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Asymmetric Exchange Rate Pass-Through between Unexpected Yen Appreciation and Depreciation: The case for Japanese machinery exports*

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Abstract

This paper empirically investigates whether Japanese exporters have changed their exchange rate pass-through (ERPT) behavior in response to large fluctuations of the yen from January 2000 to December 2022. A novel development of this study is that it incorporates exchange rate prediction errors into a nonlinear autoregressive distributed lag (NARDL) model with multiple thresholds, which enables us to rigorously distinguish not only between strong yen and weak yen periods but also between phases of unexpected yen appreciation and depreciation. We find asymmetric ERPT between the periods of strong yen and weak yen in level. More intriguingly, Japanese exporters, especially in general machinery and transport equipment industries, strategically switch their pricing behavior from ERPT to pricing-to-market (PTM) and vice versa in response to unexpected yen appreciation and depreciation. Our empirical findings have significant implications for better pricing strategies by Japanese export firms in the face of sudden, large exchange rate changes.

Keywords: Exchange rate pass-through (ERPT); pricing-to-market (PTM); invoice currency; nonlinear autoregressive distributed lag model; multiple thresholds; predicted exchange rate

JEL classification: F31; F36; F23

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1. Introduction

Exporter's pricing behavior has been empirically investigated in the literature of exchange rate pass-through (ERPT). In the 1980s, Japanese exporter's pricing behavior gained much attention, since Japan's trade surplus against the United States continued to increase even though the yen appreciated substantially against the US dollar (USD) from 254.2 in January 1985 to 123.6 in December 1988.[1] Seminal empirical works in the literature, such as Giovannini (1988), Marston (1990), and Knetter (1989, 1993), examined Japanese exporters ERPT behavior and found that exporters' selling price in the destination market was stabilized in terms of the local currency, which is typically called "pricing-to-market (PTM)" behavior.

Recent studies have paid renewed attention to possible asymmetric ERPT behavior.[2] Knetter (1994), for instance, attempted to examine possible asymmetry of ERPT in Japanese exports and imports using the H.S.7-digit commodity data. The nominal exchange rate of the yen against the USD (S_t) is decomposed to two series of exchange rates. Specifically, a positive change in the nominal exchange rate of the yen ($\Delta \ln S_t > 0$) is considered as a yen depreciation period, while a negative change ($\Delta \ln S_t < 0$) is assumed to indicate a yen appreciation period. This "zero-threshold" approach has been typically used in empirical studies on nonlinear or asymmetric ERPT of exports and imports, such as Delatte and López-Villavicencio (2012), Shin *et al*. (2014), Baharumshah *et al*. (2017), and Jammazi *et al*. (2017).

As demonstrated by Nguyen and Sato (2019), however, the zero-threshold approach does not necessarily work as an appropriate threshold to distinguish between currency appreciation and depreciation periods. Given volatile nature of nominal exchange rates, short-run positive changes in the exchange rate (i.e., currency depreciation) are often observed even during the continuous and substantial currency appreciation period.

As shown in Figure 1, for instance, the nominal exchange rate of the yen appreciated substantially against the USD from mid-2007 to 2012. Even during the strong yen period from around 90 in early 2010 to 76.77 in October 2011, there are several months that show small positive changes in the yen, which are incorrectly categorized by

[1] In this section, we show the data on the nominal exchange rate of the yen against the USD that is taken from IMF, International Financial Statistics, online.

[2] See, among others, Knetter (1994), Delatte and López-Villavicencio (2012), Shin *et al*. (2014), Baharumshah *et al*. (2017), and Jammazi *et al*. (2017). Whereas these studies basically rely on an autoregressive distributed lag (ARDL) model for empirical estimation, Nguyen and Sato (2020) employ a structural near-VAR model for an ERPT analysis of Japanese exports.

the zero-threshold approach into the yen "depreciation" period.

[Insert Figure 1 around here.]

To overcome the limitation of the zero-threshold approach, we first employ a nonlinear autoregressive distributed lag (NARLD) model with multiple thresholds proposed by Verheyen (2013).[3] By choosing 40% and 60% quantiles of the monthly series of the nominal effective exchange rate (NEER) of the yen as benchmark thresholds, we distinguish between "weak yen (depreciation)", "neutral", and "strong yen (appreciation)" periods in terms of the *level* of exchange rates.

Second, we incorporate exchange rate prediction errors obtained by comparing the actual exchange rate with the *predicted* exchange rate into the multiple threshold NARDL model. Both the strong and weak yen periods obtained by the first-stage multiple-threshold analysis are further divided into unexpected yen appreciation and unexpected yen depreciation. Then, we estimate the degree of ERPT or PTM for both unexpected yen appreciation and unexpected yen depreciation phases in each of the strong yen and weak yen periods.

To anticipate the results, we find that while PTM behavior becomes evident during the strong yen period, there is a marked difference in the degree of ERPT or PTM between unexpected yen depreciation and unexpected yen appreciation phases. More intriguingly, Japanese exporters, especially in general machinery and transport equipment industries, strategically switch the pricing behavior from ERPT to PTM and vice versa especially in response to unexpected yen appreciation and depreciation during the strong yen period. The above findings obtained from the benchmark model are supported by different values of multiple thresholds with a range of (weak yen/neutral/strong yen) periods from (36/28/36) to (43/14/43). Our empirical findings would have significant implications for better pricing strategies by Japanese export firms in the face of a sharp and substantial appreciation or depreciation of the yen.

The remainder of the paper is organized as follows. Section 2 elaborates our empirical model. Section 3 describes the data. Section 4 presents and discusses empirical results. Finally, Section 5 concludes this study.

[3] For an analysis of the multiple threshold NARDL model, see also Pal and Mitra (2016) and Jalal and Gopinathan (2022).

2. Empirical Model

2.1 ARDL Approach to ERPT

Previous studies on ERPT typically employ the following empirical model:[4]

$$p_t^x = \beta_0 + \beta_1 neer_t + \beta_2 dp_t + \beta_3 ipi_t^w + \varepsilon_t \qquad (1)$$

where p^x denotes the natural log of yen-based export price; *neer* denotes the natural log of NEER of the yen; *dp* denotes the natural log of domestic input price as a proxy for production costs; ipi^w denotes the natural log of world industrial production index as a proxy for global demand; and ε denotes error term.

Our main interest is in the coefficient β_1 that measures the degree of ERPT or PTM. Note that our NEER of the yen (*neer*) is a reciprocal of the NEER obtained from the Bank for International Settlements (BIS), which means that an increase (decrease) in the yen's NEER is defined as depreciation (appreciation) of the yen in this paper. Given our definition of the yen's NEER, the coefficient β_1 is equal to one and statistically significant when the degree of ERPT (PTM) is zero (100%). When the coefficient β_1 is equal to zero and/or not statistically significant, the degree of ERPT (PTM) is 100% (zero). Usually, the estimated coefficient β_1 lies in between zero and one, which is called incomplete ERPT or PTM.

The autoregressive distributed lag (ARDL) modeling approach, developed by Pesaran *et al*. (2001), is widely used in empirics of ERPT, which has the advantage of being able to estimate both short-run and long-run ERPT behavior. Specifically, we estimate a conditional error-correction model (ECM) to perform the bounds test for cointegration:

$$\begin{aligned} \Delta p_t^x = {} & \rho_0 + \rho_1 p_{t-1}^x + \rho_2 neer_{t-1} + \rho_3 dp_{t-1} + \rho_4 ipi_{t-1}^w \\ & + \sum\nolimits_{i=1}^{k} \gamma_{1i} \Delta p_{t-i}^x + \sum\nolimits_{i=0}^{l} \gamma_{2i} \Delta neer_{t-i} + \sum\nolimits_{i=0}^{m} \gamma_{3i} \Delta dp_{t-i} + \sum\nolimits_{i=0}^{n} \gamma_{4i} \Delta ipi_{t-i}^w + v_t \end{aligned} \qquad (2)$$

Pesaran *et al*. (2001) proposed to conduct the bounds *F*-test, the joint null hypothesis of which is H_0: $\rho_1 = \rho_2 = \rho_3 = \rho_4 = 0$. If the null hypothesis is rejected, we conclude that a long-run equilibrium relationship is found between the variables. The long-run equilibrium relationship, equivalent to Equation (1), is incorporated in Equation (2). For

[4] This empirical specification is widely used in the literature on ERPT, such as Goldberg and Knetter (1997), Campa and Goldberg (2005), Nguyen and Sato (2019).

instance, the long-run ERPT or PTM coefficient is calculated as $\beta_1 = -\rho_2 / \rho_1$ and ρ_1 is called error-correction term (ECT) that represents the speed of adjustment to equilibrium.

2.2 Nonlinear ARDL Approach

The conventional ARDL model can be extended to investigate possible asymmetric impact of exchange rate changes to export prices. Knetter (1994), Delatte and López-Villavicencio (2012), Shin *et al*. (2014), Baharumshah *et al*. (2017), and Jammazi *et al*. (2017) employ the following decomposition approach to distinguish between exchange rate depreciation and appreciation periods:

$$s_t^+ = \sum_{j=1}^{t} \Delta s_j^+ = \sum_{j=1}^{t} \max(\Delta s_j, 0) \qquad (3)$$

$$s_t^- = \sum_{j=1}^{t} \Delta s_j^- = \sum_{j=1}^{t} \min(\Delta s_j, 0) \qquad (4)$$

where s_t denotes the natural log of the nominal exchange rate of the home currency against the foreign currency. This decomposition approach utilizes the information on the short-run exchange rate changes, i.e., log-differences of the nominal exchange rate series. Specifically, a positive change in the nominal exchange rate of the home currency ($\Delta s_t > 0$) is considered as a home currency depreciation, while a negative change ($\Delta s_t < 0$) is assumed to indicate a home currency appreciation. This "zero-threshold" approach has been widely used as the NARDL model to examine possible asymmetric ERPT or PTM in exports and imports.

The zero-threshold approach, however, does not necessarily work as an appropriate threshold to distinguish between currency appreciation and depreciation periods. Figure 1 illustrates a major drawback of the zero-threshold approach. From early 2010 to late 2011, the yen appreciated substantially from around 90 to 77 against the USD, which is widely recognized as the historically high level of yen appreciation. In Figure 1, however, we observe small positive changes in the yen several times during the yen appreciation period. As shown by Nguyen and Sato (2019), if we rely on the zero-threshold approach, positive changes in the yen during the yen appreciation period would be categorized into the yen depreciation period, which prevents us from making rigorous and correct distinction between yen appreciation and depreciation periods.[5]

[5] See Figure 4 of Nguyen and Sato (2019) that clearly illustrates that the zero-threshold approach fails to make correct distinction between yen appreciation and depreciation periods.

2.3 Multiple Threshold ARDL Approach

To overcome the drawback of the zero-threshold approach, previous studies employ the multiple-threshold approach, such as Veheyen (2013), Pal and Mitra (2016), and Jalal and Gopinathan (2022), though these studies do not analyze the ERPT or PTM behavior.[6] By applying the multiple-threshold approach to Eq.(2), we may set up the following conditional ECM by using 40% and 60% quantile of NEER series as benchmark thresholds q_a and q_b, respectively:

$$\begin{aligned}\Delta p_t^x &= \rho_0 + \rho_1 p_{t-1}^x + \rho_2 neer_{t-1}^+ + \rho_3 neer_{t-1}^{\pm} + \rho_4 neer_{t-1}^- + \rho_5 dp_{t-1} + \rho_6 ipi_{t-1}^w \\ &+ \sum_{i=1}^{k} \gamma_{1i} \Delta p_{t-i}^x + \sum_{i=0}^{l} \left(\gamma_{2i} \Delta neer_{t-i}^+ + \gamma_{3i} \Delta neer_{t-i}^{\pm} + \gamma_{4i} \Delta neer_{t-i}^- \right) \\ &+ \sum_{i=0}^{m} \gamma_{5i} \Delta dp_{t-i} + \sum_{i=0}^{n} \gamma_{6i} \Delta ipi_{t-i}^w + v_t\end{aligned} \quad (5)$$

where three partial sums of the NEER series are:

$$neer_t^+ = neer_{t-1}^+ + \Delta neer_t \cdot I\{neer_t > q_b\} \quad (6)$$
$$neer_t^{\pm} = neer_{t-1}^{\pm} + \Delta neer_t \cdot I\{q_a \le neer_t \le q_b\} \quad (7)$$
$$neer_t^- = neer_{t-1}^- + \Delta neer_t \cdot I\{neer_t < q_a\} \quad (8)$$

$I\{\cdot\}$ denotes an indicator function that takes the value of one if the condition in the bracket is satisfied; otherwise, the indicator function takes the value of zero. It must be noted that this approach using equations (6) – (8) differs distinctly from the previous studies such as Veheyen (2013), Pal and Mitra (2016), and Jalal and Gopinathan (2022) that used not $neer_t$ but $\Delta neer_t$ in the above indicator functions as straightforward extension of the zero-threshold approach. This paper uses the information on a level of NEER ($neer_t$) for the decompositions, motivated by Figures 1 and 2.

[Insert Figure 2 around here.]

To illuminate our understanding, let us look at the bilateral nominal exchange rate of the yen against the USD (i.e., JPY/USD) in Figures 1 and 2. On a monthly average basis, the JPY/USD changed from the bottom (76.77) in October 2011 to peak (147.01) in October 2022. Japanese exporter's pricing behavior may be different between the yen depreciation period in 2013–2014 (i.e., (ii) in Figure 2) and another yen depreciation

[6] See also Jammazi *et al*. (2017), Asad *et al*. (2020), Kisswani (2021), Hashmi *et al*. (2022) for empirical studies using the multiple-threshold approach.

period in 2022 (i.e., (iv) in Figure 2), because the level of JPY/USD differs substantially. Specifically, the former depreciation occurred in 2013–2014, when the JPY/USD reached around 100 in 2014, which was welcomed by Japanese exporters that had suffered from foreign exchange losses arising from historically strong appreciation in 2010–2012. In contrast, the latter depreciation occurred in 2022, when the JPY/USD reached 147 in October 2022 and Japanese firms had serious concern about the inflationary side effects due to the substantial yen depreciation. These possibly different level-effects of the exchange rate will neither be captured nor considered by the multiple-threshold approach using $\Delta neer_t$ in the indicator function.

2.4 Multiple Threshold Nonlinear ARDL Approach with Prediction Errors

The multiple-threshold ARDL approach in Equations (5) – (8) we proposed is not sufficient in practice to consider different impacts of exchange rate changes. Specifically, in Figure 2, we divide the whole sample period into three sub-samples: "strong yen period" with the exchange rate level below 107.36, "neutral period" with the exchange rate level between 107.36 and 111.21, and "weak yen period" with the exchange rate level above 111.21. The threshold values, 107.36 and 111.21, are chosen by 40% and 60% quantiles, as the benchmark case.

Even in the strong yen period, for instance, there are two different exchange rate movements: one is the continuous appreciation of the yen from around 2007 to 2012 (i.e., (i) in Figure 2), and the other is the sharp and substantial depreciation from 2013 to 2014 (i.e., (ii) in Figure 2). Japanese exporter's pricing behavior is likely to differ between the two movements in the opposite direction.

To consider the two different aspects, i.e., levels and changes in the exchange rate, we propose the new approach, the multiple-threshold nonlinear ARDL approach with prediction errors (MTNARDL-PE). Specifically, we identify "unexpected" yen appreciation or depreciation by using the prediction errors obtained from differences between the actual (realized) nominal exchange rate and the predicted exchange rate, developed by Nguyen and Sato (2019).

Unexpected yen appreciation if $S_{t+1} < E_t S_{t+1}$ holds.
Unexpected yen depreciation if $S_{t+1} > E_t S_{t+1}$ holds.

S_{t+1} can be considered as the nominal exchange rate of the yen against the USD "realized" at $(t + 1)$. E_t is an expectation operator using all information available at time t, and $E_t S_{t+1}$ denotes the predicted exchange rate for time $(t + 1)$.

By using the above prediction errors, we set up the following decomposition of the NEER series of the strong yen ($neer_t^-$) to obtain the unexpected yen appreciation ($neer_t^{--}$) and unexpected yen depreciation ($neer_t^{-+}$) in the period of strong yen in levels:

$$neer_t^{--} = neer_{t-1}^{--} + \Delta neer_t^{-} \cdot I\{S_t < E_{t-1}S_t\} \quad (9)$$
$$neer_t^{-+} = neer_{t-1}^{-+} + \Delta neer_t^{-} \cdot I\{S_t > E_{t-1}S_t\} \quad (10)$$

Similarly, we decompose the NEER series of the weak yen ($neer_t^+$) to obtain the unexpected yen appreciation ($neer_t^{+-}$) and unexpected yen depreciation ($neer_t^{++}$) in the period of weak yen in levels:

$$neer_t^{+-} = neer_{t-1}^{+-} + \Delta neer_t^{+} \cdot I\{S_t < E_{t-1}S_t\} \quad (11)$$
$$neer_t^{++} = neer_{t-1}^{++} + \Delta neer_t^{+} \cdot I\{S_t > E_{t-1}S_t\} \quad (12)$$

The MTNARDL-PE can be set up as the following conditional ECM by using 40% and 60% quantile of NEER series as the benchmark thresholds:

$$\begin{aligned}\Delta p_t^x &= \rho_0 + \rho_1 p_{t-1}^x + \rho_2 neer_{t-1}^{++} + \rho_3 neer_{t-1}^{+-} + \rho_4 neer_{t-1}^{\pm} + \rho_5 neer_{t-1}^{-+} + \rho_6 neer_{t-1}^{--} \\ &+ \rho_7 dp_{t-1} + \rho_8 ipi_{t-1}^w + \sum_{i=1}^{k} \gamma_{1i} \Delta p_{t-i}^x + \sum_{i=0}^{l_2} \gamma_{2i} \Delta neer_{t-i}^{++} + \sum_{i=0}^{l_3} \gamma_{3i} \Delta neer_{t-i}^{+-} \\ &+ \sum_{i=0}^{l_4} \gamma_{4i} \Delta neer_{t-i}^{\pm} + \sum_{i=0}^{l_5} \gamma_{5i} \Delta neer_{t-i}^{-+} + \sum_{i=0}^{l_6} \gamma_{6i} \Delta neer_{t-i}^{--} \\ &+ \sum_{i=0}^{m} \gamma_{7i} \Delta dp_{t-i} + \sum_{i=0}^{n} \gamma_{8i} \Delta ipi_{t-i}^w + v_t \end{aligned} \quad (13)$$

where appropriate lag length is chosen based on the Akaike information criterion (AIC). After estimating the conditional ECM, we conduct the bounds *F*-test for cointegration, the joint null hypothesis of which is H0: $\rho_1 = \rho_2 = \rho_3 = \rho_4 = \rho_5 = \rho_6 = \rho_7 = \rho_8 = 0$.[7] If the null hypothesis is rejected, we conclude that a long-run equilibrium relationship is found between the variables.

We conduct the test for (a)symmetric ERPT or PTM in both short-run and long-run. The null hypothesis of long-run symmetry in the strong yen period is H0: $-\rho_5 / \rho_1 = -\rho_6 / \rho_1$ in Equation (13), i.e., whether the long-run ERPT (or PTM) coefficients are identical between the unexpected yen depreciation and unexpected yen appreciation phases in the period of strong yen in levels. In a similar manner, we can test

[7] Previous studies using the multiple-threshold for NADL estimation used the bounds *F*-test for cointegration developed by Pesaran *et al*. (2001) and Shin *et al*. (2014). See Veheyen (2013), Pal and Mitra (2016), and Jalal and Gopinathan (2022).

for the long-run symmetry in ERPT or PTM between the unexpected yen depreciation in the weak yen period and the corresponding yen depreciation in the strong yen period, $-\rho_2 / \rho_1 = -\rho_5 / \rho_1$ in Equation (13).

3. Data

3.1 Data for ERPT

This study uses the monthly series of Japanese export price index (on a yen basis) by industry, nominal effective exchange rate (NEER) of the yen, domestic input prices by industry, world industrial production index, bilateral nominal exchange rate of the yen vis-à-vis the USD, and the corresponding predicted exchange rate of the yen by industry. The sample period ranges from January 2000 to December 2022.

Japanese export price index by industry and domestic input price index by industry are obtained from the website of the Bank of Japan. We use four industries for export price index: one is (i) all manufacturing industries and the other three are (ii) general machinery (i.e., general purpose, production, and business-oriented machinery), (iii) electric machinery (i.e., electric and electronic products), and (iv) transport equipment. We use corresponding domestic input price index for each industry.

Domestic input price index published by the Bank of Japan is constructed by using input coefficients obtained from the latest version of the Japan's input-output table, but the data is available up to April 2022. From then on, the Bank of Japan publishes the similar input price index at a broader category, which is called "Final Demand-Intermediate Demand price indexes (FD-ID index)". We extended the domestic input price index up to December 2022 using the information on growth rates of relevant price categories calculated from the FD-ID index.

The NEER data is collected from the website of the BIS. As explained earlier, we use a reciprocal of the BIS-NEER so that an increase (decrease) in the yen's NEER that we use in this study can be defined as depreciation (appreciation) of the yen.

World industrial production index (World IPI) is constructed by taking a weighted average of IPI for 20 major trading partner countries for Japan. IPI series are obtained from the CEIC Database. The 20 partner countries are selected based on the criteria that the destination country's share is equal to one percent or larger in Japan's total exports. Seasonality is adjusted using the Census X12 method.

The export price index (yen basis), domestic input price index, NEER of the yen, and World IPI are index numbers standardized to 100 as of 2005. All series are converted to natural logarithm. We checked time-series properties of the variables using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit-root tests. Although not reported in this paper, almost all variables are found to be non-stationary in levels and stationary in first differences.[8]

3.2 Predicted Exchange Rates

The Bank of Japan publishes the data on predicted exchange rates of the yen vis-à-vis the USD that obtained from a large-scale firm-level survey, the TANKAN survey, conducted four times a year (in March, June, September, and December). The Bank of Japan sends a questionnaire to thousands of Japanese firms about predicted exchange rates of the yen vis-à-vis the USD that sample firms use for their export planning and business forecasts in each half of the fiscal year.[9]

Table 1 illustrates the structure of the data on predicted exchange rates.[10] For example, the survey carried out in March 2022 obtains the information on the firm's forecast of the exchange rate for the first half of the fiscal year 2022 (April–September 2022).[11] The predictions obtained in the March 2022 survey are updated in the June 2022 survey. Let us assume that the sample firms' answers are most reliable for the first three post-survey months, which enables us to construct the quarterly series of predicted exchange rates: the March 2022 survey provides the data on (reliable) predicted exchange rates for the first quarter (April–June 2022), the June 2022 survey for the second quarter (July–September 2022), the September 2022 survey for the third quarter (October–December 2022), and the December 2022 survey for the fourth quarter (January–March 2023).

[Insert Table 1 around here]

We finally convert the quarterly predicted exchange rates to the monthly series by assuming that firm's prediction will not be updated for the first three post-survey months, i.e., the "constant interpolation" approach. Since industry-breakdown data on predicted exchange rates are available from the Bank of Japan TANKAN, we constructed

[8] One or two series are found to be stationary in levels, but this result is slightly changed depending on whether to include either constant only or both constant and trend in the unit-root test specification. The results of unit-root tests are available upon request.

[9] In the December 2022 survey, for instance, questionnaires were sent out to 9,235 firms (3,793 for manufacturing and 5,442 for non-manufacturing firms), and the response rate was 99.4%. See the website of the Bank of Japan (https://www.boj.or.jp/statistics/tk/gaiyo/2021/index.htm).

[10] The following discussion relies on Nguyen and Sato (2019) that first developed how to construct the monthly series of predicted exchange rates based on the Bank of Japan TANKAN data.

[11] Japanese fiscal year starts in April and ends in March.

the monthly series of the predicted exchange rates for (i) all manufacturing, (ii) general machinery, (iii) electric machinery, and (iv) transport equipment. The predicted exchange rates are standardized to 100 as of 2015.

4. Empirical results

4.1 Benchmark Results

We present the estimated results of Equation (13) based on the MTNARDL-PE. In this sub-section, we present the estimated results for the benchmark case (40/20/40). Specifically, multiple-threshold values are chosen by 40% and 60% quantiles of the yen's NEER series. We reorder the monthly NEER series in descending order, and the upper 40% are considered as the weak yen period (W or +), the lower 40% are considered as the strong yen period (S or $-$), and the middle 20% are considered as the neutral period (N or $\pm$).[12] Using prediction errors between the actual (realized) nominal exchange rate of the yen vis-à-vis the USD (i.e., JPY/USD) and the predicted exchange rate, we further distinguish between unexpected yen depreciation in the weak yen period (WD or $++$) and unexpected yen appreciation in the weak yen period (WA or $+-$). Similarly, we distinguish between unexpected yen depreciation in the strong yen period (SD or $-+$) and unexpected yen appreciation in the strong yen period (SA or $--$).

4.1.1 Bounds Tests for Cointegration

Table 2 present the results of the bounds *F*-test for four industries. We have found cointegrating relationship at the 5% significance level for three machinery industries: general machinery, electric machinery, and transport equipment, whereas cointegrating relationship is not found for all manufacturing industries. As will be shown in Section 4.2, the above results are quite robust even if we choose different threshold values.

[Insert Table 2 around here]

After finding cointegrating relationships for three machinery industries, we move on to the estimation of long-run equilibrium relationships to examine possible asymmetric ERPT between yen appreciation and depreciation periods.

[12] Again, as explained in Section 3, we use a reciprocal of the BIS-NEER so that an increase (decrease) in the yen's NEER that we use in this study can be defined as depreciation (appreciation) of the yen.

4.1.2 Asymmetry in Long-Run Coefficients between Weak and Strong Yen Periods

Table 3 presents the estimated results of long-run equilibrium relationships based on Equation (13).[13] Our main interest is in the estimated coefficient of NEER that measures the degree of ERPT or PTM. Specifically, when exporters conduct PTM behavior, estimated coefficient of NEER becomes significantly positive and closer to one. In contrast, when exporters raise the degree of ERPT, estimated coefficient of NEER is not statistically significant and/or is closer to zero.

[Insert Table 3 around here]

First, the results for transport equipment exports differ markedly from those for general machinery and electric machinery exports. The long-run NEER coefficients are significantly positive in transport equipment exports for both weak and strong yen periods irrespective of whether it is unexpected depreciation or appreciation. This result suggests strong tendency for transport equipment exporters to conduct PTM behavior.

Second, long-run NEER coefficients are found to be positive and significant in the strong yen period in both general machinery exports and electric machinery exports as well, indicating PTM behavior in their export pricing. In contrast, long-run NEER coefficients in exports of these two industries are not statistically significant at all in the weak yen period, which suggests that exchange rate changes tend to be passed through to importers during that period. This is a notable finding, because the level of exchange rates significantly affects exporter's pricing behavior in both general machinery and electric machinery industries.

A question is what causes such differences in pricing behavior between weak and strong yen periods. On one hand, as visually shown in Figure 2, Japanese exporters are likely to lose export price competitiveness during the strong yen period. To maintain price competitiveness, Japanese exporters tend to stabilize their export prices strategically in destination markets. On the other hand, why the degree of ERPT becomes larger during the weak yen period is likely because Japanese exporters have incentive to strengthen their export price competitiveness in destination markets. Thanks to the yen depreciation, Japanese exporters could enjoy large foreign exchange gains. Even if they lowered their export price itself, the loss would be covered by large exchange gains. Thus, the level of exchange rates would have significant influences on exporter's pricing behavior.

[13] For reference, we estimate long-run equilibrium relationship and conditional error-correction model for all manufacturing industries as well, although cointegrating relationship was not found in Table 2.

4.1.3 Asymmetry in Long-Run Coefficients between Unexpected Yen Appreciation and Depreciation

As clearly shown in Figure 2, we observe large fluctuations of the yen in each of weak yen or strong yen period. The next question is whether asymmetric ERPT or PTM is found especially in the strong yen period.

To test for symmetry in long-run coefficients of Equation (13), we conduct the Wald test where the null hypothesis is that long-run coefficients are symmetry (identical) between unexpected yen depreciation and appreciation phases in the period of strong yen in levels. Table 4 presents the results of the symmetry test for long-run coefficients, which reveals that in general machinery and transport equipment industries, exporter's pricing behavior significantly differs between unexpected yen depreciation and unexpected yen appreciation in the strong yen period ("SD-SA"). As shown in Table 3, the degree of PTM is larger in unexpected yen depreciation (estimated coefficients of NEER_SD) than in unexpected yen appreciation (estimated coefficients of NEER_SA). In phase (i) of Figure 2, Japanese exporters could not continue to stabilize the selling price in the destination market anymore, because their profit margin was squeezed considerably, which results in weakening PTM or increasing ERPT. In phase (ii) of Figure 2, where the yen kept depreciating further than expected, Japanese exporters tend to conduct PTM because they can expect larger foreign exchange gains even in the strong yen period. Thus, by using the data on predicted exchange rates and prediction errors, we can reveal asymmetric ERPT or PTM by Japanese machinery exporters, especially general machinery and transport equipment industries.

[Insert Table 4 around here]

Table 3 shows that in exports of transport equipment, strong PTM behavior is found even in the weak yen period irrespective of whether it is unexpected yen depreciation or appreciation. Table 4 also suggests that the degree of PTM behavior is not different between unexpected yen depreciation and appreciation in the weak yen period ("WD-WA"). Thus, in the weak yen period, the direction and magnitude of unexpected exchange rate changes do not matter for exporter's pricing decisions.

One more intriguing question is whether exporter's pricing behavior differs between unexpected yen depreciation in the strong yen period and another unexpected yen depreciation in the weak yen period. The answer is obvious, because estimated long-run NEER coefficients in the weak yen period (i.e., both NEER_WD and NEER_WA) are not statistically significant at all. This result implies that exporter's pricing behavior differs significantly between the periods of yen appreciation and depreciation in levels.

4.1.4 Asymmetry in Short-Run Coefficients

Table 5 presents estimated results of ECM for all manufacturing and three machinery industries, where only the estimated results of contemporaneous short-run coefficients are reported. All short-run coefficients of NEER are positive and statistically significant, and the magnitude of estimated NEER coefficients look quite similar. All ECTs are negative and strongly significant.

We then conduct the test for symmetry in estimated short-run contemporaneous coefficients of NEER, the results of which are reported in Table 6. Since we cannot reject the null for symmetry in most cases, which suggests symmetry in the short-run ERPT or PTM across yen depreciation and appreciation periods. As shown by Gopinath *et al*. (2010), the short-run pricing behavior, either ERPT or PTM, tends to be governed by the choice of invoice currency. Thus, we may conclude that exporters are unlikely to change the invoice currency choice even when exchange rate fluctuates largely and even though the magnitude of yen depreciation or appreciation is very large.

[Insert Tables 5 and 6 around here]

4.2 Additional Analysis

4.2.1 Different Values of Multiple-Thresholds: Robustness Check

We have so far assumed specific values for two thresholds with three periods, (weak yen/neutral/strong yen), i.e., "Benchmark Case (40/20/40)" which is chosen arbitrarily. For robustness check, we try other thresholds values not only from (1/3, 1/3, 1/3) to (45/10/45) but also (50/50).

The results of bounds tests with different threshold values are presented in Table 7, which shows that we can find cointegrating relationship in most cases for three machinery industries within a range from (36/28/36) to (43/14/43). Table 8 presents estimated results of long-run coefficients in the MTNARDL-PE. It is found that our benchmark result is quite robust within a range from (36/28/36) to (43/14/43), especially from (39/22/39) to (42/16/42). Moreover, as shown in Tables 9 and 10, the benchmark results of test for symmetry in both long-run and short-run ERPT or PTM are robust within a range from (36/28/36) to (43/14/43).

[Insert Tables 7, 8, 9, and 10 around here]

Thus, the MTNARDL-PE works quite well, and our benchmark finding is quite robust within a range from (36/28/36) to (43/14/43), which implies that the neutral period should not be too small (not smaller than 14%) and not too large (not larger than 28%).

4.2.2 Discussion

Why do general machinery and transport equipment exporters increase the degree of ERPT in response to unexpected yen appreciation during the strong yen period? Why do exporters of the two industries choose different ERPT or PTM behavior during the weak yen period?

Previous studies point out that general machinery exporters tend to choose yen-invoiced exports (Ito *et al*., 2012, 2018).[14] As long as Japanese exports are invoiced in yen, the degree of ERPT (PTM) will be very high (low) and the estimated NEER coefficients become closer to zero at least in the short-run. During the yen depreciation period, general machinery exporters that tend to choose yen invoicing can continue to keep a high degree of ERPT with the improvement of export price competitiveness in the destination market, while importers can enjoy lower import prices in terms of their currency. Thus, Japanese general machinery exporters are unlikely to incur foreign exchange loss during the yen depreciation period; rather, they are likely to improve export price competitiveness during the yen depreciation period.

On the other hand, during the yen appreciation period, general machinery exporters will undertake foreign exchange losses given their strong tendency to invoice in yen, which leads to deterioration in exporter's price competitiveness. To keep their export price competitive at the local market without losing their market share, Japanese general machinery exporters strategically stabilize their export prices in terms of importer's currency. This strategic pricing behavior becomes evident in Table 3.

It is quite intriguing that pricing behavior differs markedly between general machinery and transport equipment during the weak yen period. Previous studies found that Japanese exports of transport equipment, especially automobiles, are mostly invoiced in USD or importer's currency.[15] While importer's currency invoicing causes strong

[14] Bank of Japan publishes the share of invoice currency in Japanese exports and imports by industry, whereas no destination/source breakdown data is available. According to the Bank of Japan data, about 60% of Japanese exports are invoiced in the yen in general machinery, while the share of yen-invoiced exports is much lower in transport equipment exports (29–36%) and in electric machinery exports (37–39%).

[15] See Ito *et al*. (2012, 2018). About 70% or less of transport equipment exports are invoiced in

PTM behavior in the short run, Table 4 suggests that Japanese transport equipment exporters tend to choose PTM behavior even in the long-run. The long-run PTM behavior in transport equipment exports is not different significantly between unexpected yen appreciation and depreciation during the weak yen period. Thus, PTM is their main strategy for export pricing in the transport equipment industry irrespective of short-run (i.e., invoice currency choice) and long-run (i.e., price setting behavior).

Moreover, Table 4 shows that in the case of transport equipment exports, the degree of long-run PTM behavior is larger in the depreciation phase than in the appreciation phase during the strong yen period. This suggests that when the degree of yen appreciation exceeds a certain level, even transport equipment exporters tend to lower the degree of PTM so that they can avoid exchange loss caused by the yen appreciation.

5. Concluding Remarks

We have empirically investigated how the degree of ERPT or PTM changed in response to unexpected yen depreciation and appreciation. We employed the NARDL model with multiple thresholds and expected exchange rates to rigorously distinguish between unexpected yen appreciation and depreciation phases.

We have found that whereas PTM behavior becomes evident during the strong yen period, there is a marked difference in the degree of ERPT or PTM between unexpected yen depreciation and unexpected yen appreciation. This difference is much more evident in exports of general machinery and transport equipment industries. Japanese exporters strategically switch the pricing behavior from ERPT to PTM and vice versa especially in response to unexpected yen appreciation and depreciation. The above findings obtained from the benchmark model are supported by different values of multiple thresholds with a range of (weak yen/neutral/strong yen) periods from (36/28/36) to (43/14/43). Our empirical findings would have significant implications for better pricing strategies by Japanese export firms in the face of sharp and substantial appreciation or depreciation of the yen.

In this study, we have not empirically explored what causes different pricing behavior of Japanese exporters between unexpected yen appreciation and depreciation phases. More rigorous investigation is left for our future research.

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foreign currency.

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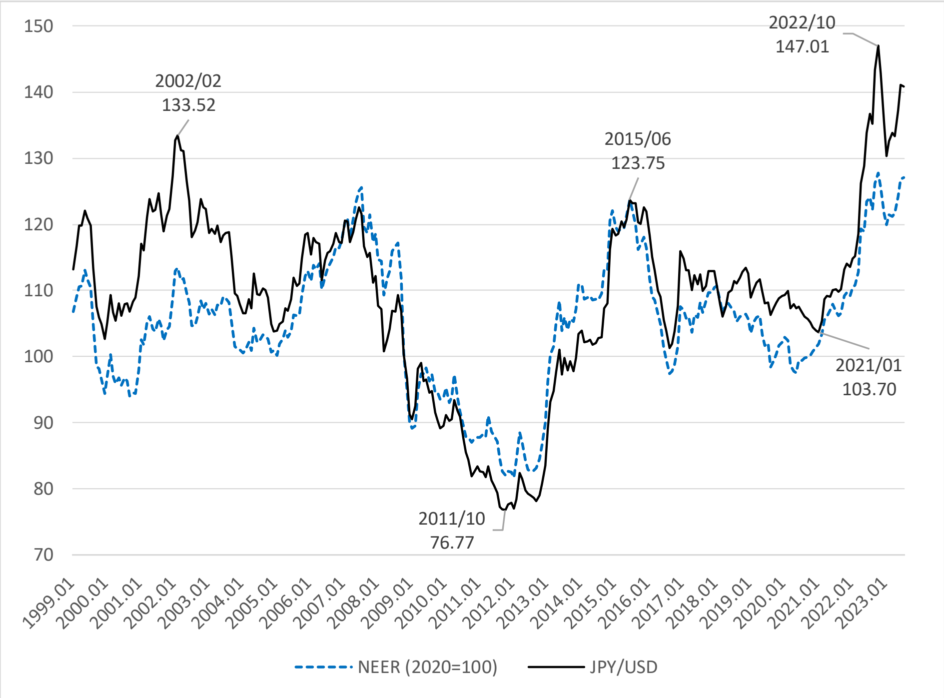
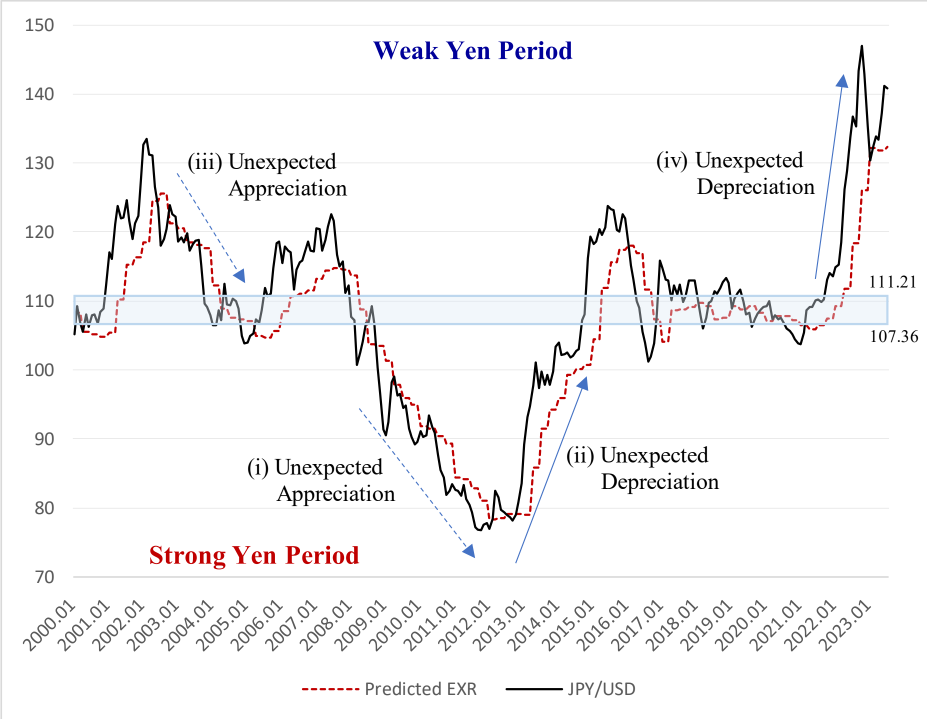
Figure 1. Bilateral Nominal Exchange Rate of the Yen vis-à-vis the US Dollar and BIS Nominal Effective Exchange Rate (2020=100): January 1999–July 2023



Note: The definition of the BIS Nominal Effective Exchange Rate (NEER) of the yen is changed as follows: An increase (decrease) in NEER means yen depreciation (appreciation), the base year of which is 2020. "JPY/USD" denotes the bilateral nominal exchange rate of the yen vis-à-vis the US dollar.

Source: Bank for International Settlements (BIS) website; IMF, International Financial Statistics, online.

Figure 2. Bilateral Nominal Exchange Rate of the Yen vis-à-vis the US Dollar: Actual and Predicted Exchange Rates (January 2000–July 2023)



Note: "JPY/USD" denotes the bilateral nominal exchange rate of the yen vis-à-vis the US dollar. "Predicted EXR" denotes the survey data on the predicted bilateral nominal exchange rate of the yen vis-à-vis the US dollar provided by the Bank of Japan (BOJ). We use the predicted exchange rate by all Japanese manufacturing firms. BOJ publishes the quarterly series of the predicted exchange rate. By using the conversion method from quarterly series to monthly series developed by Nguyen and Sato (2019), we also converted the quarterly predicted exchange rate series to the monthly series. Rectangular area shaded by light blue shows the middle 20% ranging from 107.36 to 111.21 obtained by the multiple-threshold method that decomposes the whole sample period into three periods: the yen appreciation (lower 40%), neutral (middle 20%), and depreciation (upper 40%) periods.

Source: IMF, International Financial Statistics, online; Bank of Japan, TANKAN.

Table 1. Illustration of the Bank of Japan predicted exchange rates for the 2022 fiscal year

Survey conducted in :	2022										2023		
	3	4	5	6	7	8	9	10	11	12	1	2	3
March 2022	·	E_3S_4	E_3S_5	E_3S_6	E_3S_7	E_3S_8	E_3S_9	·	·	·	·	·	·
June 2022		·	·	·	E_6S_7	E_6S_8	E_6S_9	·	·	·	·	·	·
September 2022							·	E_9S_{10}	E_9S_{11}	E_9S_{12}	E_9S_1	E_9S_2	E_9S_3
December 2022										·	$E_{12}S_1$	$E_{12}S_2$	$E_{12}S_3$

Note: The Bank of Japan TANKAN survey is conducted four times a year: in March, June, September, and December. For illustrative purposes, we show the four-times survey in 2022 (far left column) and the red circles represent the timing of the surveys. In March and September surveys, sample firms answer the questions about their predicted exchange rate for the coming two quarters (six months). For instance, $E_3S_4 = E_3S_5 = E_3S_6 = \cdots = E_3S_9$ in the March 2022 survey, where E and S denote the expectation operator and the bilateral nominal exchange rate of the yen vis-à-vis the USD, respectively. The predicted exchange rate is updated in June and December surveys. The June 2022 survey, for instance, presents the *revised* predicted exchange rate for the coming one-quarter (three months) ($E_6S_7 = E_6S_8 = E_6S_9$). Assuming that the predicted exchange rate is reliable only for the first three post-survey months, we can construct the quarterly series of predicted exchange rates: i.e., $E_3S_4 = E_3S_5 = E_3S_6$ for the first quarter of the fiscal year 2022, $E_6S_7 = E_6S_8 = E_6S_9$ for the second quarter of the fiscal year 2022, and $E_9S_{10} = E_9S_{11} = E_9S_{12}$ for the third quarter of the fiscal year 2022, and so forth. We next construct the monthly series of predicted exchange rates by making "constant" interpolation.

Table 2. Results of Bounds Test for Cointegration: Benchmark Case (40/20/40)

Benchmark (40%)	Bounds F-test
All Industries	2.360
General Machinery	3.817**
Electric Machinery	4.209**
Transport Equipment	4.247**

Note: Results of bounds F-test for cointegration in Equation (16) are reported. Double asterisks (**) denote 5% significance.

Table 3. Result of Long-Run Cointegrating Coefficients: Benchmark Case (40/20/40)

Benchmark (40%)	Input Price	World IPI	NEER_WD	NEER_WA	NEER_N	NEER_SD	NEER_SA
All Industries	0.027	-0.041	0.447	0.193	0.095	0.579**	0.624***
	(0.294)	(0.294)	(0.280)	(0.854)	(0.344)	(0.230)	(0.217)
General Machinery	0.874***	-0.170	0.238	0.152	0.108	0.705***	0.488***
	(0.295)	(0.108)	(0.162)	(0.305)	(0.128)	(0.119)	(0.088)
Electric Machinery	1.643***	-0.026	-0.924	-0.512	-0.813	1.849***	1.178***
	(0.467)	(0.601)	(0.613)	(1.086)	(0.644)	(0.496)	(0.446)
Transport Equipment	0.343**	-0.411***	0.979***	0.798**	0.410***	0.748***	0.317***
	(0.155)	(0.117)	(0.119)	(0.305)	(0.115)	(0.089)	(0.079)

Note: Triple asterisks (***) and double asterisks (**) denote 1% and 5% significance, respectively. Standard errors are in parentheses. "NEER_WD" denotes the unexpected yen Depreciation in the Weak yen period (upper 40%). "NEER_WA" denotes the unexpected yen Appreciation in the Weak yen period (upper 40%). "NEER_N" denotes the Neutral period (middle 20%). "NEER_SD" denotes the unexpected yen Depreciation in the Strong yen period (lower 40%). "NEER_SA" denotes the unexpected yen Appreciation in the Strong yen period (lower 40%).

Table 4. Wald Test for Symmetry in Long-Run Coefficients: Benchmark Case (40/20/40)

Benchmark (40%)	All	General M.	Electric M.	Trasport Eq.
WD-WA	0.084	0.065	0.151	0.364
$H_0 : -(\rho_2/\rho_1) = -(\rho_3/\rho_1)$	(0.7716)	(0.7989)	(0.6982)	(0.5470)
SD-SA	0.025	3.583*	1.727	15.678***
$H_0 : -(\rho_5/\rho_1) = -(\rho_6/\rho_1)$	(0.8738)	(0.0595)	(0.1900)	(0.0001)

Note: Triple asterisks (***) and a single asterisk (*) denote 1%, 5%, and 10% significance, respectively. Probabilities are in parentheses. The null hypothesis is based on Equation (16). "WD-WA" denotes the test for symmetry in long-run coefficients between unexpected yen Depreciation in the Weak yen period and unexpected yen Appreciation in the Weak yen period. "SD-SA" denotes the test for symmetry in long-run coefficients between unexpected yen Depreciation in the Strong yen period and unexpected yen Appreciation in the Strong yen period.

Table 5. Result of Error-Correction Model: Benchmark Case (40/20/40)

	All Industries	General Machinery	Electric Machinery	Transport Equipment
Constant	0.136**	0.105**	-0.069**	0.522**
	(0.031)	(0.019)	(0.011)	(0.088)
d(Input Price)	0.339**	-0.085	70.462**	
	(0.037)	(0.086)	(0.099)	
d(World IPI)	-0.030	-0.044*	-0.060**	
	(0.019)	(0.018)	(0.022)	
d(NEER_WD)	0.614**	0.454**	0.576**	0.750**
	(0.025)	(0.025)	(0.035)	(0.033)
d(NEER_WA)	0.643**	0.521**	0.540**	0.817**
	(0.053)	(0.058)	(0.067)	(0.080)
d(NEER_N)	0.595**	0.462**	0.609**	0.647**
	(0.037)	(0.039)	(0.050)	(0.054)
d(NEER_SD)	0.602**	0.405**	0.497**	0.746**
	(0.029)	(0.032)	(0.039)	(0.045)
d(NEER_SA)	0.549**	0.414**	0.402**	0.688**
	(0.028)	(0.029)	(0.040)	(0.034)
ECT	-0.030**	-0.078**	-0.023**	-0.109**
	(0.007)	(0.014)	(0.004)	(0.018)
Adj-R^2	0.929	0.810	0.847	0.847
D.W.	1.945	2.021	1.948	1.948

Note: Double asterisks (**) and a single asterisk (*) denote 5%, and 10% significance, respectively. Standard errors are in parentheses. "NEER_WD" denotes the unexpected yen Depreciation in the Weak yen period (upper 40%). "NEER_WA" denotes the unexpected yen Appreciation in the Weak yen period (upper 40%). "NEER_N" denotes the Neutral period (middle 20%). "NEER_SD" denotes the unexpected yen Depreciation in the Strong yen period (lower 40%). "NEER_SA" denotes the unexpected yen Appreciation in the Strong yen period (lower 40%). $d(\cdot)$ denotes the first-difference of variables. "ECT" denotes error-correction term.

Table 6. Wald Test for Symmetry in Short-Run Coefficients: Benchmark Case (40/20/40)

Benchmark (40%)		All	General M.	Electric M.	Trasport Eq.
WD-WA	$H_0 : \gamma_{20} = \gamma_{30}$	0.242	1.028	0.222	0.505
		(0.6231)	(0.3117)	(0.6380)	(0.4779)
SD-SA	$H_0 : \gamma_{50} = \gamma_{60}$	1.691	0.041	2.947*	1.484
		(0.1947)	(0.8403)	(0.0873)	(0.2242)

Note: A single asterisk (*) denote 10% significance. Probabilities are in parentheses. The null hypothesis is based on Equation (16). "WD-WA" denotes the test for symmetry in short-run coefficients between unexpected yen Depreciation in the Weak yen period and unexpected yen Appreciation in the Weak yen period. "SD-SA" denotes the test for symmetry in short-run coefficients between unexpected yen Depreciation in the Strong yen period and unexpected yen Appreciation in the Strong yen period.

Table 7. Results of Bounds Test for Cointegration: Robustness Check

One-third	Bounds F-test	Benchmark (40%)	Bounds F-test
All Industries	2.581	All Industries	2.360
General Machinery	3.442*	General Machinery	3.817**
Electric Machinery	5.05***	Electric Machinery	4.209**
Transport Equipment	1.721	Transport Equipment	4.247**
34%	Bounds F-test	41%	Bounds F-test
All Industries	2.957	All Industries	2.378
General Machinery	3.924**	General Machinery	3.755**
Electric Machinery	5.329***	Electric Machinery	4.061**
Transport Equipment	2.824	Transport Equipment	4.185**
35%	Bounds F-test	42%	Bounds F-test
All Industries	2.869	All Industries	2.453
General Machinery	3.931**	General Machinery	4.138**
Electric Machinery	5.224***	Electric Machinery	4.257**
Transport Equipment	2.881	Transport Equipment	4.080**
36%	Bounds F-test	43%	Bounds F-test
All Industries	2.733	All Industries	2.577
General Machinery	3.877**	General Machinery	4.008**
Electric Machinery	4.725***	Electric Machinery	4.059**
Transport Equipment	3.984**	Transport Equipment	4.030**
37%	Bounds F-test	44%	Bounds F-test
All Industries	2.704	All Industries	2.307
General Machinery	3.767**	General Machinery	2.801
Electric Machinery	4.719***	Electric Machinery	3.427*
Transport Equipment	4.061**	Transport Equipment	2.608
38%	Bounds F-test	45%	Bounds F-test
All Industries	2.471	All Industries	2.397
General Machinery	4.026**	General Machinery	2.542
Electric Machinery	4.909***	Electric Machinery	3.166*
Transport Equipment	2.669	Transport Equipment	3.173*
39%	Bounds F-test	50%	Bounds F-test
All Industries	2.276	All Industries	2.685
General Machinery	3.565**	General Machinery	3.213
Electric Machinery	4.190**	Electric Machinery	2.724
Transport Equipment	3.832**	Transport Equipment	3.002

Note: Triple asterisks (***), double asterisks (**), and a single asterisk (*) denote 1%, 5%, and 10% significance, respectively.

Table 8. Results of Long-Run Cointegrating Coefficients: Robustness Check

One-third	Input Price	World IPI	NEER_WD	NEER_WA	NEER_N	NEER_SD	NEER_SA
All Industries	-0.227	0.111	0.658	-0.407	-0.236	0.713*	0.711***
	(0.394)	(0.329)	(0.503)	(1.183)	(0.770)	(0.385)	(0.269)
General Machinery	1.250***	-0.350**	0.173	0.171	0.112	0.960***	0.445***
	(0.426)	(0.168)	(0.220)	(0.508)	(0.324)	(0.197)	(0.118)
Electric Machinery	1.935***	-0.551	-0.928	-1.118	-1.502	2.521***	0.891**
	(0.486)	(0.457)	(0.606)	(0.863)	(1.059)	(0.657)	(0.394)
Transport Equipment	0.140	-0.548**	0.896***	0.240	0.396	0.933***	0.200
	(0.373)	(0.270)	(0.252)	(0.627)	(0.399)	(0.229)	(0.196)
34%	**Input Price**	**World IPI**	**NEER_WD**	**NEER_WA**	**NEER_N**	**NEER_SD**	**NEER_SA**
All Industries	0.027	0.072	0.519	-0.040	-0.209	0.541**	0.685***
	(0.235)	(0.254)	(0.319)	(0.660)	(0.503)	(0.222)	(0.183)
General Machinery	1.026***	-0.272*	0.320*	0.203	-0.099	0.792***	0.430***
	(0.339)	(0.139)	(0.191)	(0.374)	(0.301)	(0.139)	(0.093)
Electric Machinery	1.543***	-0.212	-0.680	-0.630	-1.330	1.722***	1.075***
	(0.408)	(0.455)	(0.493)	(0.659)	(0.819)	(0.357)	(0.343)
Transport Equipment	0.186	-0.591**	1.067***	0.062	0.083	0.880***	0.256*
	(0.314)	(0.243)	(0.229)	(0.501)	(0.344)	(0.163)	(0.144)
35%	**Input Price**	**World IPI**	**NEER_WD**	**NEER_WA**	**NEER_N**	**NEER_SD**	**NEER_SA**
All Industries	0.037	0.108	0.462	0.016	-0.237	0.552**	0.695***
	(0.239)	(0.267)	(0.312)	(0.705)	(0.517)	(0.231)	(0.188)
General Machinery	1.011***	-0.261*	0.275	0.176	0.007	0.787***	0.442***
	(0.324)	(0.135)	(0.179)	(0.365)	(0.282)	(0.131)	(0.091)
Electric Machinery	1.498***	-0.165	-0.680	-0.506	-1.282	1.727***	1.109***
	(0.396)	(0.467)	(0.470)	(0.682)	(0.825)	(0.352)	(0.347)
Transport Equipment	0.189	-0.598**	1.042***	0.101	0.173	0.898***	0.259*
	(0.295)	(0.234)	(0.210)	(0.477)	(0.328)	(0.155)	(0.137)
36%	**Input Price**	**World IPI**	**NEER_WD**	**NEER_WA**	**NEER_N**	**NEER_SD**	**NEER_SA**
All Industries	0.028	0.040	0.446	0.081	-0.194	0.585**	0.668***
	(0.244)	(0.277)	(0.310)	(0.751)	(0.504)	(0.235)	(0.200)
General Machinery	0.990***	-0.284**	0.264	0.194	0.028	0.798***	0.437***
	(0.333)	(0.129)	(0.186)	(0.365)	(0.257)	(0.137)	(0.092)
Electric Machinery	1.552***	-0.292	-0.900	-0.539	-1.293	1.983***	1.051***
	(0.445)	(0.501)	(0.573)	(0.839)	(0.908)	(0.441)	(0.390)
Transport Equipment	0.085	-0.542***	1.086***	0.474	0.208	0.805***	0.254**
	(0.216)	(0.158)	(0.170)	(0.365)	(0.240)	(0.106)	(0.103)

37%	Input Price	World IPI	NEER_WD	NEER_WA	NEER_N	NEER_SD	NEER_SA
All Industries	0.019	-0.010	0.419	0.061	-0.167	0.628**	0.648***
	(0.253)	(0.282)	(0.309)	(0.837)	(0.440)	(0.245)	(0.210)
General Machinery	1.004***	-0.297**	0.221	0.144	0.121	0.820***	0.444***
	(0.346)	(0.132)	(0.193)	(0.393)	(0.219)	(0.142)	(0.096)
Electric Machinery	1.579***	-0.313	-0.983*	-0.784	-1.030	1.973***	1.091***
	(0.437)	(0.489)	(0.551)	(0.865)	(0.765)	(0.426)	(0.391)
Transport Equipment	0.111	-0.508	0.992***	0.369	0.205	0.811***	0.275***
	(0.204)	(0.142)	(0.145)	(0.360)	(0.193)	(0.099)	(0.096)
38%	**Input Price**	**World IPI**	**NEER_WD**	**NEER_WA**	**NEER_N**	**NEER_SD**	**NEER_SA**
All Industries	0.083	-0.036	0.401	0.261	0.104	0.653***	0.648***
	(0.245)	(0.275)	(0.247)	(0.821)	(0.279)	(0.207)	(0.198)
General Machinery	0.869***	-0.242**	0.272*	0.258	0.187	0.748**	0.433**
	(0.301)	(0.113)	(0.162)	(0.353)	(0.125)	(0.123)	(0.086)
Electric Machinery	1.278***	-0.327	-0.677*	-0.304	-0.681	1.727***	1.106***
	(0.349)	(0.391)	(0.405)	(0.805)	(0.429)	(0.309)	(0.313)
Transport Equipment	-0.112	0.047	0.446	-0.064	0.261	0.567*	0.660**
	(0.387)	(0.368)	(0.352)	(1.081)	(0.474)	(0.291)	(0.260)
39%	**Input Price**	**World IPI**	**NEER_WD**	**NEER_WA**	**NEER_N**	**NEER_SD**	**NEER_SA**
All Industries	-0.112	0.047	0.446	-0.064	0.261	0.567*	0.660**
	(0.387)	(0.368)	(0.352)	(1.081)	(0.474)	(0.291)	(0.260)
General Machinery	0.881***	-0.239**	0.218	0.114	0.156	0.761***	0.453***
	(0.298)	(0.111)	(0.179)	(0.339)	(0.145)	(0.126)	(0.087)
Electric Machinery	1.755***	-0.021	-1.098	-0.669	-0.883	1.981***	1.185**
	(0.492)	(0.642)	(0.695)	(1.151)	(0.725)	(0.525)	(0.474)
Transport Equipment	0.413**	-0.426***	0.976***	0.740**	0.411***	0.813***	0.327***
	(0.176)	(0.132)	(0.135)	(0.343)	(0.138)	(0.099)	(0.086)
Benchmark (40%)	**Input Price**	**World IPI**	**NEER_WD**	**NEER_WA**	**NEER_N**	**NEER_SD**	**NEER_SA**
All Industries	0.027	-0.041	0.447	0.193	0.095	0.579**	0.624***
	(0.294)	(0.294)	(0.280)	(0.854)	(0.344)	(0.230)	(0.217)
General Machinery	0.874***	-0.170	0.238	0.152	0.108	0.705***	0.488***
	(0.295)	(0.108)	(0.162)	(0.305)	(0.128)	(0.119)	(0.088)
Electric Machinery	1.643***	-0.026	-0.924	-0.512	-0.813	1.849***	1.178***
	(0.467)	(0.601)	(0.613)	(1.086)	(0.644)	(0.496)	(0.446)
Transport Equipment	0.343**	-0.411***	0.979***	0.798**	0.410***	0.748***	0.317***
	(0.155)	(0.117)	(0.119)	(0.305)	(0.115)	(0.089)	(0.079)

Table 8 (cont.) Results of Long-Run Cointegrating Coefficients: Robustness Check

41%	Input Price	World IPI	NEER_WD	NEER_WA	NEER_N	NEER_SD	NEER_SA
All Industries	0.033	-0.054	0.446	0.172	0.063	0.596**	0.622***
	(0.295)	(0.299)	(0.289)	(0.860)	(0.365)	(0.239)	(0.221)
General Machinery	0.868***	-0.182*	0.240	0.131	0.109	0.714***	0.489***
	(0.282)	(0.109)	(0.160)	(0.308)	(0.136)	(0.118)	(0.089)
Electric Machinery	1.625***	-0.033	-0.992	-0.600	-0.780	1.948***	1.202**
	(0.497)	(0.654)	(0.688)	(1.167)	(0.726)	(0.563)	(0.491)
Transport Equipment	0.387**	-0.409	0.971***	0.790**	0.371***	0.764***	0.322***
	(0.157)	(0.119)	(0.122)	(0.311)	(0.124)	(0.091)	(0.080)

42%	Input Price	World IPI	NEER_WD	NEER_WA	NEER_N	NEER_SD	NEER_SA
All Industries	0.005	0.025	0.458	0.009	-0.166	0.515**	0.656***
	(0.275)	(0.302)	(0.291)	(0.742)	(0.588)	(0.236)	(0.219)
General Machinery	1.081***	-0.171	0.205	0.080	-0.204	0.742***	0.500***
	(0.356)	(0.123)	(0.182)	(0.304)	(0.267)	(0.134)	(0.096)
Electric Machinery	1.821***	0.037	-0.835	-0.515	-1.784	1.732***	1.099**
	(0.470)	(0.625)	(0.601)	(0.919)	(1.096)	(0.476)	(0.445)
Transport Equipment	0.416**	-0.381***	0.993***	0.626**	0.192	0.735***	0.344***
	(0.170)	(0.129)	(0.128)	(0.314)	(0.217)	(0.097)	(0.080)

43%	Input Price	World IPI	NEER_WD	NEER_WA	NEER_N	NEER_SD	NEER_SA
All Industries	-0.030	0.120	0.560*	0.170	-0.788	0.435*	0.651***
	(0.253)	(0.322)	(0.306)	(0.677)	(0.817)	(0.249)	(0.222)
General Machinery	1.315**	-0.247	0.251	-0.011	-0.648	0.812***	0.458***
	(0.581)	(0.163)	(0.243)	(0.363)	(0.627)	(0.207)	(0.119)
Electric Machinery	1.883***	0.185	-0.867	-1.041	-3.132	2.007***	1.148*
	(0.630)	(0.886)	(0.822)	(0.991)	(2.127)	(0.698)	(0.588)
Transport Equipment	0.241	-0.488***	0.974***	0.264	0.174	0.742***	0.294***
	(0.206)	(0.150)	(0.139)	(0.289)	(0.330)	(0.111)	(0.098)

44%	Input Price	World IPI	NEER_WD	NEER_WA	NEER_N	NEER_SD	NEER_SA
All Industries	-0.286	0.085	0.547	0.087	0.695	0.334	0.606**
	(0.341)	(0.402)	(0.364)	(0.922)	(1.016)	(0.387)	(0.288)
General Machinery	1.830	-0.397	0.216	-0.114	-0.497	1.327*	0.531**
	(1.430)	(0.305)	(0.442)	(0.697)	(1.070)	(0.736)	(0.231)
Electric Machinery	2.196**	0.463	-1.231	-1.325	-4.328	4.175*	1.424
	(1.026)	(1.512)	(1.420)	(1.744)	(3.942)	(2.240)	(0.996)
Transport Equipment	0.266	-0.699***	0.909***	0.086	0.924*	0.903***	0.230
	(0.325)	(0.260)	(0.192)	(0.474)	(0.535)	(0.227)	(0.156)

45%	Input Price	World IPI	NEER_WD	NEER_WA	NEER_N	NEER_SD	NEER_SA
All Industries	-0.251	0.111	0.407	-0.005	1.237	0.164	0.605**
	(0.303)	(0.391)	(0.369)	(0.901)	(0.886)	(0.415)	(0.284)
General Machinery	2.723	-0.448	-0.163	-0.579	0.744	1.560	0.645
	(3.247)	(0.528)	(0.978)	(1.211)	(1.355)	(1.520)	(0.442)
Electric Machinery	2.718	0.988	-2.318	-3.111	-2.833	5.963	1.848
	(1.766)	(2.714)	(2.835)	(3.036)	(5.474)	(5.325)	(1.781)
Transport Equipment	0.221	-0.731***	0.858***	0.049	1.549***	0.669***	0.163
	(0.298)	(0.249)	(0.182)	(0.418)	(0.497)	(0.247)	(0.163)

50%	Input Price	World IPI	NEER_WD	NEER_WA	NEER_N	NEER_SD	NEER_SA
All Industries	-0.157	0.193	0.453*	0.073		0.378	0.697***
	(0.246)	(0.345)	(0.262)	(0.745)		(0.289)	(0.232)
General Machinery	1.178	-0.077	0.180	-0.643		0.994**	0.798**
	(0.815)	(0.322)	(0.351)	(0.666)		(0.443)	(0.332)
Electric Machinery	1.989	1.945	-3.222	-3.984		5.405	2.548
	(2.818)	(5.522)	(5.663)	(5.396)		(7.212)	(3.533)
Transport Equipment	0.361	-0.517***	0.971***	0.268		0.732***	0.345***
	(0.226)	(0.186)	(0.146)	(0.362)		(0.168)	(0.109)

Note: Triple asterisks (***), double asterisks (**), and a single asterisk (*) denote 1%, 5%, and 10% significance, respectively. Standard errors are in parentheses. See note in Table 3.

Table 9. Wald Test for Symmetry in Long-Run Cointegrating Coefficients: Robustness Check

		All	General M.	Electric M.	Trasport Eq.
One-third	WD-WA	0.633	0.001	0.037	0.921
		(0.4269)	(0.9748)	(0.8473)	(0.3382)
	SD-SA	0.000	5.373**	4.793**	6.326**
		(0.9975)	(0.0213)	(0.0295)	(0.0126)
34%	WD-WA	0.604	0.040	0.005	2.950*
		(0.4377)	(0.8413)	(0.9454)	(0.0871)
	SD-SA	0.308	4.642**	2.010	8.461***
		(0.5793)	(0.0322)	(0.1575)	(0.0040)
35%	WD-WA	0.354	0.028	0.055	2.935*
		(0.5524)	(0.8680)	(0.8153)	(0.0879)
	SD-SA	0.266	4.708**	1.849	9.392***
		(0.6064)	(0.0310)	(0.1752)	(0.0024)
36%	WD-WA	0.234	0.012	0.170	2.616
		(0.6291)	(0.9126)	(0.6804)	(0.1071)
	SD-SA	0.082	5.308**	3.283*	18.025***
		(0.7743)	(0.0221)	(0.0712)	(0.0000)
37%	WD-WA	0.177	0.016	0.048	2.639
		(0.6747)	(0.9008)	(0.8263)	(0.1055)
	SD-SA	0.004	5.720**	3.105*	19.109***
		(0.9485)	(0.0175)	(0.0793)	(0.0000)
38%	WD-WA	0.030	0.000	0.234	0.001
		(0.8623)	(0.9892)	(0.6289)	(0.9790)
	SD-SA	0.000	5.826**	2.945*	8.451***
		(0.9844)	(0.0165)	(0.0874)	(0.0040)
39%	WD-WA	0.214	0.040	0.145	0.470
		(0.6443)	(0.8414)	(0.7037)	(0.4937)
	SD-SA	0.066	5.798**	2.104	14.597***
		(0.7976)	(0.0168)	(0.1482)	(0.0002)
40%	WD-WA	0.084	0.065	0.151	0.364
		(0.7716)	(0.7989)	(0.6982)	(0.5470)
	SD-SA	0.025	3.583*	1.727	15.678***
		(0.8738)	(0.0595)	(0.1900)	(0.0001)
41%	WD-WA	0.097	0.105	0.119	0.356
		(0.7558)	(0.7460)	(0.7308)	(0.5512)
	SD-SA	0.008	3.793*	1.759	15.409***
		(0.9293)	(0.0526)	(0.1860)	(0.0001)
42%	WD-WA	0.366	0.124	0.116	1.243
		(0.5458)	(0.7251)	(0.7334)	(0.2658)
	SD-SA	0.249	3.267*	1.482	10.801***
		(0.6180)	(0.0719)	(0.2246)	(0.0012)
43%	WD-WA	0.390	0.470	0.034	6.068**
		(0.5326)	(0.4937)	(0.8544)	(0.0144)
	SD-SA	0.561	2.858*	1.459	12.076***
		(0.4544)	(0.0922)	(0.2283)	(0.0006)
44%	WD-WA	0.317	0.253	0.004	3.315*
		(0.5741)	(0.6155)	(0.9512)	(0.0699)
	SD-SA	0.457	1.493	2.165	6.720**
		(0.4997)	(0.2229)	(0.1424)	(0.0101)
45%	WD-WA	0.273	0.199	0.153	3.822*
		(0.6017)	(0.6563)	(0.6963)	(0.0517)
	SD-SA	1.157	0.525	0.918	3.486*
		(0.2831)	(0.4692)	(0.3390)	(0.0631)
50%	WD-WA	0.303	2.285	0.060	3.527*
		(0.5824)	(0.1319)	(0.8063)	(0.0615)
	SD-SA	1.077	0.334	0.321	4.217**
		(0.3003)	(0.5636)	(0.5716)	(0.0410)

Note: Triple asterisks (***), double asterisks (**), and a single asterisk (*) denote 1%, 5%, and 10% significance, respectively. Probabilities are in parentheses. See note in Table 4.

Table 10. Wald Test for Symmetry in Short-Run Coefficients in Conditional Error-Correction Model: Robustness Check

		All	General M.	Electric M.	Trasport Eq.
One-third	WD-WA	0.321	1.654	0.679	0.694
		(0.5717)	(0.1996)	(0.4107)	(0.4055)
	SD-SA	1.945	0.068	3.098*	0.393
		(0.1644)	(0.7950)	(0.0796)	(0.5312)
34%	WD-WA	0.333	1.237	0.580	0.535
		(0.5647)	(0.2672)	(0.4469)	(0.4653)
	SD-SA	1.566	0.164	2.118	0.681
		(0.2119)	(0.6855)	(0.1469)	(0.4099)
35%	WD-WA	0.477	1.513	0.385	0.521
		(0.4905)	(0.2199)	(0.5358)	(0.4712)
	SD-SA	0.940	0.440	2.140	0.668
		(0.3333)	(0.5080)	(0.1448)	(0.4144)
36%	WD-WA	0.513	1.555	0.289	0.702
		(0.4746)	(0.2136)	(0.5915)	(0.4030)
	SD-SA	0.868	0.441	2.336	0.294
		(0.3524)	(0.5074)	(0.1277)	(0.5879)
37%	WD-WA	0.211	1.423	0.533	0.387
		(0.6463)	(0.2341)	(0.4662)	(0.5346)
	SD-SA	0.883	0.447	2.327	0.540
		(0.3482)	(0.5042)	(0.1284)	(0.4633)
38%	WD-WA	0.251	1.243	0.527	0.635
		(0.6170)	(0.2660)	(0.4684)	(0.4265)
	SD-SA	1.108	0.157	3.841*	0.905
		(0.2935)	(0.6921)	(0.0512)	(0.3425)
39%	WD-WA	0.271	0.930	0.313	0.527
		(0.6032)	(0.3357)	(0.5764)	(0.4684)
	SD-SA	1.499	0.052	2.752*	1.273
		(0.2220)	(0.8197)	(0.0984)	(0.2603)

		All	General M.	Electric M.	Trasport Eq.
40%	WD-WA	0.242	1.028	0.222	0.505
		(0.6231)	(0.3117)	(0.6380)	(0.4779)
	SD-SA	1.691	0.041	2.947*	1.484
		(0.1947)	(0.8403)	(0.0873)	(0.2242)
41%	WD-WA	0.263	1.101	0.186	0.535
		(0.6088)	(0.2952)	(0.6664)	(0.4651)
	SD-SA	1.752	0.039	2.984*	1.343
		(0.1868)	(0.8443)	(0.0854)	(0.2475)
42%	WD-WA	0.134	0.884	0.289	0.585
		(0.7143)	(0.3480)	(0.5914)	(0.4451)
	SD-SA	1.164	0.113	2.805*	0.385
		(0.2817)	(0.7375)	(0.0952)	(0.5354)
43%	WD-WA	0.080	0.309	0.021	0.284
		(0.7780)	(0.5789)	(0.8856)	(0.5948)
	SD-SA	1.383	0.078	3.136*	0.302
		(0.2407)	(0.7805)	(0.0778)	(0.5829)
44%	WD-WA	0.204	0.368	0.010	0.659
		(0.6521)	(0.5447)	(0.9215)	(0.4177)
	SD-SA	1.624	0.009	5.001**	0.469
		(0.2037)	(0.9266)	(0.0262)	(0.4943)
45%	WD-WA	0.219	0.513	0.038	0.806
		(0.6404)	(0.4747)	(0.8452)	(0.3703)
	SD-SA	1.683	0.000	5.865**	0.121
		(0.1958)	(0.9917)	(0.0162)	(0.7282)
50%	WD-WA	0.164	0.969	0.141	0.594
		(0.6861)	(0.3260)	(0.7075)	(0.4415)
	SD-SA	1.651	0.433	8.265***	0.069
		(0.2000)	(0.5114)	(0.0044)	(0.7933)

Note: Triple asterisks (***), double asterisks (**), and a single asterisk (*) denote 1%, 5%, and 10% significance, respectively. Probabilities are in parentheses. See note in Table 6.