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# **Abenomics, Yen Depreciation, Trade Deficit, and Export Competitiveness**

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## Abstract

Prime Minister Shinzo Abe's economic stimulus package, Abenomics, depreciated the yen sharply from the end of 2012, which was expected to have a positive impact on Japan's trade balance. Contrary to the J-curve effect, however, Japan's trade balance has not shown any signs of improvement, even though two years have passed. There is a growing concern that Japanese firms might lose their export competitiveness in the global market. This paper shows that Japanese firms conducted a strategic relocation of their production bases by expanding their overseas production of low-end products, while domestic production is concentrated more on high-end products. This new phase of international division of labor is likely to impede the positive effect of the yen depreciation on Japan's trade balance, which is empirically supported by the auto-regressive distributed lag (ARDL) model. In addition, Japanese manufacturing export prices in terms of the contract (invoice) currency have not changed in response to the large depreciation of the yen, which is empirically confirmed by the time-varying parameter estimation of the exchange rate pass-through analysis. Thus, the slow recovery of Japan's trade balance in response to the yen depreciation can be explained by the Japanese firms' pricing behavior as well as the changes in their production and trade structure.

*JEL Classification:* F23, F31, F33

*Keywords:* Abenomics, J-curve effect, Exchange rate pass-through, Pricing-to-market (PTM), Export competitiveness, Invoice currency, Auto-regressive distributed lag (ARDL) model, Time-varying parameter estimation

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## 1. Introduction

After the collapse of Lehman Brothers in September 2008, the Japanese yen started to appreciate sharply and hit the post-war record high (75.32 vis-à-vis the US dollar) in March 2011. Such an unprecedented level of yen appreciation at around 80 or less continued up to November 2012. The economic-stimulus package initiated from the end of 2012 by Prime Minister Abe, so-called *Abenomics*, successfully reversed the yen appreciation. A rapid and large depreciation of the yen was expected to have a positive impact on Japanese trade balance. According to the J-curve effect, after initial deterioration in response to the domestic currency depreciation, trade balance will improve gradually due to a decline of export price in terms of the destination currency. However, Japanese trade balance, especially the quantity of Japanese exports, has not readily improved, even though the yen depreciated rapidly from less than 80 in 2012 to around 120 in 2014. It has been a matter of major concern for policy makers that Japanese firms might lose export competitiveness in the global market.

This paper empirically investigates why Japanese trade deficit continues to grow despite the substantial depreciation of the yen from the following two aspects. First, by using the auto-regressive distributed lag (ARDL) model, it is demonstrated that J-curve effect does not work well in Japanese trade from 1999 to 2014, while it is empirically confirmed from 1985 to 1998. Japanese firms established regional production network in Asia, but the sharp appreciation of the yen from 2008 to 2012 pushed the international division of labor one step further by concentrating domestic production more on differentiated products for exports. The low-end or less differentiated goods are shifted to overseas production by Japanese manufacturing subsidiaries. This drastic change in production and trade structure is likely to increase imports of intermediate inputs and low-end products from overseas subsidiaries, which weakens a positive impact of yen depreciation on Japanese trade balance.

Second, the above observation is empirically supported by an analysis of exchange rate pass-through of Japanese exporting firms. Casual observation of the export price data published by Bank of Japan (BOJ) shows that Japanese machinery export price in terms of the contract (invoice) currency has not changed in response to large exchange rate fluctuations of the yen. However, by conducting the time-varying parameter estimation of the exchange rate pass-through in Japanese machinery exports, we demonstrate that Japanese firms pursue different pass-through behavior in response to asymmetric exchange rate changes in the yen. Although it is widely known that Japanese exporters have a strong tendency to pursue pricing-to-market (PTM) behavior,

the unprecedented appreciation of the yen from 2009 to 2012 drastically changed the pricing behavior of Japanese exporters by raising the degree of exchange rate pass-through. In contrast, once the yen started to depreciate from the end of 2012, Japanese firms quickly came back toward, though not completely, the previous level of PTM, which hinders a decline of export price in destination countries and, hence, weakens a positive impact of yen depreciation on trade balances. Such an asymmetric response of exchange rate pass-through and PTM is observed in Japanese major machinery industries.

Thus, the slow recovery of Japanese trade balance in response to the yen depreciation can be explained by the Japanese firms' pricing behavior as well as the drastic change in Japanese firms' production and trade structure caused by the unprecedented level of yen appreciation before Abenomics. A sharp fall in the world oil price from the latter half of 2014 reduces the amount of Japanese imports, which has positive impact on trade balance. However, given growing overseas operation of Japanese firms, Japanese export quantity will not be readily increasing. It is more important to look at income balance as well as trade balance.

The remainder of this paper is organized as follows. Section 2 describes the current characteristics of Japanese trade. Section 3 empirically analyzes the impact of yen depreciation on Japanese trade balance by using the ARDL model. Section 4 observes the export price data published by BOJ and conducts a time-varying parameter estimation of the exchange rate pass-through in Japanese machinery exports. Finally, Section 5 concludes.

## **2. What are the main factors in Japanese trade deficit?**

Trade deficit has become almost the norm in Japan since the Great East Japan Earthquake that occurred in March 2011. Figure 1 shows the monthly series of Japan's trade balance and the nominal exchange rate of the yen vis-à-vis the US dollar from January 2010 to December 2014. The yen kept appreciating in 2010 and stayed at around 80 or less from the mid-2011 to the end of 2012. In October 31, 2011, the yen hit a post-war record high of 75.32. Such a high value of the yen is likely to have negative impact on trade balance through a fall of Japanese exports. Table 1 shows that, in response to the yen appreciation, the amount of Japanese exports declined from 2010 to 2012 in all industries except raw materials.

Another important factor in the growing trade deficit from 2010 to 2012 is a

sharp increase in imports of oil and mineral fuels. According to Table 1, Japanese imports of mineral-related fuels grew remarkably: The amount of imports rose by 38.5 percent from 2010 to 2012, due to a sharp increase in imports of liquefied natural gas (LNG) for generating thermal power prompted by the suspension of nuclear power plants.

From the end of 2012, the yen started to depreciate substantially. In terms of the annual average exchange rate, the yen depreciated from 79.79 in 2012 to 105.84 in 2014 (Table 1). Despite such a large depreciation by 32.6 percent, Japan's trade deficit increased further in 2013 and stayed at a high level in 2014. According to the J-curve effect, trade balance tends to deteriorate at the beginning of depreciation of the domestic currency, and the trade balance will be improving over time. The question is why such gradual improvement of trade balance cannot be observed in 2014.

First possible reason is the effect of invoice currency. Table 1 shows that Japanese imports increased in 2013 and further in 2014 in all industries. As will be shown in Section 4, the share of foreign currency invoicing is larger than that of yen invoicing in Japanese exports and imports. Since about 79 percent of imports are invoiced in foreign currencies (mostly in US dollars), the yen depreciation automatically increases the amount of imports in the yen.<sup>1</sup> However, imports of mineral-related fuels increased only slightly in 2014, even though the yen depreciated further from 97.6 in 2013 to 105.84 in 2014. Such slowdown can be attributed to a sharp and large fall in world oil prices in the latter half of 2014, which may help the trade balance improve in 2015 and after.

Second possible reason is the Japanese firms' strategic change in production place during the yen appreciation period. As shown in Figure 2, Japanese firms increased overseas production for the last two decades, which reflects active division of labor in growing regional production network, especially in Asia. The historically high level of the yen in 2011-2012 drove Japanese firms to take the division of labor one step further by moving domestic production of low-end goods to overseas subsidiaries to the limit. Instead, Japanese firms concentrated their domestic production on high-end products. Given severe competition in global markets, it is hard to keep exporting domestically produced goods during the period of unprecedented yen appreciation unless the goods are highly differentiated.

Even after the yen started to depreciate in the end of 2012, the quantity of Japanese exports does not show any clear increase. Table 2 presents the export quantity

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<sup>1</sup> The data on the invoice currency is available from the website of the Trade Statistics of Japan (<http://www.customs.go.jp/toukei/info/index.htm>).

of selected products.<sup>2</sup> Electronics parts and components including integrated circuits (ICs) exhibit a large decline in export quantity. Export quantity of audiovisual products also fell sharply. In contrast, export quantity of motor vehicles and parts of motor vehicles does not decline much compared to electronic products. This evidence supports the above argument that Japanese firms export the high-end products and produce the low-end products in the foreign countries. According to Table 3, the quantity of Japanese imports of manufacturing products such as automobile parts and ICs increased after the yen depreciation, which is another supportive evidence that Japanese firms enhanced the division of labor much further with overseas subsidiaries by importing parts and components as well as low-end products from subsidiaries.

Thus, to overcome the negative effect of yen appreciation in 2010-2012, Japanese firms drastically changed their production and export structure. Even during the yen depreciation period, Japanese exporters do not have to lower the export price, because their export products are differentiated and, hence, have strong export competitiveness. Given a large share of foreign currency invoicing as well as the above pricing behavior, Japanese exporters can enjoy exchange gains from yen depreciation. The low-end products are less differentiated and tend to be highly price elastic, but these products are produced by overseas subsidiaries and not exported from Japan. These factors are likely to impede the improvement of Japanese trade balance.

The next two sections attempt to empirically support the above argument. In Section 3, the J-curve effect of Japanese trade is tested by the ARDL model. In Section 4, Japanese exporters pricing behavior will be empirically investigated by employing the time-varying parameter estimation of the exchange rate pass-through.

### **3. Empirical analysis of J-Curve effect**

There are numerous empirical studies on the J-curve effect.<sup>3</sup> As a representative study on the trade between the United States and Japan, Rose and Yellen (1989) used the quarterly data for the period from 1960 to 1985, but they could not find both short-run and long-run relationship between bilateral real exchange rates and trade flows. Bahmani-Oskooee and Brooks (1999), on the other hand, employed the auto-regressive distributed lag (ARDL) model that incorporates both cointegration

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<sup>2</sup> The selection of products is based not only on the availability of the export quantity data but also on the amount of exports.

<sup>3</sup> Bahmani-Oskooee and Ratha (2004) provide the extensive literature review on the empirical papers of the J-curve effect.

relationship and error-correction model (ECM) between US and its trading partners. They found that the long-run effect of real depreciation of the US dollar improved the US trade balance, while the short-run effect did not follow the J-curve pattern. Using the quarterly bilateral data from 1973 to 1998, Bahmani-Oskooee and Goswami (2003) employed the ARDL model to analyze the relationship between Japan and its nine major trading partners, confirming the evidence of the J-curve effect between Japan and Germany as well as between Japan and Italy.<sup>4</sup>

In this section, we empirically analyze the effect of the real effective exchange rate (REER) on Japanese trade balance by using the ARDL model over the sample period from January 1985 to June 2014, including the recent yen depreciation period due to Abenomics. We divide the whole sample in two sub-samples: the former includes the period from January 1985 to December 1998 when the J-curve effects were empirically confirmed, and the latter ranges from January 1999 to June 2014. As shown in Figure 2, the overseas production ratio of Japanese manufacturing companies exceeded 10 percent in the end of 1998. In addition, the revised Foreign Exchange Law was enforced in April 1998 to totally liberalize cross-border transactions, which results in a drastic change of the Japanese firms' exchange rate risk management. As we have to have sufficient number of observations in each sub-sample, it is reasonable to assume that the latter sub-sample starts from January 1999.

### 3-1. Model

Following Rose and Yellen (1989) and other previous studies cited above, we employ the following log-linear equation model to consider a long-run relationship between trade balance and REER:

$$\ln TB_{Japan,t} = a + b \cdot \ln Y_{Japan,t} + c \cdot \ln Y_{World,t} + d \cdot \ln REER_{Japan,t} + \varepsilon_t \quad (1)$$

where  $TB_{Japan,t}$  is a measure of the Japan's trade balance,  $Y_{Japan,t}$  is a measure of the Japan's real income,  $Y_{World,t}$  is a measure of the foreign countries' real income, and  $REER_{Japan,t}$  is the real effective exchange rate of the yen.<sup>5</sup> As a measure of the trade balance, we adopt the ratio of Japan's real exports to the world over her real imports

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<sup>4</sup> They also found that real depreciation of the yen has favorable long-run effects in the cases of Canada, UK and the United States.

<sup>5</sup> In this analysis, we use REER of the yen (narrow indices) published by Bank for International Settlements (BIS).

from the world.<sup>6</sup>

Since we use the monthly series of the data for empirical analysis, we employ the industrial production index (IPI) as a proxy for the Japan's real income. The Japan's IPI series is taken from the website of the Ministry of Economy, Trade and Industry (METI), Japan. As for a measure of the world real output fluctuations, we calculated the World IPI, i.e., the weighted average of IPI of Japan's 20 trading partner countries.<sup>7</sup> Based on the definition of the above variables, we expect the sign of estimated coefficients as  $b < 0$ ,  $c > 0$  and  $d < 0$ . In addition, we include two dummy variables in the latter period. One is the dummy variable (Lehman dummy) for the period of the Lehman Brothers collapse when Japanese exports declined drastically. The other is the dummy variable of the Great East Japan Earthquake (*Shinsai* dummy) that reflects the prolonged negative effect of the earthquake in March 2011 on the Japan's trade deficit.<sup>8</sup>

In order to elucidate both long-run and short-run effects of real appreciation/depreciation of the yen, we follow Pesaran *et al.* (2001), which places both the level and the first difference of each variable in a single-equation ECM. We specify equation (1) as an ARDL form with lag lengths  $n$  as follows:<sup>9,10,11</sup>

$$\begin{aligned} \Delta \ln TB_{Japan,t} = & a + \sum_{k=1}^{n1} b_k \cdot \Delta \ln TB_{Japan,t-k} + \sum_{k=0}^{n2} c_k \cdot \Delta \ln Y_{Japan,t-k} + \sum_{k=0}^{n3} d_k \cdot \ln Y_{World,t-k} \\ & + \sum_{k=0}^{n4} e_k \cdot \Delta \ln REER_{Japan,t-k} + \delta_1 \cdot \ln TB_{Japan,t-1} + \delta_2 \cdot \ln Y_{Japan,t-1} \\ & + \delta_3 \cdot \ln Y_{World,t-1} + \delta_4 \cdot \ln REER_{Japan,t-1} + \delta_5 \cdot D_{Lehman} + \delta_6 \cdot D_{Shinsai} + \\ & \mu_t. \quad (2) \end{aligned}$$

<sup>6</sup> Rose and Yellen (1989) also use the real exports and imports to measure the trade balance in equation (1). We obtain the real export and real import data from the website of Bank of Japan.

<sup>7</sup> The IPI series are taken from the CEIC Database. 20 trading partner countries are chosen by the share of each trading partner country in Japan's total exports. The share of each country accounts for at least 1 percent or more in Japan's total exports as of 2005.

<sup>8</sup> The Lehman dummy takes 1 in the period between October 2008 and March 2009. The Great East Japan Earthquake (*Shinsai*) dummy takes 1 after March 2011, and takes 0 otherwise.

<sup>9</sup> Pesaran *et al.* (2001) call this model "Conditional ECM".

<sup>10</sup> The ARDL/Bounds Testing methodology of Pesaran *et al.* (2001) has some advantages over conventional cointegration testing: first, the methodology can be used with a mixture of I(0) and I(1) data; second, it involves just a single-equation set-up, making it simple to implement and interpret; and third, different variables can be assigned with different lag-lengths as they enter the model.

<sup>11</sup> We select the lag length of each variable by Akaike Information Criterion (AIC) and the Schwarz Criterion (SC).



In this setup, we focus not only on the sign and significance of the estimated coefficient,  $e_k$ , which indicates the short-run effects of REER on trade balance, but also on those of the estimated coefficient,  $\delta_4$ , which indicates the long-run effects of REER on trade balance. If we find both positive coefficient for  $e_k$  and negative coefficient for  $\delta_4$ , the J-curve phenomenon will be confirmed.

### 3-2. Results of ARDL Estimation

Before estimating equation (2), we check the time-series property of all variables. Table 4 shows that all variables are non-stationary in level and stationary in first-differences in both sub-sample periods. We also ran the Johansen cointegration test and found at least one cointegration relationship among the variables in both sub-sample periods.

The results of the ARDL estimation are presented in Table 5 (January 1985-December 1998) and Table 6 (January 1999-June 2014). At first, we have to perform both the Wald test and the Bounds  $F$ -test proposed by Pesaran *et al.* (2001), where the hypothesis is  $H_0: \delta_1=\delta_2=\delta_3=\delta_4=0$  and the rejection of  $H_0$  implies that we have a long-run equilibrium relationship. The lowest two rows in Tables 5 and 6 show the result of the Wald test and the  $F$ -test statistic of the former and latter periods is 5.670 and 3.752, respectively. According to the Table CI (iii) on page 300 on Pesaran *et al.* (2001), the lower and upper bounds for the  $F$ -test statistic (in the case of  $k=3$ ) at the 1%, 5%, and 10% significance levels are [4.29, 5.61], [3.23, 4.35], [2.72, 3.77], respectively. The  $F$ -statistic exceeds the upper bound at the 1% significance level in the former period, but it fails to exceed the upper bound in the later period. In addition, the  $t$ -statistics of  $\delta_1$  (the coefficient of Japan's trade balance) in the former and latter periods are -4.023 and -2.295, respectively. According to the Table CII (iii) on page 303 on Pesaran *et al.* (2001), the lower and upper bounds for the  $F$ -test statistics (in the case of  $k=3$ ) at the 1%, 5%, and 10% significance levels are [-3.43, -4.37], [-2.86, -3.78], [-2.57, -3.46], respectively. In the former period, our  $F$ -statistic exceeds the upper bound at the 5% significance level, but it fails to exceed the upper bound in the later period. Accordingly, we can conclude that there is evidence of a long-run relationship between trade balance, REER, Japanese IPI and World IPI only in the former period. When looking at the estimated coefficients of the lagged REER in first-differences in the former period, some of them are positive and significant. These results indicate the existence of the J-curve effects. Comparing the results between two periods, the absolute value of the estimated coefficient of  $\delta_3$  in the former period (-0.204) is larger

than in the later period (-0.094). Furthermore, the coefficients of the first-differenced REER are all positive from the current to the 9th-lag in the former period, which is clear evidence of the J-curve effect, while some of the coefficients in the latter period are negative.

In order to confirm the above results, we estimate the usual ECM as well. Assuming that the bounds test confirms the variables are cointegrated, we can estimate not only the following long-run equilibrium relationship:

$$\begin{aligned} \ln TB_{Japan,t} = & \alpha_0 + \alpha_1 \cdot \ln Y_{Japan,t} + \alpha_2 \cdot \ln Y_{World,t} + \alpha_3 \cdot \ln REER_{Japan,t} \\ & + \alpha_4 \cdot D_{Shinsai} + \alpha_5 \cdot D_{Lehman} + \varepsilon_t \end{aligned} \quad (3)$$

but also the usual ECM:

$$\begin{aligned} \Delta \ln TB_{Japan,t} = & \beta_0 + \beta_1 \cdot EC_{t-1} + \sum_{k=1}^n \gamma_k \cdot \Delta \ln TB_{Japan,t-k} + \sum_{k=0}^n \theta_k \cdot \Delta \ln Y_{Japan,t-k} \\ & + \sum_{k=0}^n \rho_k \cdot \Delta \ln Y_{World,t-k} + \sum_{k=0}^n \varphi_k \cdot \Delta \ln REER_{Japan,t-k} + \mu_t \end{aligned} \quad (4)$$

where  $EC_{t-1}$  is the error correction term which is constructed as the residual series of equation (3). We confirm that the coefficient of the error-correction term,  $\beta_1$ , is negative and significant, which is another evidence of cointegration between trade balance, Japan's IPI, World IPI, and REER of the yen. Tables 7 and 8 summarize both results in the former and latter period, respectively. From the estimated results, we can establish the following long-run equilibrium relationship between trade balance and other variables (figures in parentheses are standard errors).

Jan 1985 to Dec 1998:

$$\begin{aligned} \ln TB_{Japan,t} = & 4.600 - 0.989 \cdot \ln Y_{Japan,t} + 0.178 \cdot \ln Y_{World,t} - 0.242 \cdot \ln REER_{Japan,t} + \varepsilon_t \\ & (0.269) \quad (0.067) \quad (0.064) \quad (0.034) \end{aligned}$$

Jan 1999 to June 2014:

$$\begin{aligned} \ln TB_{Japan,t} = & -6.154 + 0.299 \cdot \ln Y_{Japan,t} + 1.083 \cdot \ln Y_{World,t} - 0.047 \cdot \ln REER_{Japan,t} \\ & (0.502) \quad (0.062) \quad (0.056) \quad (0.040) \end{aligned}$$

$$-0.207 \cdot D_{\text{shinsai}} - 0.005 \cdot D_{\text{Lehman}} + \varepsilon_t$$

(0.017)                      (0.023)

All coefficients in the latter period except for that of Japan's IPI show the correct sign, but the coefficient of REER is not statistically significant. In addition, the results of ECM estimation presented in Tables 7 and 8 also indicate that the coefficients of the contemporaneous and 11th lagged REER in first-differences are positive and significant in the former period. Again, it is clear that there is evidence of the J-curve phenomenon only in the former period. In addition, the estimated coefficient of World IPI is 1.083 and statistically significant in the latter period, which is larger than the corresponding coefficient (0.178) in the former period. Thus, our empirical examination reveals that the Japan's trade balance becomes more affected by world business cycles in recent years and far less influenced by changes in REER than before.

#### **4. Does Japanese export price decline in response to yen depreciation?**

According to the J-curve effect, Japanese export price in terms of the destination currency is expected to decline in response to the yen depreciation, which gradually increases the export volume and finally results in the improvement of Japanese trade balance.<sup>12</sup> The following export demand function is typically assumed:  $X = X(P^*, Y^*) = X(P/S, Y^*)$ , where  $X$  denotes export quantity,  $P$  denotes export price,  $S$  denotes the nominal exchange rate,  $Y$  denotes real output, and an asterisk denotes foreign variable. Suppose that the Japanese export price in the yen ( $P$ ) does not change. As long as the export is invoiced in the yen, the export price in foreign currencies ( $P^*$ ) will decline in response to the yen depreciation (i.e., an increase in  $S$ ). The question is whether Japanese export price has declined in practice during the yen depreciation period. To solve this question, we need to analyze the choice of invoice currency in Japanese exports. We first investigate the recent movement of Japanese export price on the contract (invoice) currency basis, and in the next sub-section, we empirically examine the exchange rate pass-through behavior in Japanese exports by taking into account the choice of invoice currency.

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<sup>12</sup> This is the case especially when Japanese exporters invoice their export products in the yen.

#### 4-1. Exchange Rate Changes and Export Price Index

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 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, BOJ reports export price indices both on a *yen* basis and on a *contract (invoice) currency* basis. As long as 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.<sup>13</sup>

Figure 3 shows not only the nominal exchange rate of the yen vis-à-vis the US dollar that is converted into the index (2005=100) but also the Japanese export price index (all industries).<sup>14</sup> First, while the level of the exchange rate fluctuated to a large extent from 2000, the export price on the contract currency basis appears to be relatively stable at the level of 100 until December 2014, which suggests that Japanese exporters tend to stabilize the export price in terms of the destination currency and, hence, to conduct the pricing-to-market (PTM) strategy. Second, during the yen depreciation period starting from the end of 2012, the export price index on the contract currency basis declined only slightly from 101.0 in December 2012 to 96.7 in December 2014.

Thus, the magnitude of export price changes on the contract currency basis is far smaller than that of the yen depreciation (Figure 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 2014. To make further investigation of such price movements, let us observe possible difference in export price movements across industries.

Figure 4 presents the export price indices of Japanese three major machinery industries: general machinery, electric machinery and transport equipment.<sup>15</sup> In the general machinery and transport equipment, the export price indices on the contract

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<sup>13</sup> See the BOJ website ([https://www.boj.or.jp/en/statistics/pi/cgpi\\_2010/index.htm/](https://www.boj.or.jp/en/statistics/pi/cgpi_2010/index.htm/)) for further details.

<sup>14</sup> Not the nominal *effective* exchange rate but the *bilateral* nominal exchange rate of the yen vis-à-vis the US dollar is used in Figure 3.

<sup>15</sup> Since the industry classification in Japan’s trade statistics was substantially changed for the 2010 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”. According to the BOJ price statistics, as of 2010, 66.6 percent of Japanese exports are accounted for by the sum of the three industries: general machinery (19.2), electric machinery (23.3) and transport equipment (24.1).

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 4-A). 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 4-B), while the export price index on the yen basis exhibits similar movements to the exchange rate fluctuations. Thus, the small decline in export price index of all manufacturing from 2011 may partly reflect the continuous downward movements of the export price in the electric machinery industry.

#### 4-2. Time-varying parameter estimation of exchange rate pass-through in Japanese exports

As discussed in the previous sub-section, the BOJ's export price index measured in 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 the PTM behavior. However, we have also observed that the contract currency based export price tends to show short-run fluctuations and clearly increases during the yen appreciation period from September 2008 to 2012. To confirm the possible PTM or exchange rate pass-through behavior, we conduct 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 the 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, we employ the Kalman filter technique to estimate the time-varying parameter of the following pass-through equation (5) with the state equation (6):

$$\Delta \ln P_t^{EX} = \beta_{0,t} + \beta_{1,t} \Delta \ln NEER_t^{Contract} + \beta_{2,t} \Delta \ln P_t^D + \beta_{3,t} \Delta \ln Y_t^{World} + \varepsilon_t \quad (5)$$

$$\beta_{i,t} = \beta_{i,t-1} + v_{i,t} \quad i = 0, 1, 2 \text{ and } 3 \quad (6)$$

In the observation equation (5),  $P^{EX}$  denotes the export price index on the yen basis;  $NEER^{Contract}$  stands for the 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;  $Y^{World}$  indicates the world real output;  $\varepsilon$  denotes the white-noise residuals; and  $\Delta$  represents the first-difference operator. In the state equation (6),  $\beta$  and  $\nu$  indicate, respectively, the time-varying coefficient and the Gaussian disturbances with zero mean; and  $\beta$  is assumed to follow a random walk process.

In contrast to the previous studies, this paper develops the conventional (trade-weighted) NEER into the “contract currency based NEER”, like Ceglowski (2010). As explained earlier, 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, Koibuchi, Sato and Shimizu (2012, 2013), Japanese exporters tend to use either of the US dollar, yen or euro as a contract (invoice) currency. Figure 5 shows that 53.5 percent of Japan’s exports are invoiced in US dollars, and the share of the yen accounts for just 35.7 percent of Japan’s total exports in the second-half of 2014. 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 BOJ does not publish the destination breakdown data on export 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 we 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, we 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 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, we 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.<sup>16</sup> 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  $Y^{World}$  that is a weighted average of the monthly series of industrial production index of Japan's 20 major trading partner countries.<sup>17</sup> Since our sample period includes the global financial crisis after 2008, it is necessary to include  $Y^{World}$  in equation (5) to capture possible income effect of the crisis on export prices.

Our primary interest 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.

Before performing the time-varying parameter estimation, we conduct both the ADF (Augmented Dicky-Fuller) and PP (Phillips-Perron) tests for unit-root. Although not reported in this paper, it is confirmed that all variables are non-stationary in level but stationary in first-differences. The first-difference model in equation (5) ensures the stationarity of variables.

Figure 6 presents the estimated result of the time-varying pass-through coefficient. First, the result of all manufacturing (Figure 6(1)) shows that the pass-through coefficient fluctuates at around 0.7-0.8, indicating that Japanese exporters generally pursue low (high) degree of pass-through (PTM) behavior.<sup>18</sup>

Second and more noteworthy is that the pass-through coefficient in all manufacturing exhibits a sharp decline during the yen appreciation period: from 0.847 in February 2009 to the lowest value (0.255) in January 2012 (Figure 6(1)). In response to the unprecedented yen appreciation, Japanese exporters were forced to change the pricing behavior by increasing the degree of exchange rate pass-through into export

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<sup>16</sup> 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.

<sup>17</sup> 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.

<sup>18</sup> The averaged pass-through rate (i.e., the PTM elasticity), for instance, from January 1990 to December 2009 is around 0.73, which indicates that if the nominal effective exchange rate depreciates by 1 percent, the export price on the contract currency basis declines by only 0.27 percent.

prices. As shown in Figure 6, the time-varying coefficient falls in all major machinery industries: general machinery, electric machinery and transport equipment (Figures 6(2), (3) and (4), respectively).

Third, once the yen started to depreciate from the end of 2012, Japanese firms quickly came back toward the previous level of PTM. While Japanese exporters on average have not yet completely restored their PTM practices, some of the industries, especially the general machinery industry, have completely come back to the previous level of PTM, which hinders a decline of export price in destination countries and, hence, weakens a positive impact of yen depreciation on trade balances.

Thus, we have found the asymmetric pricing behavior of Japanese exporters. Japanese firms increase the degree of exchange rate pass-through from 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 unprecedented appreciation of the yen, 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 price did not decline because they are differentiated and competitive with low price elasticity. Instead, Japanese exporters, especially in transport equipment and general machinery, return to the PTM behavior, enjoying large foreign exchange gain. This means that Japanese exporters have conducted strategic relocation of their production bases and do not lose export competitiveness of products exported from Japan.<sup>19</sup>

## 5. Conclusion

Against the backdrop of the recent increase in Japanese trade deficit under the depreciation of the yen since the end of 2012, this paper has presented the following evidence and arguments. First, a sharp appreciation of the yen following the collapse of Lehman Brothers prompted lots of Japanese companies to enhance the cross-border division of labor by expanding their production networks in Asian countries. The result is a structure where much of the export-boosting effect of a weaker yen is negated

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<sup>19</sup> Sato, Shimizu, Shrestha and Zhang (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>).



because an increase in Japan's machinery exports inevitably induces imports of parts and components produced by Japanese overseas subsidiaries. By using the ARDL model to examine the J-curve effect empirically, it is found that exchange rate fluctuations in the 2000s and after have a weaker impact on the trade balance than in the middle of 1980s to 1990s.

Second, casual observation of the export price data published by BOJ shows that Japanese machinery export price in terms of the contract (invoice) currency has not changed in response to the large exchange rate fluctuations of the yen. However, by conducting the time-varying parameter estimation of the exchange rate pass-through in Japanese machinery exports, we have demonstrated that Japanese firms pursue different pass-through behavior in response to asymmetric exchange rate changes in the yen. During the unprecedented appreciation of the yen after the Lehman Brothers collapse, Japanese firms increased the degree of exchange rate pass-through, while Japanese firms are returning to the PTM behavior in response to the rapid yen depreciation from the end of 2012, which impedes a decline of Japanese export price in the destination countries and weakens the positive impact of yen depreciation on trade balances.

Thus, the slow recovery of Japanese trade balance in response to the yen depreciation can be explained by the Japanese firms' pricing behavior as well as the active overseas operation caused by the unprecedented level of yen appreciation before Abenomics. Export boosting effect of yen depreciation is structurally mitigated, and it is more important to look at income balance as well as trade balance when we consider the impact of yen depreciation.

What are the policy implications from the above observations? First, an increase in imports of mineral fuels due to the shutdown of nuclear power plants following the Great East Japan Earthquake was a major factor contributing to Japan's trade deficit. The oil price started to fall substantially from the mid-2014, which significantly improves the Japan's trade balance. However, given that crude oil and mineral fuels tend to be invoiced in US dollars, yen depreciation will automatically increase the amount of imports in terms of the yen. To avoid a negative impact of possible oil price rebounds, it is imperative for Japan to reconsider its long-term energy policy.

Second, in order to offset a decrease in exports resulting from manufacturing offshoring by increasing income surplus, it is necessary to maintain the flows of overseas earnings repatriated to Japan. A rise in the share of overseas sales has been prompting the offshoring of research and development (R&D) activities that have been typically conducted at the headquarters in Japan. Against this backdrop, Japanese

companies become more inclined to accumulate as much earnings as possible as assets of overseas subsidiaries, giving rise to concern that Japan's income surplus may turn into a downward trend. In order to prevent a decline of income surplus, the government needs to implement necessary measures to encourage companies to undertake R&D activities in Japan and to remove tax impediments to the repatriation of overseas earnings, namely, by expanding the scope of application of tax exemption for foreign income.

Finally, the yen depreciation policy has been effective in the sense that Japanese exporting firms have enjoyed large foreign exchange gains, but Japanese importers cannot have such benefit from yen depreciation. However, a sharp fall in the world oil price from the latter half of 2014 reduces the amount of Japanese imports, which is likely to mitigate the negative impact of yen depreciation on Japanese imports. Japanese government should utilize this opportunity to implement its growth strategy, the third arrow of Abenomics, as quickly as possible so as to foster export competitiveness across a broader spectrum of industrial sectors.

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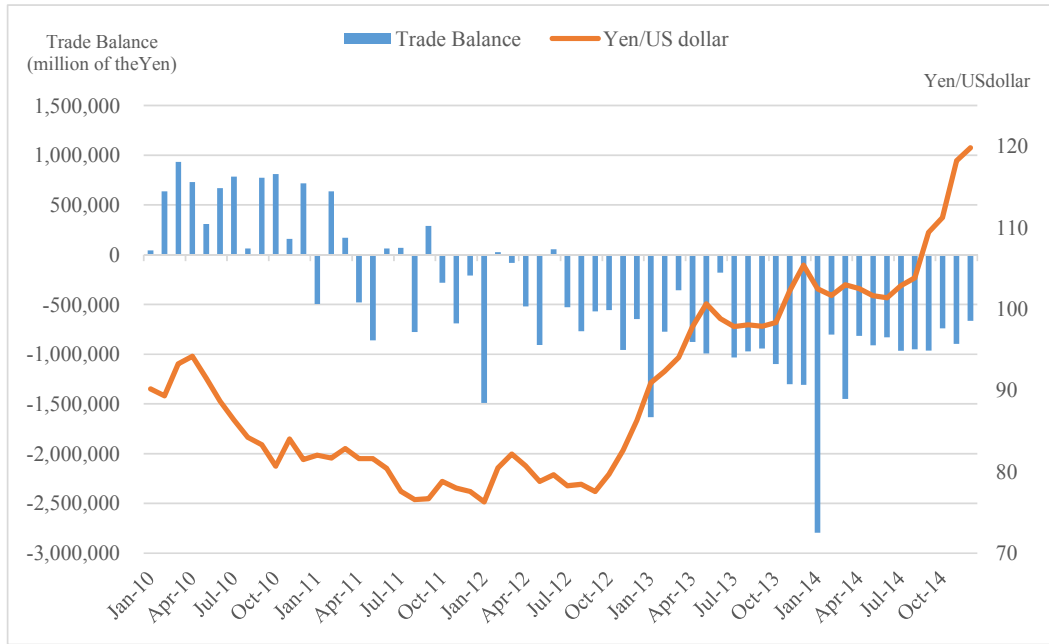
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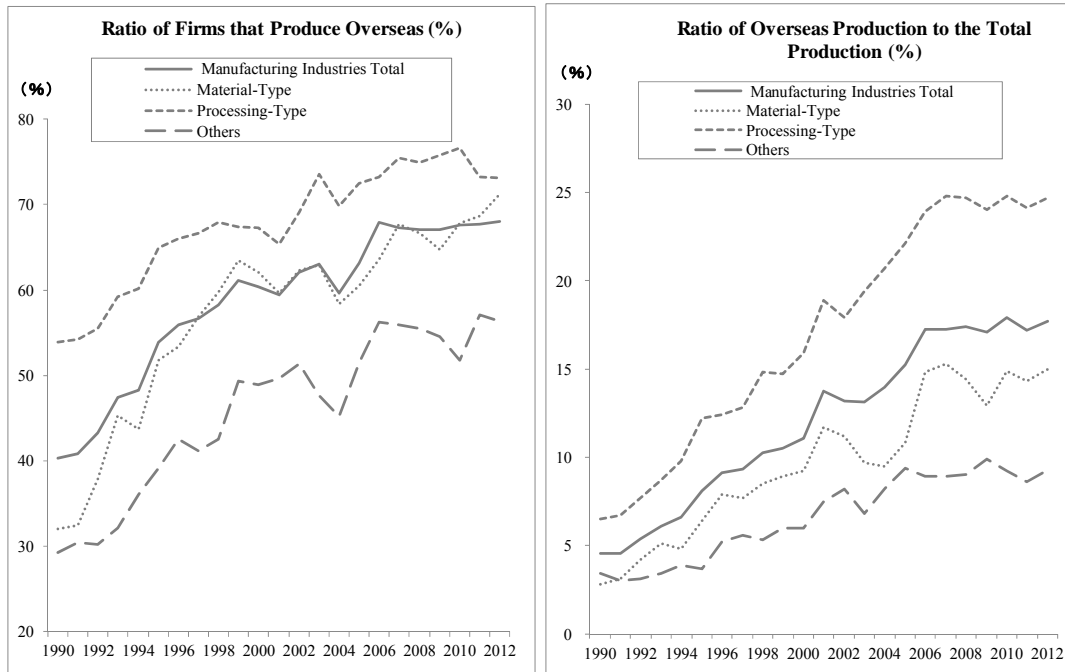
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Figure 1. Japan's Trade Balance and Yen/Dollar Exchange Rate (Jan. 2010 to Dec. 2014)



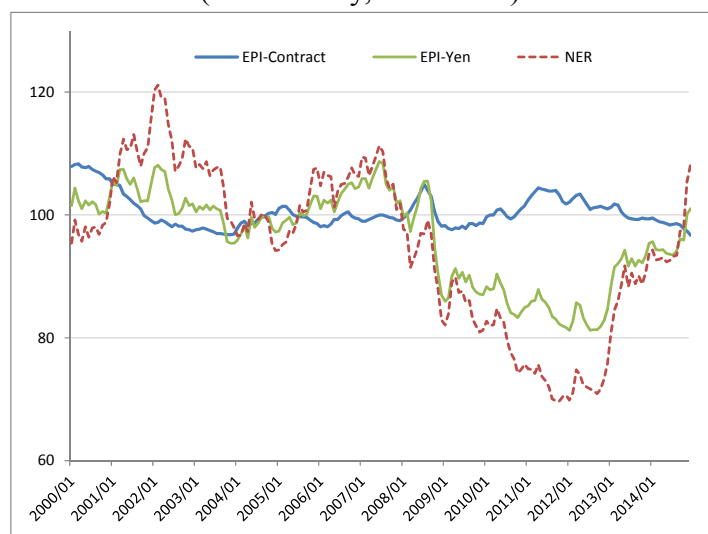
Source: Trade Statistics of Japan (Ministry of Finance) and Bank of Japan.

Figure 2. Overseas Production of Japanese Manufacturing Firms



Source: FY2012 Annual Survey of Corporate Behavior (Cabinet Office).

Figure 3. Yen/Dollar Exchange Rate and Export Price Index of Japan  
(All Industry, 2005=100)



Notes: Monthly series (2005=100) from January 2000 to December 2014. 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. NER denotes the nominal exchange rate of the yen vis-à-vis the US dollar (monthly average). All series are converted into the indices based on 2005=100.

Source: Bank of Japan; IMF, *International Financial Statistics*, CD-ROM.

Figure 4. Export Price Indices of Main Japanese Manufacturing Industries

Figure 4-A. General Machinery and Transport Equipment (2005=100)

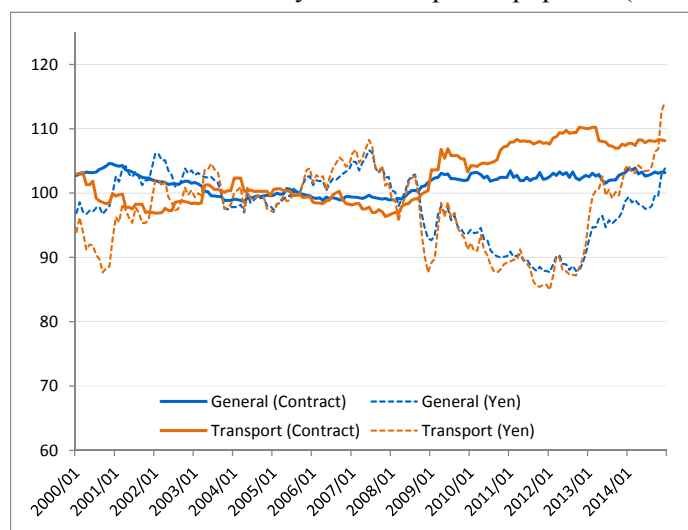
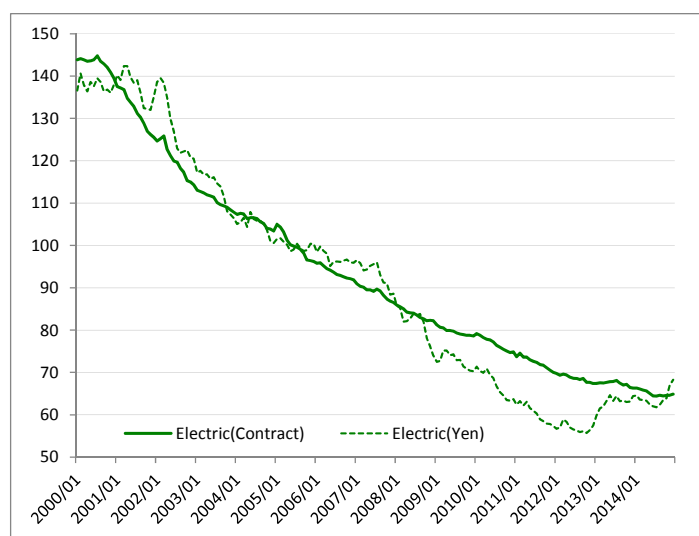


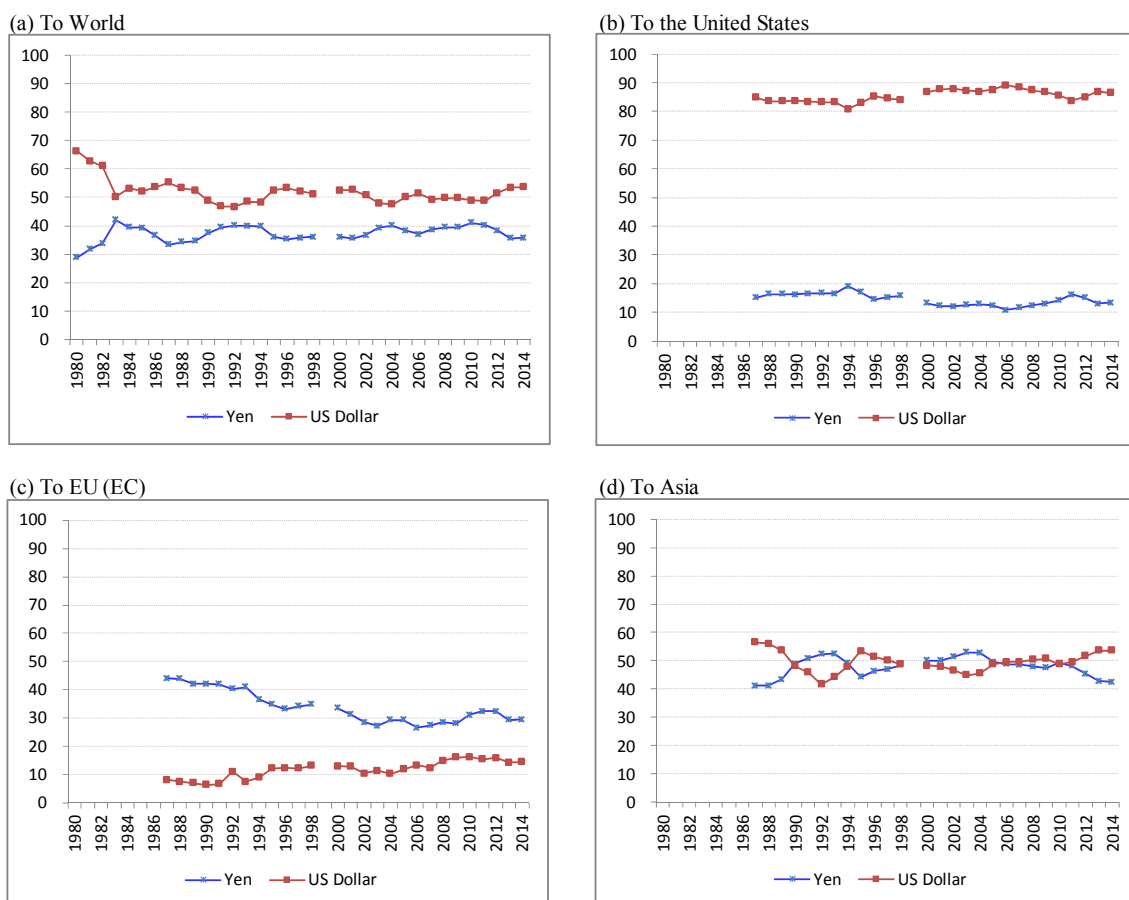
Figure 4-B. Electric Machinery (2005=100)



Notes: Monthly series (2005=100) from January 2000 to December 2014. "General Machinery" denotes "General purpose, production & business oriented machinery". "Electric Machinery" denotes "Electric & electronic products". Export price indices on the contract currency basis ("Contract") and on the yen basis ("Yen") are presented.

Source: Bank of Japan

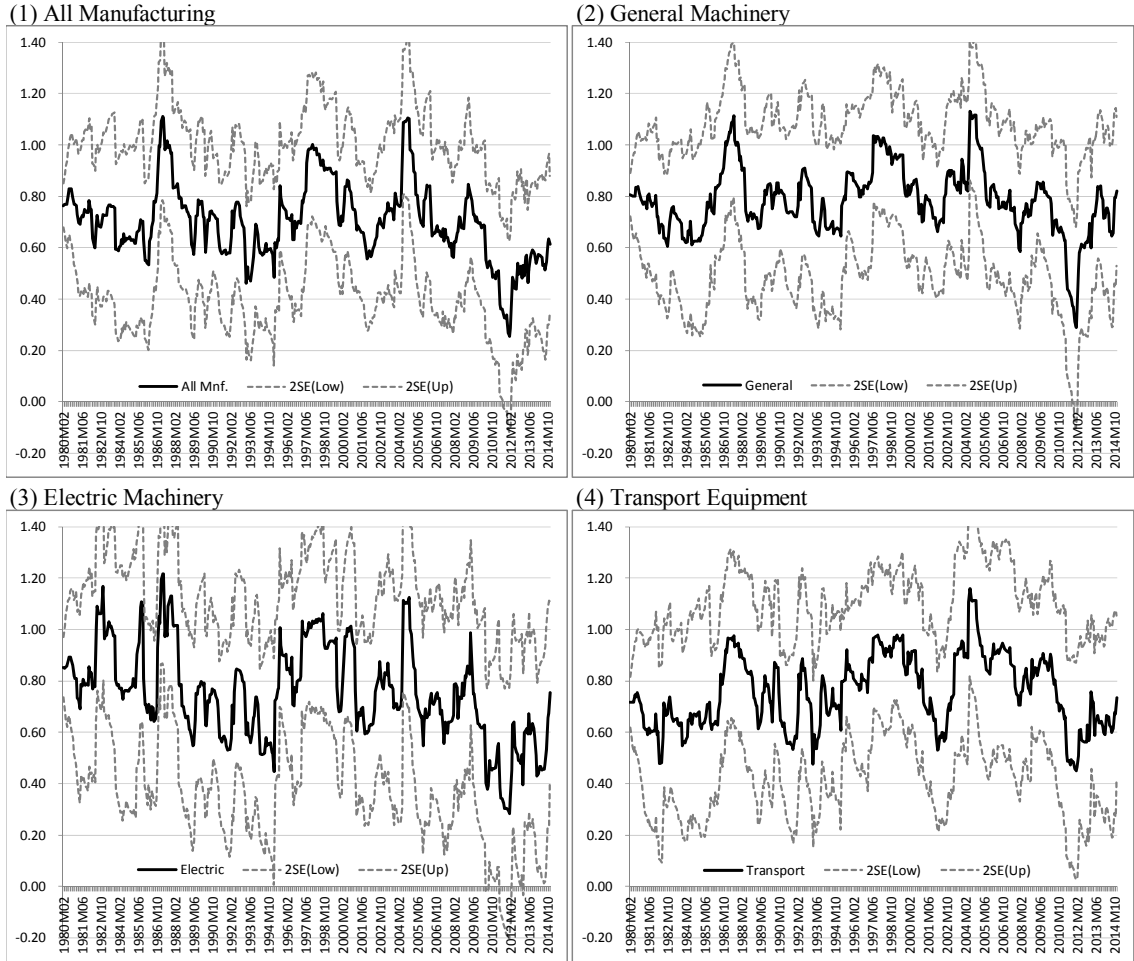
Figure 5. Share of Invoice Currency in Japanese Exports: 1980-2014 (Percent)



Notes: The data for 1999 is not available. The September data is used for 1992-97, the March data for 1998, the 2nd half of the year data for 2000-2014.

Sources: 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)*; the website of Japan Customs.

Figure 6. Time-Varying Exchange Rate Pass-Through for Major Machinery Industries  
(February 1980 - December 2014)



Note: Authors' calculation.



Table 1. Japanese Exports and Imports by Industry (Million yen; Benchmark year = 2010)

	Total	Foodstuff	Raw materials	Mineral-related fuels	Chemicals	Manufactured goods	General machinery	Electrical machinery	Transport equipment	Others	Yen/Dollar Exchange Rate
<b>Import Value</b>											
2010	60,764,957	5,199,420	4,765,880	17,397,958	5,379,439	5,378,596	4,825,708	8,101,043	1,681,355	8,035,557	87.77
2011	68,111,187 (12.1%)	5,854,222 (12.6%)	5,270,347 (10.6%)	21,816,150 (25.4%)	6,097,638 (13.4%)	6,069,200 (12.8%)	4,969,742 (3.0%)	7,988,833 (-1.4%)	1,737,577 (3.3%)	8,307,478 (3.4%)	79.78 (-9.1%)
2012	70,688,632 (16.3%)	5,852,259 (12.6%)	4,768,020 (0.0%)	24,088,214 (38.5%)	5,926,316 (10.2%)	5,507,608 (2.4%)	5,003,891 (3.7%)	8,437,814 (4.2%)	2,311,815 (37.5%)	8,792,696 (9.4%)	79.79 (-9.1%)
2013	81,242,545 (33.7%)	6,473,095 (24.5%)	5,357,616 (12.4%)	27,443,830 (57.7%)	6,464,172 (20.2%)	6,245,453 (16.1%)	5,968,882 (23.7%)	10,309,320 (27.3%)	2,788,248 (65.8%)	10,191,929 (26.8%)	97.60 (11.2%)
2014	85,889,269 (41.3%)	6,727,723 (29.4%)	5,600,602 (17.5%)	27,688,148 (59.1%)	6,863,787 (27.6%)	6,990,114 (30.0%)	6,752,859 (39.9%)	11,529,051 (42.3%)	3,052,947 (81.6%)	10,684,038 (33.0%)	105.84 (20.6%)
<b>Export Value</b>											
2010	67,399,627	406,115	946,147	1,104,977	6,925,266	8,784,805	13,316,635	12,650,452	15,258,136	8,007,092	87.77
2011	65,546,475 (-2.7%)	359,056 (-11.6%)	971,582 (2.7%)	1,247,066 (12.9%)	6,798,023 (-1.8%)	8,786,146 (0.0%)	13,803,298 (3.7%)	11,600,075 (-8.3%)	14,033,416 (-8.0%)	7,947,812 (-0.7%)	79.78 (-9.1%)
2012	63,747,572 (-5.4%)	355,401 (-12.5%)	1,059,693 (12.0%)	1,025,554 (-7.2%)	6,364,577 (-8.1%)	8,442,119 (-3.9%)	12,842,848 (-3.6%)	11,405,137 (-9.8%)	14,994,564 (-1.7%)	7,257,679 (-9.4%)	79.79 (-9.1%)
2013	69,774,193 (3.5%)	435,773 (7.3%)	1,206,274 (27.5%)	1,532,920 (38.7%)	7,507,353 (8.4%)	9,176,840 (4.5%)	13,359,015 (0.3%)	12,051,642 (-4.7%)	16,332,053 (7.0%)	8,172,322 (2.1%)	97.60 (11.2%)
2014	73,101,850 (8.5%)	481,548 (18.6%)	1,194,675 (26.3%)	1,521,403 (37.7%)	7,820,193 (12.9%)	9,464,175 (7.7%)	14,218,468 (6.8%)	12,649,949 (0.0%)	16,907,341 (10.8%)	8,844,098 (10.5%)	105.84 (20.6%)
<b>Trade Balance</b>											
2010	6,634,670	-4,793,304	-3,819,733	-16,292,981	1,545,827	3,406,209	8,490,928	4,549,409	13,576,781	-28,465	87.77
2011	-2,564,712	-5,495,166	-4,298,766	-20,569,084	700,386	2,716,946	8,833,556	3,611,242	12,295,840	-359,666	79.78
2012	-6,941,060	-5,496,857	-3,708,326	-23,062,660	438,261	2,934,511	7,838,957	2,967,323	12,682,749	-1,535,017	79.79
2013	-11,468,352	-6,037,323	-4,151,341	-25,910,909	1,043,181	2,931,387	7,390,133	1,742,322	13,543,805	-2,019,607	97.60
2014	-12,787,419	-6,246,175	-4,405,927	-26,166,745	956,407	2,474,061	7,465,609	1,120,898	13,854,394	-1,839,941	105.84

Note: Percentage change from the benchmark year is in parenthesis.

Source: Trade Statistics of Japan (Ministry of Finance).

Table 2. Quantity of Japanese Exports: Selected Products

Export Quantity	Power Gen Mach	Computer & Units	Parts of Computer	Integrated Circuits (IC)	Visual Apparatus	Video Rec or Repro App	Parts of Audio Apparatus	Motor Vehicles	Parts of Motor Vehicles
	3.45	0.66	1.89	4.06	1.38	1.23	0.82	11.72	4.57
2011	-0.9%	1.7%	-5.7%	-7.4%	-16.1%	-18.4%	-16.4%	-7.2%	-2.7%
2012	-3.2%	16.0%	-13.1%	-6.7%	-34.3%	-37.0%	-53.1%	0.6%	1.9%
2013	-7.7%	10.5%	-13.9%	-5.6%	-51.8%	-60.5%	-58.7%	-0.6%	-2.2%
2014	-8.1%	30.9%	-16.1%	-6.5%	-62.3%	-72.8%	-75.9%	-2.9%	-5.3%

*Note:* Figures in the first row are the share of the product in total amount of exports. Percentage change from the benchmark year (2010) is in parenthesis.

*Source:* Trade Statistics of Japan (Ministry of Finance).

Table 3. Quantity of Japanese Imports; Selected Products

Import Quantity	Crude Oil	LNG	Power Gen Mach	Parts of Computers	Integrated Circuits (IC)	Motor Vehicles	Parts of Motor Vehicles
	15.48	5.71	1.08	0.94	2.92	0.98	0.80
2011	-2.7%	12.2%	15.6%	-9.7%	-2.9%	18.5%	5.3%
2012	-0.7%	24.7%	23.3%	-11.2%	1.4%	43.2%	28.0%
2013	-1.3%	25.0%	12.1%	-14.3%	-1.8%	48.0%	34.9%
2014	-6.7%	26.4%	28.9%	-14.1%	12.3%	45.0%	51.0%

*Note:* Figures in the first row are the share of the product in total amount of imports. Percentage change from the benchmark year (2010) is in parenthesis.

*Source:* Trade Statistics of Japan (Ministry of Finance).

Table 4. Descriptive Statistics, Unit-Root Test and Cointegration Test

Table 4-A. Descriptive Statistics and Unit-Root Test

Descriptive Statistics of variables

Jan1985-Dec1998	Trade Balance	IPI JAPAN	IPI World	REER
Mean	0.726	95.376	63.742	106.211
Median	0.712	97.350	62.459	104.960
Maximum	0.947	106.400	77.099	143.230
Minimum	0.608	80.200	55.483	76.200
Std. Dev.	0.073	7.541	5.544	13.298
Unit Root Test (level)	-1.320	-1.244	-0.402	-1.149
Unit Root Test (1st Difference)	-15.001 ***	-4.737 ***	-18.105 ***	-6.713 ***
Jan1999-June 2014	Trade Balance	IPI JAPAN	IPI World	REER
Mean	0.861	101.146	91.135	96.090
Median	0.859	100.400	89.278	96.810
Maximum	1.071	116.400	116.417	123.640
Minimum	0.680	77.600	75.015	74.110
Std. Dev.	0.101	7.264	12.315	12.001
Unit Root Test (level)	-1.944	-2.904	-2.324	-2.106
Unit Root Test (1st Difference)	-19.134 ***	-11.633 ***	-5.769 ***	-9.769 ***

Note: Trade Balance is calculated as Real Export/Real Import.

Real Export and Real Import are taken from Bank of Japan, and REER (narrow base) is taken from BIS.

Industrial Production Index of Japan is taken from METI, Japan. Industrial Production Index of world is the weighted average of 20 Countries, whose trade share accounts for 1 percent or more in Japan's total exports as of 2010.

Unit Root Test shows Augmented Dickey-Fuller test statistic.

Table 4-B. Cointegration Test

Cointegration (Johansen) Test  
 Trend assumption: Linear deterministic trend  
 Series: LOG(TB)  
 Exogenous series: LOG(REER) LOG(IPJAPAN) LOG(IPWORLD)  
 Lags interval (in first differences): 1 to 2

Sample: 1985M01 1999M12 (Included observations: 180)				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.025776	4.700494	3.841466	0.0301
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.025776	4.700494	3.841466	0.0301

Sample: 1999M01 2014M06 (Included observations: 186)				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.048088	9.16656	3.841466	0.0025
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.048088	9.16656	3.841466	0.0025

Trace test and Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

Table 5. ARDL (Conditional ECM) Model (January 1985 – December 1998)

January 1985- December 1998

Explained variable :  $\Delta \log(\text{Real Export/Real Import})$

Method: Least Squares (Included observations: 168)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	1.209	(0.430)	2.810	0.006
$\Delta \log(\text{Real Export}(-1)/\text{Real Import}(-1))$	-0.331	(0.117)	-2.820	0.006
$\Delta \log(\text{Real Export}(-2)/\text{Real Import}(-2))$	-0.234	(0.093)	-2.532	0.012
$\Delta \log(\text{IPIJapan})$	-0.347	(0.242)	-1.430	0.155
$\Delta \log(\text{IPIJapan}(-1))$	0.113	(0.224)	0.505	0.614
$\Delta \log(\text{IPIWorld})$	0.517	(0.338)	1.530	0.128
$\Delta \log(\text{IPIWorld}(-1))$	0.228	(0.403)	0.567	0.572
$\Delta \log(\text{REER})$	0.197	(0.118)	1.667	0.098
$\Delta \log(\text{REER}(-1))$	0.222	(0.122)	1.819	0.071
$\Delta \log(\text{REER}(-2))$	0.221	(0.131)	1.681	0.095
$\Delta \log(\text{REER}(-3))$	0.134	(0.131)	1.023	0.308
$\Delta \log(\text{REER}(-4))$	0.142	(0.151)	0.937	0.350
$\Delta \log(\text{REER}(-5))$	0.146	(0.129)	1.133	0.259
$\Delta \log(\text{REER}(-6))$	0.177	(0.149)	1.192	0.235
$\Delta \log(\text{REER}(-7))$	0.306	(0.149)	2.051	0.042
$\Delta \log(\text{REER}(-8))$	0.171	(0.135)	1.267	0.207
$\Delta \log(\text{REER}(-9))$	0.075	(0.147)	0.509	0.611
$\Delta \log(\text{REER}(-10))$	-0.075	(0.127)	-0.593	0.554
$\Delta \log(\text{REER}(-11))$	0.387	(0.128)	3.024	0.003
$\log(\text{Real Export}(-1)/\text{Real Import}(-1))$ 1)	-0.400	(0.099)	-4.023	** 0.000
$\log(\text{IPIJapan}(-1))$	-0.265	(0.106)	-2.495	0.014
$\log(\text{IPIWorld}(-1))$	0.196	(0.057)	3.435	0.001
$\log(\text{REER}(-1))$	-0.204	(0.046)	-4.413	0.000
Adjusted R-squared	0.367			
Durbin-Watson stat	2.032			
F-statistic	5.410			
Prob(F-statistic)	0.000			
Wald Test ( $H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$ ) 2)				
F-statistic	5.670	***		
Prob(F-statistic)	0.000			

(Authors' calculation)

1) p.303 of Pesaran et al. (2001), in the case of  $k=3$ , the  $I(0)$  and  $I(1)$  bounds for the t-statistic at the 10%, 5%, and 1% significance levels are [-2.57, -3.46], [-2.86, -3.78], and [-3.43, -4.37], respectively.

2) p.300 of Pesaran et al. (2001), in the case of  $k=3$ , the lower and upper bounds for the F-test statistic at the 10%, 5%, and 1% significance levels are [2.72, 3.77], [3.23, 4.35], and [4.29, 5.61], respectively.

Note1) We chose lag lengths of each variables by Akaike Information Criterion and the Schwarz Criterion.

Note2) \*\*\*, \*\*, and \* denote the 1 percent, 5 percent and 10 percent significance level, respectively.

Table 6. ARDL (Conditional ECM) Model (January 1999 – June 2014)

January 1999 - June 2014  
 Explained variable  $\Delta \log(\text{Real Export/Real Import})$   
 Method: Least Squares (Included observations: 186)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.207	(0.428)	0.483	0.630
$\Delta \log(\text{Real Export}(-1)/\text{Real Import}(-1))$	-0.582	(0.085)	-6.846	0.000
$\Delta \log(\text{Real Export}(-2)/\text{Real Import}(-2))$	-0.251	(0.090)	-2.792	0.006
$\Delta \log(\text{Real Export}(-3)/\text{Real Import}(-3))$	-0.139	(0.076)	-1.834	0.069
$\Delta \log(\text{IPIJapan})$	0.224	(0.118)	1.908	0.058
$\Delta \log(\text{IPIJapan}(-1))$	0.562	(0.116)	4.849	0.000
$\Delta \log(\text{IPIJapan}(-2))$	0.096	(0.115)	0.829	0.408
$\Delta \log(\text{IPIWorld})$	0.736	(0.210)	3.507	0.001
$\Delta \log(\text{IPIWorld}(-1))$	0.386	(0.262)	1.476	0.142
$\Delta \log(\text{IPIWorld}(-2))$	0.063	(0.228)	0.275	0.784
$\Delta \log(\text{REER})$	-0.132	(0.114)	-1.160	0.248
$\Delta \log(\text{REER}(-1))$	0.084	(0.114)	0.739	0.461
$\Delta \log(\text{REER}(-2))$	0.008	(0.111)	0.077	0.939
$\Delta \log(\text{REER}(-3))$	-0.103	(0.105)	-0.987	0.325
$\Delta \log(\text{REER}(-4))$	0.201	(0.103)	1.946	0.054
$\Delta \log(\text{REER}(-5))$	0.016	(0.107)	0.151	0.880
$\Delta \log(\text{REER}(-6))$	0.244	(0.103)	2.362	0.019
$\Delta \log(\text{REER}(-7))$	-0.064	(0.101)	-0.636	0.526
$\Delta \log(\text{REER}(-8))$	0.005	(0.099)	0.050	0.960
$\Delta \log(\text{REER}(-9))$	-0.002	(0.100)	-0.021	0.983
$\Delta \log(\text{REER}(-10))$	0.081	(0.101)	0.795	0.428
$\Delta \log(\text{REER}(-11))$	0.174	(0.104)	1.672	0.097
$\log(\text{Real Export}(-1)/\text{Real Import}(-1))$ 1)	-0.117	(0.051)	-2.295	0.023
$\log(\text{IPIJapan}(-1))$	-0.036	(0.042)	-0.872	0.384
$\log(\text{IPIWorld}(-1))$	0.084	(0.062)	1.353	0.178
$\log(\text{REER}(-1))$	-0.094	(0.028)	-3.305	0.001
Shinsai Dummy	-0.029	(0.014)	-2.122	0.035
Lehman Dummy	-0.043	(0.021)	-2.044	0.043
Adjusted R-squared	0.441			
Durbin-Watson stat	2.044			
F-statistic	6.400			
Prob(F-statistic)	0.000			
Wald Test ( $H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$ ) 2)				
F-statistic	3.752			
Prob(F-statistic)	0.006			

(Authors' calculation)

1) p.303 of Pesaran et al. (2001), in the case of  $k=3$ , the  $I(0)$  and  $I(1)$  bounds for the t-statistic at the 10%, 5%, and 1% significance levels are [-2.57, -3.46], [-2.86, -3.78], and [-3.43, -4.37], respectively.

2) p.300 of Pesaran et al. (2001), in the case of  $k=3$ , the lower and upper bounds for the F-test statistic at the 10%, 5%, and 1% significance levels are [2.72, 3.77], [3.23, 4.35], and [4.29, 5.61], respectively.

Note1) We chose lag lengths of each variables by Akaike Information Criterion and the Schwarz Criterion.

Note2) \*\*\*, \*\*, and \* denote the 1 percent, 5 percent and 10 percent significance level, respectively.

Note3) The Great East Japan Earthquake (Shinsai) dummy takes 1 after April 2011, and takes 0 otherwise.

Note4) The Lehman Shock dummy takes 1 after September 2008 to February 2009, and takes 0 otherwise.

Table 7. ECM with Error Correction Term (January 1985 – December 1998)

January 1985- December 1998

< Long-term >

Explained variable :  $\log(\text{Real Export/Real Import})$

Method: Least Squares (Included observations: 168)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	4.600 ***	(0.269)	17.126	0.000
$\log(\text{IPIJapan})$	-0.989 ***	(0.067)	-14.842	0.000
$\log(\text{IPIWorld})$	0.178 ***	(0.064)	2.774	0.006
$\log(\text{REER})$	-0.242 ***	(0.034)	-7.104	0.000
Adjusted R-squared	0.693			
Durbin-Watson stat	0.722			
F-statistic	126.388			
Prob(F-statistic)	0			

< Short-term >

Explained variable :  $\Delta \log(\text{Real Export/Real Import})$

Method: Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.002	(0.003)	-0.770	0.442
ECT(-1)	-0.220 **	(0.090)	-2.435	0.016
$\Delta \log(\text{Real Export}(-1)/\text{Real Import}(-1))$	-0.404 ***	(0.098)	-4.148	0.000
$\Delta \log(\text{Real Export}(-2)/\text{Real Import}(-2))$	-0.256 ***	(0.080)	-3.153	0.002
$\Delta \log(\text{IPIJapan})$	-0.625 **	(0.247)	-2.599	0.010
$\Delta \log(\text{IPIJapan}(-1))$	-0.162	(0.227)	-0.702	0.484
$\Delta \log(\text{IPIWorld})$	0.438	(0.326)	1.258	0.211
$\Delta \log(\text{IPIWorld}(-1))$	0.161	(0.332)	0.478	0.633
$\Delta \log(\text{REER})$	0.232 *	(0.114)	1.967	0.051
$\Delta \log(\text{REER}(-1))$	0.037	(0.128)	0.339	0.735
$\Delta \log(\text{REER}(-2))$	0.082	(0.129)	0.621	0.536
$\Delta \log(\text{REER}(-3))$	-0.045	(0.134)	-0.350	0.727
$\Delta \log(\text{REER}(-4))$	-0.075	(0.133)	-0.595	0.553
$\Delta \log(\text{REER}(-5))$	-0.009	(0.132)	-0.076	0.940
$\Delta \log(\text{REER}(-6))$	0.009	(0.130)	0.121	0.904
$\Delta \log(\text{REER}(-7))$	0.142	(0.130)	1.121	0.264
$\Delta \log(\text{REER}(-8))$	0.049	(0.131)	0.337	0.737
$\Delta \log(\text{REER}(-9))$	-0.106	(0.130)	-0.810	0.419
$\Delta \log(\text{REER}(-10))$	-0.226 *	(0.132)	-1.740	0.084
$\Delta \log(\text{REER}(-11))$	0.204 *	(0.121)	1.764	0.080
Adjusted R-squared	0.306			
Durbin-Watson stat	1.982			
F-statistic	5.137			
Prob(F-statistic)	0.000			

(Authors' calculation)

Note1) We select lag lengths of each variables by Akaike Information Criterion and the Schwarz Criterion.

Note2) \*\*\*, \*\*, and \* denote the 1 percent, 5 percent and 10 percent significance level, respectively.

Table 8. ECM with Error Correction Term (January 1999 – June 2014)

January 1999 - June 2014

< Long-term >

Explained variable :  $\log(\text{Real Export/Real Import})$

Method: Least Squares (Included observations: 186)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-6.154 ***	(0.502)	-12.258	0.000
$\log(\text{IPIJapan})$	0.299 ***	(0.062)	4.812	0.000
$\log(\text{IPIWorld})$	1.083 ***	(0.056)	19.247	0.000
$\log(\text{REER})$	-0.047	(0.040)	-1.166	0.245
Shinsai Dummy	-0.207 ***	(0.017)	-12.002	0.000
Lehman Dummy	-0.005	(0.023)	-0.220	0.827
Adjusted R-squared	0.784			
Durbin-Watson stat	0.485			
F-statistic	135.235			
Prob(F-statistic)	0			

< Short-term >

Explained variable :  $\Delta \log(\text{Real Export/Real Import})$

Method: Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000	(0.003)	0.025	0.980
ECT(-1)	-0.111 **	(0.053)	-2.118	0.036
$\Delta \log(\text{Real Export}(-1)/\text{Real Import}(-1))$	-0.514 ***	(0.085)	-6.055	0.000
$\Delta \log(\text{Real Export}(-2)/\text{Real Import}(-2))$	-0.133 *	(0.077)	-1.734	0.085
$\Delta \log(\text{IPIJapan})$	0.305 **	(0.121)	2.511	0.013
$\Delta \log(\text{IPIJapan}(-1))$	0.562 ***	(0.122)	4.593	0.000
$\Delta \log(\text{IPIJapan}(-2))$	-0.028	(0.119)	-0.232	0.817
$\Delta \log(\text{IPIWorld})$	0.874 ***	(0.213)	4.105	0.000
$\Delta \log(\text{IPIWorld}(-1))$	0.353	(0.249)	1.415	0.159
$\Delta \log(\text{IPIWorld}(-2))$	0.004	(0.224)	0.020	0.984
$\Delta \log(\text{REER})$	-0.191	(0.116)	-1.646	0.102
$\Delta \log(\text{REER}(-1))$	0.017	(0.115)	0.150	0.881
$\Delta \log(\text{REER}(-2))$	-0.044	(0.109)	-0.397	0.692
$\Delta \log(\text{REER}(-3))$	-0.209 *	(0.109)	-1.924	0.056
$\Delta \log(\text{REER}(-4))$	0.145	(0.105)	1.377	0.171
$\Delta \log(\text{REER}(-5))$	0.009	(0.107)	0.089	0.930
$\Delta \log(\text{REER}(-6))$	0.210 **	(0.103)	2.036	0.043
$\Delta \log(\text{REER}(-7))$	-0.116	(0.103)	-1.127	0.261
$\Delta \log(\text{REER}(-8))$	-0.039	(0.102)	-0.383	0.702
$\Delta \log(\text{REER}(-9))$	-0.044	(0.101)	-0.435	0.664
$\Delta \log(\text{REER}(-10))$	0.106	(0.102)	1.039	0.301
$\Delta \log(\text{REER}(-11))$	0.093	(0.104)	0.894	0.373
Shinsai Dummy	-0.009	(0.006)	-1.457	0.147
Lehman Dummy	-0.011	(0.020)	-0.570	0.570
Adjusted R-squared	0.411			
Durbin-Watson stat	1.903			
F-statistic	6.572			
Prob(F-statistic)	0			

(Authors' calculation)

Note1) We select lag lengths of each variables by Akaike Information Criterion and the Schwarz Criterion.

Note2) \*\*\*, \*\*, and \* denote the 1 percent, 5 percent and 10 percent significance level, respectively.

Note3) The Great East Japan Earthquake (Shinsai) dummy takes 1 after April 2011, and takes 0 otherwise.

Note4) The Lehman Shock dummy takes 1 after September 2008 to February 2009, and takes 0 otherwise.