$

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.

[13] 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 has stagnated or slightly declined in the period. On this issue, see Tomiura (2003).

$GDP_{i,t}$ and $GDP_{j,t}$ are the gross domestic products of 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.[14] $GAP_{i,j,t}$ denotes the absolute value of the difference of the logarithm of the per-capita GDP of country (region) i and the logarithm of the per-capita GDP of country (region) j in year t. $BORDUM_{i,j}$ is a dummy variable for domestic trade. $BORDUM_{i,j}$ =1, if $i \in R$ and $j \in R$; 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 adopt 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:

$$\log(TRADE_{i,j,t}^{k}) = \alpha_0 + \alpha_1\log(SUPEX_{i,t}^{k}) + \alpha_2\log(DEMIM_{j,t}^{k}) + \alpha_3\log(DIS_{i,j}) + \alpha_4 GAP_{i,j,t} + \sum_{\tau=80}^{95} \alpha_{5\tau} BORDUM_{i,j} * YEARDUM_{t,\tau} + \sum_{\tau=80}^{95} \alpha_{6\tau} EXDUM_{i,j} * YEARDUM_{t,\tau} + \varepsilon_{i,j,t}^{k} \quad (2)$$

The border effect on imports may differ from that on exports, and in order to control for this difference, we add

[14] 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.

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:

$$\log(TRADE_{i,j,t}^{k}) = \alpha_0 + \alpha_1\log(SUPEX_{i,j,t}^{k}) + \alpha_2\log(DEMIM_{i,j,t}^{k}) + \alpha_3\log(DIS_{i,j})$$

$$+\alpha_4 GAP_{i,j,t} + \sum_{\tau=80}^{95} \alpha_{5\tau} BORDUM_{i,j} * YEARDUM_{t,\tau} + \sum_{\tau=80}^{95} \alpha_{6\tau} EXDUM_{i,j} * YEARDUM_{t,\tau}$$

$$+\alpha_7\log(NPAAFWO_{i,j,t}^{k}) + \alpha_8\log(NAFPAWO_{i,j,t}^{k}) + \alpha_9\log(NPAAFJA_{i,j}^{k}) + \alpha_{10}\log(NPAAFJA_{i,j}^{k})$$

$$+ \varepsilon_{i,j,t}^{k} \qquad (3)$$

where $NPAAFWO_{i,j,t}^{k}$ and $NAFPAWO_{i,j,t}^{k}$ denote variables for networks between Japan and foreign countries. $NPAAFWO_{i,j,t}^{k}$ 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 precise definitions of the four variables are as follows:[15]

$NPAAFWO_{i,j,t}^{k}$: 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 $j \in R$.

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

[15] In order to take logarithmic forms, we added one to each variable.

$NPAAFJA_{i,j,t}^{k}$: 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 $j \in R$).

$$\log(TRADE_{i,j,t}^{k}) = \alpha_0 + \alpha_1 \log(SUPEX_{i,j,t}^{k}) + \alpha_2 \log(DEMIM_{i,j,t}^{k}) + \alpha_3 \log(DIS_{i,j})$$
$$+\alpha_4 GAP_{i,j,t} + \sum_{\tau=80}^{95} \alpha_{5\tau} YEARDUM_{t,\tau} + \alpha_6 \log(NPAAFJA_{i,j}^{k}) + \alpha_7 \log(NPAAFJA_{i,j}^{k}) + \varepsilon_{i,j,t}^{k} \quad (4)$$

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 $j \in R$).

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

3 Estimation Results

Now we conduct econometric analysis for the equations in the last section. Tables 2, 3, 4, and 5 show the estimation result for the four machinery industries.

INSERT Tables 2, 3, 4, and 5

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 *DEMIM*. In the estimation of the standard McCallum-type equation (equation (1) in each table), 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 for 1990, based on data for the US and Canada, found that interregional trade in Canada was 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 obtain 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 developing countries. If trade mainly arises as the result of factor price differences, 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 takes 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 (equations (3) and (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 a value of 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 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 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 "exports" from the location of parent firms to establishments between Japan and foreign countries. On the other hand, in the cases of the transportation equipment, general machinery and precision machinery industries, *NAFPAJA* is greater than *NPAAFJA*. This implies that active domestic transactions in parts and components enhance “exports” from the location of the establishment to parent firms within Japan. The “re-imports” are active. Because of 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 a 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 the same in these regressions. We obtain positive estimates for the coefficients on *SUPEX* and *DEMIM*. The estimated coefficients on the network variables in many cases take positive and significant values. The coefficients on *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.

Finally, we have to mention some limits of our study, which hinge on data qualification and the weakness of the gravity equation. First, our estimations ignore price effects, which are a well-known aspect as multilateral resistance term à la Anderson and Wincoop (2003). This is due to the lack of price index data for many Asian countries as well as for Japanese regions. Second, our border effect may not fully reflect trade costs. Transportation costs and transaction costs do not always correspond to geographical distance (Anderson and Wincoop, 2004; Balistreri and Hillberry, 2006). Intermediate input trade involves transactions costs that are different from transaction costs in final goods trade. The *nature* of such transaction costs is different. The issues on the gravity estimation including transaction costs can be open to future research. Third, the *nature* of firm networks is not taken into account in our paper. Firm networks have different features and functions due to different firm organizations. This topic is also open to future research.

4. Conclusions

This paper analyzed the causes of the decline in Japan's border effect in four machinery industries (electrical, general, precision, and transportation machinery) by estimating gravity equations for Japan's international and interregional trade. 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 relations leads to greater increases in the exports from the location of the parent firm to the location of the affiliate than the other way around. Conversely, in the cases of transportation equipment, general machinery and precision machinery, the creation of domestic ownership relations leads to greater increases in the ”exports” from the location of the establishment to the location of the parent firm. 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.

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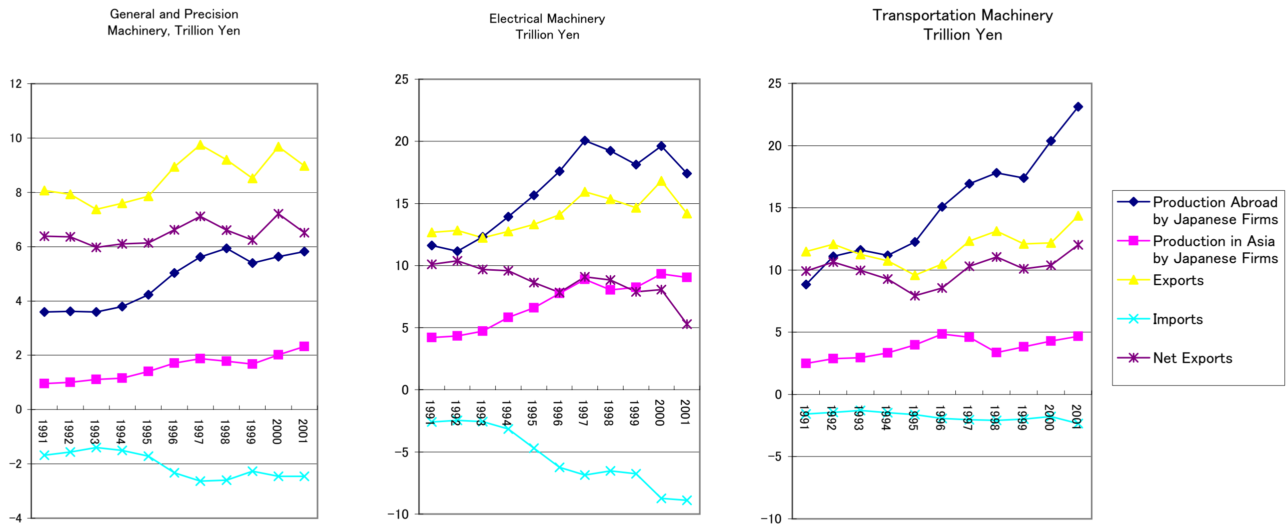
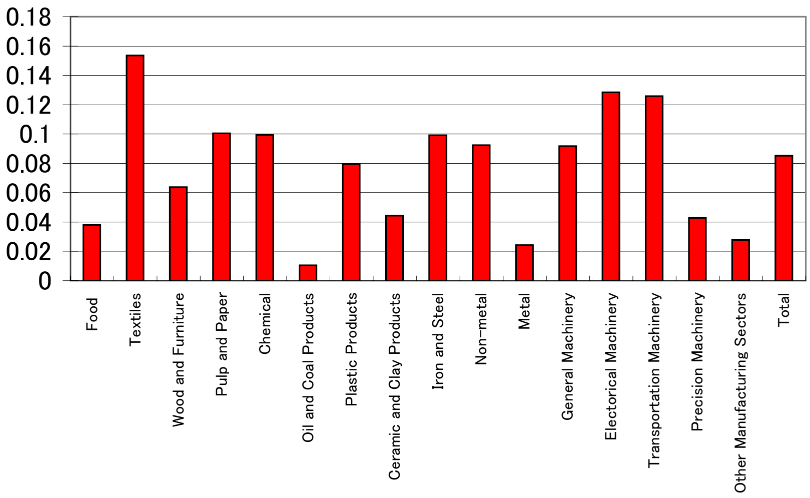
Figure 1: Japan's trade and foreign direct investment: machinery sector, 1991-2000.



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 2: Outsorcing index



Source: MITI, *Input-Output Tables of Interregional Relations* (Chiiki-kan Sangyo Renkan Hyo) 1995.

Figure 3: Share of international trade in Japanese regions' total trade: by industry

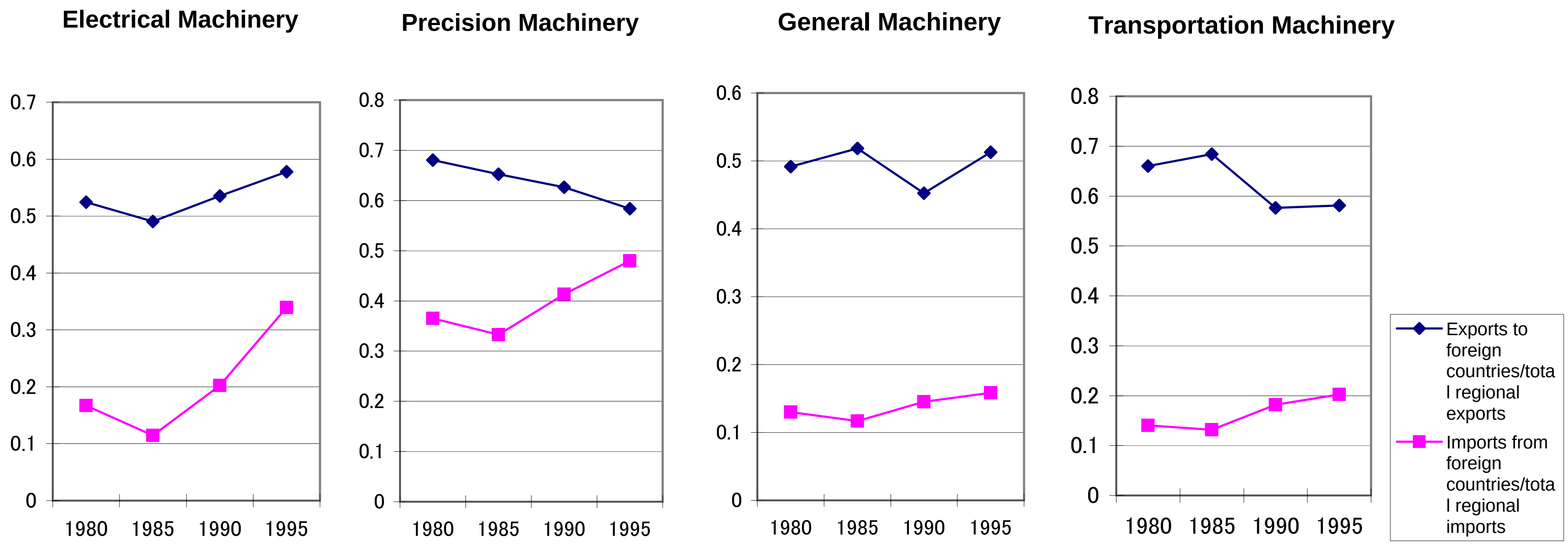


Figure 4: Firms' network linkages between Japan and foreign countries: by industry

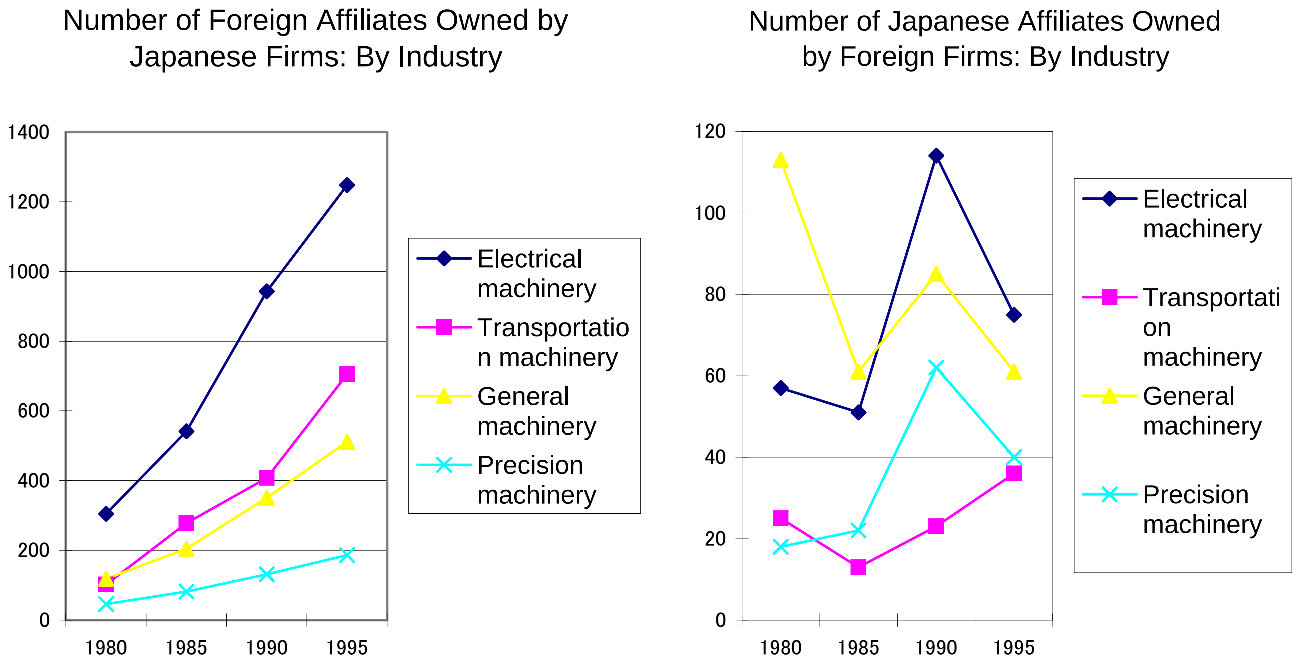


Table 1: Estimation results on border effects: a comparison between Canada and Japan

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: 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: 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 4: 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 5: 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