Exchange Rate and Japanese Exports:
New Evidence of Export Pricing, Competitiveness, and Invoice Currency

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Introduction

Japanese economy has witnessed very large and rapid changes of the nominal exchange of the yen vis-à-vis the U.S. dollar, and the exchange risk management is strategically important for Japanese firms.

Previously, Japan was well known for its large trade surplus form the 1980s. However, Japanese trade balance turned into deficit in 2011 because of economic crisis, accompanied with the large depreciation of the Japanese yen vis-à-vis the U.S. dollar. In contrast, in the end of 2012, the Japanese government initiated economic stimulus policy package, so-called *Abenomics*. This package put an end to the yen appreciation trend and dramatically turned the yen toward large depreciation. In fact, although the yen dollar exchange rate in October 2012 is 78.97, it became 97.73 in October 2013. Moreover, the yen dollar exchange rate touched around 120 in 2015.

Despite large depreciation of the Japanese yen, Japan continued to recode a large trade deficit up to early 2015 (Figure 1-1). When we see figure of trade balance, it looks improved from mid-2014. It is assumed this improvement of Japanese trade balance is likely due to a sharp decline in the world oil price from the mid-2014. Some surveys assert that the reduction of the Japanese trade deficit was caused by J-curve effect. On the other hand, this dissertation suggests that it was unlikely due to the J-curve effect, because Japanese export quantity did not exhibit a clear upward trend in response to the sharp depreciation of the yen (Figure 1-2).

This dissertation is based on the research question why Japanese export quantity has become less responsive to exchange rate depreciation. Following previous studies, this survey assumes the elucidation of this research question is closely related to the pricing strategy of Japanese exporters in reaction to large fluctuation in the yen.

Therefore, this dissertation consists of three independent research papers; "Exchange Rate Pass-Through and Export Competitiveness," "Invoicing Currency Choice and Export Competitiveness: New Evidence from Japanese Export Firms" and "Invoice Currency Choice and Exports: Why Do Japanese Exports Become Unresponsive to Exchange Rate Changes?"

The first part of this dissertation discusses pricing behavior of Japanese exporters by time-varying PTM/ERPT coefficients. Furthermore, this survey investigates the determinants of pricing strategy at a commodity level. In particular, this paper regards export competitiveness as a possible determinant of pricing behavior.

The second part of dissertation empirically investigates the invoicing currency decision in Japanese exports with a novel data set. We first estimate time-varying choice of invoicing currency in Japanese exports at a detailed commodity level and conduct a panel analysis of the invoicing currency decision using new explanatory variables constructed from annual securities reports of 831 Japanese firms.

The third part of this dissertation reveals the determinates of export quantity movement from 2003 to 2018. The main purpose of this paper is to empirically investigate what causes recent unresponsiveness of Japanese export quantity to exchange rate changes by using 35 product-level data on Japan's export quantity collected from the Ministry of Finance, Japan. Using disaggregated export data is not new, but we make the following three novel contributions. First, this paper collects firm-characteristic data from annual securities reports of 472 Japanese manufacturing firms and constructed the firm-characteristic variables for corresponding 35 export products. Second, this paper uses the data on invoice currency for 35 export products to consider how invoice currency choice affects export quantity. Third, this paper employs *product-specific* real effective exchange rate (REER) to measure the degree of export elasticity to exchange rates.

CHAPTER 1:

Exchange Rate Pass-Through and Export Competitiveness

1. Introduction

Japan was well known for its large trade surplus since the 1980s, but Japan's trade balance turned into deficit in 2011 on an annual basis (Figure 1-1). The size of the trade deficit was continued to grow from then on, even though the yen started to depreciate sharply from the end of 2012 thanks to the economic-stimulus package initiated by Prime Minister Abe, so-called *Abenomics*. A rapid and large depreciation of the yen was expected to have a positive impact on the Japanese trade balance. As shown in Figure 1-1, the yen depreciated rapidly from less than 80 in 2011-2012 to around 120 in the end of 2014, but the Japanese trade balance did not improve during that period.

Figure 1-1 also shows that Japanese trade deficit started to shrink in February 2015, after two years from the start of yen depreciation. According to the J-curve effect, after initial deterioration in response to the domestic currency depreciation, the trade balance will improve gradually, because exports will grow due to a decline of export price in terms of the destination currency.[1] Can this research say that Japanese trade balance will improve from now on due to the J-curve effect?

In fact, the recent improvement of Japan's trade balance is not due to the increase in exports. While Figure 1-1 indicates the possible improvement of trade balance from February 2015, Figure 1-2 shows that Japan's export quantity have not exhibited a large increase since the end of 2012.[2] Obviously, the recent improvement of Japanese trade balance is due to a sharp decline in crude oil prices from the mid-2014.

The question is why Japanese export quantity has not increased to a large extent in response to the substantial depreciation of the yen from the end of 2012. It has been a

[1] See, for instance, Rose and Yellen (1989), Bahmani-Oskooee and Goswami, (2003) and Bahmani-Oskooee and Ratha (2004).
[2] Japan's export quantity increased from 99.5 in December 2012 to 101.9 in December 2015.

matter of major concern for policy makers that Japanese firms might lose export competitiveness in the global market. Shimizu and Sato (2015), for instance, analyzed whether the J-curve effect is empirically supported in Japan by applying the auto-regressive distributed lag (ARDL) model developed by Pesaran *et al*. (2001), and revealed the J-curve effect does not work well in Japanese trade from 1999 to 2014.

This study uses a different approach to analyze the above question by focusing on Japanese exporter's pricing behavior. As will be discussed in the next section (Figure 1-3), Japanese export price in the contract currency tends to be less responsive to exchange rate changes, which suggests that Japanese exporters conduct pricing-to-market (PTM) behavior. Given the PTM behavior, export quantity is unlikely to increase during the yen depreciation period. Thus, this survey first examines the exchange rate pass-through (ERPT) behavior of Japanese exporters at an industry level. By using the Kalman filter technique, time-varying ERPT (or PTM) coefficients are estimated to consider possible changes in pricing behavior, which reveals that ERPT coefficients differs across industries. Second, this dissertation investigates the determinants of ERPT by constructing new explanatory variables of export competitiveness. This survey utilizes the firm-level information on R&D expenditure and construct an industry-level R&D variable as a proxy for the industry-level export competitiveness. The empirical analysis of this paper demonstrates that Japanese exporters with stronger export competitiveness and larger foreign exposure tend to increase the degree of ERPT during the yen appreciation period, while they tend to choose the PTM behavior during the yen depreciation period.

This part of dissertation is organized as follows. Section 2 shows the pricing behavior of Japanese exports from 2000 to the present. Section 3 estimates time-varying parameter of exchange rate pass-thorough in Japanese export industries. In section 4, this survey empirically analyzes the impact of export competitiveness represented by R&D expenditure on pass-through rate by using panel analysis. Section 5 concludes.

2. Pricing Behavior of Japanese Exports[3]

Bank of Japan (BOJ) publishes the monthly series of the industry/commodity breakdown data on export price indices. BOJ collects the export price data when cargo is

[3] This section is mainly based on Shimizu and Sato (2015). See Nguyen and Sato (2015) for further details of the BOJ export price indices.

loaded in Japan at the customs clearance stage, and the free on board (FOB) prices at the Japanese port of exports are surveyed. In addition, the BOJ reports export price indices both on a *yen* basis and on a *contract* (*invoice*) *currency* basis. As long as they are traded in foreign currencies, the sample prices are recorded on the original contract currency basis, and finally compiled as the "export price index on the contract currency basis". To compile the "export price index on the yen basis", the sample prices in the contract currency are converted into the yen equivalents by using the monthly average exchange rate of the yen vis-à-vis the contract currency.[4]

Figure 1-3 shows not only the nominal exchange rate of the yen vis-à-vis the U.S. dollar but also the Japanese export price index (all industries).[5] First, while the level of the exchange rate fluctuated to a large extent from 2000, the export price on the contract currency basis fluctuates within a narrow range at around the level of 100 until late 2014, which suggests that Japanese exporters tend to stabilize the export price in terms of the destination currency and, hence, conduct the pricing-to-market (PTM) strategy. Second, if this survey closely observes the export price movements, Japanese export prices on a contract currency basis exhibit an increase during the sharp appreciation period from 98.0 in January 2009 to 103.7 in September 2011. In contrast, the export price on a contract currency basis does not show a large decline from the end of 2012. While the yen depreciated substantially vis-à-vis the U.S. dollar from 83.6 in December 2012 to 119.3 in December 2014, Japanese export price exhibits only a small decline from 100.7 to 96.0 during the same period. Thus, Japanese exporters tend to conduct the PTM behavior during the yen depreciation period. From 2015, however, the export price index on the contract currency basis exhibits a large decline from 96.0 in December 2014 to 89.8 in December 2015.

Thus, the magnitude of export price changes on the contract currency basis is far smaller than that of the yen depreciation (Figure 1-3). Although to a smaller extent, however, the export price on the contract currency basis does exhibit an upward movement from 2009 to 2011 and a downward movement from 2012 to 2015. To make further investigation of such price movements, let us observe possible difference in export price movements across industries.

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[4] See the BOJ website (https://www.boj.or.jp/en/statistics/pi/cgpi_2010/index.htm/) for further details.

[5] Not the nominal *effective* exchange rate but the *bilateral* nominal exchange rate of the yen vis-à-vis the U.S. dollar is used in Figure 1-3.

Figure 1-4 presents the export price indices of Japanese four major export industries: general machinery, electric machinery, transport equipment and chemicals.[6] In general machinery and transport equipment, the export price indices on the contract currency basis show a slight upward trend from around 2008 to 2014 despite short-run fluctuations, while these two indices declined slightly and temporarily just for several months in 2013 (Figure 1-4-A and 1-4-C). In particular, the export price of transport equipment increased from 99.6 in September 2008 to 110.1 in November 2012. During the same period, the export price of general machinery also rose from 100.3 to 102.5. This evidence suggests that Japan's exporters in transport equipment and general machinery in practice raised the export price itself during the yen appreciation period.

In contrast, the export price index of the electric machinery exhibits steady downward movements over the sample period, due to the global decline of electronics prices (Figure 1-4-B), while the export price index on the yen basis exhibits similar movements to the exchange rate fluctuations. Thus, the small decline in the export price index of all manufacturing from 2011 may partly reflect the continuous downward movements of the export price in the electric machinery industry.

The export price indices of metals and chemicals fluctuates to a larger extent than the three machinery industries, which may likely reflect large fluctuations of primary product prices such as other chemical products and so on (Figure 1-4-D).

3. Time-Varying Exchange Rate Pass-Through

3.1 Empirical Model

3.1.1 Short-run Exchange Rate Pass-Through (PTM)

As discussed in the previous section, the BOJ's export price index measured in the contract (invoice) currency has been relatively stable since 2000, indicating that Japanese exporters have not changed their export prices in overseas markets regardless of exchange rate fluctuations, which is referred to as PTM behavior. However, this dissertation has

[6] Since the industry classification in Japan's trade statistics was substantially changed for the 2015 base year data, BOJ follows the revised industry classification when starting to publish the 2010 base year data. In this paper, "General machinery" denotes the "general purpose, production & business-oriented machine; and "electric machinery" denotes "electric & electronic products".

also observed that the contract currency based export price tends to show short-run fluctuations and clearly increases during the yen appreciation period from 2009 to 2011. To confirm the possible PTM or exchange rate pass-through behavior by industry, this dissertation conducts a more rigorous empirical analysis of the exporter's pricing strategy by allowing for the choice of contract (invoice) currency.

There have so far been a large number of studies on exchange rate pass-through or PTM. The single-equation model is typically used in the literature, such as Campa and Goldberg (2005). To allow for possible changes in the pass-through or PTM behavior, this research employ the Kalman filter technique to estimate the following observation equation (1) and the state equation (2):

$$\Delta \ln P_t^{EX} = \beta_{0,t} + \beta_{1,t}\Delta \ln NEER_t^C + \beta_{2,t}\Delta \ln P_t^D + \beta_{3,t}\Delta \ln Y_t^W + \varepsilon_t \quad (1)$$

$$\beta_{i,t} = \beta_{i,t} + \nu_{i,t} \qquad i = 0, 1, 2 \text{ and } 3 \quad (2)$$

In the observation equation (1), P^{EX} denotes the export price index on the yen basis; $NEER^C$ stands for the nominal effective exchange rate (NEER) weighted by the share of contract (invoicing) currency the details of which will be shown below; P^D represents the domestic input price index; Y^W indicates the world real output; ε denotes the white-noise residuals; and Δ represents the first-difference operator. In the state equation (6), β and ν indicate, respectively, the time-varying coefficient and the Gaussian disturbances with zero mean; and β is assumed to follow a random walk process.

3.1.2 Medium/Long-run Exchange Rate Pass-Through (PTM)

The above model can be extended to the long-run estimation model:

$$\Delta \ln P_t^{EX} = \beta_{0,t} + \sum_{j=0}^{n} \beta_{1,t-j}\Delta \ln NEER_{t-j}^C + \sum_{j=0}^{n} \beta_{2,t-j}\Delta \ln P_{t-j}^D + \sum_{j=0}^{n} \beta_{3,t-j}\Delta \ln Y_{t-j}^W + \varepsilon_t \quad (3)$$

$$\beta_{i,t} = \beta_{i,t} + \nu_{i,t} \qquad i = 0, 1, 2 \text{ and } 3 \quad (4)$$

As medium-run or long-run estimator, this survey includes j lags in equation (1) and is rewritten in equation (3). That is, when j is equal to 0, equation (3) is same as equation (1).

The primary interest of this paper is in the time-varying pass-through coefficient of the contract currency based NEER, $\beta_{1,t}$. If $\beta_{1,t}$ is equal to one and statistically significant, exporters choose *zero* pass-through or *complete* PTM. If $\beta_{1,t}$ is equal to zero, exporters pursue *complete* pass-through or *no* PTM.

3.2 Data

For empirical analysis, this survey selected the following major Japanese export industries: "Transport Equipment," "Electric & Electronic Products," "General Purpose, Production & Business Oriented Machinery, "Chemicals & related products." Appendix Table 1-A1 shows each commodity sector and trade weight. Industry classification of Japanese Export Price Index has seven "Group", 38 "Subgroup" and 64 "Commodity Classes". This dissertation selected all 50 commodity classes as commodity sectors from the four main export industry group. According to the BOJ price statistics, as of 2015, 77.85 percent of Japanese exports are accounted for by the sum of these four industries: transport equipment (28.5), electric & electronic products (20.5), general purpose, production & business oriented machinery (19.2) and chemicals & related products (9.8).

In contrast to the previous studies, this dissertation develops the conventional (trade-weighted) NEER into the "contract currency based NEER", like Ceglowski (2010). As explained earlier, the BOJ compiles the export price index on the contract currency basis, and the export price on the yen basis is calculated by multiplying the contract currency based export price by the nominal exchange rate of the yen vis-à-vis the contract currency. Thus, we can obtain the contract currency based NEER by dividing the yen based export price index by the contract currency based export price index.

As demonstrated by Ito *et al*. (2012, 2013), Japanese exporters tend to use either of the U.S. dollar, yen or euro as a contract (invoice) currency. According to the invoice currency data published by Japanese Ministry of Finance, 53.5 percent of Japan's exports are invoiced in U.S. dollars, and the share of the yen accounts for just 35.7 percent of Japan's total exports in the second half of 2014.[7] Since the third currency invoicing is quite large in Japanese exports, it is not the trade-weighted NEER but the contract currency based NEER that may better reflect the exchange rate pass-through or PTM behavior of Japanese exporters at the customs clearance stage in destination countries. Thus, even though the BOJ does not publish the destination breakdown data on export

[7] See Figure 2-2.

prices, the contract currency based NEER enables us to capture the weighted average of destination specific pass-through based on the exchange rate of the yen vis-à-vis the contract currency.

Another advantage over the trade-weighted NEER is that this research can use the *industry-specific* data on the contract currency based NEER. Since BOJ publishes the industry and commodity breakdown data on export price indices both on the contract currency basis and on the yen basis, this dissertation can easily calculate the contract currency based NEER by industry or by commodity. Different from the conventional effective exchange rate, the increase (decrease) in the contract currency based NEER represents a depreciation (appreciation) of the yen.

The domestic producer price index is typically used in the literature on exchange rate pass-through to allow for changes in production costs. In contrast, this survey use the domestic input price index published by BOJ that exhibits the weighted average prices of the intermediate input goods (i.e., raw and intermediate materials, fuel, and energy) and services to produce the products in respective industries.[8] Thus, BOJ input price index better reflects the domestic production cost in each industry than the producer price index.

To allow for the effect of world business cycles on the exchange rate pass-through, we include Y^W which is a weighted average of the monthly series of industrial production indices of Japan's 20 major trading partner countries.[9] Since the sample period of this survey includes the global financial crisis after 2008, it is necessary to include Y^W in equation (1) and (3) to capture possible income effect of the crisis on export prices.

Before performing the time-varying parameter estimation, this research conduct both the ADF (Augmented Dickey-Fuller) and PP (Phillips-Perron) tests for unit-root. Although not reported in this dissertation, it is confirmed that all variables are non-stationary in level but stationary in first differences. The first-difference model in equation (1) and (3) ensures the stationarity of variables.

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8 The weights are based on the input values of goods (i.e., raw and intermediate materials, fuel, and energy) and services for the manufacturing industry at purchasers' prices in the Input-Output Tables during the base year 2005, published by the Ministry of Internal Affairs and Communications.

9 The industrial production index is obtained from the CEIC Database. 20 trading partner countries are chosen by the share of each country in Japan's total exports. The export share of Japan to each country exceeds 1 percent as of 2005.

3.3 Results of Time-Varying ERPT by Industry

Figure 1-4 shows estimated time-varying ERPT/PTM coefficients for four industries.[10] This research made estimation for 50 commodity sectors, but do not present the results for all commodity sectors. Instead, this survey presents the estimated time-varying coefficients for four industries with ±two standard error confidence bands for each time-varying coefficient.

When conducting time-varying parameter estimation, this survey included lagged explanatory variables. The sum of estimated coefficients for finite distributed lags is considered "medium-run or long-run" ERPT or PTM coefficient. The ERPT/PTM coefficient for the contemporaneous exchange rate variable is considered "short-run" ERPT/PTM coefficient. This dissertation tried to estimate ERPT/PTM coefficients by changing the lag order sequentially from zero to 12, and this research presents estimated time-varying ERPT/PTM coefficients only for the case of three-lag, six-lag, nine-lag, and 12-lag. The benchmark result of this paper is the case of six lags.

Figure 1-5-A shows the time-varying ERPT/PTM coefficients for transport equipment. When looking at the short-run coefficient (the orange line with cross mark), the graph fluctuates around 0.6–0.7 up to 2008, but after then the graph declines toward zero, suggesting that Japanese exporters increased (decreased) the degree of ERPT (PTM) in the transport equipment industry during the yen appreciation period. In contrast, Figure 1-5-B indicates that Japanese exporters in the electric & electronic product industry have a strong tendency to pursue the PTM behavior, because the graph of the short-run coefficients fluctuate around 0.8 over the sample period. When observing the time-varying coefficients after the sharp depreciation of the yen from the end of 2012, Japanese exporters started to raise the degree of PTM in all industries (Figures 1-5-A through 1-5-D).

Thus, this research has found asymmetric pricing behavior of Japanese exporters. Japanese firms increased the degree of ERPT from around 2008 to 2012. Given severe competition in destination markets, it is generally hard to raise the selling price unless export products are highly differentiated and competitive. In response to the

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[10] Time-varying parameters in figure 1-4 are lag 0 ERPT/PTM coefficients estimated by equation (1) or (3).

unprecedented appreciation of the yen in 2011 and 2012, Japanese exporting firms continue to produce in Japan the differentiated and high-value-added products only, while low-value-added products are shifted in overseas production of their subsidiaries to the limit. After the yen started to depreciate from the end of 2012, however, Japanese export prices did not decline because they are differentiated and competitive with low price elasticities. Instead, Japanese machinery exporters returned to the PTM behavior, enjoying large foreign exchange gains. This means that Japanese exporters have conducted strategic relocation of their production bases and do not lose export competitiveness of products exported from Japan.[11]

4 Panel Analysis of Determinants in ERPT/PTM

4.1 Previous Studies and Data

This section econometrically investigates what determines the ERPT/PTM behavior of Japanese exporters using new determinant variables for export competitiveness. This dissertation uses the time-varying estimates of ERPT/PTM as the dependent variable. As additional explanatory variables, this survey uses the R&D expenditure, foreign sales ratio, number of employees and NEER volatility. The firm-level data on R&D investments is used as a proxy for export competitiveness. Previous studies, such as Tomita (2014), Inekwe (2014), and Lee and Choi (2015), use the R&D investment as an index of export competitiveness or productivity.

To construct proxy variable of the export competitiveness, this paper chooses major companies listed with the Tokyo Stock Exchange from each of 50 sectors, and finally 831 companies are chosen in this study (Appendix Table 1-A2). These companies are chosen by the Japan Market Share Book 2015 edition by the Yano Research Institute. This data book describes main company which produce each commodity. This paper collected firms name following the commodity sector this paper chose and construct three variables, R&D expenditure, foreign sales ratio, and the number of employees. Note that these three variables for each firm are based on consolidated data, because the annual securities

[11] Sato *et al*. (2012, 2013a, 2013b) constructs a new data set of the industry-specific real effective exchange rate (I-REER) for Japan, China and Korea as a measurement of cost competitiveness. It is demonstrated that, since the start of yen depreciation from the end of 2012, Japanese machinery industries have improved their cost competitiveness substantially. The new data of I-REER is available from the website of RIETI (http://www.rieti.go.jp/users/eeri/en/index.html).

report of Japanese firms does not necessarily present the segment-specific data of R&D expenditures and so on.

Some previous studies argued that export competitiveness plays an important role on pricing behavior of Japanese firms. However, it is difficult to construct a competitiveness variable because of data limitation. This dissertation attempts to create a proxy variable and aggregates firm-level data. This point is one of the main contributions in this investigation.

4.2 Fixed Effect Model

This study sets up a panel data set that has 13 years (from 2006 to 2018) and 50 sectors, and uses the fixed effect model:

$$PTM_{i,t} = \beta_{0,t} + \beta_{1,t} \ln RD_{i,t-1} + \beta_{2,t} FSR_{i,t-1} + \beta_{3,t} \ln NOE_{i,t-1} + \beta_{4,t} NEER\ volatility_{i,t-1} + \mu_i + \varepsilon_{i,t} \quad (5)$$

where *t* denotes a time period, and *i* indexes 50 sectors. In equation (5), *PTM* is the PTM elasticity calculated in equation (4), *lnRD* denotes the natural log of R&D expenditure, and *FSR* represents the ratio of foreign sales to the total sales. *lnNOE* denotes the number of employees of each sector as described above. *NEER volatility* denotes volatility of log-differenced commodity specific NEER. Time-invariant μ_i indicates the cross-section effect. In equation (5), this dissertation utilizes not t period explanatory variable, but variable in t-1 period. This is because ERPT/PTM is represented as medium or long effect of exchange rate on export price. In addition, this equation avoids any potential endogeneity problem.

This study divides the whole sample period into two sub-sample periods: the first one is the yen appreciation period (from 2007 to 2012) and the second one is the yen depreciation period (from 2012 to 2015). Yen started to appreciate in the mid-2007, hence this research chooses the period from 2007 to 2012 reflecting the turbulence in the global market. Data in 2012 is used for the second sub-sample period as well to ensure a sufficient number of observations.

4.3 Benchmark Result

The benchmark result with 6 lag short-run PTM of equation (5) is presented in Table 1-1 and column (4)-(6)[12]. The coefficient of the R&D expenditure is positive and significant in the yen appreciation period, which indicates that manufacturing sectors with high R&D expenditure tend to increase the degree of PTM. The estimated coefficient of foreign sales ratio positive, but not statistically significant even at the 10% significance level. The coefficient of the number of employees is positive and significant.

On the other hand, in the yen appreciation period, the R&D expenditure has a positive but not significant coefficient. Meanwhile, the coefficient of foreign sales ratio is significant and negative in the yen appreciation period. If Japanese exporters have a high foreign sales ratio, they tend to increase (decrease) the degree of ERPT (PTM). The coefficient of the number of employees takes a negative, but not significant coefficient in the yen depreciation period.

The variable of number of employees (*NOE*) indicates the size of each commodity. Previous studies suggested that large firms tend to choose PTM behavior. The results in columns (1)-(3) show that the size of commodity decreases the PTM coefficient during the yen appreciation period. This means large firms change export price and avoid large deficit by fluctuation of exchange rate. In contrast, *NOE* has a positive and significant coeffect during the yen depreciation period. This result possibly includes intra-firm trade, but this survey could not empirically prove the effect of intra-firm trade.

In terms of commodity specific NEER volatility, the coefficients in both columns (4)-(6) and (10)-(12) are positive and statistically significant during the yen appreciation period and depreciation. These means that the volatility increases PTM coefficient and change the local price. This implies that Japanese exporters tend to avoid passing through the risk of exchange rate fluctuation and make the import side firms suffer that risk.

Furthermore, both the result of short-run PTM and medium/long-run PTM are shown in Table 1-1. In case of medium/long-run PTM, the significance of R&D expenditure and number of employees disappear. In addition, the coefficient of the foreign sales ratio becomes negative and significant in the full sample period (2006 to 2018). At the same time, positive coefficient of R&D expenditure during the yen appreciation and negative coefficient of foreign sales ration in the yen depreciation period are significant

[12] As a robustness check, this paper shows appendix Table 1-A3.

in both the long-run and medium/long-run.

These results suggest two implications about the pricing behavior of Japanese exporters. Firstly, Japanese exporters with strong export competitiveness tend to the increase PTM coefficient and fix the export price. In fact, it is difficult to stabilize the export price because Japanese exporters suffer large exchange deficit and demand shock because of Lehman Brothers collapse during this yen appreciation period. For this result, Japanese exporters with strong competitiveness could maintain the local price.

Secondly, the foreign sales ratio indicates economic activity of Japanese exporters in foreign countries. Therefore, a negative impact of foreign sales ratio on the PTM coefficient means that exporters with large foreign sales tend to change the local price and try to increase market share during the yen depreciation period.

5 Conclusion

This dissertation has investigated possible effects of export competitiveness on ERPT in Japanese exports. In contrast to the previous studies, this research constructs the explanatory variables for export competitiveness to examine the determinants of ERPT: The R&D variable was constructed using the firm-level R&D expenses. This research estimated the time-varying ERPT by the Kalman filter technique and conducted a panel analysis to test the hypothesized relationship between the ERPT and the export competitiveness variable. Moreover, this research also investigated whether the above hypothesized relationship differs between the yen appreciation and depreciation periods.

The empirical results of this paper obtained from the fixed effect estimation show that export competitiveness has a significant impact on the degree of ERPT/PTM in the yen appreciation period. During the yen appreciation period, the competitive export firms with high R&D expenditure tend to decrease the degree of ERPT. Although it is well known that Japanese exporters tend to conduct PTM behavior, the empirical results of this paper suggest that Japanese exporters change the degree of ERPT/PTM in response to the rapid and large magnitude of exchange rate changes. It is also demonstrated that the export competitiveness determines the choice of ERPT or PTM with different exchange rate movements.

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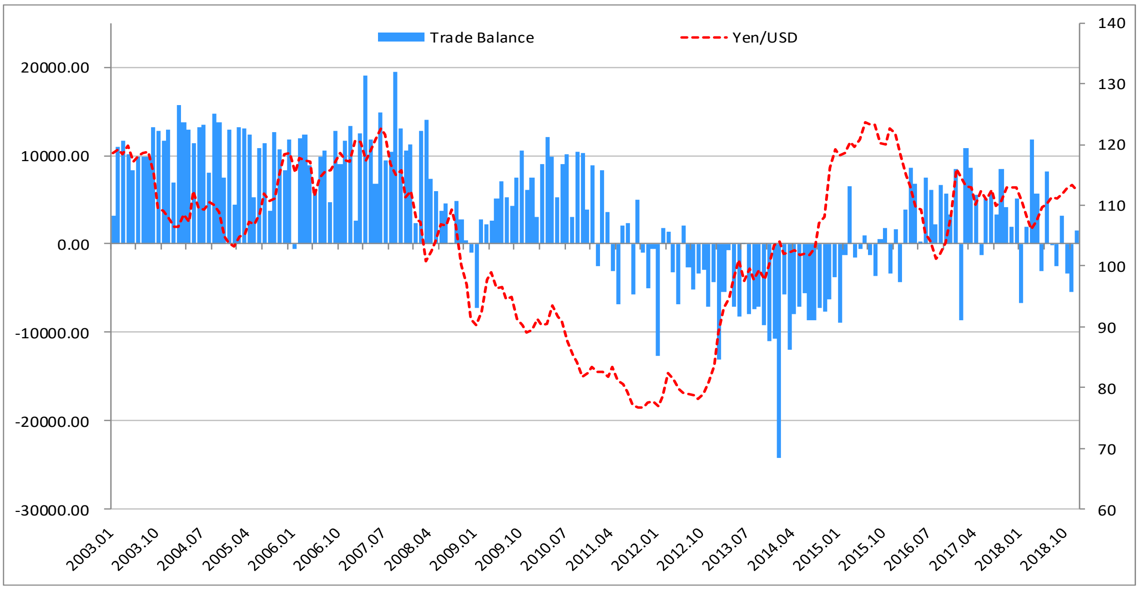
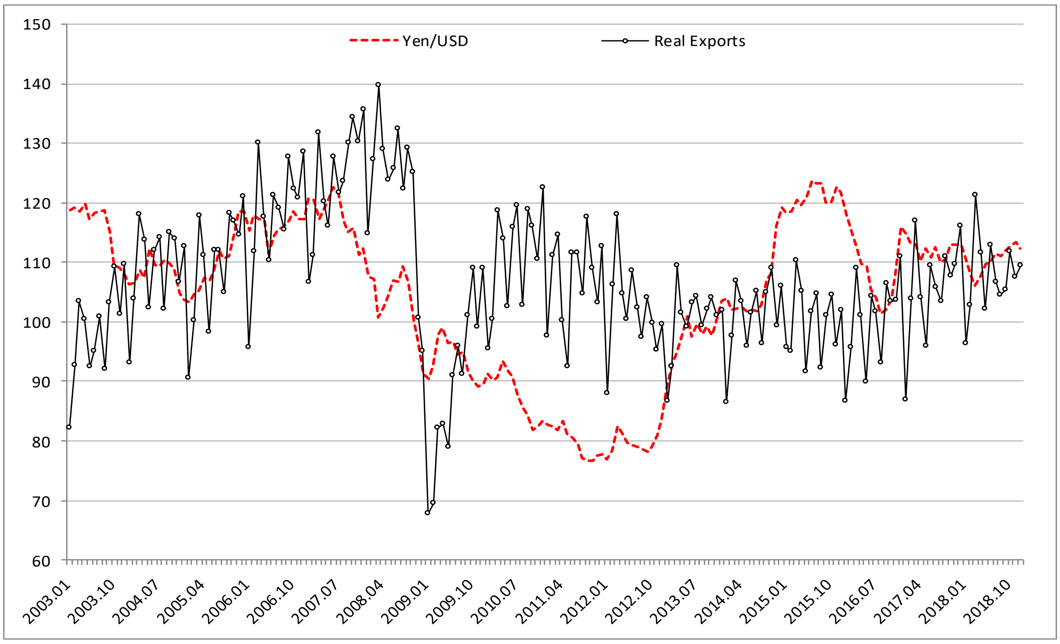
Figure 1-1. Japanese Trade Balance and Nominal Yen/Dollar Exchange Rate



Note: January 2006 through December 2019. "Trade Balance" denotes the balance on goods and services. Left axis: Japanese trade balance (100 million yen). Right axis: Nominal exchange rate of the yen vis-à-vis the U.S. dollar.

Source: CEIC Database; Website of the Ministry of Finance, Japan.

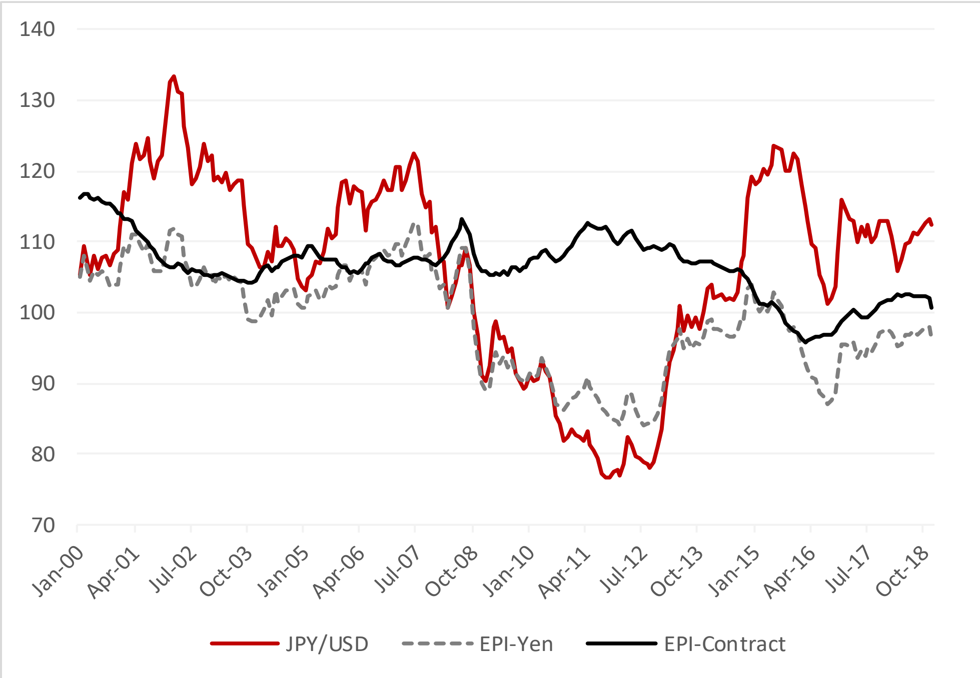
Figure 1-2. Export Quantity and Nominal Yen/Dollar Exchange Rate



Note: January 2003 through June 2019. Real Exports (2015=100) denotes export quantity.

Source: Bank of Japan and website of the Ministry of Finance, Japan.

Figure 1-3. Yen/Dollar Exchange Rate and Export Price Index of Japan (2015=100)

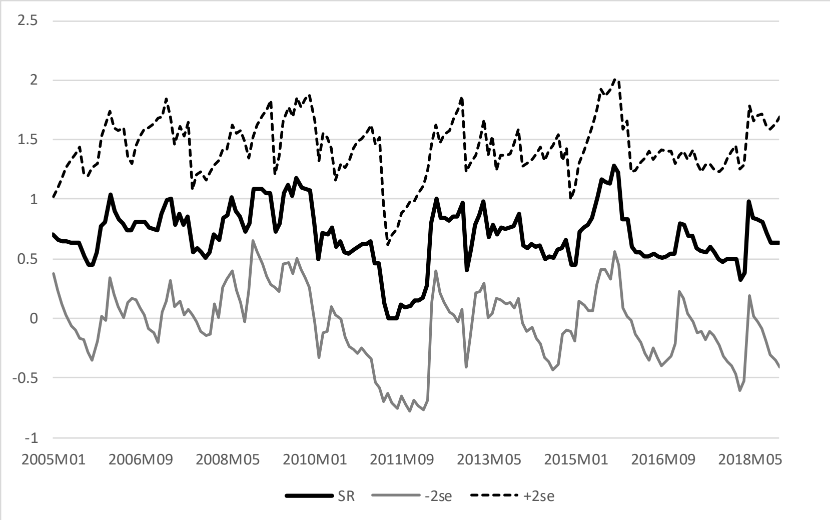


Notes: Monthly series from January 2000 to December 2018. "EPI-Contract" indicates the export price index (all industries) on the contract (invoice) currency basis, "EPI-Yen" indicates the export price (all industries) on the yen basis. These price indices are converted into the ones based on 2015=100. "JPY/USD" denotes the nominal exchange rate of the yen vis-à-vis the U.S. dollar (monthly average).

Source: Bank of Japan; CEIC Database.

Figure 1-4. Time-Varying Exchange Rate Pass-Through for Four sectors

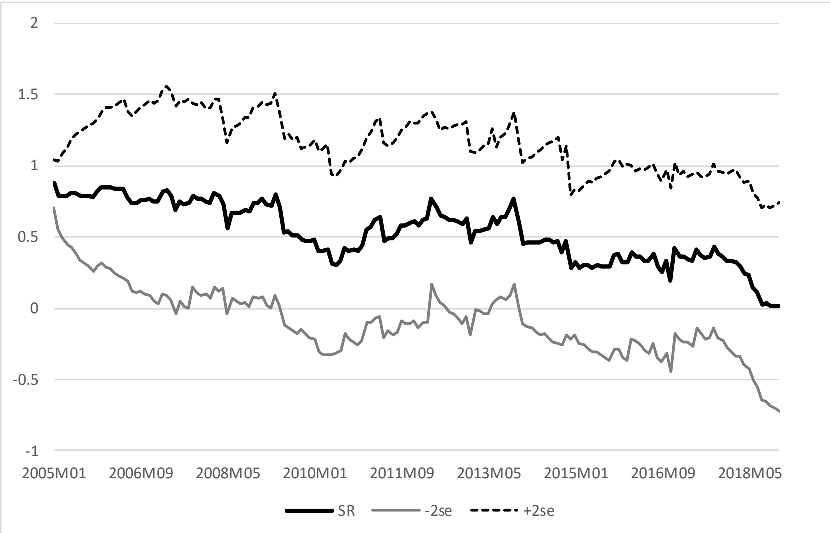
Figure 1-4-A. Passenger Cars



Notes: January 2005 to December 2018. Calculated by equation (4). SR denotes short-run pass-through.

Source: Author`s Calculation

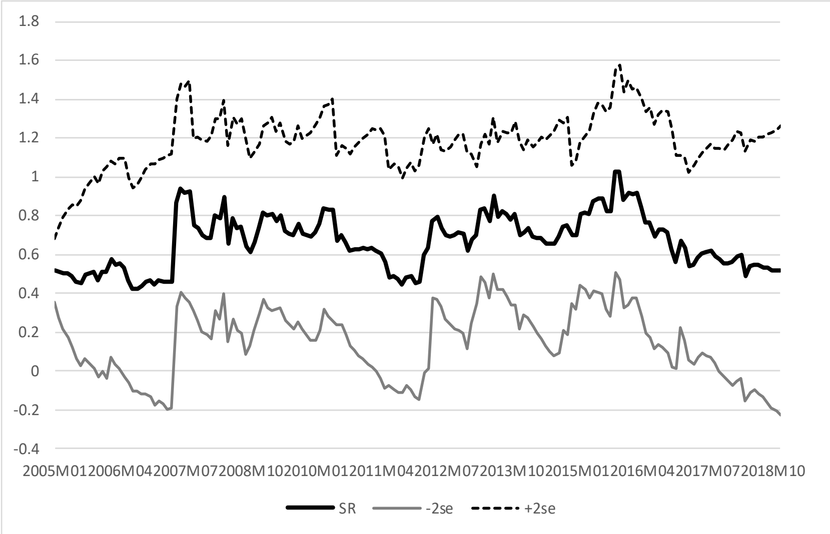
Figure 1-4-B. Integrated circuits



Notes: January 2005 to December 2018. Calculated by equation (4). SR denotes short-run pass-through.

Source: Author`s Calculation *Source*: Author`s Calculation

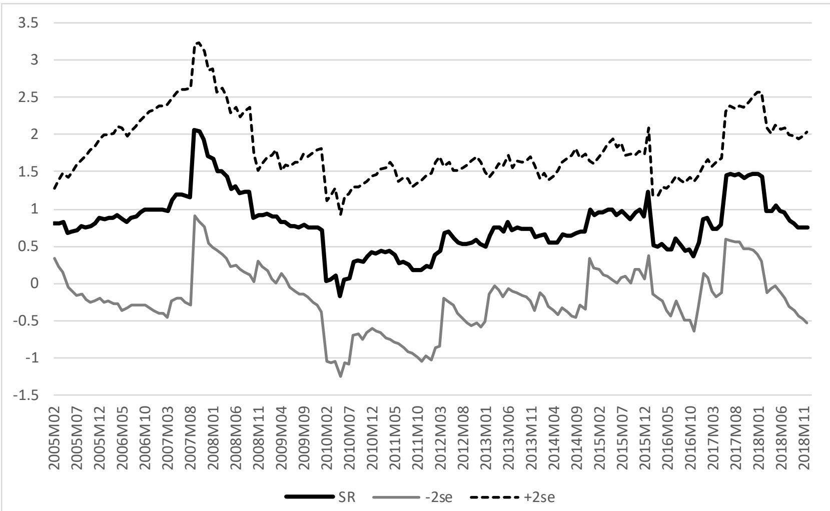
Figure 1-4-C. Engines & Parts



Notes: January 2005 to December 2018. Calculated by equation (4). SR denotes short-run pass-through.

Source: Author`s Calculation

Figure 1-4-D. Other chemical products

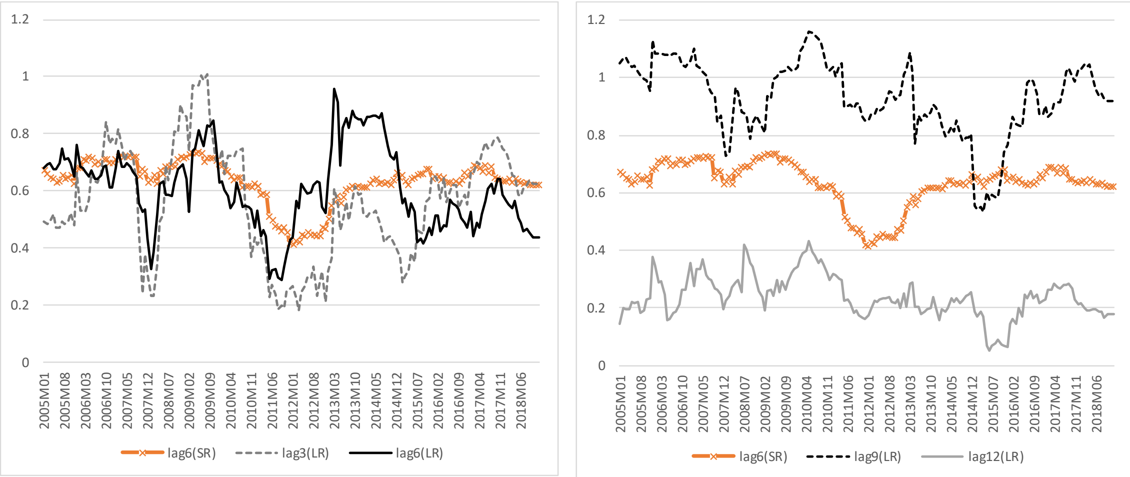


Notes: January 2005 to December 2018. Calculated by equation (4). SR denotes short-run pass-through.

Source: Author`s Calculation

Figure 1-5. Short-run and Medium/Long-run Time-Varying Pass-Through

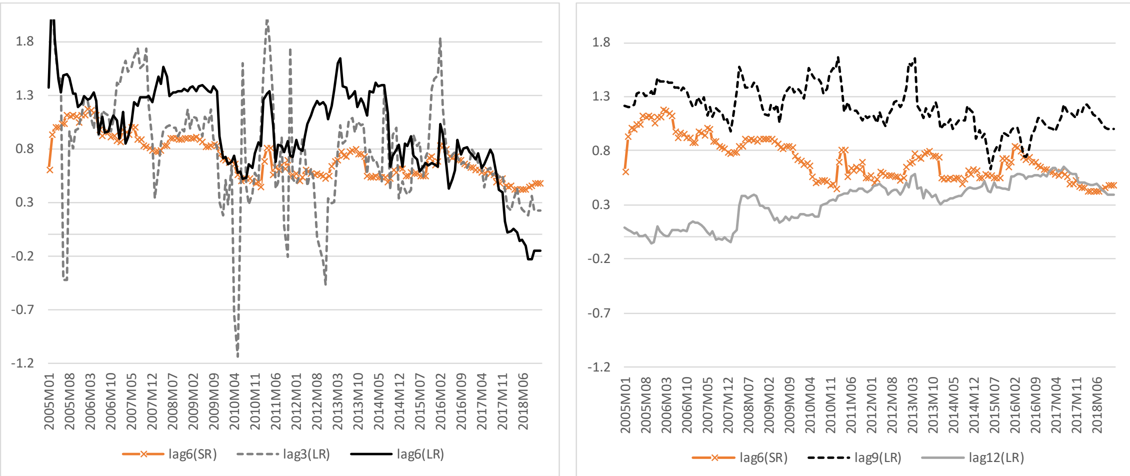
Figure 1-5-A. Transport Equipment



Notes: January 2005 to December 2018. Arithmetic mean of 9 sectors in transport equipment. Calculated by equation (4). SR denotes short-run pass-through, and LR denotes long-run pass-through

Source: Author's estimation.

Figure 1-5-B. Electric & Electronic Products

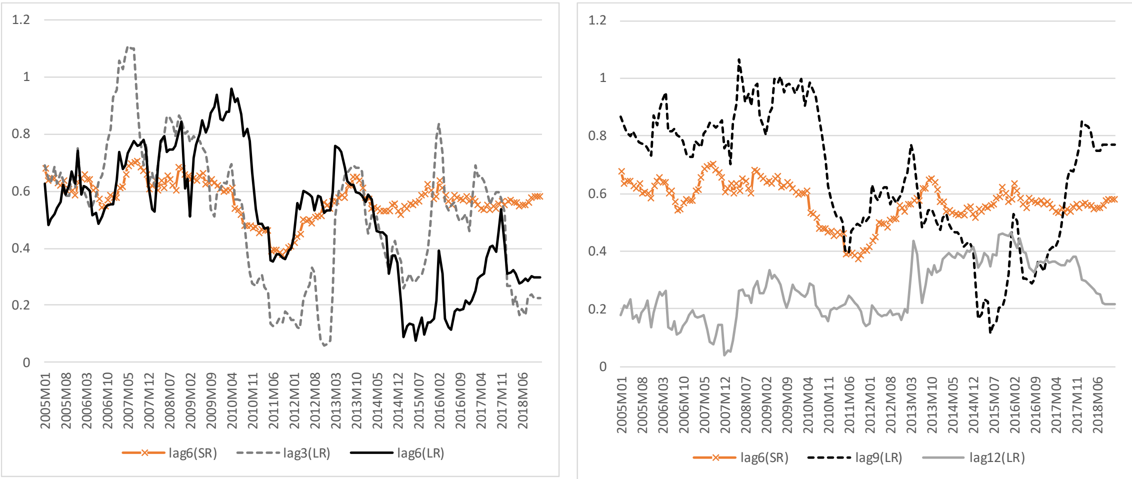


Notes: January 2005 to December 2018. Arithmetic mean of 15 sectors in electric machinery. Calculated by equation (4). SR denotes short-run pass-through, and LR denotes long-run pass-through

Source: Author's estimation.

Figure 1-5. Short-run and Medium/Long-run Time-Varying Pass-Through (cont.)

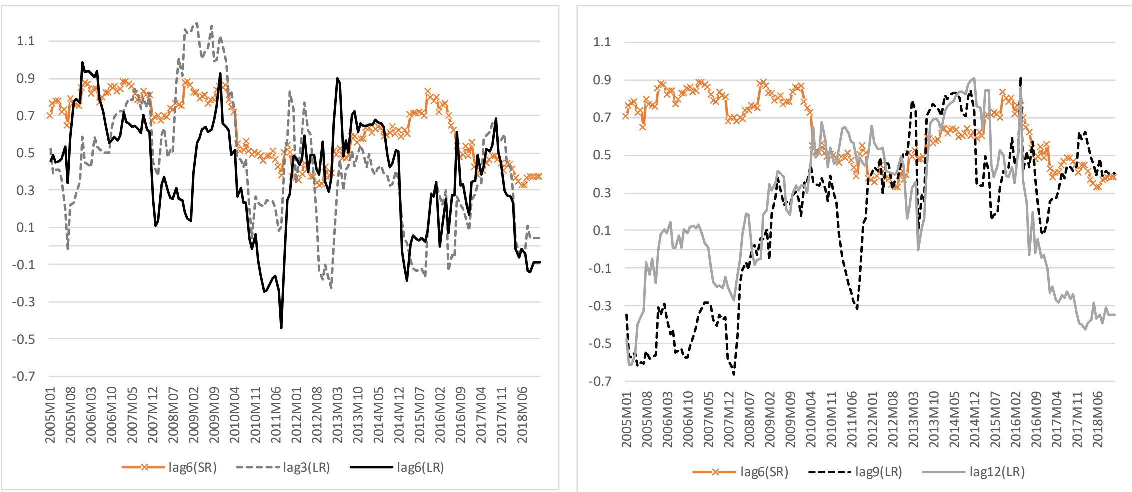
Figure 1-5-C. General Purpose, Production & Business Oriented Machinery



Notes: January 2005 to December 2018. Arithmetic mean of 18 sectors in general machinery. Calculated by equation (4). SR denotes short-run pass-through, and LR denotes long-run pass-through

Source: Authors' estimation.

Figure 1-5-D. Chemicals & Related Products



Notes: January 2005 to December 2018. Arithmetic mean of 8 sectors in chemical products. Calculated by equation (4). SR denotes short-run pass-through, and LR denotes long-run pass-through

Source: Authors' estimation.

Table 1-1. Panel Estimation

Dependent variable: PTM elasticity

Model: Fixed Effect

	(1)	(2)	(3)	(4)	(5)	(6)
Term	Short					
Lag	6					
Period	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015
Const.	3.283	14.228 *	-14.731 *	3.256	14.265 *	-14.614 *
	(2.694)	(5.408)	(6.377)	(2.700)	(5.385)	(6.334)
R&D Expenditure	0.489 *	0.455 **	-0.045	0.490 *	0.393 *	-0.089
	(0.186)	(0.172)	(0.374)	(0.186)	(0.173)	(0.367)
Foreign Sales Ratio	-0.474	0.003	0.307	-0.477	-0.061	-0.228 *
	(0.340)	(0.289)	(0.636)	(0.337)	(0.828)	(0.668)
Number of Employees	-0.736 *	-1.745 **	1.456 *	-0.735 *	-1.689 **	1.503 *
	(0.331)	(0.499)	(0.697)	(0.332)	(0.499)	(0.665)
NEER Volatility				1.397	8.404 **	13.215 **
				(2.482)	(1.826)	(4.478)
NOB	650	300	200	650	300	200
F-Test	2.44 #	5.53 **	4.20 **	2.14 #	12.64 **	6.65 **

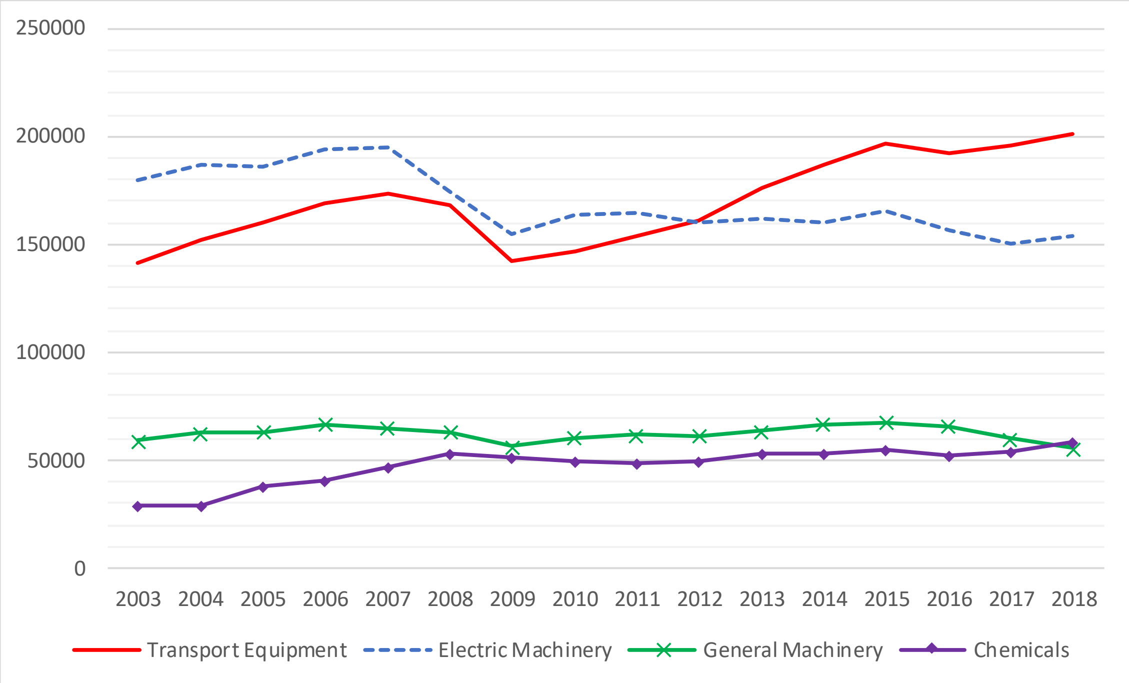
	(7)	(8)	(9)	(10)	(11)	(12)
Term	Medium/Long					
Lag	6					
Period	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015
Const.	6.425	8.708	-1.360	6.233	8.768	19.099 #
	(2.694)	(7.929)	(2.694)	(4.911)	(7.330)	(11.430)
R&D Expenditure	0.121	1.025 *	-0.646	0.124	0.924 #	-0.727
	(2.694)	(0.458)	(2.694)	(0.377)	(0.573)	(0.728)
Foreign Sales Ratio	-1.692 *	-0.263	-2.636 *	-1.713 *	-0.366	-3.642 *
	(2.694)	(0.609)	(2.694)	(0.780)	(1.397)	(1.173)
Number of Employees	-0.582	-1.806 *	-0.883	-0.578	-1.718 *	-0.794
	(2.694)	(0.753)	(2.694)	(0.363)	(2.694)	(2.694)
NEER Volatility				10.207 *	13.424 **	24.812 #
				(4.256)	(5.864)	(14.779)
NOB	650	300	200	650	300	200
F-Test	3.67 *	2.90 *	4.97 **	6.67 **	4.38 **	5.32 **

Notes: This result is calculated by regression formula (4). The number in parentheses denotes standard error. **, * and # denote the 1 percent, 5 percent and 10 percent significance level, respectively. "Foreign Sales Ratio" is equal Foreign Sales divided by Total Sales. Standard errors are robust. Number in parentheses denotes standard error.

Source: Author's Calculation

Appendix Figure 1-A1. R&D Expenditures

Period: 2003 to 2018

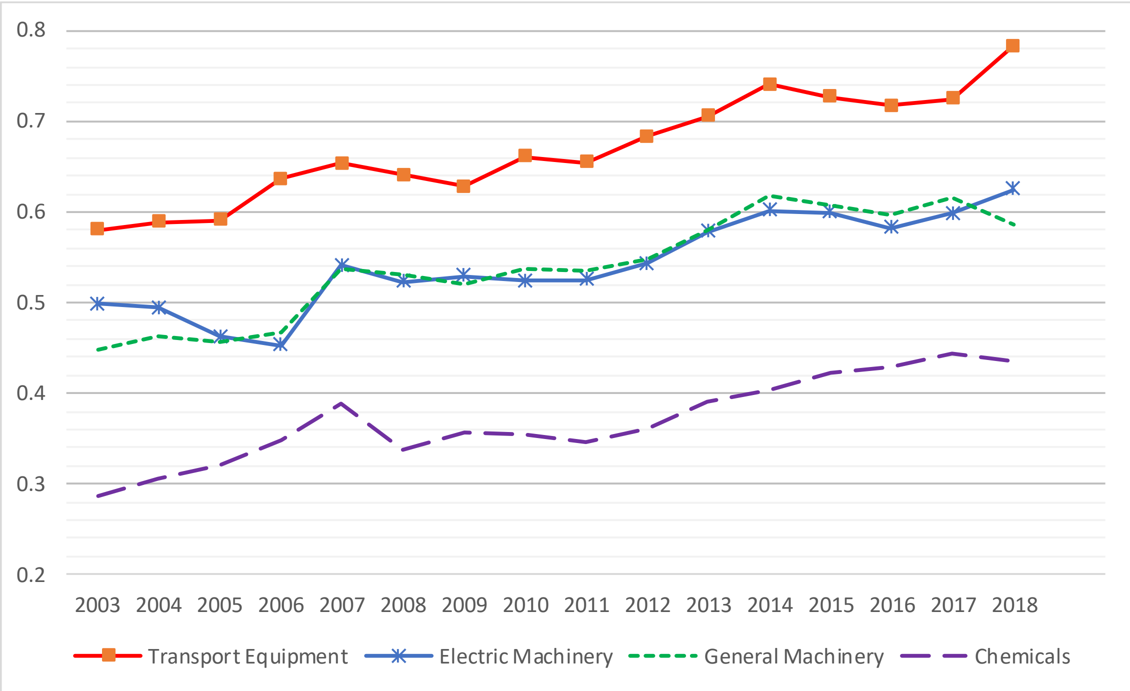


Notes: "Transport Equipment" denotes "Transportation Equipment". "General Machinery" denotes "General Purpose, Production & Business Oriented Machinery". "Chemicals" denotes "Chemicals & related products."

Source: Author's Calculation

Appendix Figure 1-2. Foreign Sales Ratio

Period: 2003 to 2018

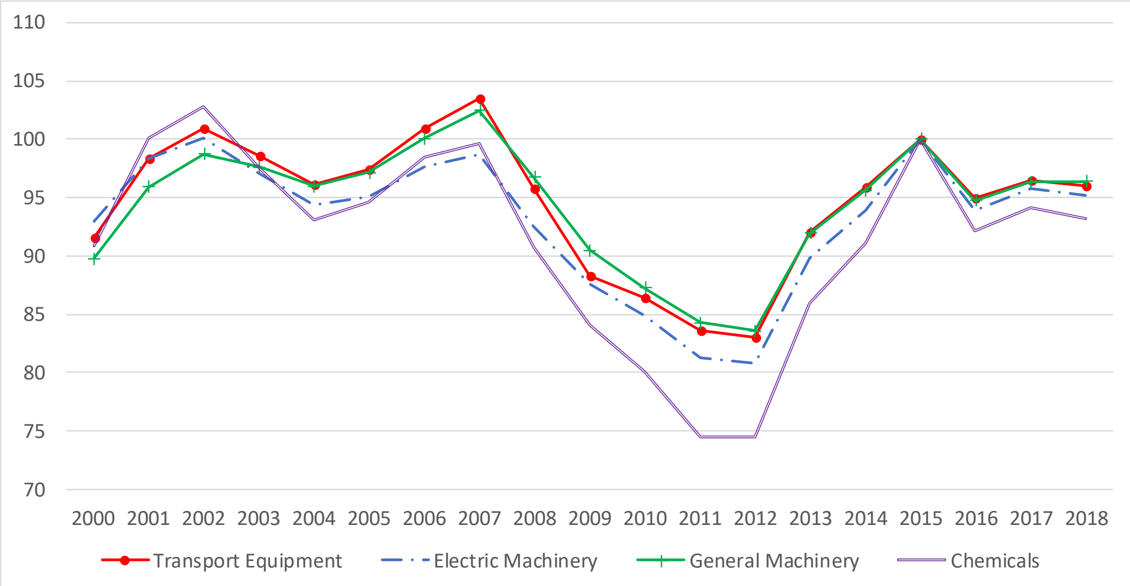


Notes: "Electric Machinery" denotes "Electric & Electronic Products". "Transport Equipment" denotes "Transportation Equipment". "General Machinery" denotes "General Purpose, Production & Business Oriented Machinery." "Chemicals" denotes "Chemicals & related products."

Source: Trade Statistics of Japan (Ministry of Finance)

Appendix Figure 1-A3. Industry-specific Nominal Effective Exchange Rate

Period: 2000 to 2018



Notes: "Electric Machinery" denotes "Electric & Electronic Products". "Transport Equipment" denotes "Transportation Equipment". "General Machinery" denotes "General Purpose, Production & Business Oriented Machinery." Arithmetic mean of sector specific NEER which this paper use in equation (1) and (3).

Source: Author's calculation

Appendix Table 1-A1. Selected Commodity Classes or Subgroups

Table 1-A1-A. Transportation Equipment and Electric & electronic products

Group	Transportation Equipment (285.2)								
Subgroup	Motor vehicles					Other transportation equipment			
Commodity Class	Passenger cars	Buses	Trucks	Motorcycles	Motor vehicle parts	Vessels & parts	Aircraft parts	Industrial trucks & parts	Bicycle parts
Weight	143	5.4	15	4	72.6	27.2	14.1	2.1	1.8

Group	Electric & electronic products (205.5)						
Subgroup	Electronic components & devices						
Commodity Class	Photoelectric converter devices	Semiconductor devices	Integrated circuits	Display devices	Passive components	Connecting components	Other electronic components
Weight	5.8	4.4	45.9	11.4	17.2	14.5	16.6

Group	Electric & electronic products (205.5)							
Subgroup	Electrical machinery & equipment							
Commodity Class	Heavy electrical apparatus	Electric bulbs and lighting & wiring devices	Electronic equipment	Electrical meters & measuring instruments	Other electrical machinery & equipment	Communications equipment	Audio & visual equipment	Electronic computers & computer equipment
Weight	17.9	4.5	8.6	16.1	20.3	6.8	8.6	6.9

Appendix Table 1-A1. Selected Commodity Classes or Subgroups (cont.)

Table 1-A1-B. General purpose, production & business-oriented machinery and Chemicals

Group	General purpose, production & business oriented machinery (189.4)							
Subgroup	General purpose machinery					Business oriented machinery		
Commodity Class	Engines	Pumps & compressors	Power transmission equipment & bearings	Refrigerating appliances	Other general purpose machinery	Instruments & appliances for measuring, checking & testing	Medical appliances	Optical instruments & lenses
Weight	10.7	16	16.9	3.2	5.9	11.3	8.9	6.8

Group	General purpose, production & business oriented machinery (189.4)							
Subgroup	Production machinery							
Commodity Class	Agricultural machinery	Machinery & equipment for construction and mining	Textile machinery	Dairy lives industry machinery	Semiconductor and flat panel & display manufacturing equipment	Basic material industry machinery	Metal cutting machine tools	Metal forming machinery
Weight	4.4	20.8	5.1	6.4	33.4	5.3	19.2	5.1
Commodity Class	Tools for machines and pneumatic & electric tools	Robots						
Weight	6.6	3.4						

Group	Chemicals & related products (98.4)							
Subgroup	Industrial inorganic chemicals	Industrial organic chemicals					Pharmaceutical products	Other chemical products
Commodity Class	Industrial inorganic chemicals	Basic petrochemicals	Aliphatic intermediates	Cyclic intermediates	Plastic resins & materials	Other industrial organic chemicals	Pharmaceutical products	Other chemical products
Weight	9.4	9.5	6.4	19.1	22.6	5.5	7.4	18.5

Notes: These groups are taken by Export Price Index from Bank of Japan. These are selected from subgroups of EPI, "Transportation Equipment," "Electric & Electronic Products" and "General Purpose, Production & Business Oriented Machinery" "Chemicals & related products".

Japanese EPI has 7 Group, 38 Subgroup and 64 Commodity Class. In this survey, this survey utilizes all 50 Commodity Class in 4 Group.

The number in weight shows total weight of each group, when weight 1000 means value of all Japanese export.

Source: Bank of Japan

Appendix Table 1-A2. Survey Companies in Panel Analysis

Table 1-A2-A. Transportation Equipment and Electric & electronic products.

Commodity Name	Firm Name
Transport Equipment	
Passenger cars	Toyota Motor,Honda Motor,Suzuki,Daihatsu Motor,Nissan Motor,MAZDA Motor,SUBARU,Mitsubishi Motors
Buses	Toyota Motor,Hino Motors,Mitsubishi Fuso Truck and Bus ,Isuzu Motors,Nissan Motor
Trucks	Toyota Motor,Suzuki,Daihatsu Motor,Nissan Motor,Isuzu Motors,Hino Motors,Mitsubishi Fuso Truck and Bus ,MAZDA Motor,Honda Motor,SUBARU,Mitsubishi Motors,UD Trucks
Motorcycles	Yamaha Motor,Honda Motor,Kawasaki Heavy Industries,Suzuki
Motor vehicle parts	Honda Motor,Kawasaki Heavy Industries,SUBARU,Mitsubishi Heavy Industries,Kubota,Yamaha Motor,Toyota Industries,Isuzu Motors,Komatsu,UD Trucks,DENSO,Calsonic Kansei,Sanden,Kehin,DAIKIN INDUSTRIES
Vessels & parts	Mitsui E&S,Namura Shipbuilding,Kawasaki Heavy Industries,Sanoyas,SUMITOMO HEAVY INDUSTRIES,Naikai Zosen
Aircraft parts	Kawasaki Heavy Industries,ShinMaywa Industries,SUBARU,Honda Motor,Mitsubishi Heavy Industries,IHI,NEC,KYB,SHIMADZU,SINFONIA TECHNOLOGY,Sumitomo Precision Products,Nabtesco,Mitsubishi Materials,MinebeaMisumi,Yokogawa Electric,Ube Industries,TORAY,Hitachi Metals,Mitsubishi Chemical
Industrial trucks & parts	Toyota Industries,Nichiyu Mitsubishi Forklift,Komatsu,SUMITOMO HEAVY INDUSTRIES,SINFONIA TECHNOLOGY,Mitsubishi Heavy Industries,Nissan Motor
Bicycle parts	MORITA HOLDINGS,Panasonic,Bridgestone

Commodity Name	Firm Name
Electric & Electronic Equipment	
Photoelectric converter devices	Stanley Electric,CCS,ROHM SEMICONDUCTOR,Sanken Electric,Panasonic,TOYODA GOSEI,Daido Steel
Semiconductor devices	Toshiba,ROHM SEMICONDUCTOR,Sanken Electric,Mitsubishi Electric,Panasonic,Shindengen Electric Manufacturing
Integrated circuits	Toshiba,Sony,Renesas Electronics,Fujitsu Semiconductor,ROHM SEMICONDUCTOR,Panasonic
Display devices	Japan Display,Sharp,Panasonic Liquid Crystal Display
Passive components	KOA,Panasonic,HOKURIKU ELECTRIC INDUSTRY,TEIKOKU TSUSHIN KOGYO,ROHM SEMICONDUCTOR,KOA,ALPS ELECTRIC,TOKYO COSMOS ELECTRIC,Nissin Electric,SHIZUKI ELECTRIC,Nichicon,Denso Yamagata,Hitachi Industrial Equipment Systems ,Mitsubishi Electric,Toshiba,Daihen,Fuji Electric,Meidensha,Takaoka Electric Mfg.,AICHI ELECTRIC
Connecting components	Japan Aviation Electronics Industry,HIROSE ELECTRIC,DDK
Other electronic components	Sony,Mitsubishi Electric,TAIYO YUDEN,Kyosha,DENSO,NITTO KOGYO,IBIDEN,Denka,Futaba,Dai Nippon Printing,Shirai Electronics,TORAY,Shin-Etsu Chemical,SUMCO
Heavy electrical apparatus	TMEIC,Hitachi,Honda Motor,Fuji Electric,Denyo,SAWAFUJI ELECTRIC,SANYO DENKI,NISHISHIBA ELECTRIC,Meidensha,TOYO DENKI SEIZO,Panasonic,YASKAWA Electric,Hitachi Industrial Equipment Systems ,Toshiba,Mitsubishi Electric,Origin Electric,Sanken Electric
Electric bulbs and lighting & wiring devices	Panasonic,TOSHIBA Lighting & Technology,Odelic,Mitsubishi Electric Lighting,IWASAKI ELECTRIC
Electronic equipment	Canon Medical Systems,GE Healthcare Japan,Hitachi
Electrical meters & measuring instruments	Aichi Tokei Denki,Azbil Kimmon,Osaka Electric,Mitsubishi Electric,Toshiba Toko Meter Systems,Fuji Electric Meter,Fukuda Denshi,NIHON KOHDEN,Suzuken,FUKUDA M-E KOGYO,OMRON COLIN,GE Healthcare Japan,Asahi Kasei Zoll Medical
Other electrical machinery & equipment	Mitsubishi Heavy Industries,Subaru,Honda Motor,Mitsubishi Electric,NGK SPARK PLUG,DENSO,Panasonic,KYOCERA,NEC,OMRON,Sharp,Toshiba,Sony,Nichicon,Maxell,Fujitsu,Showa Shell Sekiyu
Communications equipment	Pioneer,Panasonic,Clarion,DENSO,JVC KENWOOD,Alpine Electronics
Audio & visual equipment	JVC KENWOOD,Sony,Toshiba,Pioneer,Panasonic,Mitsubishi Electric,IKEGAMI TSUSHINKI,EIZO
Electronic computers & computer equipment	Toshiba,NEC,Fujitsu,Seiko Epson,Panasonic,MITSUMI ELECTRIC,Hitachi,Toshiba,SUBARU,RISO KAGAKU,RYOBI

Appendix Table 1-A2. Survey Companies in Panel Analysis (cont.)

Table 1-A2-B. General purpose, production & business-oriented machinery

Commodity Name	Firm Name
General Mahinary	
Engines	Honda Motor,Kawasaki Heavy Industries,SUBARU,Mitsubishi Heavy Industries,Kubota,Yamaha Motor,Toyota Industries,Isuzu Motors,Komatsu,UD Trucks,Babcock-Hitach,IHI,Hitachi,Toshiba,Fuji Electric
Pumps & compressors	Ebara,Hitachi Industrial Equipment Systems ,Mitsubishi Heavy Industries,Kubota,TORISHIMA PUMP MFG.,DMW,NIKKISO,Shin Nippon Machinery,TSURUMI MANUFACTURING,ShinMaywa Industries
Power transmission equipment & bearings	NSK,JTEKT,NTT,NACHI-FUJIKOSHI,MinebeaMisumi
Refrigerating appliances	Mitsubishi Electric,Mitsubishi Heavy Industries,Hitachi Building Systems,TOSHIBA Carrier,DAIKIN INDUSTRIES,Panasonic,FUJITSU GENERAL,Sharp,CORONA
Other general purpose machinery	KYB,TOKYO KEIKI,DAIKIN INDUSTRIES,TOYOOKI KOGYO,YUKEN KOGYO,NACHI-FUJIKOSHI,Nabtesco,Kuroda Precision Industries,KYOKUTO KAIHATSU KOGYO
Agricultural machinery	Kubota,ISEKI,Mitsubishi Mahindra Agricultural Machinery,Honda Motor,IHI,MARUYAMA MFG.,Yamabiko,Yamabiko
Machinery & equipment for construction and mining	Komatsu,Hitachi Construction Machinery,KOBELCO CONSTRUCTION MACHINERY ,Kubota,KATO WORKS,IHI Construction Machinery,Nippon Sharyo,SHINKO ENGINEERING,HOKUETSU INDUSTRIES,Sumitomo Construction Machinery,Takeuchi Mfg,Mitsubishi Heavy Industries,Sumitomo Heavy Industries Material Handling Systems,Mitsui E&S,IHI Transport Machinery,Hitachi Plant Technologies,TADANO,Kobelco Cranes,Sumitomo Heavy Industries Construction Cranes,AICHI,SAKAI HEAVY INDUSTRIES,Kawasaki Heavy Industries,Hitachi Construction Machinery Camino
Textile machinery	JUKI,BROTHER INDUSTRIES,JANOME SEWING MACHINE,PEGASUS SEWING MACHINE MFG. ,AISIN SEIKI,Mitsubishi Electric,TMT Machinery,Ishikawa Seisakusho,Toyota Industries,Tsudakoma,Takatori,KAJI TECHNOLOGY,SHIMA SEIKI MFG.,HISAKA WORKS,HIRANO TECSEED
Dairy lives industry machinery	Mitsubishi Heavy Industries Machinery Systems,KOMORI,TOSHIBA MACHINE,RYOBI,Tokyo Kikai Seisaksho,IHI Machinery and Furnace,Shibuya Kogyo,Mitsubishi Heavy Industries,CKD,TOYO FOOD EQUIPMENT,Hitachi Zosen
Semiconductor and flat panel & display manufacturing equipment	TOKYO SEIMITSU,Hitachi High-Technologies,SINFONIA TECHNOLOGY,Advantest,SCREEN,A&D Company,Hitachi High-Tech Science,Shibuya Kogyo,Tokyo Electron,RORZE,Hitachi Kokusai Electric,Daitron,ULVAC,Showa Shinku,Canon,Nikon,TORAY,OMRON,TOHO Chemical Industry,Sumitomo Precision Products,Hirata,DISCO,Y.A.C
Basic material industry machinery	SUMITOMO HEAVY INDUSTRIES,FANUC,NISSEI PLASTIC INDUSTRIAL,THE JAPAN STEEL WORKS,Mitsubishi Heavy Industries,TOSHIBA MACHINE,TOYO MACHINERY & METAL,MEIKI,THE JAPAN STEEL WORKS,TOSHIBA MACHINE,SUMITOMO HEAVY INDUSTRIES,Kobe Steel
Metal cutting machine tools	DMG MORI,Okuma,CITIZEN MACHINERY,JTEKT,Mitsubishi Heavy Industries,Tsugami,Komatsu NTC,Okamoto Machine Tool Works,Okamoto Machine Tool Works,Koyo Machine Industries,NACHI-FUJIKOSHI,Kuroda Precision Industries,FANUC,Makino Milling Machine,OKK
Metal forming machinery	AMADA,Kobe Steel,Kawasaki Hydromechanics,Kojima Iron Works,Komatsu,AIDA ENGINEERING,IHI,Kurimoto,NIDEC-SHIMPO,Sumitomo Heavy Industries Techno-Fort,Ube Industries,SINTOKOGIO,TOSHIBA MACHINE,TOYO MACHINERY & METAL,Mitsubishi Materials Techno,Fuji Electric
Tools for machines and pneumatic & electric tools	NACHI-FUJIKOSHI,Mitsubishi Heavy Industries,Mitsubishi Materials,OSG,Mitsubishi Hitachi Tool Engineering,DAI-ICHI SEIKO,Sumitomo Electric Hardmetal,Tungaloy,KYOCERA,Asahi Diamond Industrial,A.L.M.T.,Noritake Company,LOBTEX,TOKU PNEUMATIC TOOL MFG.,Koki,Yamada,Makita,RYOBI
Robots	YASKAWA Electric,Panasonic Smart Factory Solutions,Kawasaki Heavy Industries,FANUC,NACHI-FUJIKOSHI,Yamaha Motor,JTEKT,IHI,JANOME SEWING MACHINE,OMRON,FUJI,TOSHIBA MACHINE,JUKI,Kobe Steel,ShinMaywa Industries,Komatsu,DENSO WAVE,Mitsubishi Electric,Daihen
Instruments & appliances for measuring	TOKYO SEIMITSU,ANRITSU,NIDEC TOSOK,Olympus,Nikon,SHIMADZU,Hitachi High-Technologies,JEOL,Yokogawa Electric,Toshiba,HORIBA,DKK-TOA
Medical appliances	GE Healthcare Japan
Optical instruments & lenses	Olympus,Nikon,Scala,SHIMADZU,Sony,TAMRON,HOYA,Nikon,TOPCON,Olympus,Canon,KONICA MINOLTA,KYOCERA,Panasonic

Appendix Table 1-A2. Survey Companies in Panel Analysis (cont.)

Table 1-A2-C. Chemicals

Commodity Name	Firm Name
Chemical	
Industrial inorganic chemicals	AGC,Asahi Kasei,Denka,HOKKAIDO SODA,Ishihara Sangyo Kaisha,KANEKA,Kanto Denka Kogyo,Kureha,Nippon Light Metal,Nippon Soda,Osaka Soda,Shin-Etsu Chemical,Showa Denko,Showa Chemical Industry,SUMITOMO CHEMICAL,Toagosei,Tokuyama,TOSOH
Basic petrochemicals	Mitsui Chemicals,Osaka Oil Chemical,SUMITOMO CHEMICAL,Mitsubishi Chemical,Nippon Petrochemicals,Tonen Chemical,TOSOH,Maruzen Petrochemical,KEIYO POLYETHYLENE,Asahi Kasei,Idemitsu Kosan,Showa Denko,TonenGeneral Sekiyu,KYOKUTO PETROLEUM INDUSTRES,JXTG Nippon Oil & Energy,Nippon Petroleum Refining,KAC,Japan Energy,Cosmo Matsuyama Oil,Mitsui Chemicals,TOA Oil,SHOWA YOKKAICHI SEKIYU,Seibu Oil,Fuji Oil,NIPPON STEEL Chemical,NA aromatic,JFE Chemical,NIPPON STEEL Chemical & Material,KH Neochem,KASHIMA OIL,CM aroma,Showa Shell Sekiyu
Aliphatic intermediates	Keiyo Monomer,KANEKA,SUN ARROW,TOSOH,V-Tech,MITSUBISHI RAYON,Asahi Kasei,SUMITOMO CHEMICAL,Mitsui Chemicals,KURARAY,MITSUBISHI GAS CHEMICAL
Cyclic intermediates	Asahi Kasei,Mitsubishi Chemical,SUMITOMO CHEMICAL,Denka,NIPPON STEEL Chemical,Idemitsu Kosan,Nippon Polyurethane Industry,Mitsui Chemicals,Mitsui Chemicals,Ube Industries,TORAY,JXTG Nippon Oil & Energy,Japan Energy,Nippon Petroleum Refining,NIPPON OIL,KAC,KASHIMA OIL,Teijin,TonenGeneral Sekiyu
Plastic resins & materials	TORAY,Teijin,NIPPON-ESTER,UNITIKA TRADING,TOYOBO,KURARAY,MITSUBISHI RAYON,Kanebo Seren,Asahi Kasei,Daiwabo Polytec,SUMITOMO CHEMICAL,Mitsubishi Chemical,Mitsubishi Chemical,Mitsui Chemicals,NUC,Ube Industries,TOSOH,TOSOH,Japan polyethylene,Prime Polymer,Evolue Japan,Mitsui Chemicals,Asahi Kasei Chemicals,Maruzen Polymer,UMG ABS,Techno Polymer,NIPPON A&L,Denka,SunAllomer,Tokuyama,KANEKA,Shin Dai-ichi Vinyl,AGC,Nissan Chemical,Mitsui Chemicals,Mitsubishi Chemical MKV,The Nippon Synthetic Chemical Industry ,Shin-Etsu Chemical,Unitika,MITSUBISHI GAS CHEMICAL,DAIKIN INDUSTRIES,Chemours-Mitsui Fluoroproducts,Kureha,Asahi Kasei Epoxy,NIPPON STEEL Epoxy Manufacturing ,DIC,Nippon Kayaku,NIPPON EPOXY RESIN MANUFACTURING,Teijin Chemicals,Idemitsu Kosan,Sumika Polycarbonate,NIPPON SHOKUBAI,San-Dia Polymers,Sumitomo Seika Chemicals,Kao,JAPAN VAM & POVAL,Shin-Etsu Chemical
Other industrial organic chemicals	JSR,Zeon,SUMITOMO CHEMICAL,Nippon Elastomer,Mitsubishi Chemical,Asahi Kasei,Ube Industries,JSR,Denka,Showa Denko,TOSOH,Mitsui Chemicals
Pharmaceutical products	Takeda Pharmaceutical,Astellas Pharma,Daiichi Sankyo,CHUGAI PHARMACEUTICAL,Mitsubishi Tanabe Pharma,Otsuka Pharmaceutical,Eisai,Kyowa Hakko Kirin Company,Sumitomo Dainippon Pharma,SHIONOGI
Other chemical products	Lion,Kao,Shiseido,Kanebo Cosmetics,KOSE,POLA ORBIS,FANCL,SUMITOMO CHEMICAL,Nippon Soda,Nihon Nohyaku,Ishihara Sangyo Kaisha,Mitsui Chemicals Agro,Kumiai Chemical Industry,Nissan Chemical,SDS Biotech,OAT Agrio,Hokko Chemical Industry

Notes: There are main companies in several segment sales from “the Company’s Securities Report.” This dissertation selected these firms by the Japan Market Share Book 2015 edition by the Yano Research Institute. This share is possibly different from actual shares of each commodity because “Segment Sales” are not under restriction and that often include other commodities.

Appendix Table 1-A3. Robustness Check with Different PTM Elasticity

Dependent variable: PTM elasticity

	Short-run			Medium/Long-run		
	(1)	(2)	(3)	(4)	(5)	(6)
lag		0			0	
Period	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015
R&D Expenditure	0.174	0.287	-0.142	—	—	—
s.e.	(0.284)	(0.237)	(0.322)	—	—	—
lag		3			3	
Period	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015
R&D Expenditure	0.624 **	0.495 *	-0.339	1.098 **	1.272 **	-0.640
s.e.	(0.180)	(0.228)	(0.368)	(0.285)	(0.398)	(0.605)
lag		6			6	
Period	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015
R&D Expenditure	0.489 *	0.455 *	-0.045	0.121	1.025 *	-0.646
s.e.	(0.186)	(0.172)	(0.374)	(0.378)	(0.458)	(0.712)
lag		9			9	
Period	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015
R&D Expenditure	0.334 *	0.248 *	0.090	-0.028	0.183	-0.002
s.e.	(0.147)	(0.112)	(0.332)	(0.396)	(0.417)	(0.792)
lag		12			12	
Period	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015
R&D Expenditure	0.108	0.257 #	0.008	-0.219	-0.111	-0.447
s.e.	(0.104)	(0.144)	(0.161)	(0.338)	(0.485)	(0.586)

The number in parentheses denotes standard error.

**, *, and # denote the 1 percent, 5 percent and 10 percent significance level, respectively.

Source: Author's calculation

CHAPTER 2:

Invoicing Currency Choice and Export Competitiveness: New Evidence from Japanese Export Firms

1. Introduction

Japanese economy has witnessed very large and rapid changes of the nominal exchange of the yen vis-à-vis the U.S. dollar, and the exchange risk management is strategically important for Japanese firms. Figure 2-1 shows that the yen appreciated substantially from 122.6 in June 2007 to 76.8 in October 2011. The yen kept fluctuating at around 80 until the late 2012, but thanks to "Abenomics", the Prime Minister Abe's economic stimulus package, the yen started to depreciate rapidly from the end of 2012 and reached 101.0 in May 2013. In late 2014, Mr. Kuroda, the Governor of the Bank of Japan (BOJ), conducted massive expansionary monetary policy, and the yen depreciated to 123.2 in July 2015.

As discussed in Ito *et al*. (2018), Japanese export firms use several hedging instruments including forward hedging, marry and netting, and invoicing currency choice. The choice of invoicing currency is particularly important in considering the firms' exchange risk management. As will be shown in this dissertation, the share of U.S. dollar invoicing is higher than that of yen invoicing in Japanese exports. As long as the U.S. dollar is chosen as the invoicing currency, the export price in U.S. dollars is stabilized in the local market and Japanese export firms shoulder the exchange rate risk, which is called "pricing-to-market (PTM)". On the other hand, if invoicing in the yen, Japanese export firms do not take any exchange rate risk at least in the short-run, which is equivalent to the exchange rate pass-through (ERPT). To discuss the exchange risk management of Japanese firms, this paper needs to check which currency Japanese firms tend to choose in their exports by destination and by industry or commodity.

However, it is difficult to use the detailed data on the choice of invoicing currency of Japanese exports, because of the limited availability of the data. Currently, this survey can rely on just two data sources. First, the Japanese Ministry of Finance publishes the semi-annual data on the choice of invoicing currency of Japanese exports and imports. Although industry/commodity breakdown data are not available, this dissertation can get the information on destination and source country breakdown of invoicing currency choice: in exports to and imports from the world, the United States, the European Union (EU), and East Asia. Second, the BOJ publishes not the destination/source country breakdown data but the industry breakdown data on the invoicing currency choice, although the BOJ publishes the data for only December (see Table 2-1 below).

Recent studies such as Gopinath *et al*. (2010), Chung (2016), Goldberg and Tille (2016), Deveraux *et al*. (2017) used the transaction level data collected at customs in the United States, UK, and Canada and conducted a large cross-section and panel estimation. Such data are not publicly available, and it is very hard to obtain the information of the choice of invoicing currency at a detailed commodity level in Japanese trade, which impedes a rigorous empirical examination on what determines the choice of invoicing currency.[13]

In contrast to the previous studies, the original contribution of this dissertation is two-fold. First, this dissertation shows the estimated share of invoicing currency in Japanese exports at a commodity level, using the empirical method developed by Ito *et al*. (2016, 2018). By using the two-types of Japanese export price indexes published by the BOJ and by employing the Kalman filter technique, this dissertation obtained time-varying estimates of the invoicing currency choice at a detailed commodity level, which enables us to reveal how Japanese export firms have changed their choice of invoicing currency over time.

The Second and more important contribution is to construct new explanatory variables of the *commodity*-level invoicing currency choice based on the *firm*-level data collected from annual securities reports of 831 Japanese major manufacturing firms. This survey focuses on the four major machinery industries, “transport equipment,” “electric and electronic products,” “general machinery (general purpose, production and business-oriented machinery),” and “chemical and related products.” The four industries account

[13] Goldberg and Tille (2008) and Ito and Kawai (2016) examined the determinants of invoicing currency using the aggregated (country-level) data and conducted a panel estimation.

for about 78% of Japanese total exports, from which this survey chose 50 products that are based on the BOJ's classification of export price index. This survey matched the data between 831 firms and 50 products, and finally constructed the product-level explanatory variables that reasonably reflect firm characteristics in Japanese exports of 50 products. To my knowledge, this is the first study that used firm-level information extensively to construct the explanatory variables for an analysis of determinants in invoicing currency.

The dissertation is organized as follows. Section 2 presents the invoicing currency choice in Japanese exports that are available from the Ministry of Finance and the BOJ. Section 3 estimates the time-varying invoicing currency share of 50 export products. Section 4 examines the determinants of invoicing currency in Japanese exports by a panel analysis. Finally, Section 5 concludes this study.

2. Choice of Invoicing Currency: Theory and Evidence

2.1 Theory of Invoicing Currency Choice

The previous studies such as Giovannini (1988), Friberg (1998), and Bacchetta and van Wincoop (2005) have revealed that invoicing currency choice depends on the price elasticity of export goods and the degree of product differentiation of export goods. Specifically, assuming a partial equilibrium model where the exchange rate is the only source of uncertainty, export firms set the export price before the exchange rate at the period of settlement is known. Export firms have two choices, either to invoice in the domestic (exporters') currency or in the foreign (importers') currency. Which currency is chosen depends on expected profits obtained from respective choices of invoicing currency. Previous studies show that if the profit function is concave (convex) to exchange rate, the importer's (exporter's) currency is chosen. The curvature of the profit function in turn depends on that of the demand function. It is revealed that the lower (higher) the price elasticity of export goods, the more likely that exporter's (importer's) currency is chosen. Friberg (1998) and Bacchetta and van Wincoop (2005) also demonstrated that when considering the third currency invoicing as well, the choice of invoicing currency, either exporter's, importer's, or the third currency, depends not only on the degree of product differentiation of export goods, but also on the exchange rate volatility between the third countries and importer's currencies as well as between the exporter's and importer's currencies.

The next question is how previous empirical studies analyzed the above hypothetical relationship that "differentiated products tend to be invoiced in the exporter's currency." Previous studies often used the Rauch (1999) index that can distinguish between differentiated and homogenous goods to set up a binary dummy variable. However, the Rauch (1999) index is just a rough measurement of product differentiation and is hard to be used for rigorous empirical examination.

Unlike the previous studies, this research assumes that firms' R&D investment is a source of export competitiveness and construct a new explanatory variable as a proxy for export competitiveness by collecting the firm-level data on R&D investment. Ito *et al*. (2012, 2018) pointed out that R&D investment plays a key role in enhancing the degree of export competitiveness of the product traded. Kwon *et al*. (2008) empirically showed that R&D investment has a positive and statistically significant effect on the total factor productivity (TFP). Berman *et al*. (2012) and Le *et al*. (2015) used the TFP as an explanatory variable in estimating the degree of ERPT or PTM. Thus, these empirical studies revealed that the degree of price elasticity and product differentiation, which is typically regarded as a key determinant of invoicing currency choice, has a relationship with TFP and, hence, R&D investment. In this dissertation, a variable of R&D investment is constructed to test the above hypothetical relationship between R&D investment and invoicing currency choice.

2.2 Evidence of Invoicing Currency Choice in Japanese Exports

Figure 2-2 presents the share of invoicing currency in Japanese exports by destination from 1980 to 2017. First, in Japanese exports to the world, the share of the yen never exceeds that of the U.S. dollar (Figure 2-2(a)). The share of the U.S. dollar is particularly high in Japan's exports to the United States (Figure 2-2(b)). In exports to the EU, although not reported in Figure 2-2(c), the share of the European currencies including the euro, the U.K. pound, and the Sweden kronor is 56.0% in 2017. The share of the yen is just 29.5%, which is much smaller than the local (importer's) currency invoicing. This evidence strongly suggests that Japanese exporters tend to choose the PTM behaviour in exports to advanced countries. More interesting evidence can be found in Japanese exports to Asia, where the share of U.S. dollar invoicing exceeds that of yen invoicing in 2017, even though Japanese firms have established regional production network in Asia where intra-firm trade is actively conducted between Japan and Asian-based subsidiaries.

Table 2-1 shows the industry-breakdown data of invoicing currency share in Japanese exports, whereas destination-breakdown data is not available. First, the share of yen-invoiced exports is surprisingly small in the electric and electronics products and the transport equipment industries, which also indicates that the share of U.S. dollar-invoiced exports is very large in these industries. Second, the share of yen-invoiced exports is particularly large in the general machinery industry, where 60.7% of exports are invoiced in the yen as of December 2017, which is consistent with the findings of Ito *et al*. (2018) that stated that the high share of yen-invoiced exports is due to strong export competitiveness of the general machinery industry. Third, "chemicals and related products" shows a large share of U.S. dollar invoicing, which suggests that Japanese non-machinery exports tend to be invoiced in U.S. dollars.

3. Estimation of Invoicing Currency Choice

3.1 Estimation Method

This section relies on the method of estimation developed by Ito *et al*. (2016, 2018) and estimates the share of invoicing currency in Japanese exports at the commodity level.

The BOJ publishes two types of price indices for Japanese exports and imports: (i) a *yen*-based export/import price index and (ii) *contract-currency*-based export/import price index. The BOJ first collects information on export prices based on contract (invoicing) currency from sample firms and then calculates the yen-based export price by using the bilateral nominal exchange rate (monthly average) of the yen vis-à-vis each contract currency.

Suppose that Japanese export firms use just three currencies for export invoicing: the yen, U.S. dollar and euro. The BOJ constructs the yen-invoiced export price (P_{yen}), U.S. dollar invoiced export price (P_{usd}) and euro-invoiced export price (P_{eur}).[14] Then, we can define the yen-based export price index (P_{yen}^{EX}) as follows:

$$P_{yen}^{EX} = (P_{yen})^{\alpha}(P_{usd} \cdot E_{\frac{yen}{usd}})^{\beta}(P_{eur} \cdot E_{\frac{yen}{eur}})^{\gamma} P_{yen}^{EX}$$

$$= (P_{yen})^{\alpha}(P_{usd} \cdot E_{yen/usd})^{\beta}(P_{eur} \cdot E_{yen/eur})^{\gamma}$$

(1)

where α, β and γ represent the share of yen-invoiced, U.S. dollar-invoiced and euro-invoiced exports, respectively, and $\alpha + \beta + \gamma = 1$; $E_{yen/usd}$ and $E_{yen/eur}$ denote the bilateral nominal exchange rate of the yen vis-à-vis the U.S. dollar and euro, respectively. The export price based on contract currencies (P_c^{EX}) can be defined as $P_c^{EX} = (P_{yen})^{\alpha}(P_{usd})^{\beta}(P_{eur})^{\gamma}$. Thus, the yen-based export price index (P_{yen}^{EX}) can be reformulated into:

$$\begin{aligned} P_{yen}^{EX} &= (P_{yen})^{\alpha}(P_{usd})^{\beta}(P_{eur})^{\gamma}(E_{yen/usd})^{\beta}(E_{yen/eur})^{\gamma} \\ &= P_c^{EX} \cdot (E_{yen/usd})^{\beta}(E_{yen/eur})^{\gamma} \end{aligned} \qquad (2)$$

By dividing both sides of equation by P_c^{EX} and taking the natural logarithm, this research obtains:

$$\frac{ln(P_{yen}^{EX}}{P_c^{EX})_t} = \beta \cdot ln\, E_{\frac{yen}{usd},t} + \gamma \cdot \frac{ln\, E_{\frac{yen}{eur},t}\, ln(P_{yen}^{EX}}{P_c^{EX})_t}$$

$$= \beta \cdot ln\, E_{yen/usd,t} + \gamma \cdot ln\, E_{yen/eur,t} \qquad (3)$$

By definition, the share of US dollar invoicing (β) and euro invoicing (γ) can be

[14] This is not an extreme assumption. According to the BOJ statistics, for instance, these three currencies account for 95.3 percent of invoice currencies of Japanese total exports as of December 2017.

estimated by equation (3). The share of yen invoiced exports can be obtained by subtracting the shares of both U.S. dollar and euro-invoiced exports from unity: $\alpha = 1 - \beta - \gamma$. To ensure the stationarity of variables, the first-difference model for OLS estimation is used:

$$\Delta\, ln(P_{yen}^{EX}/P_{c}^{EX})_t = \beta \cdot \Delta\, ln\, E_{yen/usd,t} + \gamma \cdot \Delta\, ln\, E_{yen/eur,t} + \varepsilon_t \quad (4)$$

where Δ is the first-difference operator, and ε is an independently and normally distributed error term with zero mean and a constant variance.

Next, the above constant parameter model is extended to the time-varying parameter model by employing the Kalman filter technique. Equation (4) can be reformulated into the observation equation (5) and the state equations (6) and (7) as follows:

$$\Delta\, ln(P_{yen}^{EX}/P_{c}^{EX})_t = \beta_t \cdot \Delta\, ln\, E_{yen/usd,t} + \gamma_t \cdot \Delta\, ln\, E_{yen/eur,t} + \varepsilon_t \quad (5)$$

$$\beta_t = \beta_{t-1} + \nu_t \quad (6)$$

$$\gamma_t = \gamma_{t-1} + \mu_t \quad (7)$$

where β_t and γ_t represent the time-varying coefficient, and ν_t and μ_t indicate the Gaussian disturbances with zero mean.

Furthermore, this dissertation put three restrictions on equation (5). The first restriction is that summation of US dollar, euro and yen invoice currency share equals one. This restriction is consistent with equation (1) and its explanation. As the second restriction, when estimators of invoice currency share of US dollar and euro are positive and statistically significant, they are zero. The third restriction is when invoice currency share of US dollar is over 1 (100%), it is equal to 1. Theoretically, the upper limit of invoice currency shares is 1, and lower limit of them is 0. In fact, because of the use of commodity data, results may include some unexpected result. These restrictions will minimize those problems.

3.2 Results of Time-Varying Share of Invoicing Currency

The BOJ publishes the export price index which is classified into four levels: Group, Subgroup, Commodity Class and Commodity. For instance, "Transport Equipment" is categorized into Group, "Motor Vehicle" into Subgroup, "Passenger Cars" into Commodity Class, and "Small Passenger Cars" into Commodity.

In this dissertation, the export price index at Commodity Class is used. Ideally, it is better to use the export price index at Commodity, the most disaggregated data. But, the Commodity-level data is often available only from 2010 or 2015, and it is difficult to get the longer time-series data for all 209 Commodity classifications. Instead, this survey chooses the Commodity class data, which is less disaggregated than the Commodity data, but 79 export price indexes are available. This research focuses on four major industries (Groups): General Machinery, Electric and Electronic Products, Transport Equipment, and Chemicals and Related Products. Finally, this research uses 50 export price indexes at Commodity level during the period from January 1995 to December 2018.

All monthly series of the nominal exchange rate are taken from IMF's *International Financial Statistics*. The yen's exchange rate vis-à-vis the deutschemark (DM) is used as a substitute for the yen–euro exchange rate from January 1995 to December 1998. To connect the yen–DM rate to the yen–euro rate, this dissertation uses the euro conversion rate published on the European Central Bank's website.

This dissertation estimates the time-varying parameter model from January 1995 to December 2018 using equations (5)–(8). Table 2-2 presents the annual average of monthly time-varying estimates of invoicing currency for every five years. First, even in the same industry (Group), the share of invoicing currency differs across Commodity classes. In the General Machinery, for instance, the share of the yen is extremely high and almost 100% in some products such as "semiconductor and flat panel & display manufacturing equipment" as of 2018, while the share of the yen is about 64.7% in "power transmission equipment & bearings." In the Transport Equipment, the share of the yen is about 33.7% in "passenger cars" as of 2018, while that of the yen is 62.4% in "motor vehicle parts." Since the share of invoicing currency varies widely across Commodity classes, it is difficult to discuss any factors in determining the choice of invoicing currency just by observing Table 2-2. In the next section, this dissertation conducts a panel analysis to investigate possible determinants of invoicing currency.

4. Determinants of Invoicing Currency

4.1 Empirical Method and Data Description

This survey investigate the determinants of invoicing currency in Japanese exports by conducting the fixed effect model where the time-varying estimates of the yen-invoicing share (α_t) and the dollar-invoicing share (β_t) are used as the dependent variable.

$$Invoice_{it} = a_1 + \boldsymbol{Z}'_{it}\boldsymbol{c}_z + \mu_i + \varepsilon_{it} \qquad (8)$$

where $Invoice_{it}$ denotes the time-varying share of yen-invoiced or dollar-invoiced exports (α_{it}) for Commodity class i at year t. A vector $\boldsymbol{Z}$ includes key explanatory variables discussed below. μ_i denotes individual effect across Commodity classes and ε_{it} denotes error term.

In this empirical examination, this survey uses the four explanatory variables: R&D expenditures, foreign sales ratio (= foreign sales/total sales), nominal effective exchange rate (NEER), volatility of $\Delta \ln NEER$. Furthermore, this survey constructs variables foreign sales by area, and utilizes the foreign sales ratio in U.S., Europe and Asia. Because of multicollinearity problem, this dissertation aggregates U.S. foreign sales and Europe foreign sales as "foreign sales in U.S. and Europe."

In the previous section, this survey obtained the monthly series of estimated invoicing currency share. But, for the panel analysis, the firm-level data to construct explanatory variables for each Commodity class is used. The firm-level data is available from firm's annual securities reports on a fiscal-year basis, and this research takes an annual average of the time-varying estimates of invoicing currency share.

As discussed in Section 2, export firms tend to choose the exporter's currency invoicing if the firms have strong export competitiveness or export differentiated products (Friberg, 1998; Bacchetta and van Wincoop, 2005).However, It is generally hard to obtain a variable that measures export competitiveness.

This dissertation uses R&D expenditures as a proxy variable of export competitiveness. Some previous studies discussed about the important role of R&D expenditures on export competitiveness. Ito *et al*. (2012, 2018) pointed out that R&D investigation plays a key role of export competitiveness. In addition, Kwon *et al.* (2008) empirically showed the relationship between R&D and productivity. Moreover, the degree of price elasticity and product differentiation has a non-trivial relationship with R&D (Berman *et al.* 2012 and Lie *et al.* 2012). Following these papers, this dissertation assumes that R&D expenditure is a source of firms' export competitiveness. Therefore, this survey collects the data of R&D expenditure from 831 Japanese manufacturing firms and categorize the firm-level data into the 50 Commodity Classes to construct the R&D expenditure variable.

This dissertation also uses the firms' foreign sales ratio (*FSR*) as a proxy for their exchange exposure, which is obtained by dividing foreign sales by total sales on a consolidated basis. Japanese firms expand their production and sales network globally and maximize their profits on a consolidated basis. *FSR* can capture the effect of changes in exchange rates and foreign demands especially in the case of globally operating firms.

This research has two interpretations of the *FSR* effect on invoicing currency choice. First, the larger the foreign sales, the larger the exchange exposure that Japanese firms face. To avoid a larger risk of exchange rate changes, firms may increase the share of yen-invoiced exports, which can be called the "foreign exchange exposure effect." Second, in the face of severe competition in the foreign markets, Japanese firms may choose the PTM behavior by invoicing their exports in the local (importer's) currency, which leads to a decline in the share of yen-invoiced exports ("market share effect"). As will be shown below, this research uses the NEER as well for an additional explanatory variable. Thus, the exchange exposure effect can be captured by the NEER, and *FSR* may reflect the market share effect. The increase of NEER means yen depreciation.

As shown by the previous studies such as Bacchetta and van Wincoop (2005), the choice of invoicing currency is conditional on the exchange rate fluctuations. In this study, the commodity specific NEER constructed by Sato *et al*. (2013) is employed.

The full sample period (2005–2016) is divided into two sub-samples: the first sub-sample ranges from 2007 to 2012 that corresponds to the substantial yen appreciation period (see Figure 2-1), and the second sub-sample includes the rapid yen depreciation period from 2012 to 2015. These sub-samples are based on the visual inspection of Figure 2-1, but it is also empirically supported by Nguyen and Sato (2015, 2018) who developed a method of identifying yen appreciation and depreciation periods.

4.2 Results of Empirical Analysis

Table 2-3 presents the results of fixed effect estimation where the share of yen-invoiced exports is the dependent variable. Firstly, the columns (1)–(3) show the results using the R&D expenditure and *FSR* as an explanatory variable. In the whole sample period (column (1)), the coefficient of R&D expenditure is positive and significant. In column (2), the coefficient of the R&D expenditure is significantly positive at the 1% level, while that of FSR is positive, but not significant at the 10% level. This suggests that the export firms with high R&D expenditure and, hence, with strong export competitiveness, tend to increase the yen-invoiced exports during the substantial yen-appreciation period.

In contrast, in column (3), both the coefficients of the R&D expenditure and *FSR* are not significant. On the other hand, the level of commodity specific NEER and NEER volatility have significant result in yen depreciation period. The coefficient of NEER is negative and significant. This result suggests that yen depreciation tends to decrease the share of yen invoice currency. This is possibly because Japanese exporter could enjoy exchange rate surplus in the yen depreciation period. The coefficient of NEER volatility is significantly positive in the yen depreciation period. This result shows that a large yen depreciation increases the yen invoice currency share and Japanese export firms try to get market share in local country. Furthermore, Japanese exporters could afford to decrease local price due to the large exchange rate surplus.

In terms of *FSR*, the coefficients in column (1)-(3) are not significant. *FSR* includes both impact of export and foreign production. Toyota, the Japanese famous automobile company, produces 60% of its products in a foreign country[15]. In these kinds of cases, Japanese exports cannot obtain the full impact of foreign sales and production. For this reason, *FSR* is a complicated variable to interpret. Thus, *FSR* was decomposed into *FSR* in specific regions.

Columns (4)–(5) show the results with area specific *FSR*. The result of R&D expenditure and NEER volatility are approximately same with the results in columns (1)–(3). The level of NEER has a negative coefficient in the yen depreciation period, but it is not significant at least the 10% significant level. In terms of area specific *FSR*, *FSR* in U.S. and Europe has a significant and negative impact on Japanese yen invoiced exports. This means Japanese exporters with large foreign sales in the U.S. and the euro area tend to decrease JPY invoiced exports. In other words, they enjoy the exchange rate gain in the yen depreciation period. This is consistent with the result of NEER in column (3).

Columns (7)–(12), present the results for estimation of equation (8) with the U.S. dollar invoice currency share. In columns (7)-(9), the signs of R&D expenditure, commodity specific NEER and NEER volatility are completely the opposite of the results in column (1)-(3). Regarding the results of R&D expenditure in columns (7)–(12), the degree of significance become lower than the results with JPY invoiced exports, especially during the yen appreciation period. In contrast, foreign sales ratio in U.S. and euro area has a positive and significant coefficient in the full sample period (column 10). This result means Japanese exporter's economic activity in U.S. and Europe increase the USD invoiced exports.

[15] Toyota's the number of products in foreign production in 2018 is 6,337,060. Its total production is 1,468,819. We can see that data in Toyota's homepage. https://global.toyota/

5. Concluding Remarks

This dissertation has employed a new estimation method of invoicing currency choice by using the BOJ's export price index, and empirically investigated what determines the Japanese firms' choice of invoicing currency. This dissertation extensive collected firm-level data from 831 Japanese manufacturing firms and constructed the product-level explanatory variables for panel estimation.

It was shown that Japanese export firms strategically changed the choice of invoicing currency during the yen appreciation and depreciation periods. Japanese export firms with high R&D expenditure tend to increase the share of yen-invoiced exports during the full sample period and the yen appreciation period likely due to their strong export competitiveness. In contrast, Japanese export firms with large foreign sales in U.S. and Europe tend to decrease the share of yen-invoiced exports during the yen depreciation period, which suggests that yen-invoiced exports will be chosen depending on an economic activity in foreign countries. The Japanese firms with weaker export competitiveness may utilize the U.S. dollar as an invoice currency because they try to avoid the change of local currency in order to maintain their market share.

The findings of this paper may have some policy implications for the Japanese trade balance. As shown in Figure 2-1, Japanese trade balance turned into deficit in 2011, and trade deficit continued up to 2015 even though the yen started to depreciate dramatically from the end of 2012. During the yen appreciation period, especially when the yen reached the historically high level from 2011 to the late 2012, Japanese firms that produced relatively low-tech products shifted their production to foreign countries such as the Asian countries. Instead, domestic production was concentrated in the high-tech products with strong export competitiveness. Although the yen started to depreciate from the end of 2012, Japanese export firms with strong export competitiveness did not decrease their export price but pursued the PTM behavior by increasing the foreign currency invoiced exports. In such a situation, the yen depreciation did not accelerate or increase the quantity of exports, whereas the amount of exports in terms of the yen increased thanks to the yen depreciation. Of course, while the Japanese trade balance is not solely determined by the effect of exchange rate changes, the empirical findings of this survey at least partly explain the slow recovery of Japanese trade balance and export quantity in recent years.

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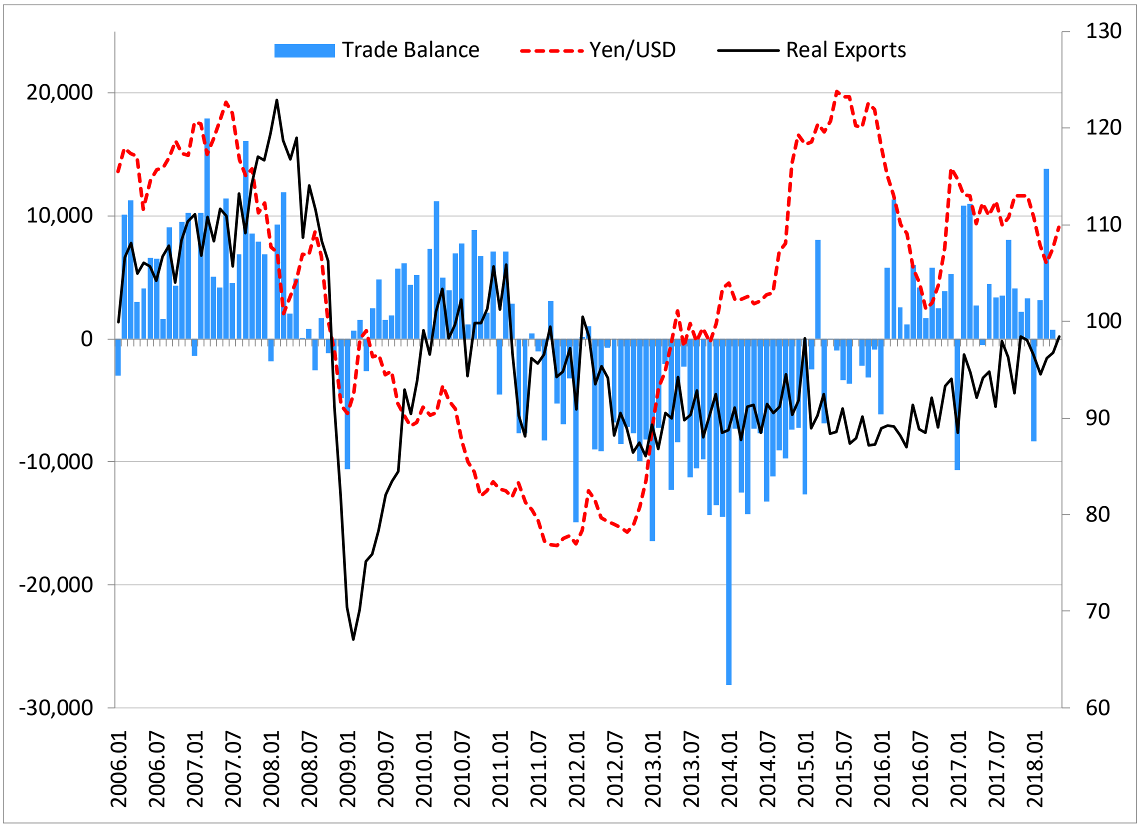
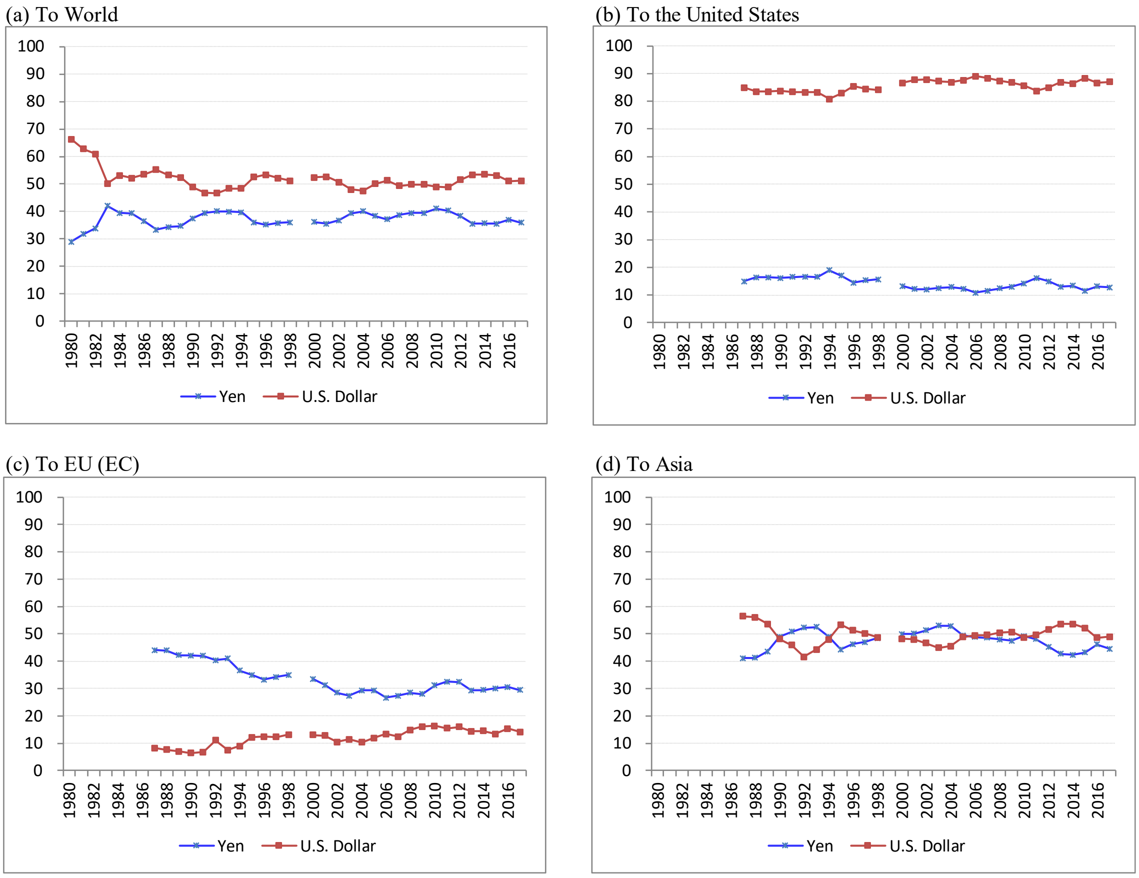
Figure 2-1. Japan's Trade Balance, Yen/USD Exchange Rate, and Export Quantity



Note: Monthly series from January 2006 to May 2018. "Trade Balance" denotes trade balance of goods and services (100 million yen; left-hand side axis). "Yen/USD" denotes the nominal exchange rate of the yen vis-à-vis the U.S. dollar (right-hand side axis). "Real exports" denote the quantum index (2010=100) of Japan's exports to the world (right-hand side axis), where seasonality is adjusted.

Source: Japan's Ministry of Finance, and IMF, *International Financial Statistics*.

Figure 2-2. Invoicing Currency Choice in Japan's Exports by Destination



Note: Data for 1999 are not available. September data are used for 1992–1997, March data for 1998, the second half of the year data for 2000–2017.

Source: Bank of Japan, *Yushutsu Shinyojo Tokei* (*Export Letter of Credit Statistics*); MITI, *Yushutsu Kakunin Tokei* (*Export Confirmation Statistics*); MITI, *Yushutsu Hokukosho Tukadate Doko* (*Export Currency Invoicing Report*); MITI, *Yushutsu Kessai Tsukadate Doko Chosa* (*Export Settlement Currency Invoicing*); website of Japan Customs, Ministry of Finance.

Table 2-1. Invoicing Currency Choice in Japan's Exports by Industry

Table 2-1-A. Yen-invoiced exports (%)

	Textiles (1.38)	Chemicals & related products (9.84)	Metals & related products (10.85)	General machinery (18.94)	Electric & electronic products (20.55)	Transport equipment (28.52)	Other primary products & manufactured goods (9.92)	**Total Exports (100.00)**
1999	9.1	9.2	14.8	64.1	19.7	12.8	16.2	**26.7**
2000	9.1	9.7	17.1	58.7	30.3	12.8	17.8	**29.7**
2001	9.4	9.9	11.1	56.6	19.4	9.0	20.1	**24.3**
2002	24.0	17.3	7.8	46.8	27.5	22.5	29.7	**28.5**
2003	24.0	19.8	15.5	46.3	35.7	22.2	27.9	**31.8**
2004	27.0	19.6	15.7	47.9	36.8	21.0	29.9	**32.3**
2005	27.0	21.1	15.4	51.0	36.8	21.0	34.9	**33.3**
2006	27.2	20.4	18.1	49.2	39.8	21.0	33.3	**34.0**
2007	21.2	20.3	16.4	45.6	37.3	23.9	34.3	**32.1**
2008	16.0	20.0	13.2	44.8	36.9	19.0	34.8	**30.3**
2009	16.0	20.3	12.2	43.6	36.1	19.8	35.0	**30.0**
2010	16.0	20.6	12.7	44.9	35.5	21.0	28.0	**30.0**
2011	17.8	23.5	19.1	49.3	37.3	19.8	24.3	**31.7**
2012	10.8	28.7	19.4	64.1	40.8	32.3	35.3	**38.6**
2013	7.5	29.4	21.1	64.0	41.3	29.8	34.5	**38.1**
2014	9.5	28.9	21.5	61.9	37.3	29.8	33.0	**36.7**
2015	9.5	26.4	21.9	59.4	36.0	29.8	34.0	**35.9**
2016	38.8	28.6	20.2	59.8	37.6	35.7	30.1	**37.8**

Note: December data of each year. Figures in parentheses denote the share of export amounts in the total exports for each industry.
Source: The BOJ website and Author's calculation.

Table 2-1. Invoicing Currency Choice in Japan's Exports by Industry (cont.)

Table 2-1-B. U.S. dollar-invoiced exports (%)

	Textiles (1.38)	Chemicals & related products (9.84)	Metals & related products (10.85)	General machinery (18.94)	Electric & electronic products (20.55)	Transport equipment (28.52)	Other primary products & manufactured goods (9.92)	**Total Exports (100.00)**
1999	88.2	90.2	82.8	26.8	74.8	52.1	78.2	**62.4**
2000	88.2	89.6	82.8	32.1	64.4	52.1	76.6	**59.6**
2001	87.8	87.8	88.9	33.3	72.4	51.6	74.3	**62.8**
2002	75.7	79.1	90.9	34.7	64.3	53.4	61.4	**59.0**
2003	75.7	76.4	83.2	34.6	55.5	54.4	63.7	**55.5**
2004	72.7	76.4	83.1	34.9	53.2	49.6	60.8	**53.8**
2005	72.7	74.7	83.4	32.1	53.8	49.6	55.9	**53.0**
2006	72.8	75.3	80.7	33.6	52.5	53.0	57.6	**53.4**
2007	78.8	75.6	82.6	36.6	54.1	48.3	57.5	**54.4**
2008	78.8	76.7	85.8	36.9	53.1	49.1	57.3	**54.7**
2009	78.8	76.3	86.8	38.7	54.1	52.4	52.0	**55.7**
2010	78.8	76.4	86.3	36.4	54.1	52.8	63.2	**56.0**
2011	66.7	74.8	80.2	35.6	52.6	54.8	67.7	**55.3**
2012	69.9	70.3	80.0	24.4	49.2	48.7	59.6	**51.4**
2013	73.3	68.5	78.2	23.2	49.2	50.3	60.3	**51.2**
2014	79.8	69.4	77.8	26.0	53.5	50.3	62.3	**53.1**
2015	79.8	70.5	77.4	27.7	55.6	48.3	60.7	**53.3**
2016	51.1	69.4	78.8	26.0	54.6	46.3	62.0	**51.6**

Note: December data of each year. Figures in parenthesis denote the share of export amounts in the total exports for each industry.
Source: The BOJ website and Author's calculation.

Table 2-2. Summary Result of Time-Varying Estimates of Invoicing Currency Choice

	Weight	U.S. Dollar					Yen				
Transportation Equipment	**285.2**	**2000**	**2005**	**2010**	**2015**	**2018**	**2000**	**2005**	**2010**	**2015**	**2018**
Passenger cars	143	83.1	80.9	77.4	75.7	66.3	16.9	19.1	22.6	24.3	33.7
Buses	5.4	97.5	91.5	89.5	53.3	67.0	2.5	8.5	10.5	44.6	33.0
Trucks	15	67.0	55.2	33.4	29.3	10.5	33.0	44.8	66.6	70.7	89.5
Motorcycles	4	47.8	56.1	38.3	15.8	30.9	52.2	42.8	61.7	70.2	48.8
Motor vehicle parts	72.6	15.3	21.8	41.6	44.4	37.6	84.7	78.2	58.4	55.6	62.4
Vessels & parts	27.2	50.7	0.0	15.5	60.1	61.1	49.3	100.0	84.5	39.9	38.9
Aircraft parts	14.1	59.2	25.5	3.3	0.0	0.0	40.8	74.5	96.7	100.0	100.0
Industrial trucks & parts	2.1	46.9	45.8	40.4	24.9	25.6	53.1	36.7	37.7	75.1	74.4
Bicycle parts	1.8	23.7	14.2	15.5	25.3	26.9	69.9	70.6	55.7	46.9	44.0
Electric & electronic products	**205.5**	**2000**	**2005**	**2010**	**2015**	**2018**	**2000**	**2005**	**2010**	**2015**	**2018**
Photoelectric converter devices	5.8	44.1	51.4	59.0	68.8	66.5	36.2	36.2	22.3	10.7	14.8
Semiconductor devices	4.4	1.9	3.0	4.8	7.1	8.4	98.1	94.6	90.3	85.6	83.4
Integrated circuits	45.9	55.5	57.3	41.1	49.1	38.8	44.5	42.7	58.9	50.9	61.2
Display devices	11.4	0.0	1.6	19.2	45.7	51.1	100.0	98.4	80.8	49.9	45.5
Passive components	17.2	33.5	23.4	35.1	45.6	41.8	66.5	76.6	48.8	50.4	58.2
Connecting components	14.5	84.2	59.4	61.8	70.5	64.9	0.0	2.3	11.4	15.4	18.6
Other electronic components	16.6	16.0	14.1	15.9	11.3	9.8	84.0	75.9	51.9	70.3	74.4
Heavy electrical apparatus	17.9	38.7	42.4	43.5	27.6	22.3	61.3	50.9	17.7	55.9	61.4
Electric bulbs and lighting & wiring devices	4.5	48.9	46.2	59.2	52.2	45.8	2.4	44.1	17.5	15.8	15.6
Electronic equipment	8.6	0.0	15.6	28.6	32.0	27.9	100.0	77.6	56.9	45.7	54.6
Electrical meters & measuring instruments	16.1	49.7	47.0	24.7	7.9	24.8	50.3	53.0	67.4	92.1	75.2
Other electrical machinery & equipment	20.3	56.6	14.4	0.0	0.0	0.0	43.4	85.6	100.0	100.0	100.0
Communications equipment	6.8	0.0	2.0	5.4	7.1	9.3	100.0	86.7	81.0	78.7	73.4
Audio & visual equipment	8.6	69.7	85.7	67.1	70.8	66.5	30.3	11.0	1.6	1.6	0.0
Electronic computers & computer equipment	6.9	78.5	81.8	82.2	86.2	84.8	21.5	18.2	17.8	13.8	15.2

	Weight	U.S. Dollar					Yen				
General purpose, production & business oriented machinery	**189.4**	**2000**	**2005**	**2010**	**2015**	**2018**	**2000**	**2005**	**2010**	**2015**	**2018**
Engines	10.7	0.0	0.0	0.0	2.9	0.0	100.0	100.0	100.0	97.1	100.0
Pumps & compressors	16	9.1	9.7	21.7	26.5	26.6	90.9	71.4	47.3	50.7	53.1
Power transmission equipment & bearings	16.9	0.0	5.2	13.3	20.9	22.7	100.0	94.8	78.7	66.5	64.7
Refrigerating appliances	3.2	0.0	27.4	20.2	17.6	12.6	100.0	72.6	78.9	82.4	87.4
Other general purpose machinery	5.9	39.5	38.2	23.3	0.0	0.0	60.5	61.8	76.7	89.2	84.2
Agricultural machinery	4.4	57.9	58.0	62.8	64.3	53.8	27.7	22.3	18.3	17.2	30.9
Machinery & equipment for construction and mining	20.8	0.0	1.5	14.5	18.7	25.1	100.0	98.5	78.3	68.1	68.2
Textile machinery	5.1	83.8	62.3	65.7	71.1	72.5	16.2	7.3	20.2	14.3	7.0
Dairy lives industry machinery	6.4	100.0	100.0	100.0	100.3	100.0	0.0	0.0	0.0	-0.3	0.0
Semc. and flat panel & display manufacturing equipment	33.4	100.1	100.1	100.0	100.5	100.1	-0.1	-0.1	0.0	-0.5	-0.1
Basic material industry machinery	5.3	28.6	30.1	31.5	31.0	34.6	70.6	66.7	65.6	69.0	65.4
Metal cutting machine tools	19.2	91.6	40.2	29.9	34.9	32.3	-0.6	16.3	-0.6	2.9	0.0
Metal forming machinery	5.1	0.0	5.4	16.5	21.9	24.7	100.0	94.6	77.4	66.8	62.7
Tools for machines and pneumatic & electric tools	6.6	11.4	13.2	17.7	40.9	42.6	88.6	86.8	82.3	55.5	57.4
Robots	3.4	100.0	100.1	99.9	100.4	99.9	0.0	-0.1	0.1	-0.4	0.1
Instruments & appliances for measuring, checking & testing	11.3	93.7	49.4	52.0	39.8	67.6	6.3	50.6	48.0	60.2	32.4
Medical appliances	8.9	80.0	72.8	66.5	80.7	67.1	10.9	26.4	33.5	19.3	32.9
Optical instruments & lenses	6.8	63.3	54.2	29.5	14.5	43.4	36.7	45.8	70.5	85.5	56.6
Chemicals & related products	**98.4**	**2000**	**2005**	**2010**	**2015**	**2018**	**2000**	**2005**	**2010**	**2015**	**2018**
Industrial inorganic chemicals	9.4	29.5	37.1	57.2	43.7	29.1	63.0	48.0	20.9	46.1	53.5
Basic petrochemicals	9.5	7.6	3.9	0.0	0.0	0.0	80.9	96.1	100.0	100.0	100.0
Aliphatic intermediates	6.4	42.2	35.8	32.4	32.1	31.7	18.3	23.6	41.3	67.0	68.3
Cyclic intermediates	19.1	74.3	55.0	70.3	74.2	78.3	25.7	45.0	29.7	25.8	21.7
Plastic resins & materials	22.6	37.8	43.0	39.8	41.3	39.9	50.9	34.0	46.9	51.3	60.1
Other industrial organic chemicals	5.5	91.4	88.0	99.8	100.3	100.1	8.6	12.0	0.2	-0.3	-0.1
Pharmaceutical products	7.4	0.0	63.2	40.4	33.4	43.2	0.0	36.8	59.6	66.6	56.8
Other chemical products	18.5	0.0	52.9	50.7	37.8	26.1	0.0	47.1	42.6	61.1	70.1

Note: "Semc. and flat panel & display manufacturing equipment" denotes "Semiconductor and flat panel & display manufacturing equipment."

Source: Author's calculation.

Table 2-3. Determinants of Invoice Currency Choice in Japan's Exports

Dependent variable: Invoice currency share

Model: Fixed Effect

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Invoice	JPY Invoice			JPY Invoice			USD Invoice			USD Invoice		
Period	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015	2006-2018	2007-2012	2012-2015
Const.	-2.626 **	-2.761 *	0.522	-2.496 **	-2.601 *	0.139	2.089 *	2.152 #	1.285	2.277 *	2.314 #	1.523
	(0.882)	(1.111)	(1.335)	(0.929)	(1.156)	(1.350)	(0.782)	(1.087)	(1.299)	(0.864)	(1.187)	(1.276)
R&D Expenditure	0.308 **	0.349 **	0.072	0.294 **	0.333 **	0.099	-0.200 *	-0.191 #	-0.154	-0.206 *	-0.203	-0.168
	(0.088)	(0.113)	(0.139)	(0.092)	(0.122)	(0.141)	(0.084)	(0.110)	(0.133)	(0.088)	(0.112)	(0.213)
Foreign Sales Ratio	-0.029	0.236	-0.097				0.059	-0.250	0.147			
	(0.149)	(0.205)	(0.189)				(0.122)	(0.184)	(0.190)			
FSR US & Euro Area				0.013	0.151	-0.356 #				0.235 #	0.070	0.321 #
				(0.186)	(0.261)	(0.199)				(0.135)	(0.235)	(0.187)
FSR Asia				0.151	0.286	0.542				-0.356	-0.335	-0.514
				(0.314)	(0.341)	(0.389)				(0.304)	(0.322)	(0.353)
NEER	-0.066	-0.167	-0.177 #	-0.069	-0.153	-0.155	0.117 #	0.114	0.175 #	0.087	0.080	0.162 *
	(0.076)	(0.110)	(0.105)	(0.074)	(0.106)	(0.097)	(0.076)	(0.110)	(0.105)	(0.054)	(0.089)	(0.078)
Volatility	-0.461	-1.607	4.378 *	0.354	0.155	0.115 *	-0.079	0.952	-2.689 *	0.133	1.109	-2.065
	(1.241)	(1.352)	(1.652)	(1.209)	(1.477)	(1.782)	(1.241)	(1.352)	(1.652)	(1.072)	(1.422)	(1.373)
NOB	600	300	200	650	300	200	600	300	200	600	300	200
F-Test	5.77 **	6.37 **	0.50 #	4.19 **	5.61 **	2.00 #	2.29 #	3.10 *	2.30 #	2.39 #	2.01 #	1.73

Notes: The dependent variable is the share of yen invoiced exports and dollar invoiced exports. This result is calculated by regression formula (8). The number in parenthesis denotes standard error. **, * and # denote the 1 percent, 5 percent and 10 percent significance level, respectively. "Foreign Sales Ratio" is equal Foreign Sales divided by Total Sales. "FSR US & Euro area" denotes foreign sales in U.S. and euro area divided by total sales. "FSR Asia" denotes foreign sales in Asia divided by total sales. This dissertation made estimation for the three sample periods: the whole sample (2006–2018), the yen appreciation period (2007–2012), and the yen depreciation period (2012–2015). Standard error of this equation is robust standard error. Number in parentheses denotes standard error.
Source: Author's Calculation

CHAPTER 3:

Invoice Currency Choice and Exports: Why Do Japanese Exports Become Unresponsive to Exchange Rate Changes?

1. Introduction

Japan's exports appear to have become unresponsive to exchange rate changes. Although Japan was famous for a large amounts of trade surplus up to 2010, Japan's trade balance turned into deficit in March 2011 and the amounts of trade deficit continued to increase rapidly until mid- 2015. Japan's trade balance appears to have been affected by the exchange rate changes. The nominal exchange rate of the yen vis-à-vis the U.S. dollar (red dotted line graph) appreciated substantially from around 120 in 2007 to less than 80 in 2011 and mid-2012, which was accompanied by the considerable decline in trade surplus (blue bar graph) during the same period with the exception of the global financial crisis (GFC) period from 2008 to 2009 (Figure 3-1).

More interestingly, Japan's export quantity (black line graph) did not increase in response to sharp depreciation of the yen vis-à-vis the U.S. dollar: Export quantity index changed from 86.0 in December 2012 to 87.5 in December 2015, whereas the yen depreciated dramatically from 83.58 to 121.92 during the same period (Figure 3-1). This evidence clearly suggests that Japan's exports became unresponsive to exchange rate changes.

Previous studies empirically investigated why Japanese trade balance did not recover from the end of 2012 even though the yen depreciated rapidly. Shimizu and Sato (2015) showed that in response to the historic high value of the yen in 2011–2012, Japanese firms promoted overseas production for low-tech and high price-elasticity products, while keeping domestic production for differentiated and low price-elasticity products. Due to this strategic relocation of production bases, Shimizu and Sato (2015) argued that Japan's exports became unresponsive to rapid depreciation of the yen from the end of 2012, suggesting that J-curve effect did not work in Japanese exports. Bahmani-Oskooee and Karamelikli (2018) examined possible asymmetry in exchange rate elasticity of Japan's bilateral trade balance with the United States at a commodity level. They found asymmetric elasticity of trade balance to real exchange rate changes for several commodities but did not investigate why such asymmetric elasticity was observed. Sasaki and Yoshida (2018) made more comprehensive empirical analysis of what caused recent deficit of Japan's trade balance and argued that changes in price and income elasticities as well as exchange rate pass-through (ERPT) behavior caused Japan's trade deficit in recent years. Although presenting interesting evidence, however, these previous studies fail to examine what factors caused changes in ERPT behavior and price and income elasticities of exports and imports.

The main purpose of this paper is to empirically investigate what causes recent unresponsiveness of Japanese export quantity to exchange rate changes by using 35 product-level data on Japan's export quantity collected from the Ministry of Finance, Japan. Using disaggregated export data is not new, but this paper makes the following three novel contributions. First, this paper collects firm-characteristic data from annual securities reports of 472 Japanese manufacturing firms and constructed the firm-characteristic variables for corresponding 35 export products, such as firms' R&D expenditure (as possible source of export competitiveness) and foreign sales ratio (FSR; as possible measure of firms' overseas production and sales activities). Second, this paper uses the data on invoice currency for 35 export products to consider how invoice currency choice affects export quantity. Following Ito *et al*. (2016 and 2018), this paper estimated the share of invoice currency (both yen and the U.S. dollar) for 35 product-level exports. Recent studies such as IMF (2019), Adler *et al*. (2020), Boz *et al*. (2020) argued that the choice of invoice currency as well as global value chains (GVCs) could affect the degree of exchange rate effect on trade, but these studies typically employ a country-level aggregated data on invoice currency choice for a large-scale cross-country panel analysis, because more disaggregated data at an industry or commodity level is not readily available (Adler *et al*. 2020; Boz *et al*. 2020; Gopinath *et al*. 2020). Third, this paper employs *product-specific* real effective exchange rate (REER) to measure the degree of export elasticity to exchange rates. This paper uses export quantity data that is not destination specific and, hence, this paper use Japan's REER data for empirical analysis. Following Sato *et al*. (2013, 2020), this paper collects industry-level producer price index (PPI) of 28 destination countries for Japan's exports and the corresponding Japan's export price index for 35 export products to construct product-specific REERs.

The empirical analysis of this paper demonstrates that REER changes do not affect export quantity in Japanese exports, which supports the recent findings of unresponsiveness of Japan's trade balance to exchange rate changes. But, if taking into account invoice currency choice, export quantity becomes responsive to REER changes. Specifically, an interaction term of REER with yen-invoiced share exhibits negative and statistically significant, which indicates that if the share of yen-invoiced exports increases, REER appreciation has negative and significant effect on Japan's export quantity. In contrast, if instead including the share of U.S. dollar invoiced exports, estimated coefficients are not statistically significant, which conforms to the pricing-to-market (PTM) behavior and recent debate of "dominant currency pricing" (Adler *et al*., 2020). Regarding firm-characteristic variables, *FSR* has negative and statistically significant effect on Japan's export quantity. Since *FSR* captures both Japan's exports and sales/exports of overseas subsidiaries, these empirical results suggest that export quantity becomes less responsive to REER if Japanese firms expand overseas production and sales. Firms' R&D expenditure is found to have positive and significant effect on Japan's export quantity. Since R&D is often considered a source of export competitiveness[1], this result suggests that an increase in firm's export competitiveness will promote Japan's export quantity.

The remainder of this paper is structured as follows. Section 2 elaborates empirical methods and describes the data for empirical analysis. Section 3 presents empirical results. Finally, Section 4 concludes this paper.

[1] Kwon *et al*. (2008) empirically showed that R&D investment has a positive and statistically significant effect on the total factor productivity (TFP).

2. Empirical Methods and Data

2.1 Empirical Model

This paper conducts the following panel analysis to investigate what determines the recent unresponsiveness of Japanese export quantity to real exchange rate changes.

$$\begin{aligned}\ln EXQ_{it} &= \beta_1 \ln REER_{it} + \beta_2 Invoice_{it} + \beta_3 \ln REER_{it} \times Invoice_{it} \\ &+ \beta_4 REERVol_{it} + \beta_5 FSR_{it} + \beta_6 \ln R\&D_{it} + \beta_7 OutputGap_t \\ &+ \beta_8 ExrDummy_t + \alpha_i + \varepsilon_{it}\end{aligned}$$

where *EXQ* denotes Japan's export quantity to the world. *i* denotes an export product and this paper choose 35 manufacturing products that account for around two-thirds of Japan's total exports to the world. *Invoice* denotes the *product-specific* invoice currency share of the U.S. dollar or the yen in Japanese exports to the world. *REER* denotes the *product-specific* real effective exchange rate (REER) of Japanese yen. *REERVol* denotes the REER volatility that is defined as the standard deviation of log-differences of the product-specific REER; *FSR* denotes foreign sales ratio of export firms that are selected as major exporters of each export product. Foreign sales ratio is defined as an average of foreign sales amounts to the consolidated total sales for the selected firms.[2] *R&D* denotes the R&D expenditure that is an average of the annual R&D expenditures of selected export firms. For both FSR and R&D variables, this paper chose representative export firms for each of 35 export products based on 472 firms. *OutputGap* denotes the real output gap that is computed by applying the Hodrick-Prescott (HP) filter to the weighted average of industrial production index of 20 countries that are major destination for Japan's exports. The identified cyclical components are used as a proxy for world business cycles for Japan. *ExrDummy* denotes the dummy for (1) yen appreciation period from 2007 to 2012 and (2) yen depreciation period from 2013 to 2015. α_i denotes individual fixed effect and ε denotes error term.

[2] We chose a simple arithmetic average, not a weighted average, of each firm's foreign sales ratio (FSR). Thus, the computed FSR this paper uses may not reflect differences in sales and export amounts across selected firms.

2.2 Data

Export quantity. This paper collects product level data of Japanese export quantity published by the Ministry of Finance (MOF), Japan. Although destination-breakdown data on export quantity is not publicly available from MOF, this paper use the export quantity data for 35 major export products that account for around two-thirds of Japanese total exports in terms of export amounts.

Foreign sales ratio and R&D expenditure. To calculate firm foreign sales ratio, this paper collects the data of both foreign sales and total sales amounts from annual securities reports published by the selected firms. R&D expenditure data is also obtained from annual securities reports of 472 Japanese firms.

Output Gap. To allow for world demand for Japanese exports, this paper collected the monthly series of industrial production index of 20 countries each of which accounts for at least one percent of Japan's export destination in Japan's total exports in terms of export amounts. These 20 destination countries in total account for around 85 percent of Japan's total exports. All data of industrial production index and amounts of exports are obtained from the CEIC Database and IMF, Direction of Trade Statistics. After calculating the weighted average of industrial production indices, this paper made seasonal adjustment of averaged industrial production index. Then, this paper applied HP filter to obtain cyclical components of the averaged industrial production index as a proxy for world demand or business cycles.

Product-specific REER of the yen. In contrast to existing studies, this paper attempted to construct product-specific REERs (*PsREER*). Utilizing the industry-specific REERs (*IsREER*) developed by Sato *et al*. (2013, 2020), this paper made following data construction:

$$PsREER_i = IsREER_k \times \left(\frac{P_i}{P_k}\right) = \prod_n \left(NER_n \cdot \frac{P_k}{P_{k,n}^*}\right)^{\alpha_n} \times \left(\frac{P_i}{P_k}\right)$$

where i, k, and n denote product, industry, and destination country, respectively. α_n denotes an export weight of destination country n and a single asterisk (*) denotes foreign variable. NER denotes the bilateral nominal exchange rate of currency *n* against the yen. P_k denotes the domestic (Japanese) producer price index of k-industry, while P_i represents the Japanese export price of i-product. i-product is more disaggregated than k-industry, and this paper made efforts to match P_i with P_k. Thus, to obtain *PsREER* for i-product, this paper multiply corresponding *IsREER* for k-industry by (P_i / P_k). The product-specific REERs (*PsREER*) this paper utilizes is more appropriate to capture different impact of exchange rate changes on export quantity across commodities.

Invoice currency share. The Bank of Japan (BOJ) publishes two types of price indices for Japanese exports and imports: (i) a *yen*-based export/import price index and (ii) *contract-currency*-based export/import price index. The BOJ first collects information on export prices based on contract (invoicing) currency from sample firms and then calculates the yen-based export price by using the bilateral nominal exchange rate (monthly average) of the yen vis-à-vis each contract currency.

Suppose that Japanese export firms use just three currencies for export invoicing: the yen, U.S. dollar and euro. The BOJ constructs the yen-invoiced export price (P_{yen}), U.S. dollar invoiced export price (P_{usd}) and euro-invoiced export price (P_{eur}).[3] Then, this paper can define the yen-based export price index (P_{yen}^{EX}) as follows:

$$P_{yen}^{EX} = (P_{yen})^{\alpha}(P_{usd} \cdot E_{yen/usd})^{\beta}(P_{eur} \cdot E_{yen/eur})^{\gamma}$$

where $\alpha, \beta,$ and γ represent the share of yen-invoiced, U.S. dollar-invoiced and euro-invoiced exports, respectively, and $\alpha + \beta + \gamma = 1$; $E_{yen/usd}$ and $E_{yen/eur}$ denote the bilateral nominal exchange rate of the yen vis-à-vis the U.S. dollar and euro, respectively. The export price based on contract currencies (P_c^{EX}) can be defined as:

$$P_c^{EX} = (P_{yen})^{\alpha}(P_{usd})^{\beta}(P_{eur})^{\gamma}$$

Thus, the yen-based export price index (P_{yen}^{EX}) can be reformulated into:

3 This is not an extreme assumption. According to the BOJ statistics, for instance, these three currencies account for 95.3 percent of invoice currencies of Japanese total exports as of December 2017.

$$
\begin{aligned}
P_{yen}^{EX} &= (P_{yen})^{\alpha}(P_{usd})^{\beta}(P_{eur})^{\gamma}(E_{yen/usd})^{\beta}(E_{yen/eur})^{\gamma} \\
&= P_{c}^{EX}\cdot(E_{yen/usd})^{\beta}(E_{yen/eur})^{\gamma}
\end{aligned}
$$

By dividing both sides of equation by P_c^{EX} and taking the natural logarithm, this paper obtains:

$$\ln(P_{yen}^{EX}/P_c^{EX})_t = \beta\cdot\ln E_{yen/usd,t} + \gamma\cdot\ln E_{yen/eur,t}$$

By definition, the share of US dollar invoicing (β) and euro invoicing (γ) can be estimated by the above equation. The share of yen invoiced exports can be obtained by subtracting the shares of both U.S. dollar and euro-invoiced exports from unity: $\alpha = 1 - \beta - \gamma$. To ensure the stationarity of variables, this paper use the first-difference model for OLS estimation:

$$\Delta\ln(P_{yen}^{EX}/P_c^{EX})_t = \beta\cdot\Delta\ln E_{yen/usd,t} + \gamma\cdot\Delta\ln E_{yen/eur,t} + \varepsilon_t$$

where Δ is the first-difference operator, and ε is an independently and normally distributed error term with zero mean and a constant variance.

This paper next extends the above constant parameter model to the time-varying parameter model by employing the Kalman filter technique. The above equation can be reformulated into the following observation equation and the two state equations:

$$\Delta\ln(P_{yen}^{EX}/P_c^{EX})_t = \beta_t\cdot\Delta\ln E_{yen/usd,t} + \gamma_t\cdot\Delta\ln E_{yen/eur,t} + \varepsilon_t$$

$$\beta_t = \beta_{t-1} + \nu_t$$

$$\gamma_t = \gamma_{t-1} + \mu_t$$

where β_t and γ_t represent the time-varying coefficient, and ν_t and μ_t indicate the Gaussian disturbances with zero mean.

For illustrative purpose, this paper plots the time-series data in Figures 3-2-A through 3-2-H for export quantity, product-specific REER, estimated invoice currency share of the yen and the U.S. dollar.

3. Results

The result of fixed effect panel estimation is presented in Table 3-1. First, in the columns (1) to (6) shows the result during whole sample (2003-2018). In the columns (1)–(2) and (5)–(6), this paper found that the product-specific REER positively affect export quantity in Japanese exports. On the other hand, the columns (3) and (4) shows that the coefficient of product-specific REER is not significant when only the Output Gap variable the invoice currency variable, either share of the yen, is included as an explanatory variable. In contrast, the columns (7) to (12) show the result in Pre-GFC period (2003-2008). The signs of all result in Pre-GFC are negative, but only the columns (7) and (8) have significant results. In the Post-GFC (columns (13)–(18)), the coefficients of the product-specific REER is positive and significant. Moreover, this paper added the explanatory variables from firm-level data, R&D and FSR (columns (19)-(36)).

Second, regarding firm-characteristic variables, the REER volatility has negative and significant effect on Japan's export quantity in some cases. As exchange rate volatility typically measures the degree of exchange rate risk, this paper may say that the export quantity will decline if Japanese export firms face larger the exchange rate risk. Firms' R&D expenditure is found to have positive and significant effect on Japan's export quantity in the whole sample. Since R&D is often considered a source of export competitiveness, this result suggests that Japanese export firms with strong export competitiveness tend to increase their export quantity. Foreign sales ratio (*FSR*) has positive and statistically significant effect on Japan's export quantity in Pre-GFC. Since *FSR* covers both (i) Japan's exports to foreign countries and (ii) Japanese overseas subsidiaries' sales in local markets and exports to other countries.

Third, the yen invoice share can affect export quantity through interaction term with the R&D expenditure in the whole sample period, as shown in columns (5), (23) and (24) in Table 3-1. The coefficient of the yen invoice share tends to be negative even if instead including the interaction term of REER or REER volatility.

Finally, this paper divided the sample period into Pre-GFC and Post-GFC. Especially, in the Pre-GFC period (the columns (7)-(12) and (25)-(30)), the coefficients of the explanatory variables are not statistically significant, except FSR. On the other hand, in the Post-GFC period (the columns (13)-(18) and (31)-(36)), the coefficient of the explanatory variables tends to be statistically significant. These results capture different impact on export quantity between Pre-GFC period and Post-GFC period.

4. Conclusion

First, the empirical evidence reveals the difference among the Pre-GVC period (2003-2008), the Post-GVC period (2011-2018) and the whole sample (2003-2018) in terms of the determinants of export quantity fluctuation. During the Pre -GVC period, the REER appreciation (depreciation) tends to have negative (positive) effect on Japan's export quantity. This result is consistent with previous studies. Furthermore, the foreign sales ratio has a positive impact on export quantity. This result means export firms which have large foreign sales ratio tend to increase export quantity due to foreign activity like global value chains or large foreign market share.

On the other hand, in the Post-GVC and the whole period, the REER appreciation (depreciation) have negative (positive) effect on export quantity. The Japanese yen invoiced export tend to have negative coefficient. As shown by Ito *et al*. (2018), more than 50 percent of Japan's exports are invoiced in U.S. dollars and other advanced country's currencies, while the yen accounts for at most more than 30 percent of Japan's total exports. Thus, as long as U.S. dollar invoiced exports account for the largest share, Japanese exports would not improve in response to REER depreciation of the yen.

The empirical results of this paper also reveal that the REER volatility has negative effect on Japan's export quantity. As long as Japanese export firms face larger exchange rate volatility, Japan's export quantity is likely to decline. In addition, higher R&D expenditure will lead to an increase in export quantity. If Japanese firms continue to promote R&D expenditure and export competitiveness, the export quantity is likely to increase.

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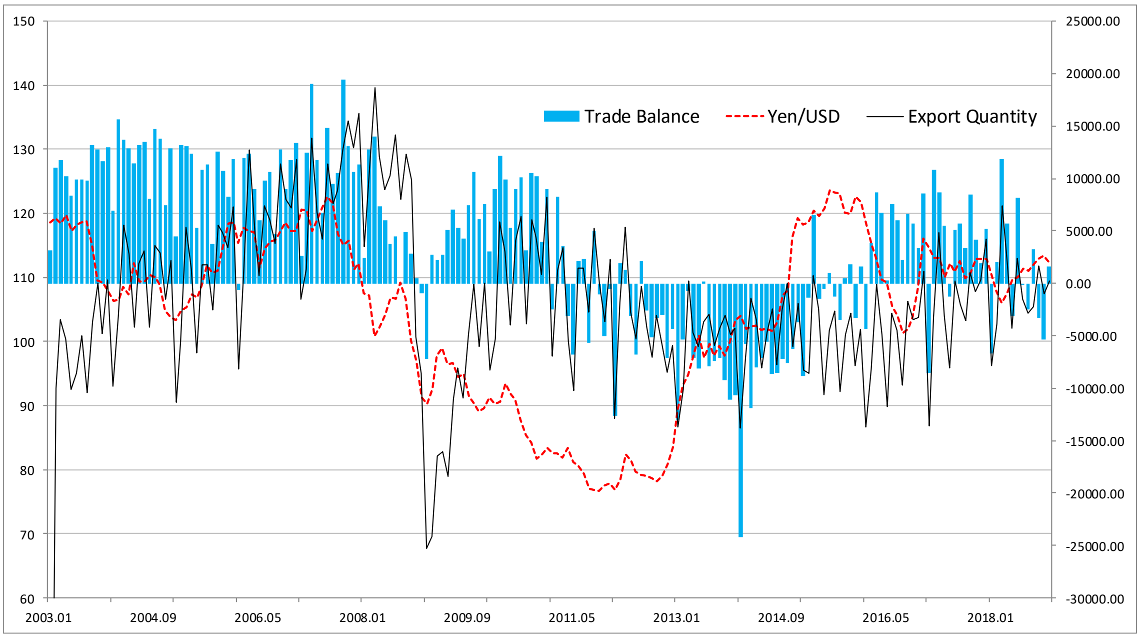
Figure 3-1. Japan's Trade Balance, Yen/USD Exchange Rate, and Export Quantity

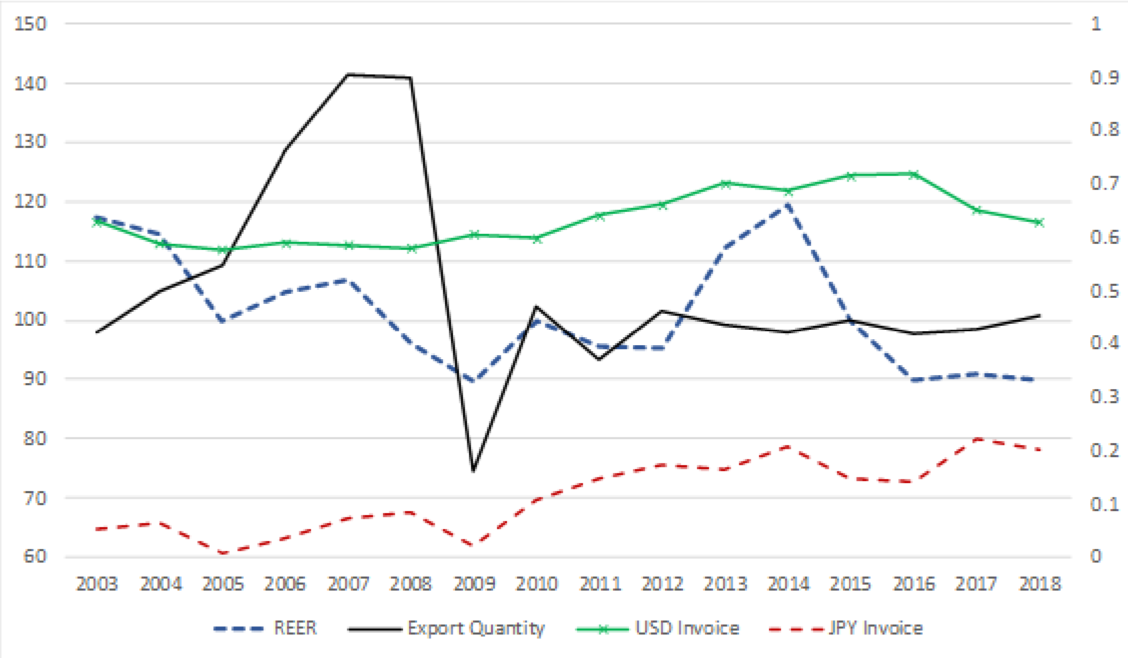


Note: Monthly series from January 2003 to December 2018. "Trade Balance" denotes trade balance of goods and services (100 million yen; right-hand side axis). "Yen/USD" denotes the nominal exchange rate of the yen vis-à-vis the U.S. dollar (left-hand side axis). "Export Quantity" denote the export quantum index (2015 = 100) of Japan's exports to the world (left-hand side axis), where seasonality is adjusted.

Source: Japan's Ministry of Finance, and IMF, *International Financial Statistics*.

Figure 3-2. Commodity Specific Export Quantum,
Japanese Invoicing Currency Share and Real Effective Exchange Rate

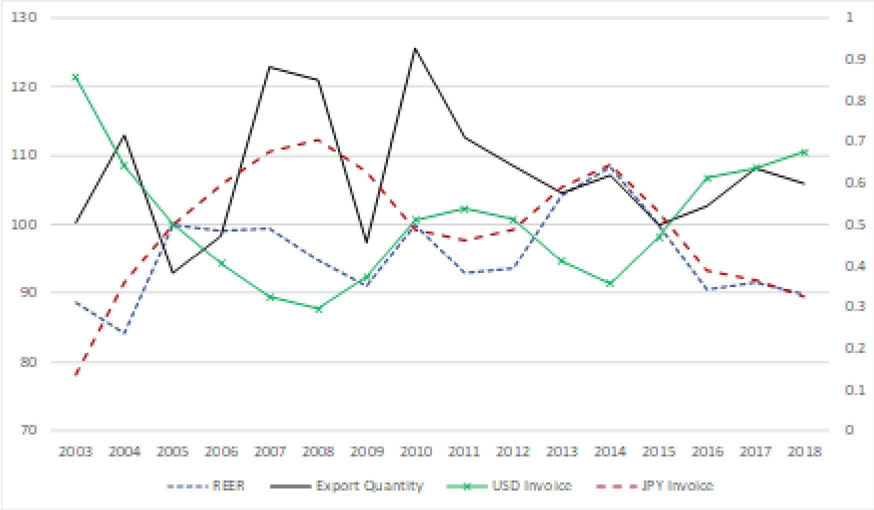
Figure 3-2-A. Passenger Cars



Note: Monthly data from 2003 to 2018. "REER" denotes product-specific real effective exchange rate (2015 = 100; left-hand side axis). "Export Quantity" denotes export quantum index (2015 = 100; left-hand side axis). "JPY Invoice" denotes the yen invoice share of Japanese exporters (right-hand side axis).

Source: Ministry of Finance and author's calculation.

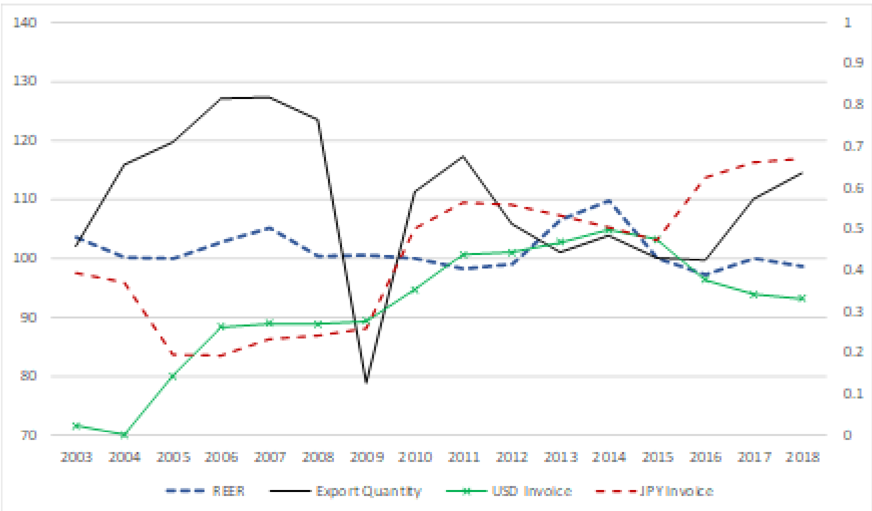
Figure 3-2-B. Electronic Integrated Circuits



Note: Monthly data from 2003 to 2018. "REER" denotes product-specific real effective exchange rate (2015 = 100; left-hand side axis). "Export Quantity" denotes export quantum index (2015 = 100; left-hand side axis). "JPY Invoice" denotes the yen invoice share of Japanese exporters (right-hand side axis).

Source: Ministry of Finance and author's calculation.

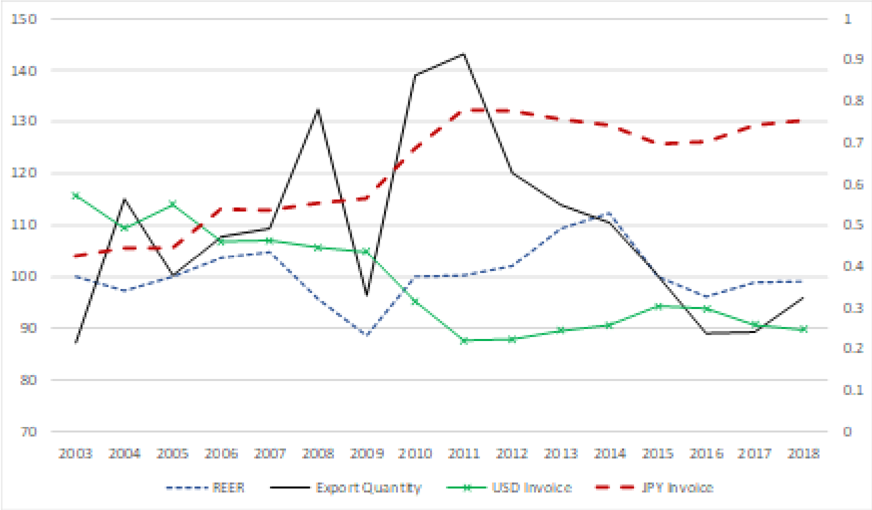
Figure 3-2-C. Power Generating Machinery



Note: Monthly data from 2003 to 2018. "REER" denotes product-specific real effective exchange rate (2015 = 100; left-hand side axis). "Export Quantity" denotes export quantum index (2015 = 100; left-hand side axis). "JPY Invoice" denotes the yen invoice share of Japanese exporters (right-hand side axis).

Source: Ministry of Finance and author's calculation.

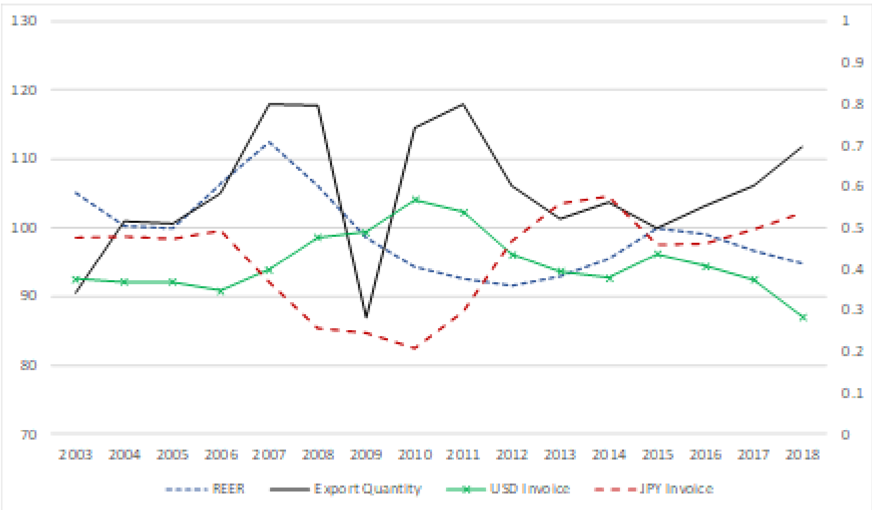
Figure 3-2-D. Pump Centrifuges



Note: Monthly data from 2003 to 2018. "REER" denotes product-specific real effective exchange rate (2015 = 100; left-hand side axis). "Export Quantity" denotes export quantum index (2015 = 100; left-hand side axis). "JPY Invoice" denotes the yen invoice share of Japanese exporters (right-hand side axis).

Source: Ministry of Finance and author's calculation.

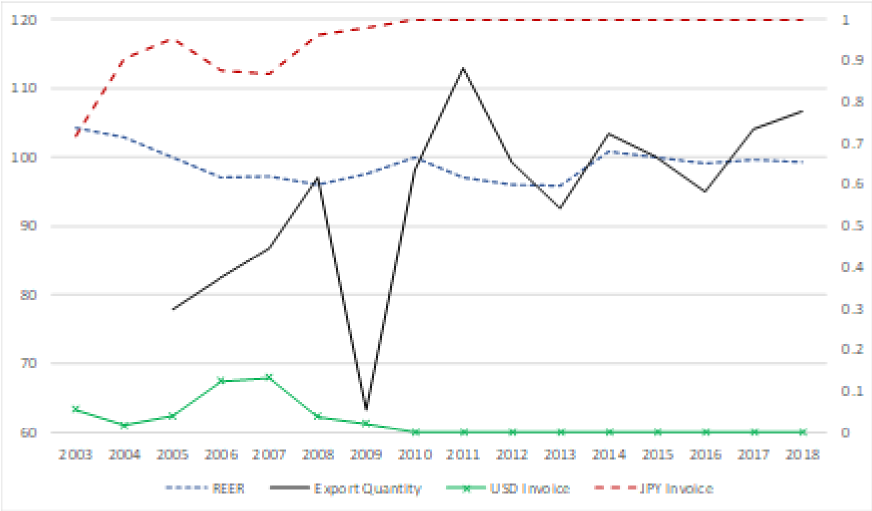
Figure 3-2-E. Mechanical Handling Equipment



Note: Monthly data from 2003 to 2018. "REER" denotes product-specific real effective exchange rate (2015 = 100; left-hand side axis). "Export Quantity" denotes export quantum index (2015 = 100; left-hand side axis). "JPY Invoice" denotes the yen invoice share of Japanese exporters (right-hand side axis).

Source: Ministry of Finance and author's calculation.

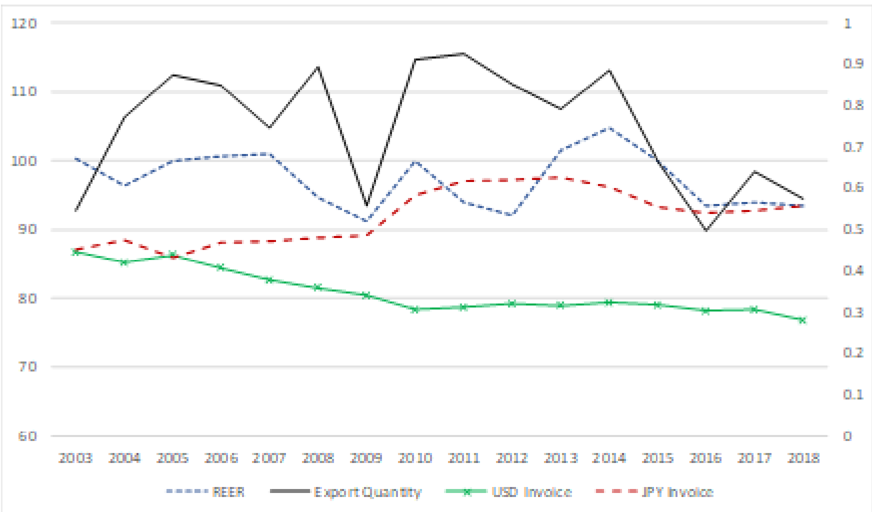
Figure 3-2-F. Semicon Machinery etc.



Note: Monthly data from 2003 to 2018. "REER" denotes product-specific real effective exchange rate (2015 = 100; left-hand side axis). "Export Quantity" denotes export quantum index (2015 = 100; left-hand side axis). "JPY Invoice" denotes the yen invoice share of Japanese exporters (right-hand side axis).

Source: Ministry of Finance and author's calculation.

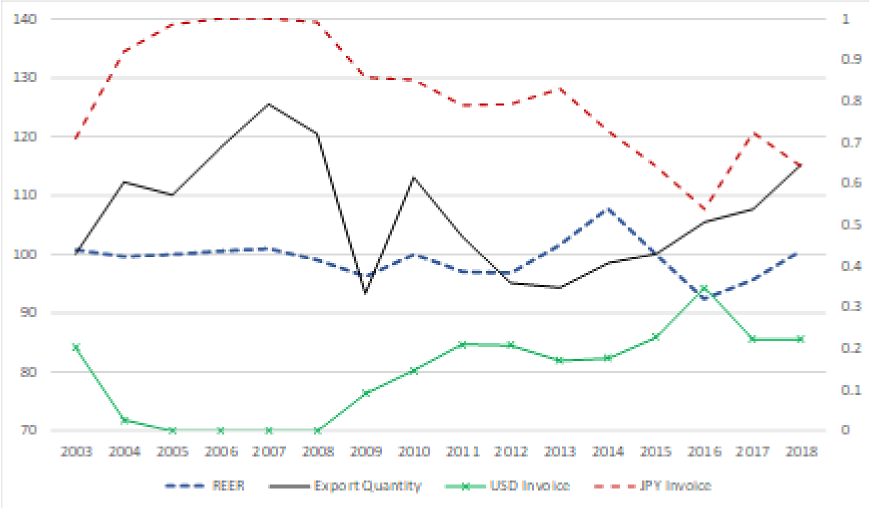
Figure 3-2-G. Scientific & Optical Equipment



Note: Monthly data from 2003 to 2018. "REER" denotes product-specific real effective exchange rate (2015 = 100; left-hand side axis). "Export Quantity" denotes export quantum index (2015 = 100; left-hand side axis). "JPY Invoice" denotes the yen invoice share of Japanese exporters (right-hand side axis).

Source: Ministry of Finance and author's calculation.

Figure 3-2-H. Medical Products



Note: Monthly data from 2003 to 2018. "REER" denotes product-specific real effective exchange rate (2015 = 100; left-hand side axis). "Export Quantity" denotes export quantum index (2015 = 100; left-hand side axis). "JPY Invoice" denotes the yen invoice share of Japanese exporters (right-hand side axis).

Source: Ministry of Finance and author's calculation.

Table 3-1. Determinants of Export Quantity

Figure 3-1-A. Benchmark Result (1)

Dependent variable: Commodity specific Export Quantum Index

Model: Fixed Effect

Dep: Export Quantity	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Period	2003-2018						2003-2008						2011-2018					
ln REER	0.384	0.352	0.532 #	0.532 #	0.509	0.508	-0.324 *	-0.311 *	-0.236	-0.235	-0.242	-0.190	0.280 #	0.281 #	0.346 *	0.343 *	0.371	0.380 *
	(0.254)	(0.242)	(0.282)	(0.271)	(0.182)	(0.274)	(0.126)	(0.123)	(0.282)	(0.160)	(0.341)	(0.160)	(0.150)	(0.152)	(0.148)	(0.141)	(0.214)	(0.133)
REER Volatolity		-7.045 #	-6.221	-6.215	-6.576	-6.570		-7.045	2.430	2.450	1.260	-0.423		-3.657	-2.951	-2.976	-2.905	-2.928 #
		(3.962)	(4.208)	(4.332)	(4.532)	(7.160)		(2.313)	(4.208)	(2.368)	(2.269)	(5.865)		(3.571)	(3.696)	(3.692)	(3.563)	(5.457)
Output Gap			3.043 **	3.045 **	2.722	2.722 **			0.988	0.996	0.576	0.660			1.981 **	1.941 **	2.246 **	2.239 **
			(0.718)	(0.645)	(0.789)	(0.689)			(0.804)	(0.794)	(1.019)	(0.831)			(0.718)	(0.507)	(0.480)	(0.495)
JPY Invoice				-0.003	-3.951 **	-0.029				-0.027	-1.647	0.114				0.027	-0.181	-0.138
				(0.243)	(4.241)	(0.298)				(0.096)	(1.622)	(0.179)				(0.126)	(2.542)	(0.156)
JPY Invoice * REER					0.862						0.370						0.047	
					(0.952)						(0.361)						(0.584)	
JPY Invoice * Vol.						3.906						4.401						19.454 *
						(14.813)						(6.539)						(8.942)
Constant	2.989 *	3.194 **	2.385 **	2.385 **	3.563 **	2.397 #	6.346 **	6.269 #	5.926 **	5.934	7.089 **	5.997 **	3.414 **	2.397 **	3.139 **	3.141 **	3.223 **	3.398 **
	(1.152)	(1.083)	(1.263)	(1.268)	(0.808)	(1.295)	(0.582)	(0.567)	(0.732)	(0.747)	(1.561)	(0.769)	(0.665)	(0.659)	(0.640)	(0.635)	(0.930)	(0.603)
NOB	558	558	558	558	558	558	208	208	208	208	208	208	280	280	280	280	280	280
F test	2.27	1.86	9.78 **	7.65 **	9.90 **	6.31 **	6.62 *	3.65 *	4.92 **	3.81 *	5.21 **	4.66 **	3.45 #	1.77	11.50 **	8.81 **	7.95 **	7.00 **

Notes: Figures in parenthesis represent robust standard error. **, * and # denote the 1 percent, 5 percent and 10 percent significance level, respectively. “Foreign Sales Ratio” is equal to foreign sales divided by total sales.

Source: Author’s Calculation

Figure 3-1-B. Benchmark Result (2)

Dependent variable: Commodity specific Export Quantum Index

Model: Fixed Effect

Dep: Export Quantity	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)
Period	2003-2018						2003-2008						2011-2018					
ln REER	0.509 #	0.508	0.508 #	0.506	0.503 #	0.499 #	-0.242	-0.190	-0.245	-0.187	-0.187	-0.188	0.371 *	0.380 *	0.325 *	0.343 #	0.348 *	0.292 #
	(0.265)	(0.306)	(0.267)	(0.314)	(0.279)	(0.286)	(0.153)	(0.155)	(0.282)	(0.161)	(0.162)	(0.168)	(0.146)	(0.167)	(0.139)	(0.161)	(0.154)	(0.147)
REER Volatolity	-6.576	-6.570	-7.466	-7.449	-5.980	-7.574	1.260	-0.423	2.046	-0.221	-0.396	-0.210	-2.905	-2.928	-10.083 #	-10.083 #	-2.829	-10.034 #
	(4.221)	(4.404)	(6.727)	(6.614)	(4.220)	(6.823)	(2.644)	(3.015)	(3.503)	(4.222)	(2.978)	(4.211)	(3.627)	(3.660)	(5.480)	(5.491)	(3.779)	(5.624)
Output Gap	2.722 **	2.722 **	2.705 **	2.703 **	2.689 **	2.655 **	0.576	0.660	0.577	0.660	0.661	0.661	2.246 **	2.239 **	2.337 **	2.337 **	1.950 **	2.047 **
	(0.649)	(0.661)	(0.686)	(0.705)	(0.616)	(0.650)	(0.820)	(0.798)	(0.820)	(0.799)	(0.803)	(0.805)	(0.497)	(0.506)	(0.464)	(0.476)	(0.540)	(0.521)
JPY Invoice	-0.022	-0.022	-0.043	-0.043	-4.265 *	-4.353 *	-0.058	-0.049	-0.044	-0.046	-0.212	-0.206	0.012	0.012	-0.144	-0.144	-2.197 *	-2.374 *
	(0.241)	(0.233)	(0.292)	(0.290)	(1.937)	(1.838)	(0.096)	(0.096)	(0.107)	(0.106)	(0.902)	(0.920)	(0.120)	(0.122)	(0.153)	(0.155)	(0.956)	(0.970)
JPY Invoice * Vol.			3.134	3.186		5.801			-3.089	-0.775		-0.718			18.619 *	18.623 *		18.754 #
			(14.024)	(14.907)		(13.816)			(7.510)	(7.809)		(7.891)			(8.989)	(9.100)		(9.297)
ln R&D	0.299 #	0.299 *	0.297 #	0.298 *	0.123	0.120 **	0.160	0.138	0.159	0.138	0.133	0.133	0.154 #	0.148 #	0.132	0.132 #	-0.003	-0.021
	(0.149)	(0.138)	(0.149)	(0.137)	(0.144)	(0.140)	(0.117)	(0.115)	(0.117)	(0.116)	(0.118)	(0.118)	(0.081)	(0.074)	(0.081)	(0.072)	(0.070)	(0.064)
Foreign Sales Ratio		-0.003		-0.015	-0.118	-0.141		0.485 *		0.484 *	0.486 *	0.484 *		0.052		-0.002	0.011	-0.045
		(0.375)		(0.408)	(0.293)	(0.326)		(6.539)		(0.214)	(0.213)	(0.215)		(8.942)		(0.243)	(0.228)	(0.230)
JPY Invoice * R&D					0.390 *	0.395 *					0.014	0.014					0.221 *	0.223 *
					(0.188)	(0.183)					(0.080)	(0.080)					(0.103)	(0.107)
Constant	-0.844	-0.842	-0.820	-0.814	1.192	1.266	4.197 *	3.974 *	4.216 *	3.979 *	4.016 *	4.020 *	1.299	1.290	1.809	1.810	3.053 **	3.592 **
	(2.613)	(2.705)	(2.650)	(2.760)	(2.211)	(2.226)	(1.658)	(1.689)	(1.690)	(1.725)	(1.651)	(0.769)	(1.397)	(1.416)	(1.383)	(1.412)	(1.064)	(0.978)
NOB	558	558	558	558	558	558	208	208	208	208	208	208	280	280	280	280	280	280
F test	8.19 **	9.32 **	6.68 **	7.90 **	8.24 **	7.39 **	5.26 **	5.02 **	5.16 **	5.03 *	4.33 **	4.41 **	7.11 **	5.98 **	7.18 **	6.27 **	5.96 **	7.30 **

Notes: Figures in parenthesis represent robust standard error. **, * and # denote the 1 percent, 5 percent and 10 percent significance level, respectively. “Foreign Sales Ratio” is equal to foreign sales divided by total sales.

Source: Author’s Calculatio

Appendix Table 3-A1. Survey Commodity and Companies

Table 3-A1-A. Machinery & Equipment (1)

Commodity Name	Company Name (company form contracted)	The Number of Firms
Machinery & Equipment		
Passenger Motor Car	Toyota Motor,Honda Motor,Suzuki,Daihatsu Motor,Nissan Motor,MAZDA Motor,SUBARU,Mitsubishi Motors	8
Buses, Tracks	Toyota Motor,Suzuki,Daihatsu Motor,Nissan Motor,Isuzu Motors,Hino Motors,Mitsubishi Fuso Truck and Bus ,MAZDA Motor,Honda Motor,SUBARU,Mitsubishi Motors,UD Trucks	12
Parts of Motor Vehicles	Honda Motor,Kawasaki Heavy Industries,SUBARU,Mitsubishi Heavy Industries,Kubota,Yamaha Motor,Toyota Industries,Isuzu Motors,Komatsu,UD Trucks,DENSO,Calsonic Kansei,Sanden,Kehin,DAIKIN INDUSTRIES	15
Motor Cycles	Yamaha Motor,Honda Motor,Kawasaki Heavy Industries,Suzuki	4
Ships	Mitsui E&S,Namura Shipbuilding,Kawasaki Heavy Industries,Sanoyas,SUMITOMO HEAVY INDUSTRIES,Naikai Zosen	6
Aircraft	Kawasaki Heavy Industries,ShinMaywa Industries,SUBARU,Honda Motor,Mitsubishi Heavy Industries,IHI,NEC,KYB,SHIMADZU,SINFONIA TECHNOLOGY,Sumitomo Precision Products,Nabtesco,Mitsubishi Materials,MinebeaMisumi,Yokogawa Electric,Ube Industries,TORAY,Hitachi Metals,Mitsubishi Chemical	19
Electric Power Machinery	TMEIC,Hitachi,Honda Motor,Fuji Electric,Denyo,SAWAFUJI ELECTRIC,SANYO DENKI,NISHISHIBA ELECTRIC,Meidensha,TOYO DENKI SEIZO,Panasonic,YASKAWA Electric,Hitachi Industrial Equipment Systems,Toshiba,Mitsubishi Electric,Origin Electric,Sanken Electric	17
Electrical Apparatus	Japan Aviation Electronics Industry,HIROSE ELECTRIC,DDK	3
Visual apparatus	Sharp,Panasonic,Toshiba,Sony,EIZO	5
Audio Apparatus	Sony, JVC KENWOOD, Pioneer,	4
Parts of Audio,Visual App.	JVC KENWOOD,Sony,Toshiba,Pioneer,Panasonic,Mitsubishi Electric,IKEGAMI TSUSHINKI,EIZO	8
Telecom.Equip.	Pioneer,Panasonic,Clarion,DENSO,JVC KENWOOD,Alpine Electronics	6
Dom.Electrical Equip.	Mitsubishi Heavy Industries,Subaru,Honda Motor,Mitsubishi Electric,NGK SPARK, PLUG,DENSO,Panasonic,KYOCERA,NEC,OMRON,Sharp,Toshiba,Sony,Nichicon,Maxell,Fujitsu,Showa Shell Sekiyu	18
Batterries and accumulators	Panasonic, GS Yuasa, NEC, Hitachi, Showa Denko Materials, Mitsubishi Heavy Industries, TOSHIBA, Sony, NISSAN MOTOR, SHARP, Idemitsu Kosan, KYOCERA, MITSUBISHI ELECTRIC, KANEKA, ULVAC	15
Transistors and diodes	Stanley Electric,CCS,ROHM SEMICONDUCTOR,Sanken Electric,Panasonic,TOYODA GOSEI,Daido Steel, Toshiba,Mitsubishi Electric,Shindengen Electric Manufacturing	10
Electronic integrated circuits	Toshiba,Sony,Renesas Electronics,Fujitsu Semiconductor,ROHM SEMICONDUCTOR,Panasonic	6
Electrcal measuring and controlling instruments	Aichi Tokei Denki,Azbil Kimmon,Osaka Electric,Mitsubishi Electric,Toshiba Toko Meter Systems,Fuji Electric Meter,Fukuda Denshi,NIHON KOHDEN,Suzuken,FUKUDA M-E KOGYO,OMRON COLIN,GE Healthcare Japan,Asahi Kasei Zoll Medical	13
Condenser	KOA,Panasonic,HOKURIKU ELECTRIC INDUSTRY,TEIKOKU TSUSHIN KOGYO,ROHM SEMICONDUCTOR,KOA,ALPS ELECTRIC,TOKYO COSMOS ELECTRIC,Nissin Electric,SHIZUKI ELECTRIC,Nichicon,Denso Yamagata,Hitachi Industrial Equipment Systems ,Mitsubishi Electric,Toshiba,Daihen,Fuji Electric,Meidensha,Takaoka Electric Mfg.,AICHI ELECTRIC	20

Notes: There are main companies in several segment sales from "the Company's Securities Report." This paper selected these firms by the Japan Market Share Book 2015 edition by the Yano Research Institute. This share is possibly different from real share of each commodity because "Segment Sales" are not under restriction and that often conclude other commodities.

Appendix Table 3-A1. Survey Commodity and Companies (cont.)

Table 3-A1-B. Machinery & Equipment (2)

Commodity Name	Company Name (company form contracted)	The Number of Firms
Machinery & Equipment		
Power generating machinery	Honda Motor,Kawasaki Heavy Industries,SUBARU,Mitsubishi Heavy Industries,Kubota,Yamaha Motor,Toyota Industries,Isuzu Motors,Komatsu,UD Trucks,Babcock-Hitach,IHI,Hitachi,Toshiba,Fuji Electric	15
Agricultural Machinery	Kubota,ISEKI,Mitsubishi Mahindra Agricultural Machinery,Honda Motor,IHI,MARUYAMA MFG.,Yamabiko,Yamabiko	8
Office machines	Toshiba,NEC,Fujitsu,Seiko Epson,Panasonic,MITSUMI ELECTRIC,Hitachi,Toshiba,SUBARU,RISO KAGAKU,RYOBI	11
Metal Working machines	AMADA,Kobe Steel,Kawasaki Hydromechanics,Kojima Iron Works,Komatsu,AIDA ENGINEERING,IHI,Kurimoto,NIDEC-SHIMPO,Sumitomo Heavy Industries Techno-Fort,Ube Industries,SINTOKOGIO,TOSHIBA MACHINE,TOYO MACHINERY & METAL,Mitsubishi Materials Techno,Fuji Electric	16
Textile Mach.	JUKI,BROTHER INDUSTRIES,JANOME SEWING MACHINE,PEGASUS SEWING MACHINE MFG. ,AISIN SEIKI,Mitsubishi Electric,TMT Machinery,Ishikawa Seisakusho,Toyota Industries,Tsudakoma,Takatori,KAJI TECHNOLOGY,SHIMA SEIKI MFG.,HISAKA WORKS,HIRANO TECSEED	15
Construction Machines	Komatsu,Hitachi Construction Machinery,KOBELCO CONSTRUCTION MACHINERY ,Kubota,KATO WORKS,IHI Construction Machinery,Nippon Sharyo,SHINKO ENGINEERING,HOKUETSU INDUSTRIES,Sumitomo Construction Machinery,Takeuchi Mfg,Mitsubishi Heavy Industries,Sumitomo Heavy Industries Material Handling Systems,Mitsui E&S,IHI Transport Machinery,Hitachi Plant Technologies,TADANO,Kobelco Cranes,Sumitomo Heavy Industries Construction Cranes,AICHI,SAKAI HEAVY INDUSTRIES,Kawasaki Heavy Industries,Hitachi Construction Machinery Camino	23
Heating or Cooling Machine	Mitsubishi Electric,Mitsubishi Heavy Industries,Hitachi Building Systems,TOSHIBA Carrier,DAIKIN INDUSTRIES,Panasonic,FUJITSU GENERAL,Sharp,CORONA	9
Pump Centrifuges	Ebara,Hitachi Industrial Equipment Systems ,Mitsubishi Heavy Industries,Kubota,TORISHIMA PUMP MFG.,DMW,NIKKISO,Shin Nippon Machinery,TSURUMI MANUFACTURING,ShinMaywa Industries	10
Mechanical Handling Equipments	Mitsubishi Heavy Industries, IHI, SUMITOMO HEAVY INDUSTRIES, Hitachi	4
Bearings	NSK,JTEKT,NTT,NACHI-FUJIKOSHI,MinebeaMisumi	5
Semicon Machinery etc.	TOKYO SEIMITSU,Hitachi High-Technologies,SINFONIA TECHNOLOGY,Advantest,SCREEN,A&D Company,Hitachi High-Tech Science,Shibuya Kogyo,Tokyo Electron,RORZE,Hitachi Kokusai Electric,Daitron,ULVAC,Showa Shinku,Canon,Nikon,TORAY,OMRON,TOHO Chemical Industry,Sumitomo Precision Products,Hirata,DISCO,Y.A.C	23

Notes: There are main companies in several segment sales from "the Company's Securities Report." This paper selected these firms by the Japan Market Share Book 2015 edition by the Yano Research Institute. This share is possibly different from real share of each commodity because "Segment Sales" are not under restriction and that often conclude other commodities.

Appendix Table 3-A1. Survey Companies in Panel Analysis (cont.)

Table 3-A1-C. Machinery & Equipment (3)

Commodity Name	Company Name (company form contracted)	The Number of Firms
Machinery & Equipment		
Organic Chemicals	Mitsui Chemicals,Osaka Oil Chemical,SUMITOMO CHEMICAL,Mitsubishi Chemical,Nippon Petrochemicals,Tonen Chemical,TOSOH,Maruzen Petrochemical,KEIYO POLYETHYLENE,Asahi Kasei,Idemitsu Kosan,Showa Denko,TonenGeneral Sekiyu,KYOKUTO PETROLEUM INDUSTRES,JXTG Nippon Oil & Energy,Nippon Petroleum Refining,KAC,Japan Energy,Cosmo Matsuyama Oil,TOA Oil,SHOWA YOKKAICHI SEKIYU,Seibu Oil,Fuji Oil,NIPPON STEEL Chemical,NA aromatic,JFE Chemical,NIPPON STEEL Chemical & Material,KH Neochem,KASHIMA OIL,CM aroma,Showa Shell Sekiyu,Keiyo Monomer,KANEKA,SUN ARROW,V-Tech,MITSUBISHI RAYON,KURARAY,MITSUBISHI GAS CHEMICAL,Denka,Nippon Polyurethane Industry,Ube Industries,TORAY,NIPPON OIL,Teijin	44
Inorganic Chemicals	AGC,Asahi Kasei,Denka,HOKKAIDO SODA,Ishihara Sangyo Kaisha,KANEKA,Kanto Denka Kogyo,Kureha,Nippon Light Metal,Nippon Soda,Osaka Soda,Shin-Etsu Chemical,Showa Denko,Showa Chemical Industry,SUMITOMO CHEMICAL,Toagosei,Tokuyama,TOSOH	18
Dyeing Tanning,Colouring	Nippon Paint, KANSAI PAINT, SK KAKEN, CHUGOKU MARINE PAINTS, Dai Nippon Toryo Company, SHINTO PAINT, ROCK PAINT	7
Medical Products	Takeda Pharmaceutical,Astellas Pharma,Daiichi Sankyo,CHUGAI PHARMACEUTICAL,Mitsubishi Tanabe Pharma,Otsuka Pharmaceutical,Eisai,Kyowa Hakko Kirin Company,Sumitomo Dainippon Pharma,SHIONOGI	10
Plastic Materials	TORAY,Teijin,NIPPON-ESTER,UNITIKA TRADING,TOYOBO,KURARAY,MITSUBISHI RAYON,Kanebo Seren,Asahi Kasei,Daiwabo Polytec,SUMITOMO CHEMICAL,Mitsubishi Chemical,Mitsubishi Chemical,Mitsui Chemicals,NUC,Ube Industries,TOSOH,TOSOH,Japan polyethylene,Prime Polymer,Evolue Japan,Mitsui Chemicals,Asahi Kasei Chemicals,Maruzen Polymer,UMG ABS,Techno Polymer,NIPPON A&L,Denka,SunAllomer,Tokuyama,KANEKA,Shin Dai-ichi Vinyl,AGC,Nissan Chemical,Mitsui Chemicals,Mitsubishi Chemical MKV,The Nippon Synthetic Chemical Industry ,Shin-Etsu Chemical,Unitika,MITSUBISHI GAS CHEMICAL,DAIKIN INDUSTRIES,Chemours-Mitsui Fluoroproducts,Kureha,Asahi Kasei Epoxy,NIPPON STEEL Epoxy Manufacturing ,DIC,Nippon Kayaku,NIPPON EPOXY RESIN MANUFACTURING,Teijin Chemicals,Idemitsu Kosan,Sumika Polycarbonate,NIPPON SHOKUBAI,San-Dia Polymers,Sumitomo Seika Chemicals,Kao,JAPAN VAM & POVAL,Shin-Etsu Chemical	57
Scientific & Optical Equipment	Canon Medical Systems,GE Healthcare Japan,Hitachi	3
Watches and Clocks	Citizen Watch, CASIO COMPUTER, Seiko Holdings, RHYTH, Jeco	5

Notes: There are main companies in several segment sales from "the Company's Securities Report." This paper selected these firms by the Japan Market Share Book 2015 edition by the Yano Research Institute. This share is possibly different from real share of each commodity because "Segment Sales" are not under restriction and that often conclude other commodities.

Conclusion

This dissertation is based on the research question why Japanese export quantity has become less responsive to exchange rate depreciation. In order to elucidate this question, this dissertation conduct three analysis about Japanese exports and pricing behavior.

The first paper investigates possible effect of export competitiveness on exchange rate pass-through in Japanese exports. This paper has two main contribution; this paper utilizes Kalman filter technique and estimate time-varying parameter of ERPT by export commodity. Moreover, this paper extensively collected the firm-level data from 831 Japanese manufacturing firms and constructed the product-level explanatory variables, R&D expenditure, foreign sales ratio and number of employees.

The two main contributions of this paper; the first contribution is that this paper reveal the asymmetric pricing behavior of Japanese exporters. Japanese firms increased the degree of ERPT from around 2008 to 2012. In contrast to yen appreciation period, Japanese export price did not decline because they are differentiated and competitive with low price elasticity. Instead, Japanese machinery exporters returned to the PTM behavior, enjoying large foreign exchange gains. Furthermore, this paper found that the pricing behaviors differ between commodity. As the second contribution, this paper reveals R&D expenditure, as a proxy variable, has the positive and significant impact on PTM behavior in yen appreciation period. This is possibly because Japanese exporters with strong export competitiveness tried to keep local price although they suffered large exchange rate deficit during yen appreciation period.

The second part of this dissertation estimated time-varying parameter of invoice currency share of Japanese exporters and conduct empirical analysis with panel method so as to demonstrate Japanese export firms strategically changed the choice of invoicing currency during the yen appreciation and depreciation periods. This paper prepared invoice currency share of 50 commodity sectors and aggregated firm-level data, as with the first paper of this dissertation. Moreover, this paper conducts panel analysis with time-varying invoice currency share and firm-level data, such as R&D expenditure, foreign sales and number of employees.

There are two main findings in the second paper. Firstly, it is found that the choice of invoicing currency of Japanese exporters differ across period and industry. Secondly, this paper discusses the factors in determining the choice of invoicing currency. Additionally, this paper focuses on export competitiveness. As a result of panel analysis, it is revealed that exporters with export competitiveness significantly tended to increase yen invoiced exports and tried to avoid the deficit from exchange rate depreciation during yen appreciation period (2007 - 2012).

As compared to the first paper, the effect of export competitiveness is different from the result of the second paper. In general, the choice of invoicing currency captures the short-run impact of exchange rate on pricing strategy. On the other hand, in terms of the long-run strategy, exporters could change or not change the export price not only by invoicing currency choice, but also product price and so on. In summary, this dissertation argues that the Japanese export firms with strong competitiveness tended to utilize Japanese yen as an invoice currency and avoid the risk of sharp depreciation in the short-run pricing strategy. In contrast, they tried to keep the local price and conduct PTM behavior in the long-run pricing strategy.

In the third paper, it was conducted to investigate the unresponsiveness of Japanese export quantity to exchange rate changes by using 35 product-level data on Japan's export quantity. As with the first and second papers, this survey also collected firm-characteristic data from annual security reports of 472 Japanese export companies. In addition, this paper construct product-specific real effective exchange rate to measure the degree of elasticity of exchange rate.

This paper reveals the difference between the Pre-GFC period, the Post-GFC period in terms of the determinants of export quantity fluctuation. In the Pre-GFC period, the REER appreciation (depreciation) has negative (positive) effect on Japan's export quantity. Moreover, higher foreign sales ratio will lead to an increase in export quantity before the GFC. In contrast, after the GFC, the product-level REER appreciation tends to increase Japan's export quantity. In addition, as a result of the third paper, it is found that the REER volatility has negative effect on Japan's export quantity. Moreover, Firms' R&D expenditure is found to have positive and significant effect on Japan's export quantity. Since R&D is often considered a source of export competitiveness, this result suggests that Japanese export firms with strong export competitiveness tend to increase their export quantity. These results demonstrate that the determinants of export quantity were drastically changed between Pre-GFC and Post-GFC.

Finally, for these surveys, this dissertation implies that the quantity of Japanese exports is significantly affected by pricing behavior of exporters and export competitiveness. It is important to develop the export competitiveness in order to promote Japanese export, suffering under unstable exchange rate fluctuation.