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International Production Networks and Export/Import Responsiveness to Exchange Rates: The Case of Japanese Manufacturing Firms[+]

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Abstract: This paper examines how international production/distribution networks provide individual firms with exporting/importing responsiveness to exchange rate movements. With the micro-data of Japanese manufacturing firms from 1994 to 2004, we find that firms' exports tend to respond to exchange rate movements, in particular (1) when firms are large in size, (2) when majority-owned affiliates are dominant among their foreign affiliates, and (3) when their intra-firm trade ratio is moderately high. Furthermore, these tendencies are more salient for machinery firms, one of the major players in international production networks in East Asia. The results suggest that Japanese manufacturing firms, particularly machinery firms, with greater foreign operations under their own corporate control would better absorb shocks of exchange rate movements by adjusting intra-firm transactions more significantly. We do not find such tendencies for imports, however. The study provides implications for international production networks, which have developed drastically in East Asia.

***Keywords*:** International production networks, Trade, Exchange rates, Japanese MNEs.
***JEL Classification*:** F10, F23, F31, L23.

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1. Introduction

The recent growth of globalizing corporate activities through various transaction channels has developed international networks of productions and distributions within/among firms (international production networks, hereafter) as an important phenomenon. Under evolving international production networks especially in East Asia, for example, Japanese firms have not only increased the number of affiliates in the region, but have also developed dense relationships between headquarters and foreign affiliates as well as among foreign affiliates. In addition to such intra-firm transactions, the international production networks also involve a myriad of inter-firm transactions with other foreign firms, and with local firms. Given an increasing importance of international production networks, scholars in international economics have investigated patterns of such networks and/or explanations for the mechanisms behind them.[1]

In contrast with the existing literature on international production networks, most of which have paid attention to investigating their patterns and mechanisms, our study provides evidences on *how international production networks influence individual firms' exporting/importing responsiveness to exchange rate movements.* For multinational enterprises (MNEs) or globalizing firms, exchange rate fluctuation is among the most important risks. A tremendous volume of prior studies has found that volatility of exchange decreases volume of trade between countries; however, evidence

[1] See, Kimura & Ando (2005), for example. They propose the two-dimensional fragmentation model, which is an extended conceptual framework of Jones and Kierzkowski (1990) and investigate the development of international production/distribution networks with the micro-data of Japanese firms. Ando and Kimura (2005) demonstrate three features of international production/distribution networks, specifically in machinery industries in East Asia: their significance in each economy, their geographical extensiveness involving many countries at different income levels in the region, and their sophisticated intra-firm and arm's length transactions. For the fragmentation theory, see for example Jones and Kierkowzki (1990) and Arndt and Kierzkowski (2001).

of this relationship is not conclusive.[2] At the same time, it is reasonable to expect that firms' abilities to respond to exchange rate movements are heterogeneous. Some firms might better deal with exchange rate fluctuations by adjusting their cross-border operations than would others. Accordingly, factors influencing to firms' responsiveness to exchange rate should be an important concern.

In economics, to the authors' best knowledge, there have been no, or very few, studies to investigate export/import response to exchange rate movements by incorporating firms' characteristics. First, as argued above, many scholars have empirically investigated whether exchange rate *volatility* discourages trade volume or not. However, they have not investigated how much firms increase (decrease) their trade volume upon appreciation (depreciation) of their home country's currency. Second, numerous studies in the macroeconomics field have examined how exchange rate movements influence to trade volume and/or trade balance. Nonetheless, these studies have tended to focus on trade at the country level or at the industry level. Studies examining how *individual* firms change their export/import in response to exchange rate movements have been very scarce.

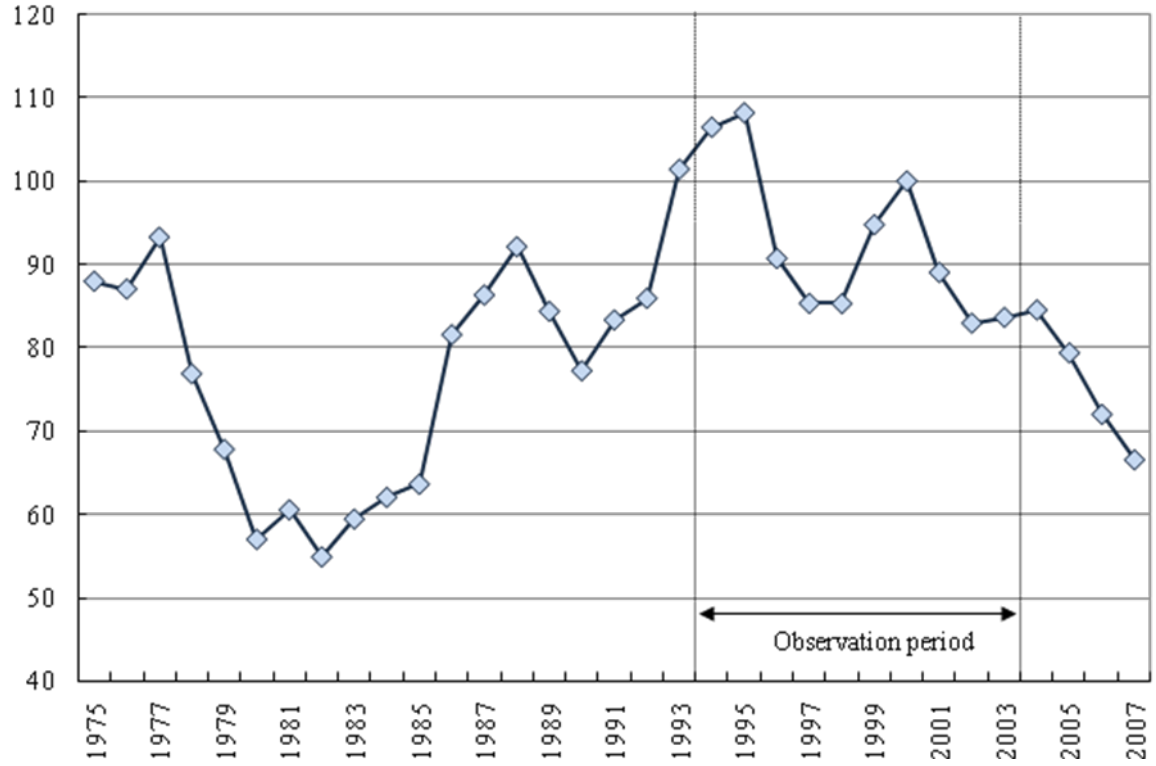
Apart from the economics literature, there have been several attempts to understand firms' flexibility against exchange rate movements, especially in the management literature. Kogut & Kulatilaka (1994), for example, provide the model using the "real options" concept, suggesting that firms' operations in multiple countries contribute to risk hedging against exchange rate fluctuations. They argue that, put

[2] See, Pozo (1992), for example. She examines the influence of exchange rate volatility on macro-level bilateral trade flow between the U.S. and U.K. from 1900 to 1994, and finds that exchange volatility decreased trade flow between the two countries. McKenzie (1999) conducted a comprehensive literature survey on this issue, and concludes that the prior empirical studies have provided the mixed results on the negative influence of exchange volatility to trade volume.

simply, the more countries firms operate in, the more flexibly they can switch their operations across countries in response to exchange rate movements. Rangan (1998) is probably the only one who empirically examined how firms change their operations in response to exchange rate movements. Using aggregated data of foreign firms located in the U.S., he found that foreign firms in the U.S. decreased (increased) their local content ratio in response to appreciation (depreciation) of U.S. dollars. As his study employs the aggregated data at the industry-level, however, he did not address *which* firms are more highly responsive than others. Consequently, further studies in this stream are required both in the economics and management fields.

This study examines export/import changes at firm level in response to exchange rate movements, using the micro-data of Japanese manufacturing firms from 1994 to 2004. Our analysis is novel in both economics and management literatures, in that it employs the micro-level longitudinal dataset for a ten-year window. This empirical setting enables us to trace overtime changes over time in firm-level exports/imports, and to examine how a firm's characteristics influences those changes. In addition, the context of Japan is ideal as it experienced significant exchange rate fluctuations during this time window (See, Figure 1). After testing whether Japanese parent firms increase (decrease) their exports/imports for depreciation (appreciation) of Japanese Yen as a baseline analysis, the paper investigates factors of firms' responsiveness to exchange rate movements, focusing on aspects of their operations in international production networks.

Figure 1. Japanese Real Effective Exchange Rates (Index: 2000=100)



Data source: World Bank (2008).

Note: An upward change means an appreciation of Japanese real effective exchange rates.

Our regression analysis found that Japanese manufacturing firms tend to increase (decrease) their exports in response to depreciation (appreciation) of the Japanese Yen, which is consistent with the consensus of macro-economic theory. More importantly, the analysis found that firms tend to more largely adjust their exports, responding to exchange rate movements, (1) when the firms are large in size, (2) when majority-owned affiliates are dominant among their foreign affiliates, and (3) when their intra-firm trade ratio is moderately high. These tendencies are more salient for machinery firms, one of the major players in international production networks in East Asia. The results suggest that Japanese manufacturing firms, particularly machinery

firms, with greater foreign operations under their own corporate control would better absorb shocks of exchange rate movements by adjusting intra-firm transactions. We do not find such tendencies for imports, however.

The plan of this paper is as follows: the next section provides the data description of micro-data employed in this study and briefly summarizes patterns and characteristics of Japanese firms' foreign direct investment (FDI) activities. Section 3 explains the model specification and estimation methods. Section 4 shows the obtained results, followed by implications and discussions derived from the results. Section 5 concludes the paper.

2. Japanese Manufacturing FDI at the Firm Level: Overview

2.1. Data Description

Our analysis employs *The Basic Survey of Business Structure and Activity,* i.e., the firm-level statistics compiled by the Ministry of Economy, Trade, and Industry (METI), Government of Japan (the former name was the Ministry of International Trade and Industry (MITI)). METI first conducted the survey in 1991, and has conducted it annually since 1994. This database provides detailed information on (parent) firms located in Japan as well as on their foreign affiliates with no less than 20 percent Japanese ownership.

The samples in the survey cover firms with more than 50 workers, capital of more than 30 million yen, and establishments in mining, manufacturing, wholesale/retail trade, and restaurants. As for trade activities, which are our particular interest, the database

includes not only numerical information of total exports/imports for each firm but also numerical information of intra-firm exports/imports. Intra-firm exports/imports are available only for each firm's transaction with all rest of the world: the data by country/region are not available. The database also includes the information of ownership structure of each foreign affiliate in three groups: wholly-owned, majority-owned, and 20-50 percent-owned. The database can identify the location of foreign affiliates based on the region basis, i.e. foreign countries as a whole, Asia, North America, and Europe.

2.2. Characteristics of Japanese Manufacturing FDI

This subsection provides an overall picture of Japanese FDI with an emphasis on manufacturing industries. Table 1 presents the number of 1) all sized firms and 2) small and medium enterprises (SMEs) with affiliates in East Asia/North America/Europe and the number of affiliates in these regions by industry of parent firms and by industry of affiliates.[3] In 2004, over 80 percent of the Japanese firms operating abroad have at least one affiliate in East Asia.[4] Among them, Japanese manufacturing parent firms, particularly machinery parent firms, are active investors in East Asia; almost 70 percent of the Japanese firms with affiliates in East Asia are in the manufacturing sector and close to a half of them are in machinery industries. Moreover, Japanese manufacturing affiliates, regardless of industry affiliation of their parent firms, account for 61 percent of the total Japanese affiliates in the region, while 39 percent of North American affiliates, and 34 percent of European affiliates.

[3] SMEs are defined as firms with less than 300 regular workers.
[4] See Ando and Kimura (2008) for more details.

Table 1. Sectoral Patterns of Japanese Parent Firms and Their Affiliates in East Asia, North America, and Europe for 2004

Industry of parent firm	Share by the industry of parernt firms		Share by the industry of affiliate				Share by the industry of parernt firms		Share by the industry of affiliate			
			Affiliates						Affiliates			
	Parent firms: all-sized	Affiliates	Manufacturing (machinery)		Non-manufacturing (wholesales)		Parent firms: SMEs	Affiliates	Manufacturing (machinery)		Non-manufacturing (wholesales)	
	(a-1) East Asia						(a-2) East Asia					
Manufacutring	68%	70%	73%	(38%)	27%	(18%)	66%	62%	84%	(39%)	16%	(12%)
-Machinery	31%	37%	69%	(65%)	31%	(20%)	27%	29%	82%	(76%)	18%	(14%)
Non-manufacturing	32%	30%	33%	(8%)	67%	(42%)	34%	38%	35%	(9%)	65%	(55%)
-Wholesales	21%	25%	36%	(9%)	64%	(50%)	27%	35%	36%	(9%)	64%	(60%)
Total	100%	100%	61%	(29%)	39%	(25%)	100%	100%	65%	(28%)	35%	(28%)
	(b-1) North America						(b-2) North America					
Manufacutring	68%	69%	49%	(29%)	51%	(24%)	60%	61%	55%	(29%)	45%	(33%)
-Machinery	36%	43%	44%	(41%)	56%	(25%)	32%	35%	50%	(47%)	50%	(40%)
Non-manufacturing	32%	31%	16%	(4%)	84%	(40%)	40%	39%	11%	(6%)	89%	(66%)
-Wholesales	19%	23%	20%	(4%)	80%	(51%)	29%	31%	13%	(7%)	87%	(78%)
Total	100%	100%	39%	(21%)	61%	(29%)	100%	100%	38%	(20%)	62%	(46%)
	(c-1) Europe						(c-2) Europe					
Manufacutring	70%	73%	42%	(24%)	58%	(37%)	56%	56%	48%	(17%)	52%	(43%)
-Machinery	38%	49%	34%	(33%)	66%	(42%)	28%	31%	34%	(31%)	66%	(56%)
Non-manufacturing	30%	27%	13%	(4%)	87%	(43%)	44%	44%	18%	(14%)	82%	(63%)
-Wholesales	19%	23%	15%	(5%)	85%	(50%)	35%	40%	20%	(16%)	80%	(68%)
Total	100%	100%	34%	(19%)	66%	(39%)	100%	100%	35%	(16%)	65%	(52%)

Data source: Authors' calculation, based on METI database.

Notes: The figures for (a-1, b-1, c-1) are those of all sized parent firms and figures for (a-2, b-2, c-2) are of parernt SMEs. The figures for "share" for manufacuring, machinery, non-manufacturing, and wholesales expresse the shares of manufacturing affiliates, machinery affiliates, non-manufacturing affiliates, and wholesales affiliates in total number of affiliates of all sized/SMEs firms in each sectoral category.

A parent firm often conducts multiple types of foreign operations simultaneously. Japanese manufacturing (parent) firms have 73 percent of their total affiliates in East Asia in the manufacturing sector. This means that Japanese manufacturing (parent) firms also have non-manufacturing affiliates in East Asia (27 percent of total affiliates of manufacturing firms), particularly in the wholesales sector (18 percent) to establish distribution networks by internalizing wholesale trade activities. The ratio of manufacturing parent – manufacturing affiliate is higher for SMEs; 84 percent of their affiliates in East Asia are manufacturing. Such investment patterns by SMEs reflect a typical strategy for firms involved in manufacturing activities aimed at supplying intermediate goods for other firms and/or for their own affiliates and forming a critical mass of industrial clusters in the manufacturing sector.

In North America and Europe, in contrast, the share of manufacturing affiliates of manufacturing parent firms is low. Also, the share of their non-manufacturing affiliates is as high as 51 percent for the case of North America and 58 percent for Europe. These figures indicate that Japanese manufacturing investment in North America or Europe aims at selling their products, or producing goods to be sold there, rather than at being involved in dense vertical production chains, as is observed for East Asia.

Table 2 shows the number of manufacturing parent firms by size of parent firms and by the number of foreign affiliates in 2004. Apparently, larger firms are likely to have the greater number of foreign affiliates. Table 3 presents export/import ratios (to total sales/purchases), intra-firm trade ratios, and ratios of majority-owned affiliates to total foreign affiliates for manufacturing parent firms. Most of these variables tend to increase over the sample period. In particular, import ratios sharply increase from less

than 10 percent in the middle of the 1990s to around 15 percent in 2004. These data suggest a substantial expansion of globalizing activities by Japanese manufacturing during that period. They also suggest that Japanese firms' imports to total purchases have rapidly increased with the development of international production networks in East Asia.

Table 2. The Number of Manufacturing Parent Firms by the Size of Parent Firm and the Number of Foreign Affiliates: 2004

	The number of foreign affiliates										
	1	2	3	4	5	6	7	8	9	10 or more	Total
SMEs	893	341	147	65	30	17	10	6	6	11	1526
(Share in total, %)	59%	22%	10%	4%	2%	1%	1%	0%	0%	1%	100%
Large firms with 300-499 workers	195	95	59	33	20	16	9	9	6	14	456
(Share in total, %)	43%	21%	13%	7%	4%	4%	2%	2%	1%	3%	100%
Large firms with 500-999 workers	127	95	60	47	31	28	26	14	16	48	492
(Share in total, %)	26%	19%	12%	10%	6%	6%	5%	3%	3%	10%	100%
Large firms with workers of 1000 or	49	50	22	32	20	32	25	18	24	290	562
(Share in total, %)	9%	9%	4%	6%	4%	6%	4%	3%	4%	52%	100%

Data source: Authors' calculation, based on METI database.

Table 3. Export/import Ratio, Intra-firm Trade Ratio, and Ratio of Majority-owned Affiliates for Manufacturing Parent Firms (Average)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Export ratio (to total sales)	14%	14%	14%	15%	15%	16%	15%	15%	16%	16%	17%
Import ratio (to total purchases)	9%	8%	9%	10%	10%	10%	13%	13%	15%	14%	15%
Intra-firm export ratio	57%	53%	53%	55%	56%	56%	59%	59%	57%	59%	58%
Intra-firm import ratio	68%	67%	68%	70%	68%	70%	71%	72%	72%	72%	71%
Ratio of majority-owned affiliates to total foreing affiliates	69%	69%	69%	70%	72%	72%	73%	75%	76%	77%	80%

Data source: Authors' calculation, based on METI database.

Note: Export/import ratios and intra-firm ratios are for firms having exports/imports.

3. Empirical Method and Data

This section quantitatively analyzes the exporting/importing responsiveness of Japanese manufacturing parent firms to exchange rate movements. Our baseline concern is whether exports and imports at the firm level respond to exchange rate changes in the direction predicted by the macro-economic theory's consensus. Further, more importantly, the analysis investigates which types of firms more strongly respond to the changes, depending on the firms' characteristics reflecting their degree of corporate control over their foreign operations.

The equations for our annual panel data analyses in the period 1994-2004 are as follows:

$$Trade_{t+1,i} = \beta_0 + \beta_1 E\hat{X}R_t + \beta_2 Trade_{t,i} + \beta_3 SIZE_{t,i} + \beta_4 KLratio_{t,i} + \beta_5 R\&D_{t,i} + \beta_6 Asia_i + \varepsilon \quad \text{(I)},$$

$$Trade_{t+1,i} = \beta_0 + \beta_1 E\hat{X}P_t \cdot D_{t,i} + \beta_2 Trade_{t,i} + \beta_3 SIZE_{t,i} + \beta_4 KLratio_{t,i} + \beta_5 R\&D_{t,i} + \beta_6 Asia_i + \varepsilon \quad \text{(II)},$$

where $Trade_{t,i}$ expresses trade activities of firm i in year t. This study employs the following four types of variables for trade activities (*Trade*): i) exports ($EX_{t,i}$) (natural log), ii) export ratio to total sales ($EXratio_{t,i}$), iii) imports ($IM_{t,i}$) (natural log), or iv) import ratio to total purchases ($IMratio_{t,i}$). $EX_{t,i}$ and $IM_{t,i}$ are exports/imports at the absolute terms and $EXratio_{t,i}$ and $IMratio_{t,i}$ are exports/imports at the relative terms. Accordingly, this approach enables us to compare effects of the firms' characteristics on responsiveness for four different types of trade activities. Note that dependent variable is one of these trade activities in year $t+1$, and the same variable in year t is included on the right-hand side in order to control the inertia.

$\hat{EXR}_t$ is a change in Japanese real effective exchange rates from the year $t-1$ to the year t; a positive figure means an appreciation of Japanese yen and a negative figure its depreciation. Since several key pieces of information such as the number of foreign affiliates and intra-firm trade cannot be identified by country, as explained in section 2, this analysis employs exports to, or imports from, the world for each firm. Accordingly, Japanese real effective exchange rates are employed. In equation (I), a change in exchange rates is included as an independent variable to investigate whether exports/imports do increase/decrease in response to the exchange rate change. As the macro economic theory in general predicts that the volume of exports increases (or decreases) under depreciation (appreciation) of the currency of the exporters' home country over foreign currencies.[5] Thus, on the export side, if a firm reduces exports when the Japanese Yen is appreciated, the coefficient for $\hat{EXR}_t$ is expected to be negative. On the other hand, the coefficient on the import side is expected to be positive.

Equation (II), instead of simply including a variable for exchange rate changes, involves slope dummy variables, i.e. interaction terms of exchange rate changes with dummy variables representing firms' characteristics ($D_{t,i}$). This equation tests whether responsiveness of exports/imports differ among firms, depending on the degree of corporate control over their foreign operations within the firm. First, this study examines the size of the parent firm (SIZE). While the firm size might capture characteristics other than those related to our focus, it also gauges the degree of the firms' ability to conduct extensive foreign operations. In general, large firms tend to hold a greater number of foreign affiliates than do SMEs. Our basic data description

[5] See, Obstfeld & Rogoff (1996), for example.

confirms that this holds for Japanese manufacturing firms (See Section 2). In the management field, as discussed above, Kogut & Kulatilaka (1994) suggest that the greater number of foreign affiliates enable firms to switch operations across country, and thus to more effectively mitigate the risk of exchange rate volatility. Furthermore, large firms often have richer financial resources than SMEs, which might help their flexible operation effectiveness.

Second, this study examines the ratio of majority-owned (including wholly owned) affiliates in each parent firm's total foreign affiliates (MOFA). The higher ownership structure confers more control rights on investing firms (e.g., voting rights on the board).[6] A firm enjoys more operation controls of its foreign affiliate when it is a wholly owned-affiliate or majority-owned joint venture. When firms need trade adjustments to exchange rate movements, therefore, the higher degree of controllability, reflected in the ratio of majority-owned affiliates, would help them to more easily adjust intra-firm transactions and/or to switch their operations among countries.

Finally, intra-firm trade ratio (intra-firm exports share in total exports and intra-firm imports share in total imports) (INTRA) for each parent firm is included. In many cases, transactions within a firm are more controllable than are arm's length transactions. The classical notion by Coase (1937), for example, suggests that arm's length transactions often entail greater costs of contracting or transacting. If transactions are internalized within firms, they can reduce such costs, and thus more smoothly adjust their operations, responding to environment movements.

[6] For theoretical rationales of ownership and control rights in the economic field, see, Fama & Jensen (1983), for example. In the management field, there are a large number of studies empirically examining influences of foreign affiliates' ownership structure. See, for instance, Dhanaraj & Beamish (2004), as a recent example.

Consequently, firms with higher ratio of intra-firm trade would more likely enjoy smooth transaction-adjustments under exchange rate movements.[7]

Considering that the relationship between trade adjustments and the size/ratios might not be simply linear, we create dummy variables used for interaction terms as follows: as for the size of firms (SIZE), the benchmark is SMEs with fewer than 300 regular workers (SIZE0). Large firms are classified into three groups: firms with 300 to 499 regular workers (SIZE1), those with 500 to 999 workers (SIZE2), and those with 1000 or more workers (SIZE3). Three dummy variables are constructed for the groups of large firms (SIZE1dummy, SIZE2dummy, and SIZE3dummy). As for ratios of majority-owned foreign affiliates (MOFA), firms are categorized into five groups: firms with ratio less than 0.2 (MOFA0), firms with ratio from 0.2 to less than 04 (MOFA1), those with ratio from 0.4 to less than 0.6 (MOFA2), those with ratio from 0.6 to less than 0.8 (MOFA3), and those with ratio equal to 0.8 or more (MOFA4). Four dummy variables (MOFA1dummy, MOFA2dummy, MOFA3dummy, and MOFA4dummy) are constructed with the benchmark group of MOFA0. Similarly, the benchmark group and dummy variables are constructed for intra-firm trade ratios (INTRA): INTRA1dummy for firms with ratio from 0.2 to less than 04 (INTRA1), INTRA2dummy for firms with ratio from 0.4 to less than 0.6 (INTRA2), INTRA3dummy for firms with ratio from 0.6 to less than 0.8 (INTRA3), and INTRA4dummy for firms with ratio equal to 0.8 or more (INTRA4), using the benchmark case of INTRA0 (firms with ratio less than 0.2 (INTRA0)). As we expect all of the three size/ratios to strengthen parents firms' controllability of their operation

[7] Kimura & Ando (2005) claim, in the framework of two-dimensional fragmentation, that service link costs on the axis of disintegration (or controllability) are larger for arm's length transactions than for intra-firm transactions. This is because firms lose controllability, which incurs larger transaction costs.

in foreign affiliates, all interaction terms are expected to have the *negative* signs (as the lowest degree group of each size/ratio is the benchmark group (=0)). Furthermore, it is expected that, among interactions, groups with larger size/ratio will have larger and negative coefficients, if the relationship between trade responsiveness and the size/ratios is simply linear.

Other independent variables are included as control variables for each parent firm and for the year t: the size of the firm in terms of its number of regular workers (natural log) ($SIZE_{t,i}$), capital-labor ratio in terms of tangible assets per regular workers (natural log) ($KLratio_{t,i}$), in-house research and development (R&D) expenditures ratio (in total sales) ($R\&D_{t,i}$), and Asia dummy ($Asia_{t,i}$); these are all for domestic (parent) firms. Capital-labor ratio and R&D activities are proxy variables of firm specific assets. Asia dummy is 1 if a firm has at least one affiliate in Asia and is zero otherwise. This is included in the equation, considering that East Asia is a region where Japanese manufacturing FDI are active, and where the international production networks have been developed particularly in machinery industries.

Our panel dataset comprises the data from 1994 to 2004, which are the latest and most comprehensively available years for us. The dataset is unbalanced because some manufacturing parent firms entered the export/import market during the observation. All the data regarding Japanese firms' activities are obtained from *The Basic Survey of Business Structure and Activity*. Japanese real effective exchange rates are available from World Bank (2008).

All regression analyses employ the random effect estimation.[8] In addition, our analysis employs not only the full sample with all manufacturing parent firms but the sub-sample with machinery parent firms only. Japanese firms in machinery sectors may have a stronger responsiveness than other Japanese manufacturing firms, since the international production/distribution networks have been developed mainly in machinery industries, particularly in East Asia, with active FDI by Japanese firms. We thus attempt to compare the subsample of machinery firms with the full sample of manufacturing firms.

4. Empirical Results and Discussions

4.1. Results

This section presents results of the analysis examining whether firms' exports and imports respond to changes in exchange rates and which types of firms more strongly respond to the changes.[9] Table 4 reports results for exports. Equation (1) involves variables for exports with one-year lag, changes in exchange rates, control variables, and Asia dummy. The coefficient for changes in exchange rates is negative with statistical significance. It suggests that Japanese firms decrease (increase) their exports in response to appreciation (depreciation) of Japanese Yen over foreign currencies, which is consistent with the general prediction of macro economic theory.

[8] We also conducted the same analysis with the fixed effect estimation, which presented the similar results to the reported in this paper.

[9] See Tables A1 and A2 for summary statistics and correlation matrix.

Table 4. Results for Manufacturing Firms' Responsiveness to Exchange Rate Movements: Exports

Independent variables	(1)	(2)	(3)	(4)
Constant	-0.050	-0.038	-0.052	-0.055
	(-0.96)	(-0.73)	(-0.99)	(-0.94)
EX	0.802 ***	0.802 ***	0.802 ***	0.793 ***
	(166.63)	(166.74)	(166.66)	(145.19)
EXR^	-0.405 ***			
	(-6.02)			
EXR^・SIZE3dummy		-0.367 ***		
arge firms with over 1000 workers)		(-2.99)		
EXR^・SIZE2dummy		-0.546 ***		
(large firms with 500-999 workers)		(-3.72)		
EXR^・SIZE1dummy		-0.457 ***		
(large firms with 300-499 workers)		(-2.72)		
EXR^・MOFA4dummy			-0.509 ***	
(ratios equal to 0.8 or more)			(-5.27)	
EXR^・MOFA3dummy			-0.383 **	
(ratios from 0.6 to less than 0.8)			(-2.06)	
EXR^・MOFA2dummy			-0.191	
(ratios from 0.4 to less than 0.6)			(-0.95)	
EXR^・MOFA1dummy			-0.223	
(ratios from 0.2 to less than 0.4)			(-0.64)	
EXR^・INTRA4dummy				-0.255 *
(ratios equal to 0.8 or more)				(-1.94)
EXR^・INTRA3dummy				-0.387 *
(ratios from 0.6 to less than 0.8)				(-1.89)
EXR^・INTRA2dummy				-0.739 ***
(ratios from 0.4 to less than 0.6)				(-3.95)
EXR^・INTRA1dummy				-0.466 **
(ratios from 0.2 to less than 0.4)				(-2.51)
SIZE	0.219 ***	0.217 ***	0.219 ***	0.229 ***
	(22.27)	(22.04)	(22.27)	(20.61)
KLratio	0.016	0.017	0.016	0.019
	(1.43)	(1.48)	(1.45)	(1.48)
R&Dratio	1.412 ***	1.418 ***	1.414 ***	1.319 ***
	(5.32)	(5.34)	(5.33)	(4.69)
ASIA	0.036 *	0.367 *	0.038 *	0.053 **
	(1.72)	(1.75)	(1.79)	(2.24)
R2（within）	0.201	0.201	0.201	0.200
R2(between)	0.942	0.942	0.942	0.935
R2(overall)	0.908	0.908	0.908	0.912
Number of observations	15263	15263	15263	12531

Data source: Authors' calculation, based on METI database.

Notes: figures in parenthesis are t-statistics. *** indicates that the results are statistically significant at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Equation (2) through equation (4) show the results of estimation including interaction terms of exchange rate changes with three firm's characteristics, that is, the size of firm (SIZE) in equation (2), the ratio of majority owned affiliates in total foreign affiliates (MOFA) in equation (3), and intra-firm trade ratio (INTRA) in equation (4). As for SIZE, all the three interaction terms have negative coefficients as is expected. This suggests that large firms with more than 300 regular workers decrease (increase) their exports in response to appreciation (depreciation) of Japanese Yen over foreign currencies to the greater extent than do SMEs. [10] It is notable, however, that the coefficient is negative and the largest for the group of SIZE2 (firms with 500-900 workers).

Regarding controllability of foreign operations in terms of MOFA, firms with higher shares of majority owned affiliates in total foreign affiliates are more likely to adjust their exports: the coefficient is negative with statistical significance for the group of MOFA4 (firms with ratios of 0.8 or more) and MOFA3 (0.6 to less than 0.8). In addition, the coefficient for the group of MOFA4 is larger in absolute term than is that for the group of MOFA3, which implies that the relationship between the degree of trade responsiveness and the ratio is linear.

As for another variable representing controllability of foreign operations, INTRA, all of the four interaction terms have negative and significant coefficients. This implies that firms with high ratios of intra-firm trade are more likely to adjust their exports to exchange rate changes. [11] Interestingly, however, the absolute term of

[10] We also conducted regression analysis based on the equation (I), instead of on equation (II), by separating sample set into SMEs and large firms. The results obtained are consistent with the results discussed here.

[11] The number of observations for the analysis using intra-firm trade ratios is smaller than that for other analyses. This is due to the missing data for intra-firm trade for some firms.

coefficient is the largest for the group of INTRA2 (firms with ratios from 0.4 to less than 0.6), indicating that export adjustments to exchange rate changes are not linear to the ratios of intra-firm trade. In other words, firms tend to most strongly adjust its exporting behavior in response to their exchange rate movements when the share of intra-firm exports is about 40 percent to 60 percent.[12]

The coefficients for the size of firm at home, R&D-sales ratio, and Asian dummy are positive and statistically significant in all equations. These findings indicate that Japanese manufacturing firms with a larger employment size at home, R&D intensive manufacturing firms, and manufacturing firms investing in Asia are more likely to have greater exports. The coefficient for capita-labor ratio is positive but not statistically significant in all models.

Table 5, in turn, demonstrates the results for export ratio to total sales (foreign and domestic sales). Similarly to the results for exports, the coefficient for changes in exchange rates is negative and significantly differs from zero. This suggests that Japanese manufacturing firms decrease (increase) their exports in response to appreciation (depreciation) of the Japanese Yen not only in the absolute term but also in the relative term in comparison with domestic sales.

[12] The following sub-section will discuss this non-linear relationship further.

Table 5. Results for Manufacturing Firms' Responsiveness to Exchange Rate Movements: Export Ratio

Independent variables	(1)	(2)	(3)	(4)
Constant	0.014 ***	0.014 ***	0.014 ***	0.020 ***
	(3.79)	(3.76)	(3.80)	(4.13)
EXratio	0.908 ***	0.908 ***	0.908 ***	0.863 ***
	(246.3)	(246.4)	(247.0)	(180.0)
EXR^	-0.063 ***			
	(-8.94)			
EXR^・SIZE3dummy		-0.060 ***		
arge firms with over 1000 workers)		(-6.87)		
EXR^・SIZE2dummy		0.002		
(large firms with 500-999 workers)		(0.14)		
EXR^・SIZE1dummy		-0.018		
(large firms with 300-499 workers)		(-0.93)		
EXR^・MOFA4dummy			-0.073 ***	
(ratios equal to 0.8 or more)			(-7.34)	
EXR^・MOFA3dummy			-0.099 ***	
(ratios from 0.6 to less than 0.8)			(-5.14)	
EXR^・MOFA2dummy			-0.053 **	
(ratios from 0.4 to less than 0.6)			(-2.54)	
EXR^・MOFA1dummy			-0.017	
(ratios from 0.2 to less than 0.4)			(-0.47)	
EXR^・INTRA4dummy				-0.041 ***
(ratios equal to 0.8 or more)				(-2.98)
EXR^・INTRA3dummy				-0.096 ***
(ratios from 0.6 to less than 0.8)				(-4.47)
EXR^・INTRA2dummy				-0.093 ***
(ratios from 0.4 to less than 0.6)				(-4.73)
EXR^・INTRA1dummy				-0.087 ***
(ratios from 0.2 to less than 0.4)				(-4.51)
SIZE	0.001	0.001	0.001	0.001
	(1.04)	(1.06)	(1.01)	(1.34)
KLratio	-0.002 **	-0.002 **	-0.002 *	-0.003 **
	(-2.00)	(-1.99)	(-1.95)	(-2.29)
R&Dratio	0.083 ***	0.083 ***	0.084 ***	0.084 ***
	(3.89)	(3.88)	(3.93)	(3.21)
ASIA	0.003 *	0.003 *	0.003 *	0.003
	(1.67)	(1.68)	(1.74)	(1.56)
R2（within）	0.165	0.165	0.166	0.180
R2(between)	0.947	0.947	0.947	0.927
R2(overall)	0.853	0.853	0.853	0.864
Number of observations	15263	15263	15263	12531

Data source: Authors' calculation, based on METI database.

Notes: Figures in parenthesis are t-statistics. *** indicates that the results are statistically significant at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

The results for interaction terms are also similar to those for exports, although there are slight differences between them. As for SIZE, only the interaction term with SIZE3 (the largest size group) has a negative and significant coefficient. Regarding MOFA, the coefficients of all of four interaction terms are negative and statistically significant except for the group of MOFA1. Again, controllability of foreign operations in terms of MOFA seems also to be an important aspect for the firms' exporting adjustments to exchange rate changes. As for INTRA, all of the four interaction terms have negative and significant coefficients. Similar to the results for exports, the absolute term of coefficient is the largest for the group of INTRA2 (firms with ratios from 0.4 to less than 0.6) and INTRA3 (ratios from 0.6 to less than 0.8), suggesting that the relationship between intra-firm trade ratio and firms' adjustments is not linear.

As for controls, the firm size is not statistically significant. This result may be reasonable as exports of the dependent variable are normalized by total sales. The coefficient for capita-labor ratio is negative and statistically significant in all models, suggesting that labor-intensive firms have higher export-sales ratio.[13] Furthermore, R&D-sales ratio and Asia dummy have positive coefficients with statistical significance for most equations, which is consistent with the analysis of exports.

The results for imports are displayed in Table 6. Surprisingly, the coefficient for exchange rate movements is negative though it is statistically insignificant. Moreover, most coefficients for interaction terms in equations (2) to (4) have negative signs without statistical significance. These signs contradict the general prediction of macro economic theory, although they are mostly statistically insignificant. In general, the

[13] Although this is not the expected sign, the coefficient for the same variable becomes positive and insignificant if the sample is limited to machinery firms (Table A4).

exchange rate appreciation facilitates firms' imports, and thus a positive sign is expected. This point is further discussed in the following sub-section. As for control variables and Asia dummy, coefficients for the size of firm and Asia dummy are positive and statistically significant in all equations, which is consistent with the case of exports. The coefficient for capita-labor ratio is positive and statistically significant in all models, suggesting that capital-intensive firms tend to have greater imports. The coefficient for R&D-sales ratio is negative but is statistically insignificant.

For the analysis of import ratio, that is imports as a share of total purchases (domestic and foreign procurement), the exchange rate variable has a negative coefficient with statistical significance (Table 7). In addition, most of the coefficients for interaction terms have negative signs, although they are not necessarily statistically significant. They tend to be significant for larger firm size, higher ratio of majority owned foreign affiliates, and higher intra-firm trade. These results are unexpected as we predicted positive signs.[14] As for other variables, the coefficient for size of firm is negative and statistically significant in all equations. It suggests that a smaller firm has a higher import-purchases ratio. The Asia dummy has a positive and statistically significant sign, suggesting that Japanese manufacturing firms tend to have higher import ratio when they invest in Asia.

[14] As discussed later, however, when the sample is limited to machinery firms, rather than to manufacturing firms as a whole, the coefficients for all interaction terms become statistically insignificant (Table A6).

Table 6. Results for Manufacturing Firms' Responsiveness to Exchange Rate Movements: Imports

Independent variables	(1)	(2)	(3)	(4)
Constant	-0.058	-0.002	-0.010	0.086
	(-0.08)	(-0.03)	(-0.14)	(1.07)
IM	0.730 ***	0.730 ***	0.730 ***	0.738 ***
	(121.35)	(121.32)	(121.31)	(112.33)
EXR^	-0.114			
	(-1.17)			
EXR^・SIZE3dummy		-0.109		
arge firms with over 1000 workers)		(-0.62)		
EXR^・SIZE2dummy		-0.073		
(large firms with 500-999 workers)		(-0.35)		
EXR^・SIZE1dummy		-0.166		
(large firms with 300-499 workers)		(-0.70)		
EXR^・MOFA4dummy			-0.308 **	
(ratios equal to 0.8 or more)			(-2.19)	
EXR^・MOFA3dummy			-0.120	
(ratios from 0.6 to less than 0.8)			(-0.46)	
EXR^・MOFA2dummy			0.340	
(ratios from 0.4 to less than 0.6)			(1.15)	
EXR^・MOFA1dummy			0.316	
(ratios from 0.2 to less than 0.4)			(0.64)	
EXR^・INTRA4dummy				-0.135
(ratios equal to 0.8 or more)				(-0.90)
EXR^・INTRA3dummy				-0.405
(ratios from 0.6 to less than 0.8)				(-1.25)
EXR^・INTRA2dummy				-0.146
(ratios from 0.4 to less than 0.6)				(-0.42)
EXR^・INTRA1dummy				-0.432
(ratios from 0.2 to less than 0.4)				(-1.28)
SIZE	0.231 ***	0.230 ***	0.231 ***	0.215 ***
	(18.55)	(18.48)	(18.58)	(15.82)
KLratio	0.037 **	0.038 **	0.038 **	0.035 **
	(2.40)	(2.41)	(2.40)	(2.06)
R&Dratio	-0.317	-0.317	-0.320	-0.434
	(-0.87)	(-0.87)	(-0.88)	(-1.09)
ASIA	0.224 ***	0.224 **	0.225 ***	0.206 ***
	(7.03)	(7.03)	(7.08)	(5.58)
R2（within）	0.171	0.171	0.171	0.166
R2(between)	0.885	0.885	0.885	0.884
R2(overall)	0.832	0.832	0.832	0.839
Number of observations	12122	12122	12122	9891

Data source: Authors' calculation, based on METI database.

Notes: figures in parenthesis are t-statistics. *** indicates that the results are statistically significant at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 7. Results for Manufacturing Firms' Responsiveness to Exchange Rate Movements: Import Ratio

Independent variables	(1)	(2)	(3)	(4)
Constant	0.146 ***	0.146 ***	0.146 ***	0.134 ***
	(13.57)	(13.57)	(13.58)	(11.74)
IMratio	0.516 ***	0.516 ***	0.516 ***	0.573 ***
	(68.23)	(68.20)	(68.24)	(69.24)
EXR^	-0.042 ***			
	(-3.06)			
EXR^・SIZE3dummy		-0.053 ***		
arge firms with over 1000 workers)		(-3.08)		
EXR^・SIZE2dummy		0.020		
(large firms with 500-999 workers)		(0.59)		
EXR^・SIZE1dummy		0.043		
(large firms with 300-499 workers)		(1.13)		
EXR^・MOFA4dummy			-0.044 **	
(ratios equal to 0.8 or more)			(-2.21)	
EXR^・MOFA3dummy			-0.081 **	
(ratios from 0.6 to less than 0.8)			(-2.19)	
EXR^・MOFA2dummy			-0.011	
(ratios from 0.4 to less than 0.6)			(-0.26)	
EXR^・MOFA1dummy			-0.005	
(ratios from 0.2 to less than 0.4)			(-0.08)	
EXR^・INTRA4dummy				-0.041 *
(ratios equal to 0.8 or more)				(-1.88)
EXR^・INTRA3dummy				-0.093 **
(ratios from 0.6 to less than 0.8)				(-1.98)
EXR^・INTRA2dummy				-0.023
(ratios from 0.4 to less than 0.6)				(-0.47)
EXR^・INTRA1dummy				-0.031
(ratios from 0.2 to less than 0.4)				(-0.64)
SIZE	-0.013 ***	-0.013 ***	-0.013 ***	-0.012 ***
	(-8.15)	(-8.15)	(-8.17)	(-6.98)
KLratio	0.000	0.000	0.000	-0.001
	(-0.17)	(-0.17)	(-0.16)	(-0.49)
R&Dratio	0.048	0.048	0.050	0.038
	(0.93)	(0.93)	(0.97)	(0.68)
ASIA	0.011 **	0.011 **	0.011 **	0.010 **
	(2.38)	(2.37)	(2.39)	(2.00)
R2（within）	0.036	0.036	0.036	0.036
R2(between)	0.721	0.721	0.721	0.746
R2(overall)	0.550	0.550	0.550	0.574
Number of observations	12122	12122	12122	9891

Data source: Authors' calculation, based on METI database.

Notes: Figures in parenthesis are t-statistics. *** indicates that the results are statistically significant at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Before moving to further discussion of the results of our empirical investigation, let us compare the results for manufacturing firms (including machinery firms) with those for machinery firms. The results on the export side in Tables A3 and A4 show a negative sign for exchange rate changes. Moreover, some coefficients for interaction terms become statistically significant for machinery firms, while they are insignificant for manufacturing firms as a whole; for instance, all three interaction terms with SIZE dummy variables are negative and statistically significant for machinery firms only, while only one interaction variable with SIZE dummy shows a statistically significant coefficient for manufacturing firms (Table A4). Furthermore, interestingly, the coefficients for exchange rate changes and most interaction terms are larger in absolute terms with statistical significance for machinery firms than those for all manufacturing firms. All of these results suggest that machinery firms tend to more easily absorb shocks of exchange rate movements by adjusting intra-firm transactions than do non-machinery manufacturing firms. This result is notable given that Japanese machinery firms have been involved in sophisticated international production networks particularly in East Asia. On the import side, a coefficient with statistical significance for the analysis of imports is not observed except for the interaction term with MOFA4. In addition, no interaction term presents statistically significant results for the analysis of import ratio. In sum, machinery firms, which have been particularly involved in the production networks in East Asia, are more flexible by benefiting from their global operations than are other manufacturing firms.

4.2. Implications and Discussion

Our empirical analysis demonstrates that firms tend to increase (decrease) their exports, or export ratio to total sales, in response to depreciation (appreciation) of the Japanese Yen. This is consistent with the fundamental consensus of macro-economic theory. More importantly, the analysis found that firms are more likely to adjust their exports (1) when they are large in size, (2) when majority-owned affiliates are dominant among their foreign affiliates, and (3) when their intra-firm trade ratio is moderately high. In particular, these tendencies are more salient for machinery firms, who are one of the major players in international production networks in East Asia. The results suggest that manufacturing firms, particularly machinery firms, with greater foreign operations under their own corporate control, would better absorb shocks of exchange rate movements by adjusting intra-firm transactions more significantly.

In addition to such important findings, two interesting insights emerge from the results. First, while the large size and controllability of foreign operations in general help the firms' exporting adjustments to exchange rate movements, this relationship is not always linear: Japanese manufacturing firms flexibly adjust exports to exchange rate movements to the greatest extent when their intra-firm export ratio is about 40 percent to 60 percent (or 40 percent to 80 percent for export ratio). We consider two possible explanations for this non-linear effect of intra-firm trade ratio. First, this result may reflect low responsiveness caused by high pass-through of international competitive firms: if extremely high intra-firm ratio represents firms' export competitiveness to some extent, for instance, such firms would not have to drastically adjust their exports to exchange rate movements because they can still transfer Yen appreciation into prices

in their export price.[15] Another possible reason for non-linear responsiveness would be Japanese firms' extensive dollar-based operations. In the electric machinery sectors in particular, dollar-based operations largely occupy foreign operations of Japanese firms, and thus dollar depreciation (on the other side of yen appreciation) encourages expanding operations for a whole group of the firm, resulting in an increase in exports of parts and components from Japan to their affiliates abroad. This would be interpreted not as low responsiveness but as adjustments within the whole group of the firm.

Second, our regression analyses do not provide strong evidences on import responsiveness to exchange rate movements. One potential explanation is that most Japanese firms import raw materials. It may sound reasonable that, under the yen's appreciation, firms reduce their imports (raw materials) because they need to reduce exports that they utilized imported raw materials to produce.[16]

5. Conclusion

This paper seeks to shed new light on the literature of international product/distribution networks and of international economics in general by investigating

[15] See Sazanami, Kimura, & Kawai (1997), for example. They conduct a cross-sectional analysis to investigate the relationship between the globalization of firms' activities and export pass-through.

[16] One might consider the well-known J-curve effect: for example, if the volume of imports does not increase enough to fully adjust the Japanese Yen's appreciation, a fall in the import's unit price due to the yen's appreciation might be significantly reflected in the value of imports. Thus, the speed of volume/unit price adjustment against exchange rate movements might be asymmetric between exports and imports. In this paper, however, this asymmetry might not be a serious concern because quantitative adjustments in general would be delayed by half a year or so at most, while our study employs annual data.

how firms adjust their exports/imports against exchange rate movements. With the panel data of Japanese manufacturing firms from 1994 to 2004, we found that firms tend to adjust their exports, responding to exchange rate movements, in particular (1) when they are large in size, (2) when majority-owned affiliates are dominant among their foreign affiliates, and (3) when their intra-firm trade ratio is moderately high. In addition, these tendencies are more salient for machinery firms. The results suggest that Japanese manufacturing firms, particularly machinery firms, with greater foreign operations under their own corporate control would better absorb shocks of exchange rate movements by adjusting their intra-firm transactions more significantly. We did not find such tendencies for imports, however. Our findings complement the studies on production sharing. These prior works have witnessed the dramatic development of sophisticated production networks firms in East Asia. The results provided by this study imply that such networks might serve as a "buffering" system for manufacturing firms to mitigate risks of exchange rate fluctuations.

Table A1. Summary Statistics

	Observations	Mean	Std. Dev.	Minimum	Maximum
Exports (millions JPYen)	18508	18445	126424	1	4616233
Export ratio (to total sales)	18508	0.15	0.18	0.00	1.00
Imports (millions JPYen)	15271	6246	41705	1	1123522
Import ratio (to total purchases)	15271	0.14	0.20	0.00	1.00
EXR^	18508	-0.02	0.08	-0.16	0.11
SIZE (number of regular workers)	18508	1391	4144	50	77185
KL ratio (tangible assets per workers) (millions JPY	18495	13	14	0	269
R&D ratio (to total sales)	16958	0.027	0.033	0	1
Asia dummy	18508	0.817	0.387	0	1
MOFA ratio	18508	0.724	0.363	0	1
INTRA EX ratio	13277	0.566	0.351	0	1
INTRA IM ratio	10830	0.708	0.348	0	1

Table A2. Correlation Matrix for Manufacturing Firms

	EX (log)	IM (log)	EXratio	IMratio	SIZE	KLratio (log)	R&D ratio	ASIA	EXR^	EXR^・SIZE3D	EXR^・SIZE2D	EXR^・SIZE1D	EXR^・MOFA4D	EXR^・MOFA3D	EXR^・MOFA2D	EXR^・MOFA1D	EXR^・INTRAEX4D	EXR^・INTRAEX3D	EXR^・INTRAEX2D	EXR^・INTRAEX1D	EXR^・INTRAIM4D	EXR^・INTRAIM3D	EXR^・INTRAIM2D	EXR^・INTRAIM1D
EX (log)	1.00																							
IM (log)	0.58	1.00																						
EXratio	0.61	0.25	1.00																					
IMratio	0.06	0.43	0.21	1.00																				
SIZE	0.67	0.56	0.10	-0.12	1.00																			
KLratio (log)	0.26	0.27	-0.01	-0.01	0.32	1.00																		
R&D ratio	0.33	0.19	0.18	-0.03	0.31	0.10	1.00																	
ASIA	0.10	0.18	0.01	0.04	0.11	0.00	-0.05	1.00																
EXR^	0.01	0.01	0.01	0.00	0.01	-0.01	-0.01	-0.01	1.00															
EXR^・SIZE3D	-0.08	-0.07	-0.01	0.00	-0.13	-0.05	-0.05	-0.03	0.54	1.00														
EXR^・SIZE2D	-0.01	0.01	0.01	0.01	-0.02	-0.01	0.01	0.00	0.45	-0.01	1.00													
EXR^・SIZE1D	0.02	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.40	-0.01	-0.01	1.00												
EXR^・MOFA4D	0.04	0.03	0.00	-0.01	0.05	0.01	0.00	0.03	0.69	0.21	0.32	0.32	1.00											
EXR^・MOFA3D	-0.04	-0.02	-0.02	0.00	-0.04	-0.02	0.00	-0.02	0.36	0.38	0.15	0.09	-0.01	1.00										
EXR^・MOFA2D	-0.01	-0.01	0.02	0.00	-0.01	-0.01	0.00	-0.02	0.33	0.22	0.16	0.12	-0.01	-0.01	1.00									
EXR^・MOFA1D	-0.01	-0.01	0.01	0.01	-0.01	-0.01	0.00	-0.02	0.19	0.11	0.15	0.07	-0.01	0.00	0.00	1.00								
EXR^・INTRAEX4D	0.04	0.02	0.02	0.01	0.02	0.02	0.02	-0.02	0.48	0.21	0.20	0.18	0.37	0.17	0.12	0.07	1.00							
EXR^・INTRAEX3D	-0.01	0.00	0.00	-0.01	0.00	-0.02	-0.02	-0.01	0.32	0.24	0.16	0.09	0.20	0.15	0.10	0.06	-0.01	1.00						
EXR^・INTRAEX2D	-0.03	-0.01	-0.01	-0.01	-0.01	0.00	-0.02	0.00	0.34	0.24	0.15	0.11	0.20	0.15	0.11	0.10	-0.01	-0.01	1.00					
EXR^・INTRAEX1D	-0.02	0.00	-0.01	0.00	0.00	0.00	0.00	-0.01	0.34	0.20	0.16	0.14	0.22	0.16	0.13	0.08	-0.01	-0.01	-0.01	1.00				
EXR^・INTRAIM4D	0.01	0.03	0.00	0.00	0.02	0.01	0.01	-0.02	0.62	0.27	0.29	0.26	0.45	0.21	0.19	0.11	0.49	0.23	0.21	0.19	1.00			
EXR^・INTRAIM3D	-0.02	-0.02	-0.02	-0.01	0.00	0.01	-0.01	-0.01	0.27	0.18	0.12	0.11	0.18	0.13	0.08	0.09	0.12	0.14	0.14	0.12	-0.01	1.00		
EXR^・INTRAIM2D	0.00	-0.01	0.00	-0.01	0.00	0.00	-0.01	-0.03	0.26	0.18	0.12	0.08	0.18	0.14	0.08	0.06	0.11	0.11	0.12	0.13	-0.01	0.00	1.00	
EXR^・INTRAIM1D	-0.01	-0.02	0.01	0.00	-0.02	-0.02	0.01	0.00	0.27	0.22	0.11	0.11	0.15	0.15	0.09	0.04	0.08	0.11	0.14	0.14	-0.01	0.00	0.00	1.00

Table A3. Results for Machinery Firms' Responsiveness to Exchange Rate Movements: Exports

Independent variables	(1)	(2)	(3)	(4)
Constant	-0.822	-0.071	-0.083	-0.090
	(-1.22)	(-1.05)	(-1.23)	(-1.18)
EX	0.772 ***	0.773 ***	0.772 ***	0.758 ***
	(114.9)	(114.9)	(114.7)	(100.0)
EXR^	-0.437 ***			
	(-5.01)			
EXR^・SIZE3dummy		-0.344 **		
arge firms with over 1000 workers)		(-2.20)		
EXR^・SIZE2dummy		-0.563 ***		
(large firms with 500-999 workers)		(-2.97)		
EXR^・SIZE1dummy		-0.532 **		
(large firms with 300-499 workers)		(-2.42)		
EXR^・MOFA4dummy			-0.485 ***	
(ratios equal to 0.8 or more)			(-3.96)	
EXR^・MOFA3dummy			-0.579 **	
(ratios from 0.6 to less than 0.8)			(-2.38)	
EXR^・MOFA2dummy			-0.437	
(ratios from 0.4 to less than 0.6)			(-1.59)	
EXR^・MOFA1dummy			0.279	
(ratios from 0.2 to less than 0.4)			(0.61)	
EXR^・INTRA4dummy				-0.406 **
(ratios equal to 0.8 or more)				(-2.44)
EXR^・INTRA3dummy				-0.265
(ratios from 0.6 to less than 0.8)				(-1.08)
EXR^・INTRA2dummy				-0.708 ***
(ratios from 0.4 to less than 0.6)				(-2.95)
EXR^・INTRA1dummy				-0.427 *
(ratios from 0.2 to less than 0.4)				(-1.84)
SIZE	0.262 ***	0.260 ***	0.263 ***	0.280 ***
	(19.68)	(19.52)	(19.70)	(18.63)
KLratio	0.045 ***	0.045 ***	0.045 ***	0.048 ***
	(2.86)	(2.92)	(2.89)	(2.75)
R&Dratio	1.177 ***	1.192 ***	1.196 ***	1.140 ***
	(3.53)	(3.58)	(3.59)	(3.24)
ASIA	0.044	0.044 *	0.046 *	0.047
	(1.63)	(1.66)	(1.70)	(1.61)
R2（within）	0.181	0.181	0.181	0.185
R2(between)	0.937	0.937	0.937	0.928
R2(overall)	0.909	0.909	0.909	0.912
Number of observations	8665	8665	8665	7330

Data source: Authors' calculation, based on METI database.

Notes: Figures in parenthesis are t-statistics. *** indicates that the results are statistically significant at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table A4. Results for Machinery Firms' Responsiveness to Exchange Rate Movements: Export Ratio

Independent variables	(1)	(2)	(3)	(4)
Constant	0.011 **	0.014 ***	0.011 **	0.017 **
	(2.06)	(2.62)	(2.12)	(2.42)
EXratio	0.904 ***	0.905 ***	0.904 ***	0.855 ***
	(187.36)	(187.24)	(187.62)	(136.30)
EXR^	-0.082 ***			
	(-7.66)			
EXR^・SIZE3dummy		-0.103 ***		
arge firms with over 1000 workers)		(-5.31)		
EXR^・SIZE2dummy		-0.076 ***		
(large firms with 500-999 workers)		(-3.28)		
EXR^・SIZE1dummy		-0.086 ***		
(large firms with 300-499 workers)		(-3.20)		
EXR^・MOFA4dummy			-0.077 ***	
(ratios equal to 0.8 or more)			(-5.13)	
EXR^・MOFA3dummy			-0.151 ***	
(ratios from 0.6 to less than 0.8)			(-5.07)	
EXR^・MOFA2dummy			-0.112 ***	
(ratios from 0.4 to less than 0.6)			(-3.32)	
EXR^・MOFA1dummy			0.028	
(ratios from 0.2 to less than 0.4)			(0.51)	
EXR^・INTRA4dummy				-0.049 **
(ratios equal to 0.8 or more)				(-2.41)
EXR^・INTRA3dummy				-0.107 ***
(ratios from 0.6 to less than 0.8)				(-3.56)
EXR^・INTRA2dummy				-0.122 ***
(ratios from 0.4 to less than 0.6)				(-4.16)
EXR^・INTRA1dummy				-0.101 ***
(ratios from 0.2 to less than 0.4)				(-3.56)
SIZE	0.001	0.000	0.001	0.001
	(0.82)	(0.28)	(0.75)	(1.33)
KLratio	0.001	0.001	0.001	0.000
	(0.75)	(0.79)	(0.80)	(0.25)
R&Dratio	0.073 **	0.074 **	0.076 **	0.072 *
	(2.31)	(2.35)	(2.41)	(1.92)
ASIA	0.005 **	0.005 **	0.005 **	0.006 **
	(2.21)	(2.22)	(2.26)	(2.04)
R2（within）	0.149	0.150	0.150	0.169
R2(between)	0.940	0.940	0.940	0.920
R2(overall)	0.843	0.843	0.843	0.852
Number of observations	8665	8665	8665	7330

Data source: Authors' calculation, based on METI database.

Notes: figures in parenthesis are t-statistics. *** indicates that the results are statistically significant at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table A5. Results for Machinery Firms' Responsiveness to Exchange Rate Movements: Imports

Independent variables	(1)	(2)	(3)	(4)
Constant	-0.083	-0.082	-0.088	0.046
	(-0.83)	(-0.82)	(-0.88)	(0.420)
IM	0.707 ***	0.707 ***	0.708 ***	0.724 ***
	(85.64)	(85.60)	(85.89)	(81.59)
EXR^	-0.147			
	(-1.09)			
EXR^・SIZE3dummy		0.085		
arge firms with over 1000 workers)		(0.36)		
EXR^・SIZE2dummy		-0.360		
(large firms with 500-999 workers)		(-1.25)		
EXR^・SIZE1dummy		-0.046		
(large firms with 300-499 workers)		(-0.14)		
EXR^・MOFA4dummy			-0.360 *	
(ratios equal to 0.8 or more)			(-1.87)	
EXR^・MOFA3dummy			0.225	
(ratios from 0.6 to less than 0.8)			(0.62)	
EXR^・MOFA2dummy			0.491	
(ratios from 0.4 to less than 0.6)			(1.14)	
EXR^・MOFA1dummy			0.033	
(ratios from 0.2 to less than 0.4)			(0.05)	
EXR^・INTRA4dummy				-0.298
(ratios equal to 0.8 or more)				(-1.49)
EXR^・INTRA3dummy				-0.119
(ratios from 0.6 to less than 0.8)				(-0.27)
EXR^・INTRA2dummy				-0.219
(ratios from 0.4 to less than 0.6)				(-0.45)
EXR^・INTRA1dummy				0.521
(ratios from 0.2 to less than 0.4)				(1.04)
SIZE	0.264 ***	0.2641 ***	0.264 ***	0.232 ***
	(15.34)	(15.32)	(15.35)	(12.57)
KLratio	0.000	0.000	-0.001	0.000
	(-0.02)	(-0.01)	(-0.02)	(0.00)
R&Dratio	-0.049	-0.029	-0.032	-0.095
	(-0.10)	(-0.06)	(-0.06)	(-0.18)
ASIA	0.338 ***	0.339 ***	0.340 ***	-0.321 ***
	(7.64)	(7.66)	(7.68)	(6.41)
R2（within）	0.186	0.186	0.186	0.189
R2(between)	0.877	0.877	0.877	0.874
R2(overall)	0.826	0.826	0.826	0.835
Number of observations	6570	6570	6570	5492

Data source: Authors' calculation, based on METI database.

Notes: Figures in parenthesis are t-statistics. *** indicates that the results are statistically significant at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table A6. Results for Machinery Firms' Responsiveness to Exchange Rate Movements: Import Ratio

Independent variables	(1)	(2)	(3)	(4)
Constant	0.126 ***	0.127 ***	0.127 ***	0.116 ***
	(9.27)	(9.33)	(9.27)	(7.82)
IMratio	0.510 ***	0.510 ***	0.510 ***	0.566 ***
	(49.77)	(49.78)	(49.73)	(50.24)
EXR^	-0.032 *			
	(-1.67)			
EXR^・SIZE3dummy		-0.021		
ırge firms with over 1000 workers)		(-0.64)		
EXR^・SIZE2dummy		-0.059		
(large firms with 500-999 workers)		(-1.46)		
EXR^・SIZE1dummy		-0.010		
(large firms with 300-499 workers)		(-0.22)		
EXR^・MOFA4dummy			-0.033	
(ratios equal to 0.8 or more)			(-1.24)	
EXR^・MOFA3dummy			-0.049	
(ratios from 0.6 to less than 0.8)			(-0.98)	
EXR^・MOFA2dummy			-0.001	
(ratios from 0.4 to less than 0.6)			(-0.01)	
EXR^・MOFA1dummy			-0.022	
(ratios from 0.2 to less than 0.4)			(-0.22)	
EXR^・INTRA4dummy				-0.042
(ratios equal to 0.8 or more)				(-1.46)
EXR^・INTRA3dummy				-0.044
(ratios from 0.6 to less than 0.8)				(-0.70)
EXR^・INTRA2dummy				0.005
(ratios from 0.4 to less than 0.6)				(0.07)
EXR^・INTRA1dummy				0.032
(ratios from 0.2 to less than 0.4)				(0.45)
SIZE	-0.012 ***	-0.012 ***	-0.012 ***	-0.012 ***
	(-5.89)	(-5.95)	(-5.90)	(-5.31)
KLratio	-0.004	-0.004	-0.004	-0.002
	(-1.19)	(-1.19)	(-1.18)	(-0.61)
R&Dratio	0.118 *	0.119 *	0.120 *	0.119
	(1.72)	(1.75)	(1.76)	(1.63)
ASIA	0.029 ***	0.029 ***	0.029 ***	0.029 ***
	(4.83)	(4.84)	(4.84)	(4.29)
R2（within）	0.039	0.039	0.039	0.042
R2(between)	0.698	0.698	0.698	0.713
R2(overall)	0.508	0.508	0.508	0.548
Number of observations	6570	6570	6570	5492

Data source: Authors' calculation, based on METI database.

Notes: figures in parenthesis are t-statistics. *** indicates that the results are statistically significant at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

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