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Firm Predicted Exchange Rates and Nonlinearities in Pricing-to-Market*

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Abstract

This paper employs the nonlinear autoregressive distributed lag (NARDL) model to investigate possible short- and long-run asymmetry in the pricing-to-market (PTM) behavior of Japanese exporters. In contrast to the conventional threshold specification, this study uses firms' predicted exchange rates, collected from a large-scale firm-level survey by the Bank of Japan, to distinguish between yen appreciation and depreciation periods. Using Japanese export price data at an industry level, we demonstrate that (1) the short-run PTM is almost complete and symmetric in all industries over the entire sample period from 1997 to 2015 and (2) during the latter sub-sample period from 2007 to 2015, Japanese exporters tend to engage in asymmetric PTM behavior in the long run. In the yen appreciation period, most industries choose incomplete but relatively strong long-run PTM. However, in the yen depreciation period, competitive industries tend to conduct complete PTM in the long run, while less-competitive industries tend to raise the degree of exchange rate pass-through (ERPT) in the long run. These empirical findings have important policy implications for the recent unresponsiveness of Japanese real exports to the substantial depreciation of the yen from the end of 2012.

Keywords: Predicted exchange rate, Pricing-to-market (PTM), Exchange rate pass-through (ERPT), Nonlinear Autoregressive distributed lag (NARDL) model, Yen appreciation and depreciation, Japanese exports
JEL classification: C22, D22, E31, F31

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1. Introduction

Since Japan adopted a floating exchange rate in 1971, the Japanese economy has faced a large yen appreciation period three times. The latest period corresponds to the subprime mortgage crisis in 2007, witnessing a sharp appreciation of the yen vis-à-vis the U.S. dollar from around 120 in 2007 to the post-WWII record high of 75.32 yen/USD in the end of October 2011 (Figure 1). In late 2012, however, Prime Minister Shinzo Abe initiated his economic stimulus package, known as "Abenomics," targeting steady currency depreciation. This put an end to the yen appreciation trend and dramatically turned the yen toward large depreciation from 83.6 in December 2012 to 123.2 in August 2015 vis-à-vis the U.S. dollar.[1]

The question of how Japanese export firms reacted to such large fluctuations in the yen from 2007 warrants investigation. Existing studies have typically found strong evidence of pricing-to-market (PTM) or weak evidence of exchange rate pass-through (ERPT) in Japanese exports, implying that Japanese exporters tend to stabilize their export prices in response to exchange rate changes.[2] For instance, using rolling regression, Ceglowski (2010) demonstrated that Japanese exporters increased the degree of PTM from the late 1990s to 2007, which is consistent with Taylor (2000) that argued a decline in ERPT. However, Japanese firms are likely to have changed their export pricing behavior from 2007 in response to the rapid and large appreciation and depreciation periods.

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[1] The monthly average data of the nominal exchange rate of the yen vis-à-vis the U.S. dollar is taken from IMF, *International Financial Statistics*.

[2] See Marston (1990), Knetter (1994), Parsons and Sato (2008), and Yoshida (2010).

Figure 1 plots the contract currency-based price[3] of Japanese manufacturing exports that exhibits fairly stable fluctuations at around 100 during the rapid and substantial yen appreciation period from 2007 to 2012. Contract currency-based export price is published by the Bank of Japan (BOJ) that reflects the choice of contract (invoicing) currency by Japanese export firms. Given that a large portion of Japanese exports are invoiced in foreign currencies,[4] Figure 1 indicates that Japanese exporters were likely to pursue PTM behavior during the above yen appreciation period. In contrast, the contract currency-based export price started to decline from the late 2013 in response to the further yen depreciation from around 100 to 120 (Figure 1). Moreover, when observing export prices at an industry level (Figure 2), two major Japanese machinery industries, transport equipment and general machinery,[5] exhibit different pricing behaviors in their exports from all manufacturing exports presented in Figure 1. The contract currency-based export prices appear to increase to some extent in response to yen appreciation, while they have stayed at the same level despite the sharp, large depreciation of the yen from the end of 2012 to the present. This visual inspection suggests that Japanese exporters' pricing behaviors are likely to differ not only across industries but also between yen appreciation and depreciation periods.

The main purpose of this study is to empirically investigate possible differences in Japanese exporters' pricing behaviors between yen appreciation and depreciation periods. But, the question is how to distinguish between yen appreciation and depreciation periods,

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[3] The details of the contract currency-based export price published by the Bank of Japan are explained in Section 3 and Appendix A.

[4] As shown in Appendix Table A1, more than 60% of Japanese exports are invoiced in foreign currencies.

[5] General machinery stands for "general-purpose, production and business-oriented machinery."

and how to estimate possible nonlinear relationship.

Recent studies, such as Delatte and Lopez-Villacencio (2012) and Fedoseeva and Werner (2016), employed the nonlinear autoregressive distributed lag (NARDL) model proposed by Shin et al. (2014) which has an advantage in testing the hypothesis of nonlinear PTM or ERPT not only in the short run but also in the long run, an effect that cannot be captured via conventional first-differenced models.

However, the current NARDL studies have two drawbacks. First, they rely on the conventional appreciation/depreciation threshold specification in which exchange rate changes are simply divided into positive and negative changes.[6] In the medium- and long-run currency appreciation period, for instance, a small, short-lived depreciation often occurs, which is included in the yen depreciation period by the conventional approach.[7] Thus, it is unclear whether the above conventional approach can distinguish correctly between yen appreciation and depreciation periods.

Second, most studies have not considered exporters' expectations of the future exchange rate that can play a non-trivial role in their pricing decision. Specifically, export firms are typically forward-looking and set their predicted exchange rates for their export planning and business forecasts. Unless the realized exchange rate exceeds the level of the predicted exchange rate, for example, export firms would not revise their pricing behavior. However, the conventional threshold approach, which uses the realized exchange rate to calculate its changes, fails to capture the exporters' expectations of the

[6] The conventional threshold specification approach is widely used in the literature, see for example Knetter (1994), Mahdavi (2002) and Delatte and Lopez-Villacencio (2012). We discuss this further in Section 2.

[7] In Figure 1, the yen appreciated substantially from 2007 to 2012. During this appreciation period, we observe a number of short-run depreciations.

future exchange rate. In contrast, our study proposes a new empirical method of threshold specification using firms' predicted exchange rates published by the Bank of Japan (BOJ), "Short-Term Economic Survey of Enterprises in Japan (TANKAN)." The BOJ administers an extensive survey on exporting firms' predicted exchange rate that is used for making their business plans and projections. Another advantage of the BOJ's predicted exchange rate is that industry-level data are available, which enables us to capture differences in exporters' predictions reflecting their export competitiveness.

Utilizing the BOJ's predicted exchange rates and the new threshold approach for the estimation of the NARLD model, we present new empirical evidence that Japanese exporters tend to pursue different pricing behavior across industries from 2007 to 2015 when the exchange rate fluctuated rapidly and substantially. Specifically, we find evidence of long-run asymmetry in PTM across industries in the yen depreciation period, whereas most industries exhibit incomplete but relatively strong PTM during the yen appreciation period. The transport equipment and general machinery industries, which are known to have strong export competitiveness,[8] tend to conduct full PTM during the yen depreciation period. In contrast, other industries with less-differentiated products significantly lower (increase) the degree of PTM (ERPT) during the yen depreciation period. In the short run, however, almost full and symmetric PTM is found across all industries for all sample periods, which is consistent with the findings of previous studies that firms' short-run PTM or ERPT behaviors are strongly affected by the invoice currency choice (Gopinath et al., 2010).

Understanding Japanese exporters' PTM or ERPT behaviors is crucially important

[8] See Ito et al. (2018) for a discussion of export competitiveness and firms' pricing behavior.

in considering the impact of exchange rate volatility on the Japanese economy. We reveal different pricing behavior not only across industries but also between yen appreciation and depreciation periods. Given that the transport equipment and general machinery, two of the three main manufacturing industries in Japan, do not pass through yen depreciation to their export prices, it is hard to reasonably expect a decline in export prices in response to currency depreciation. Although trade balance is not solely determined by such a price factor, our empirical results at least partly answer the question as to why the Japanese trade balance has been unresponsive to yen depreciation since the end of 2012.

The remainder of this paper is organized as follows. Section 2 addresses the empirical model and Section 3 discusses the data used in this study. Empirical results are presented and discussed in Section 4. Finally, Section 5 concludes this study.

2. Empirical methods

2.1. Review of previous studies on asymmetric PTM and ERPT

While theoretical literature has explored possible nonlinearity, there are not many studies that empirically investigated asymmetric PTM or ERPT between currency appreciation and depreciation periods. Knetter (1994), Mahdavi (2002), and Pollard and Coughlin (2004) were among the first to analyze differences in the short-run ERPT between appreciation and depreciation periods. Even though they found some evidence of asymmetric ERPT, these empirical methods are arguably limited because their models only estimate a short-run relationship by using log-differenced data and they use the conventional zero threshold approach to specify currency regimes, i.e., positive and negative exchange rate changes are regarded as currency depreciation and appreciation, respectively:

$\Delta \ln E_t > 0$ means a depreciation of the home currency,

$\Delta \ln E_t < 0$ means an appreciation of the home currency,

where E_t denotes the nominal exchange rate of the home currency vis-à-vis the foreign currency, and Δ denotes the first-difference operator.

The NARDL model developed by Shin et al. (2014) has enabled us to conduct empirical studies on asymmetric PTM and ERPT. First, using the NARDL model, we can test both short-run and long-run asymmetry. When using first-differenced variables as in most previous studies, long-run asymmetry cannot be tested rigorously. Moreover, the NARDL model can be combined with flexible threshold specification. For instance, Delatte and Lopez-Villacencio (2012) investigated the asymmetric effect of exchange rate variations on consumer price indices using a mark-up model with zero threshold. They found evidence that exchange rate changes are passed through to prices more in the depreciation period than in the appreciation period, which suggests a weak competition structure. Fedoseeva and Werner (2016) used destination-specific German beer exports to test for nonlinear PTM. Specifically, they used the exchange rate standard deviation as a threshold to distinguish between large appreciation, small change, and large depreciation. Although not directly examining the ERPT, Verheyen (2013) used two threshold regimes to distinguish between large appreciation and depreciation with "inaction bands" and analyzed the exchange rate impact on EMU export quantities to the

United States.[9]

Although the NARDL approach is useful in allowing for asymmetric PTM and ERPT, most previous studies employed the conventional threshold approach to distinguishing yen appreciation and depreciation regimes. We contribute to the literature by developing a new method of distinguishing between appreciation and depreciation periods by using the firm's predicted exchange rate, data that has not previously been considered in the literature.[10]

2.2 ARDL model for PTM

The ARDL modeling approach (Pesaran and Shin, 1999) is similar to the error correction model (ECM), which tests long-run cointegration relationships among variables. While the model can be easily derived from the ECM, the ARDL model has several advantages over the ECM: (1) the ARDL model does not require all variables to be integrated of the same order, and (2) the level coefficients can be bounds tested to detect the existence of long-run relationships among variables.[11]

To investigate possible nonlinearity of Japanese exporters' pricing behavior, we first present a conventional PTM or ERPT approach proposed by Goldberg and Knetter (1997), in which the export price is explained by the primary "control" variable, the exchange rate, and other control variables. In our model, the (log) yen-based export price index, *ex*, is explained by the (log) nominal effective exchange rate, *e*, the (log) input price, *dp*, as

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[9] The method of inaction bands has been used by other studies including Balke and Fomby (1997) and Belke et al. (2009, 2012).

[10] There are a few exceptions such as Morikawa (2016) that uses the BOJ predicted exchange rate, but his paper examines not ERPT but the effect of exchange rate volatility on export quantities.

[11] See Pesaran *et al*. (2001).

the production cost, and the (log) world industrial production index, *ipi*, as a proxy for world demand.

The ECM has two steps, with Step 1 estimating a long-run cointegration relationship:

$$ex_t = \alpha + \beta_1 e_t + \beta_2 dp_t + \beta_3 ipi_t + \varepsilon_t \qquad (1)$$

β_1 denotes the effect of exchange rate on yen-based export price, i.e., PTM (or ERPT) level in the long run.

If the residuals $\hat{\varepsilon}_t$ obtained from Equation (1) are found to be stationary, we can conclude that the variables are cointegrated and proceed to Step 2 estimating an ECM:[12]

$$\Delta ex_t = \alpha + \rho\hat{\varepsilon}_{t-1} + \sum_{i=1}^{k-1}\gamma_1\Delta ex_{t-i} + \sum_{i=0}^{k}\left(\gamma_2\Delta e_{t-i} + \gamma_3\Delta dp_{t-i} + \gamma_4\Delta ipi_{t-i}\right) + \upsilon_t \qquad (2)$$

where k is the lag order of a four-variable VAR model in first differences and υ_t is an *iid* process. The coefficient ρ that explains the speed of adjustment from long-run disequilibrium should have a negative, statistically significant sign.

For variables that are not integrated of the same order, the ECM cannot be estimated. Instead, we can use the ARDL model that is easily obtained from the ECM:

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[12] The estimated residuals show the estimated values of the deviations from the long-run disequilibrium.

$$\Delta ex_t = \alpha + \rho_1 ex_{t-1} + \rho_2 e_{t-1} + \rho_3 dp_{t-1} + \rho_4 ipi_{t-1} + \sum_{i=1}^{k} \gamma_{1i} \Delta ex_{t-i} + \sum_{i=0}^{l} \gamma_{2i} \Delta e_{t-i} + \sum_{i=0}^{m} \gamma_{3i} \Delta dp_{t-i} + \sum_{i=0}^{n} \gamma_{4i} \Delta ipi_{t-i} + \upsilon_t \qquad (3)$$

Note that another advantage of the ARDL model is that the lag orders can differ among variables. Our interest is in the long-run PTM coefficient that can be calculated as $\beta_1 = -\frac{\rho_2}{\rho_1}$. The null hypothesis of cointegration relationship $H_1 : \rho_1 = \rho_2 = \rho_3 = \rho_4 = 0$ and $H_1 : \rho_1 = 0$ can be tested with the bounds *F*-test and bounds *t*-test, respectively. The conclusion of long-run relationship is derived if the null is rejected.

2.3 NARDL model for PTM

Shin et al. (2014) developed the ARDL model to allow for asymmetry of the variables in question. The main feature of this framework is the decomposition of possible asymmetric variables (i.e., exchange rates in this study) into partial sums using thresholds. The conventional approach of dividing exchange rate changes into positive and negative changes corresponds to:

$$e_t^+ = \sum_{j=1}^{t} e_j^+ = \sum_{j=1}^{t} \max(\Delta e_j, 0), \quad e_t^- = \sum_{j=1}^{t} e_j^- = \sum_{j=1}^{t} \min(\Delta e_j, 0) \qquad (4)$$

However, as discussed above, this conventional threshold specification has a drawback. Since the exchange rate tends to be volatile, we can observe, for instance, short-lived periods of depreciation even during unambiguous appreciation periods. If we follow the conventional threshold approach, such short-run depreciation will be ultimately included in the yen depreciation period, which might cause misspecification problems.

To overcome the drawback of this approach, we develop a new threshold approach using firms' predicted exchange rates. Specifically, firms typically set their assumed or predicted exchange rates for the purposes of planning and management, which suggests that the predicted exchange rate itself contains important information on a firm's trade and pricing strategy. For instance, if the actual (realized) bilateral exchange rate turns out to be higher (lower) than the firm's predicted exchange rate, it would be considered an *unexpected* depreciation (appreciation) of the home currency.[13]

Figure 3 shows the actual bilateral nominal exchange rate of the yen vis-à-vis the U.S. dollar and the corresponding predicted exchange rate of all manufacturing exporters from 1997 to 2015. On one hand, firms might be conservative in revising their predicted exchange rates given that such revisions could impact their business plans. On the other hand, firms are willing to revise their predicted exchange rates quickly in response to exchange rate changes, especially during currency depreciation periods.[14] Hence, the adjustment speed of a firm's predicted exchange rate in response to realized exchange rate movements provides us with useful information on whether the current exchange rate level is regarded as unexpectedly overvalued (appreciated) or undervalued (depreciated) from the firm's point of view.

We use a mean of prediction errors as a threshold, and the partial sum takes the following form:

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[13] Without employing predicted exchange rates, Nguyen and Sato (2015) developed the method of calculating the firm's reference exchange rate in levels as a threshold.

[14] See Nguyen (2018) for an investigation of how Japanese firms revise the predicted exchange rate by industry and by firm size.

$$e_t^{+} = \sum_{j=1}^{t} e_j^{+} = \sum_{j=1}^{t} \Delta e_j I\{er_t > mean(er)\}, \quad e_t^{-} = \sum_{j=1}^{t} e_j^{-} = \sum_{j=1}^{t} \Delta e_j I\{er_t < mean(er)\} \quad (5)$$

where *er* and mean(*er*) denote the prediction error (realized minus predicted exchange rate) and the mean of prediction error, respectively. $I\{Z\}$ is an indicator function that takes a value of one if condition Z is satisfied and zero otherwise. As a robustness exercise, we also apply the zero value instead of the mean of prediction errors as a threshold value for regression, and the results are found to be very similar.[15]

From Shin et al. (2014), we can modify the ARDL model in Equation (3) into the NARDL model to allow asymmetry:

$$\begin{aligned} \Delta ex_t = {} & \alpha + \rho_1 ex_{t-1} + \rho_2 e_{t-1}^{+} + \rho_3 e_{t-1}^{-} + \rho_4 dp_{t-1} + \rho_5 ipi_{t-1} + \\ & \sum_{i=1}^{k} \gamma_{1i} \Delta ex_{t-i} + \sum_{i=0}^{l} \left(\gamma_{2i}^{+} \Delta e_{t-i}^{+} + \gamma_{2i}^{-} \Delta e_{t-i}^{-} \right) + \sum_{i=0}^{m} \gamma_{3i} \Delta dp_{t-i} + \sum_{i=0}^{n} \gamma_{4i} \Delta ipi_{t-i} + \upsilon_t \end{aligned} \quad (6)$$

We estimate Equation (6) with maximum six-lag and reduce the longest lag sequentially to the optimal lag length based on the Schwartz's information criterion.[16]

To check for long-run relationships, a test can be performed by either the t_{BDM} statistic under the null hypothesis, $H_1 : \rho_1 = 0$, or the F_{PSS} statistic testing the joint null hypothesis, $H_1 : \rho_1 = \rho_2 = \rho_3 = \rho_4 = \rho_5 = 0$. Due to dependence between the series e_t^{+} and e_t^{-}, the true value of *k*, i.e., the number of regressors entering the long-run

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[15] The result of this robustness exercise is not presented in this paper, but available upon request.

[16] A maximum lag length needs to be at least 12 or longer when using the monthly series. However, due to the small number of observations in this study, we finally choose six-lag as a maximum lag length.

relationship, is not clear, but it lies between three and four because we have three explanatory variables and four regressors. Shin et al. (2014) suggested that rejecting the null of no long-run relationship using lower k provides strong evidence for the existence of a long-run relationship.[17]

Finally, we can test for nonlinearity of PTM in the short- and long-runs by performing Wald tests. The null hypothesis of symmetry in the long-run is $H_1 : -\frac{\rho_2}{\rho_1} = -\frac{\rho_3}{\rho_1}$, testing the equality of long-run exchange rate coefficients. As for symmetry of PTM in the short-run, two standard Wald tests can be performed based on the following nulls: (i) $H_1 : \gamma_{2i}^{+} = \gamma_{2i}^{-}$ for $i = 0, \ldots, l$ or (ii) $H_1 : \sum_{i=0}^{l} \gamma_{2i}^{+} = \sum_{i=0}^{l} \gamma_{2i}^{-}$.

3. Data descriptions

3.1 Predicted exchange rate

The BOJ conducts a large-scale firm-level survey, the TANKAN survey, in March, June, September, and December each year,[18] which poses a question about the predicted exchange rate of the yen vis-à-vis the U.S. dollar that sample firms use for their export planning and business forecasts in each half of the fiscal year.

Table 1 illustrates how we construct the monthly series of the predicted exchange rate from the corresponding semi-annual series obtained from the BOJ. For example, the

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[17] The mis-sizing could be resolved by bootstrapping, but this is beyond the scope of our current inquiry.

[18] In the March 2015 survey, for instance, questionnaires were distributed to 11,126 firms.

survey carried out in March 2015 obtains the information on the firm's forecast of the exchange rate for the first half of the fiscal year 2015 (April–September 2015).[19] These predictions are updated in the June 2015. We assume that the sample firms' answers are most reliable for the first three post-survey months. Then we can construct the quarterly series of predicted exchange rates: the March 2015 survey provides the data for the first quarter (April–June), the June 2015 survey for the second quarter (July–September), and the September 2015 survey for the third quarter (October–December). Further details are presented in Table 1.

Moreover, we convert the quarterly predicted exchange rates to the monthly series by making the non-trivial assumption that once the predictions were made, firms would not change them for three months. Then the predicted exchange rate of the first quarter (April–June) in 2015 is used to construct monthly series of predicted exchange rates for April, May, and June 2015.[20]

3.2 Distinction between yen appreciation and depreciation using prediction errors

We can obtain the series of prediction errors by simply subtracting the (log) *predicted* exchange rate of the yen vis-à-vis the U.S. dollar from the (log) corresponding actual (realized) exchange rate. Normally, the error fluctuates around zero, and if the error is positive, it suggests yen depreciation as the yen depreciates beyond the level of what firms predicted. We choose to utilize this prediction error to obtain thresholds. Since we

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[19] In Japan, fiscal year stars from April.

[20] We use the predicted exchange rate for all firms in each industry. Most industry categories in TANKAN data correspond well with the categories of the BOJ export price data except for Metal and other products which does not appear in the TANKAN data. Thus, instead we have to defer to its sub-sectors: Iron and steel, nonferrous metal and processed metal. We calculate the predicted exchange rate for the Metal industry using the sub-sector data weighted by export price.

use the nominal effective exchange rate (NEER) as an independent variable, it could be advisable to use the prediction error for NEER and not for the bilateral exchange rate of the yen vis-à-vis the U.S dollar. However, we do not use the prediction error for NEER for three reasons. First and foremost, it is hard to collect the data of the predicted NEER. Second, since it is an index number, the level of NEER is conditional on the choice of the base year. Hence, it is unclear whether the prediction error computed from NEER is informative. Third, we do not use the prediction error directly to estimate the NARDL model but only to distinguish between yen appreciation and depreciation periods, which provides us with a reasonable distinction that will be discussed below.

The superiority of our method can be visualized in Figure 4. As discussed in Section 1, it is a common understanding that Japanese firms experienced an unprecedented yen appreciation period from the subprime loan crisis in 2007 to the end of 2012. A yen depreciation period followed; the yen started to depreciate rapidly and substantially from the end of 2012 concomitant with the onset of Abenomics. However, the conventional zero threshold approach based on the direction of exchange rate changes fails to distinguish clearly between yen appreciation and depreciation periods, as plotted in Figure 4(a).[21] In contrast, our new method using the firms' predicted exchange rates distinguishes reasonably between yen appreciation and depreciation periods, as shown in Figure 4(b). Thus, the appreciation and depreciation periods are distinguished more precisely by our new method, especially when focusing on the 2007–2012 appreciation period and the 2013–2015 depreciation period, which is superior to other threshold specifications in the literature.

[21] To plot the graph in Figures 4(a) and 4(b), we use the same series, the contract currency based NEER that is explained in Section 3.3 below, with different threshold methods.

3.3 Contract currency-based NEER

In contrast to previous studies, we use the contract currency-based NEER (henceforth, contract NEER) that Ceglowski (2010) first used to measure the degree of exporters' price responses to changes in the yen vis-à-vis invoice currencies. As shown in the study by Ito et al. (2012, 2018), Japan's exports are invoiced mainly in U.S. dollars and yen.[22] Conventional NEERs provided by the BIS are based on a trade weight, which cannot reflect a large role of the third currency (U.S. dollar) in invoicing of Japanese exports. As shown in Appendix A, the contract NEER can be calculated using both the yen-based and contract currency-based export prices. The contract NEER has two notable advantages. First, we can calculate an industry-specific NEER on a contract currency basis because the BOJ publishes industry- and commodity-specific data on export price indices on both a yen basis and contract currency basis. Second, and more importantly, the contract NEER reflects the degree of exchange rate risk that exporters face, which is likely to be different across industries.

3.4 Other data

We use the monthly series of variables for a sample period from April 1997 to December 2015.

Domestic input prices and yen-based export prices are obtained from the BOJ website, with base years of 2005 and 2010 at an industry-specific level for aggregated and seven

[22] According to data on Japan's trade invoice currency published by the Ministry of Finance, in the second-half of 2014, 53% of Japanese world exports were invoiced in U.S. dollars compared to 35.7% in yen. This invoice currency share is quite consistent with Appendix Table A1 obtained from the BOJ.

specific industries: (i) all manufacturing; (ii) textiles; (iii) chemicals and related products (henceforth, chemical); (iv) metal and related products (henceforth, metal); (v) general machinery (general purpose, production, and business-oriented machinery); (vi) electric and electronic products (henceforth, electric machinery); (vii) transport equipment; and (viii) other manufacturing. Although the domestic producer price index is generally used in previous empirical studies on PTM and ERPT, the BOJ domestic input price index is constructed using input coefficients calculated from Japanese input-output data; hence, it better reflects the actual production costs of each industry.[23]

The world industrial production index is calculated by taking an average of the industrial production index (2010 base year) of 20 major trading partner countries for Japan.[24] The 20 partner countries are selected based on the criterion that the destination country's share is equal to one percent or larger in Japan's total exports. All series are standardized to 100 as of the 2010 base year. Seasonality is adjusted using the Census X12 method.

We explore time-series properties of variables using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Although not reported in this paper, the results of both ADF and PP unit-root tests suggest that all variables are non-stationary in levels but stationary in first differences.

To analyze whether the degree of ERPT/PTM has changed over time, we divide the

[23] Input price index is constructed as a weighted average of the prices of intermediate input goods, (i.e., raw materials, including fuel and energy, intermediate parts, and components) and services to produce products in these industries. Thus, the BOJ input price index reflects the domestic production cost in each industry better than the producer price index.

[24] The 20 countries and areas are France, Germany, the Netherlands, Australia, Canada, Hong Kong, Korea, Singapore, the United States, the United Kingdom, mainland China, India, Indonesia, Malaysia, the Philippines, Thailand, Vietnam, Russia, Mexico, and Taiwan.

entire sample period into two sub-periods: one from April 1997 to December 2006 and the other from January 2007 to December 2015. The breakpoint of 2007 is chosen by considering empirical yen fluctuations: from the subprime loan crisis in 2007 to 2015, the yen has substantially fluctuated up and down. We focus particularly on this period to investigate whether Japanese exporters changed their pricing behavior in response to large exchange rate fluctuations.

4. Empirical results

We first briefly explain the sign and the meaning of coefficients in Equation (6). As ρ_1 represents the adjustment speed from long-run disequilibrium, it should have a negative and significant sign. The long-run exchange rate coefficients in the depreciation and appreciation periods are $\beta_1^+ = -\frac{\rho_2}{\rho_1}$ and $\beta_1^- = -\frac{\rho_3}{\rho_1}$, respectively. Those long-run coefficients represent the level of PTM, which can be interpreted as a percentage change in the yen-based export price corresponding to a one-percent change in the exchange rate in the long run. Since the contract NEER increases when the yen depreciates, the sign of either β_1^+ or β_1^- should be positive; hence, ρ_2 and ρ_3 should be positive. ρ_2 and ρ_3 need to be statistically significant, but they are not sufficient to conclude that the exchange range responses differ by regime. To reveal possible nonlinearities, we need to test for not only a long-run relationship to confirm the long-run coefficients are meaningful but also the hypothesis of $\beta_1^+ = \beta_1^-$. As for the domestic input price, an increase in the input price should lead to an increase in the export price, which indicates that ρ_4 should be significantly positive. Since an increase in world demand can result in either an increase in price or a fall in price, the sign of ρ_5 is ambiguous. The same sign is expected for all variables in the short run. We hereafter focus on the relationship between the exchange rate and export price.

4.1. Short-run ERPT

Tables 2–4 show the results of PTM levels in both the short- and long runs in all industries for the entire sample (1997–2015), first sub-sample (1997–2006), and second sub-sample (2007–2015), respectively.[25] ERPT of Japanese exports in the short run is found to be almost zero among all seven industries and all manufacturing in all sample periods. This finding is consistent with the literature on Japanese export ERPT (Marston, 1990; Knetter, 1994; and Parson and Sato, 2008), in which PTM strategies are strongly confirmed. However, even though the results are highly significant, we cannot find any evidence of asymmetric ERPT in the short run.

Gopinath et al. (2010) discussed the relationship between ERPT and currency choice, implying that the invoice currency choice is related more to the short-run ERPT than to the long-run alternative and that the local or third (vehicle) currency invoicing results in the low ERPT in the short run. This is consistent with the empirical pattern of invoice currency choice in Japanese exports presented in Appendix Table 1, in which foreign currencies account for a larger share in most industries. Given such a large share, complete PTM is typically observed in the short run.

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[25] Detailed results of NARDL model estimations in each sample with the mean threshold approach are shown in Appendix Tables 2, 3, and 4.

For comparative purposes, the standard ARDL model is also estimated for the entire sample and sub-samples.[26] Appendix Table 5 presents the summary results of PTM coefficient estimates for each sample period. The short-run coefficients in the NARDL model present the same pattern as in the ARDL model, suggesting the robustness of symmetric and full PTM in the short run for Japanese exports.

4.2. Long-run ERPT

Let us first look at the results for the entire sample (1997–2015) in Table 2. Although the t_{BDM} and F_{PSS} bounds tests for all manufacturing and textile show strong evidence for cointegration, we cannot find a long-run relationship for other industries.[27] Among them, only all manufacturing shows evidence of asymmetric PTM in the long run, with a higher PTM level in the appreciation period. Table 3 presents the results for the first sub-sample (1997–2006), where a cointegrating relationship is found only in other manufacturing in terms of both t_{BDM} and F_{PSS} bounds tests. Long-run symmetry of PTM is also rejected strongly in other manufacturing, implying that this industry employs different price-setting strategies with higher ERPT in the yen depreciation period.

Our main findings emanate from the second sub-sample results (2007–2015) in Table 4. First, we found a significant cointegrating relationship in not only all manufacturing but also four of seven industries: textile, metal, general machinery, and transport equipment. In addition, although chemical does not show a significant

26 Detailed results from ARDL modeling are available upon request.

27 The number of observations for the entire sample, first sub-sample, and second sub-sample is 225, 117, and 108, respectively. Narayan (2005) posits a small-sample bound *F*-test (up to 80 observations). However, conclusions do not change even when we use Narayan's test (for n=80).

cointegrating relationship when assuming $k = 3$, a significant cointegrating relationship for chemical does exists if assuming $k = 4$.[28] Second, the tests for nonlinearities of PTM in all manufacturing, metal, general machinery, transport equipment, and possibly chemical, if we accept its significance at $k = 4$, reject the null hypothesis of symmetric PTM in the long run. Thus, we can conclude that Japanese exporters in the above four industries and all manufacturing conduct different pricing strategies between yen appreciation and depreciation periods. It must also be noted that we found symmetric PTM behavior in the short run for the second sub-sample from 2007 to 2015 in all industries except other manufacturing.

Let us next focus more on the asymmetric PTM in the long run. First, in the yen appreciation period, all manufacturing and five industries (textile, chemical, metal, general machinery, and transport equipment) exhibit an incomplete long-run PTM, the coefficient of which ranges from 0.54 to 0.86. This finding suggests a low degree of ERPT, i.e., just 14–46% of exchange rate changes are passed through to importers. This pricing strategy, i.e., incomplete but relatively strong PTM in the long run, is common in the above five industries. Second, in the yen depreciation period, however, exporters pricing strategies become divergent across the above five industries. The long-run PTM coefficients for chemical and metal are 0.29 and 0.06, respectively, implying that these industries tend to raise the degree of ERPT in the yen depreciation period. In contrast, the long-run PTM coefficients for general machinery and transport equipment are 1.08 and 0.92, respectively, which suggests that exporters in these industries choose almost complete PTM to fully exploit exchange gains when the yen depreciates.

[28] As discussed in Section 3.2, Shin et al. (2014) suggested that we can get stronger evidence when choosing smaller k (i.e., the number of regressors in the long-run relationship).

4.3. Interpretation

The above results can be interpreted as follows. First, Japanese firms are likely to change their long-run pricing strategies in response to rapid and substantial changes in exchange rates, whereas almost complete PTM is generally observed in the short run, reflecting the choice of invoice currency. As shown in Figures 1 and 3, the extent of exchange rate changes is much larger in the second sub-sample period than in the first sub-sample period. Figure 4 also reveals that our new threshold approach with prediction errors can correctly distinguish between the yen appreciation and depreciation periods.

Second, in the latter sub-sample from 2007 to 2015, the long-run PTM coefficient becomes smaller or statistically insignificant in chemical and metal during the yen depreciation period, suggesting greater ERPT by lowering the export price in the destination currency to gain export price competitiveness. In contrast, the long-run PTM coefficient converges toward unity in general machinery and transport equipment, which implies that almost complete PTM is conducted by stabilizing the local or vehicle currency export price to reap large exchange gains.

Third, the difference between the above two industry groups may be related to the degree of product differentiation as discussed in the literature. Export products of general machinery and transport equipment are well known to be differentiated and to have strong export competitiveness, whereas the automobile markets are highly competitive, especially in the United States.[29] Their strong competitiveness enables them to fully

[29] Indicators of trade balance (METI, 2014) and unit labor cost (Ito and Shimizu, 2015) as well as a firm-level interview analysis (Ito et al., 2012, 2018) support the strong competitiveness of these two industries compared with others.

exploit the exchange gains from yen depreciation while passing through some exchange losses to importers during the period of yen appreciation.[30] In contrast, less-competitive firms in chemical and metal tend to raise the degree of ERPT during the yen depreciation period by lowering the export price in the local market to stimulate local demand.

Fourth, previous studies that employ the conventional ARDL model typically assume symmetric PTM, but we have demonstrated that the symmetric PTM assumption is too restrictive. When using the conventional ARDL model, we could find a long-run cointegrating relationship only for textile and transport equipment in the second sub-sample period (Appendix Table 5). In addition, when using the conventional ARDL model, we cannot confirm asymmetric PTM in the long run, especially during the second sub-sample from 2007 to 2015 (Appendix Table 5 and Table 4).

Our empirical findings provide us with insight into why Japanese trade balance has not improved even though the yen started to depreciate substantially from the end of 2012. General machinery and transport equipment account for 43% of all Japanese exports.[31] Given such a large export share and complete PTM behavior in these two industries when the yen depreciates, that depreciation is less likely to boost real Japanese exports.

5. Conclusion

The aim of this paper is to test for possible nonlinearities in the PTM behavior of

[30] This finding is in the same vein as Berman et al. (2012) who find that high-performance firms react to a depreciation by increasing their markup significantly more than their export volume.

[31] The BOJ price data provides information on Japanese export shares by industry as of 2010.

Japanese exports between yen appreciation and depreciation periods. We propose a new threshold approach for distinguishing between yen appreciation and depreciation periods using large-scale firm-level survey data on Japanese firms' exchange rate predictions published by the BOJ. Our new threshold method considers both the change and the level of exchange rates by calculating the difference between the actual exchange rate and firms' predicted exchange rates. Using the NARDL modeling approach, possible asymmetric PTM behavior is investigated in both the long- and short runs.

In the short run, we found complete and symmetric PTM in all industries for both the first and second sub-sample periods. This result is consistent with the previous studies that found strong PTM in Japanese exports, reflecting their tendency to choose foreign currency invoicing. In the long run, we revealed evidence of cointegrating relationships and asymmetric PTM in several industries, especially in the 2007–2015 period when the yen fluctuated substantially. Four of seven industries and all manufacturing show evidence of long-run relationships, and most of them exhibit nonlinearities in long-run PTM coefficients. On one hand, these industries specifically seem to follow the same pricing strategy in the appreciation regime, i.e., incomplete but relatively stronger PTM is conducted, and around 60–80% of exchange rate changes are taken by Japanese exporters. On the other hand, less-competitive industries, like chemical and metal, choose to increase the degree of ERPT when the yen depreciates, which implies that exporters in those industries tend to decrease the local currency export price to stimulate importers' demand, even though they must squeeze their profit margins. In contrast, relatively competitive industries, like general machinery and transport equipment, raise the level of PTM to almost 100% so they can fully exploit foreign exchange gains during the yen depreciation period.

Understanding Japanese exporters' PTM or ERPT behavior will be crucially important in considering the impact of exchange rate volatility on the Japanese economy. We revealed different pricing behaviors not only across industries but also between yen appreciation and depreciation periods. Given that at least two of the three main manufacturing industries in Japan, i.e., general machinery and transport equipment, do not pass through yen depreciation to their export prices, it may be unreasonable to expect a decline in export prices in response to currency depreciation. Although trade balance is not solely determined by such a price factor, our empirical results at least partly answer the question as to the unresponsiveness of Japanese trade balance to the yen depreciation witnessed since the end of 2012.

Appendix A: Calculation of Contract NEER

The contract NEER can be constructed using export price indices published by the BOJ. Specifically, the BOJ publishes two types of export price indices by industry/commodity: one in yen and the other on a contract (invoice) currency basis.[32] For simplicity, suppose only three currencies are used in Japanese exports: the yen, U.S. dollar, and euro. Export price indices on a contract currency basis (P_{con}^{EX}) and on a yen basis (P_{yen}^{EX}) can be expressed as follows:[33]

$$P_{con}^{EX} = (P_{yen})^{\alpha}(P_{usd})^{\beta}(P_{eur})^{\gamma} \quad \text{(A.1)}$$

$$P_{yen}^{EX} = (P_{yen})^{\alpha}(E_{yen/usd}P_{usd})^{\beta}(E_{yen/eur}P_{eur})^{\gamma} \quad \text{(A.2)}$$

The BOJ collects information on the choice of contract currency when surveying Japanese exporters at a port level. Using a nominal exchange rate for the yen versus the contract currency, the BOJ constructs export price indices on a contract currency basis and converts the indices into yen-based export price indices. Dividing Equation (A.2) by Equation (A.1), we obtain the following formula of the contract NEER:

$$NEER_{yen}^{Contract} = \frac{P_{yen}^{EX}}{P_{con}^{EX}} = (E_{yen/usd})^{\beta}(E_{yen/eur})^{\gamma} . \quad \text{(A.3)}$$

The above discussion, based on the three contract (invoice) currencies, can be generalized to a case of four or more contract currencies. As shown in Appendix Table 1,

32 The BOJ collects export price data when cargo is loaded in Japan at the customs clearance stage, and when free-on-board (FOB) prices at a Japanese port of exports are surveyed. Provided they are traded in foreign currencies, sample prices are recorded in the original contract currency and finally compiled as the “export price index on the contract currency basis." To compile the “export price index on the yen basis," sample prices in the contract currency are converted into yen equivalents by using the monthly average exchange rate of the yen vis-à-vis the contract currency. See the BOJ website (https://www.boj.or.jp/en/statistics/pi/cgpi_2010/index.htm/) for further details.

33 By definition, the sum of the weights in equations (A.1) and (A.2) is assumed to be unity.

as of December 2014, 96.8% of Japan’s total exports were invoiced in yen, U.S. dollars, and the euro, whereas only 3.2% were invoiced in other currencies. Such a small share of invoices in other currencies is also captured by the contract NEER used in the following analysis.

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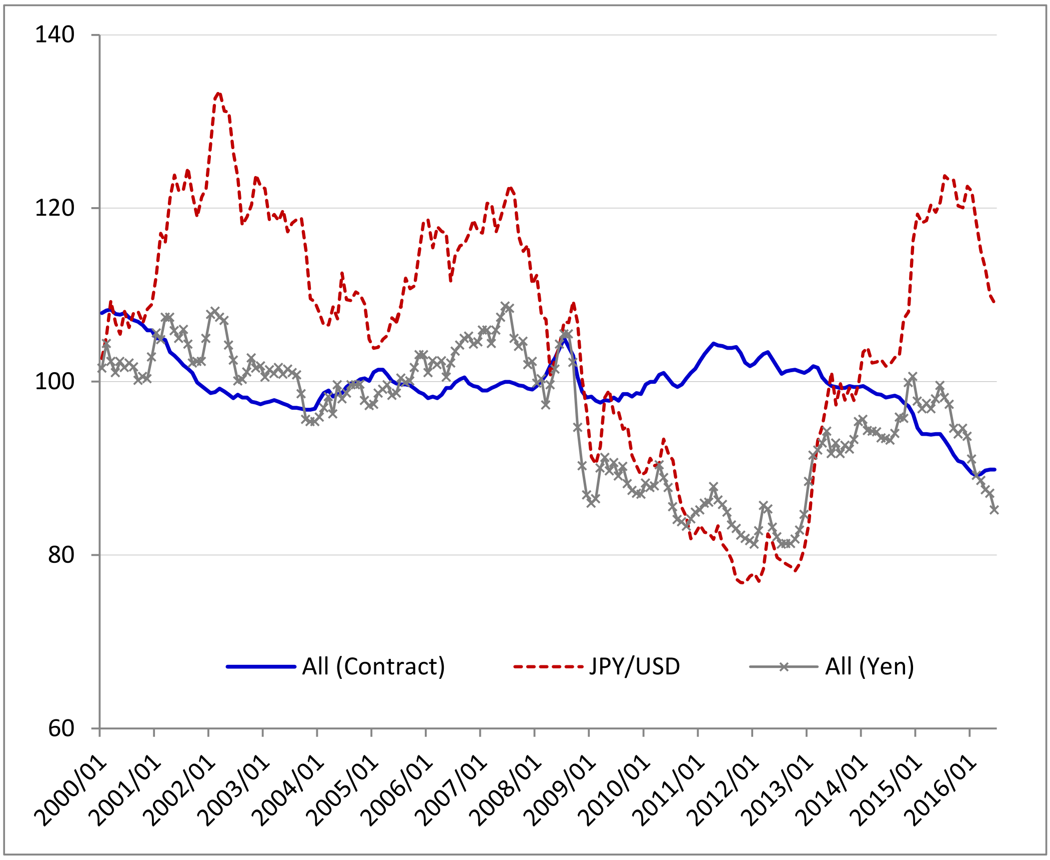
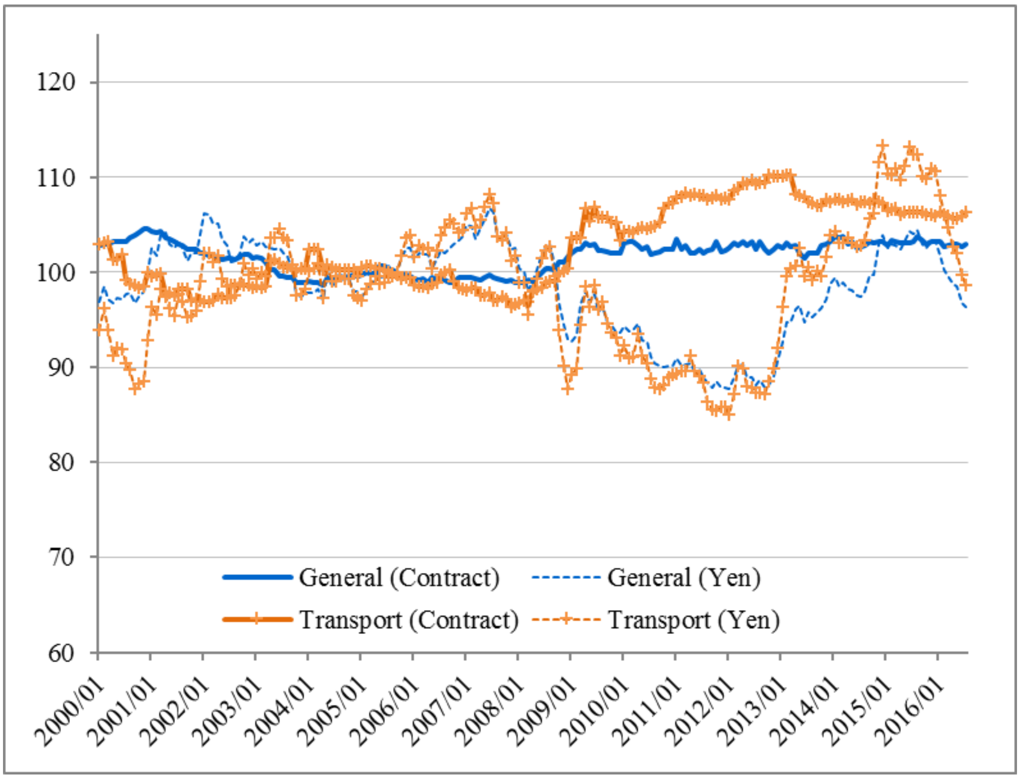
Figure 1: Yen-based and contract currency-based Japanese export prices (2005 = 100)



Note: Sample period ranges from January 2000 to June 2016. All (Contract) and All (Yen) denote the contract currency-based and yen-based export price indices (2005 = 100) of all manufacturing, respectively. JPY/USD is the bilateral nominal exchange rate of the yen vis-à-vis the U.S. dollar.

Figure 2: Yen-based and contract currency-based Japanese export price (2005 = 100)



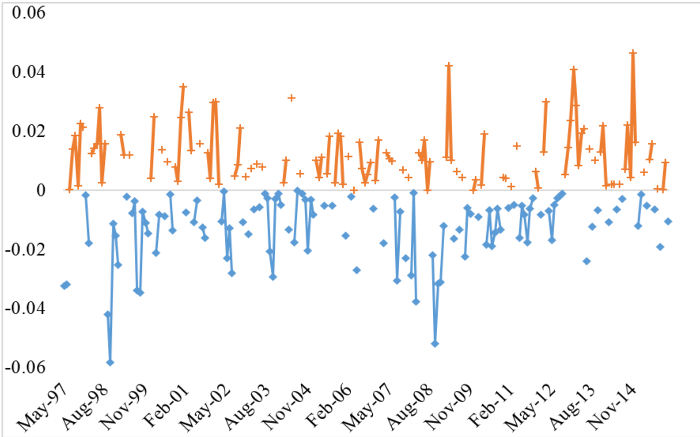
Note: Sample period ranges from January 2000 to June 2016. General (contract), General (yen), Transport (Contract), and Transport (yen) denote the contract currency-based and yen-based export price indices (2005 = 100) of general machinery and transportation equipment industries.

Figure 3: Actual and predicted exchange rates of the yen vis-à-vis the U.S. dollar

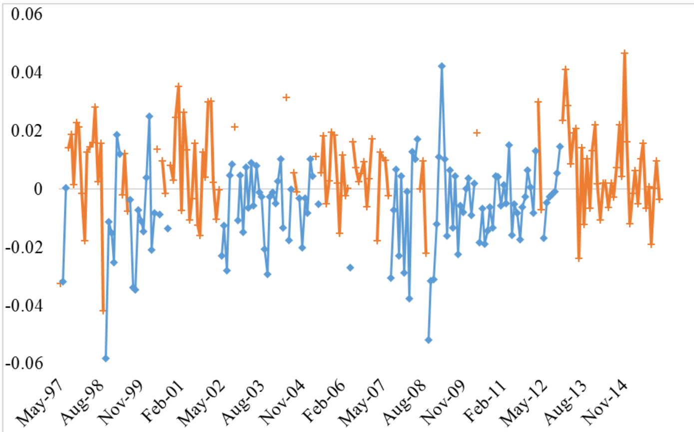
Note: Sample period ranges from the second quarter of 1997 to the fourth quarter of 2015. The solid orange line shows the predicted exchange rate of the yen vis-à-vis the U.S. dollar. The solid blue line with + markers shows the actual nominal exchange rate of the yen vis-à-vis the U.S. dollar.

Figure 4: Distinction of yen appreciation and depreciation periods

(a) Conventional 0 threshold approach



(b) New method using the predicted exchange rates



Note: The solid orange line with + markers and the solid blue line with rhombus markers denote depreciation and appreciation periods of the yen, respectively. In Figure 4(a), the short-run change of the realized exchange rate is used to distinguish between yen appreciation and depreciation periods. In contrast, in Figure 4(b), firms' predicted exchange rate is used to calculate the prediction error for the distinction between yen appreciation and depreciation periods. Note that the contract currency based NEER is applied in making figures for both 4(a) and 4(b). The contract currency-based NEER is addressed in Section 3.3.

Table 1: Illustration of BOJ predicted exchange rates for the 2015 fiscal year

Survey	2015									
conducted in :	3	4	5	6	7	8	9	10	11	12
March 2015	⊙	E_3S_4	E_3S_5	E_3S_6	E_3S_7	E_3S_8	E_3S_9	•	•	•
June 2015		•	•	⊙	E_6S_7	E_6S_8	E_6S_9	•	•	•
September 2015							⊙	E_9S_{10}	E_9S_{11}	E_9S_{12}
December 2015										⊙

Note: The BOJ TANKAN survey is conducted four times a year: in March, June, September, and December. As an example, the above table shows the surveys conducted in March, June, September, and December 2015 (far left column) during the period from March 2015 to December 2015 (second row). Red circles denote the timing of the surveys. In the survey conducted in March and September, TANKAN reports the predicted exchange rate for the coming two quarters (six months): for example, $E_3S_4 = E_3S_5 = E_3S_6 = \cdots = E_3S_9$ in the March 2015 survey, where E and S denote the expectation operator and the bilateral nominal exchange rate of the yen vis-à-vis the U.S. dollar, respectively. The predicted exchange rate is updated in June and December surveys. The June 2015 survey, for example, presents the updated predicted exchange rate for the two quarters from April to September, but it actually reflects the firms' prediction of the exchange rate for the coming one-quarter (three months) ($E_6S_7 = E_6S_8 = E_6S_9$) given the information available up to June 2015. Assuming that the predicted exchange rate for the first three post-survey months is reliable in the March and September surveys, 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 2015, $E_6S_7 = E_6S_8 = E_6S_9$ for the second quarter of the fiscal year 2015, $E_9S_{10} = E_9S_{11} = E_9S_{12}$ for the third quarter of the fiscal year 2015, and so forth. We next assume that predicted exchange rates are the same within each quarter. Then, we can finally construct the monthly series of predicted exchange rates.

Table 2: NARDL estimation results using the mean threshold approach for the whole sample (1997–2015)

	Whole Sample (1997-2015)							
	Cointegration Test		Short-run PTM			Long-run PTM		
Industry	t_{BDM}	F_{PPS}	SR^+ Coefficient	SR^- Coefficient	SR Symmetry	LR^+ Coefficient	LR^- Coefficient	LR Symmetry
All	-4.620 ***	6.683 ***	0.897 ***	0.946 ***	0.590	0.497 ***	0.900 ***	0.000 ***
Textile	-5.116 ***	7.726 ***	0.991 ***	0.879 ***	0.658	0.534 ***	0.456 ***	0.171
Chemical	-2.309	3.144	0.824 ***	0.829 ***	0.303	0.504 **	0.135	0.198
Metal	-2.985	2.505	0.751 ***	0.748 ***	0.635	0.456 **	0.234	0.086 *
Machinery	-2.747	3.927 *	1.042 ***	1.006 ***	0.883	0.725 **	0.801 **	0.515
Electric	-1.203	2.132	0.957 ***	0.919 ***	0.417	0.649	0.341	0.870
Transport	-2.539	3.801 *	0.999 ***	1.016 ***	0.760	0.837 **	0.575 *	0.155
Others	-1.915	3.382	0.930 ***	1.000 ***	0.011 **	-0.431	0.098	0.053 *

Note: (a) */**/*** denote significance at 10%, 5%, and 1%, respectively. For cointegration testing, the significance is based on both t_{BDM} and F_{PPS} bounds tests for $k = 3$. (b) The LR^+ and LR^- coefficients represent the PTM behavior in the exchange rate depreciation and appreciation periods, respectively. (c) p-values are reported for symmetry tests for both long-run (LR) and short-run (SR) coefficients.

Table 3: NARDL estimation results using the mean threshold approach for the first sub-sample (1997–2006)

	First Sub-Sample (1997-2006)							
	Cointegration Test		Short-run PTM			Long-run PTM		
Industry	t_{BDM}	F_{PPS}	SR^+ Coefficient	SR^- Coefficient	SR Symmetry	LR^+ Coefficient	LR^- Coefficient	LR Symmetry
All	-2.772	2.129	0.886 ***	0.926 ***	0.579	0.466 **	0.856 **	0.000 ***
Textile	-3.862 **	3.763	0.924 ***	0.808 ***	0.625	0.536 **	0.331 *	0.002 ***
Chemical	-2.294	2.355	0.734 ***	0.766 ***	0.330	0.010	-0.023	0.873
Metal	-3.072	3.178	0.831 ***	0.720 ***	0.316	0.377 *	0.010	0.003 ***
Machinery	-1.880	4.530 **	0.991 ***	0.962 ***	0.629	0.260	0.261	0.898
Electric	-1.718	2.876	0.901 ***	0.887 ***	0.837	0.160	0.585	0.659
Transport	-3.014	3.411	0.979 ***	0.988 ***	0.903	0.911 ***	0.858 **	0.798
Others	-3.581 *	4.868 **	0.934 ***	0.978 ***	0.263	0.550 ***	0.924 ***	0.000 ***

Note: (a) */**/*** denote significance at 10%, 5%, and 1%, respectively. For cointegration testing, the significance is based on both t_{BDM} and F_{PPS} bounds tests for $k = 3$. (b) The LR^+ and LR^- coefficients represent the PTM behavior in the exchange rate depreciation and appreciation periods, respectively. (c) p-values are reported for symmetry tests for both long-run (LR) and short-run (SR) coefficients.

Table 4 : NARDL estimation results using the mean threshold approach for the second sub-sample (2007–2015)

	Second Sub-Sample (2007-2015)							
	Cointegration Test		Short-run PTM			Long-run PTM		
Industry	t_{BDM}	F_{PPS}	SR^+ Coefficient	SR^- Coefficient	SR Symmetry	LR^+ Coefficient	LR^- Coefficient	LR Symmetry
All	-3.917 **	6.472 ***	0.888 ***	0.936 ***	0.329	0.584 ***	0.858 ***	0.000 ***
Textile	-4.107 **	6.139 ***	1.063 ***	1.005 ***	0.824	0.412 **	0.574 ***	0.166
Chemical	-3.059	3.591	0.806 ***	0.883 ***	0.688	0.291 *	0.670 **	0.058 *
Metal	-4.633 ***	6.566 ***	0.663 ***	0.795 ***	0.733	0.061	0.728 ***	0.000 ***
Machinery	-3.909 **	5.427 **	1.116 ***	0.996 ***	0.605	1.077 ***	0.766 ***	0.000 ***
Electric	-2.322	2.078	0.989 ***	0.957 ***	0.043	0.855	1.529	0.013 **
Transport	-5.676 ***	11.785 ***	1.039 ***	0.987 ***	0.950	0.922 ***	0.540 ***	0.000 ***
Others	0.590	3.298	0.965 ***	1.137 ***	0.005 ***	2.590	-0.243	0.563

Note: (a) */**/*** denote significance at 10%, 5%, and 1%, respectively. For cointegration testing, the significance is based on both t_{BDM} and F_{PPS} bounds tests for $k = 3$. (b) The LR^+ and LR^- coefficients represent the PTM behavior in the exchange rate depreciation and appreciation periods, respectively. (c) p-values are reported for symmetry tests for both long-run (LR) and short-run (SR) coefficients.

Appendix Table A1. Share of invoice currency in Japanese export and import indices as of December 2014 (%)

Industry :	Export Price Index				*Industry* :	Import Price Index			
	JPY	USD	EUR	Others		JPY	USD	EUR	Others
					Foodstuffs (75.8)	30.3	62.6	3.8	3.3
Textiles (12.5)	9.5	79.8	10.7	0.0	Textiles (53.5)	57.5	40.9	0.7	0.9
Chemicals (95.4)	28.9	69.4	1.7	0.0	Chemicals (83.3)	51.5	36.2	9.8	2.5
Metals (118.2)	21.5	77.8	0.6	0.0	Metals (117.1)	11.0	87.0	0.0	2.0
					Wood & Lumber (16.5)	4.1	70.3	16.1	9.4
					Petroleum (305.4)	8.7	91.3	0.0	0.0
General Machinery (192.0)	61.9	26.0	9.0	2.9	General Machinery (53.9)	40.1	54.4	2.7	2.7
Electric Machinery (232.9)	37.3	53.5	8.3	1.1	Electric Machinery (184.3)	44.9	54.0	0.2	0.9
Transport Equipment (240.6)	29.8	50.3	10.3	9.7	Transport Equipment (34.1)	42.1	42.8	15.1	0.0
Other Products (108.4)	33.0	62.3	3.1	1.5	Other Products (76.1)	21.9	71.9	3.2	3.0
All Industries (1,000.0)	36.7	53.1	6.9	3.2	All Industries (1,000.0)	27.2	69.0	2.4	1.5

Note: Figures in parentheses under the name of each industry (commodity group) denote the weight of the corresponding industry. The weight of all industries is 1,000.0.

Source: Bank of Japan, Export and Import Price Indices (2010 base).

Appendix Table A2: NARDL estimation results for the entire sample (1997–2015)

	All manufacturing	Textile	Chemical	Metal	Machinery	Electric	Transport	Other
Constant	0.384***	0.327***	0.209**	0.096	0.155*	-0.102	0.121	0.025
ex_{t-1}	-0.131***	-0.198***	-0.063**	-0.069***	-0.060***	-0.011	-0.063**	-0.027*
$neer^{+}_{t-1}$	0.065***	0.106***	0.032*	0.031**	0.043**	0.007	0.052**	-0.012
$neer^{-}_{t-1}$	0.118***	0.091***	0.008	0.016	0.048**	0.004	0.036	0.003
dp_{t-1}	0.037***	0.054**	0.041	0.076***	0.027***	0.037**	0.048**	0.029*
ipi_{t-1}	0.022**	0.080***	-0.025	-0.028*	0.000	-0.005	-0.011	-0.005
Δex_{t-1}	0.165***	-0.098	0.492***	0.217***	-0.191***	0.028	-0.023	0.474***
Δex_{t-2}			-0.368***					-0.074***
$\Delta neer^{+}_{t}$	0.897***	0.991***	0.824***	0.751***	1.042***	0.957***	0.999***	0.930***
$\Delta neer^{+}_{t-1}$	-0.117*	0.119	-0.546***	-0.264***	0.159**			-0.505***
$\Delta neer^{+}_{t-2}$			0.469***					
$\Delta neer^{-}_{t}$	0.946***	0.879***	0.829***	0.748***	1.006***	0.919***	1.016***	1.000***
$\Delta neer^{-}_{t-1}$	-0.191***	0.173*	-0.522***	-0.310***	0.204***			-0.373***
$\Delta neer^{-}_{t-2}$			0.256***					
Δdp_{t}	0.325***	0.335**	0.682***	0.828***	-0.271	0.361***	0.101	0.502***
Δdp_{t-1}					0.218**			-0.179
Δipi_{t}	0.010	-0.010	-0.002	0.045	0.009	-0.058**	0.040	-0.049
LR^{+} coefficent	0.497	0.534	0.504	0.456	0.725	0.649	0.837	-0.431
LR^{-} coefficent	0.900	0.456	0.135	0.234	0.801	0.341	0.575	0.098
$Adj.R^2$	0.962	0.743	0.832	0.872	0.924	0.918	0.889	0.887
t_{BDM}	-4.620***	-5.116***	-2.309	-2.985	-2.747	-1.203	-2.539	-1.915
F_{PSS}	6.683***	7.726***	3.144	2.505	3.927*	2.132	3.801*	3.382
SR symmetry	0.590	0.658	0.303	0.635	0.883	0.417	0.760	0.011**
LR symmetry	0.000***	0.171	0.198	0.086*	0.515	0.870	0.155	0.053*

Note: (a) */**/*** denote significance at 10%, 5%, and 1%, respectively. (b) The LR^{+} and LR^{-} coefficients represent the long-run PTM coefficients in the exchange rate depreciation and appreciation periods, respectively. (c) t_{BDM} and F_{PPS} are the bounds *t*- and *F*-statistics, respectively, for long-run cointegrating relationships, where critical values for $k = 3$ are invoked. (d) *p*-values are reported for the SR symmetry tests for the hypothesis that additive short-run PTM coefficients are different between yen depreciation and appreciation periods. (e) *p*-values are reported for the LR symmetry tests for the hypothesis that long-run PTM coefficients are different between yen depreciation and appreciation periods.

Appendix Table A3: NARDL estimation results for the first sub-sample (1997–2006)

	All manufacturing	Textile	Chemical	Metal	Machinery	Electric	Transport	Other
Constant	0.376***	0.281*	0.332*	0.343358	0.124	-0.076	0.860*	0.407***
ex_{t-1}	-0.119***	-0.208***	-0.107**	-0.083***	-0.057	-0.025*	-0.165***	-0.153***
$neer^{+}_{t-1}$	0.056**	0.111**	0.001	0.031***	0.015	0.004	0.150***	0.084***
$neer^{-}_{t-1}$	0.102**	0.069*	-0.002	-0.001	0.012	-0.014	0.141**	0.142***
dp_{t-1}	0.049***	0.099***	0.153**	0.107	0.036	0.081*	0.024	0.050**
ipi_{t-1}	-0.003	0.052	-0.119*	-0.103***	-0.006	-0.042	-0.042	0.023
Δex_{t-1}	0.170*	0.020	0.391***	0.347***	-0.139	0.020	-0.037	0.011
Δex_{t-2}			-0.371***					0.022
$\Delta neer^{+}_{t}$	0.886***	0.924***	0.734***	0.831***	0.991***	0.901***	0.979***	0.934***
$\Delta neer^{+}_{t-1}$	-0.133	-0.028	-0.468***	-0.337***	0.133			
$\Delta neer^{+}_{t-2}$			0.554***					
$\Delta neer^{-}_{t}$	0.926***	0.808***	0.766***	0.720***	0.962***	0.887***	0.988***	0.978***
$\Delta neer^{-}_{t-1}$	-0.209**	0.003	-0.440***	-0.347***	0.192*			
$\Delta neer^{-}_{t-2}$			0.250**					
Δdp_{t}	0.349***	0.118	0.861***	0.880***	0.019	0.457***	1.053***	0.218*
Δdp_{t-1}				-0.344***				
Δipi_{t}	0.012	-0.070	-0.019	0.031	0.009	-0.059	0.073	-0.022
Δipi_{t-1}								
LR^{+} coefficent	0.466	0.536	0.010	0.377	0.260	0.160	0.911	0.550
LR^{-} coefficent	0.856	0.331	-0.023	0.010	0.261	0.585	0.858	0.924
$Adj.R^2$	0.961	0.754	0.781	0.891	0.957	0.912	0.895	0.965
t_{BDM}	-2.772	-3.862*	-2.294	-3.072	-1.880	-1.718	-3.014	-3.581*
F_{PSS}	2.129	3.763	2.355	3.178	4.530**	2.876	3.411	4.868**
SR symmetry	0.579	0.625	0.330	0.316	0.629	0.837	0.903	0.263
LR symmetry	0.000***	0.002***	0.873	0.003***	0.898	0.659	0.798	0.000***

Note: (a) */**/*** denote significance at 10%, 5%, and 1%, respectively. (b) The LR^{+} and LR^{-} coefficients represent the long-run PTM coefficients in the exchange rate depreciation and appreciation periods, respectively. (c) t_{BDM} and F_{PPS} are the bounds *t*- and *F*-statistics, respectively, for long-run cointegrating relationships, where critical values for $k = 3$ are invoked. (d) *p*-values are reported for the SR symmetry tests for the hypothesis that additive short-run PTM coefficients are different between yen depreciation and appreciation periods. (e) *p*-values are reported for the LR symmetry tests for the hypothesis that long-run PTM coefficients are different between yen depreciation and appreciation periods.

Appendix Table A4: NARDL estimation results for the second sub-sample (2007–2015)

	All manufacturing	Textile	Chemical	Metal	Machinery	Electric	Transport	Other
Constant	0.614***	-0.017	0.013	-0.512***	1.101**	0.557**	0.693	0.145
ex_{t-1}	-0.200***	-0.246***	-0.192***	-0.232***	-0.272***	-0.085**	-0.251***	0.018
$neer^{+}_{t-1}$	0.111***	0.101**	0.056*	0.014	0.293***	0.072**	0.231***	-0.047**
$neer^{-}_{t-1}$	0.163***	0.141***	0.129**	0.169***	0.208***	0.129**	0.135***	0.004
dp_{t-1}	0.058***	0.118	0.081*	0.189***	0.065*	0.009	0.115*	-0.075
ipi_{t-1}	0.012	0.146**	0.125*	0.183***	-0.032**	-0.035*	-0.015	0.030
Δex_{t-1}	0.051**	-0.213**	0.477***	0.161***	-0.220**	-0.156*	-0.286***	0.467***
Δex_{t-2}			-0.321***					-0.198***
$\Delta neer^{+}_{t}$	0.888***	1.063***	0.806***	0.663***	1.116***	0.989***	1.039***	0.965***
$\Delta neer^{+}_{t-1}$		0.338**	-0.467***	-0.069	0.212*	0.278**	0.358***	-0.578**:
$\Delta neer^{+}_{t-2}$			0.381***					
$\Delta neer^{-}_{t}$	0.936***	1.005***	0.883***	0.795***	0.996***	0.957***	0.987***	1.137***
$\Delta neer^{-}_{t-1}$		0.351**	-0.486***	-0.253**	0.280***	0.145	0.416***	-0.341***
$\Delta neer^{-}_{t-2}$			0.219					
Δdp_{t}	0.384***	0.172	0.595***	0.770***	-0.229*	0.291**	-0.193	0.318
Δdp_{t-1}			0.141*					
Δipi_{t}	-0.018	0.041	0.012	0.065	0.002	-0.089***	0.024	-0.059
LR^{+} coefficent	0.584	0.412	0.291	0.061	1.077	0.855	0.922	2.590
LR^{-} coefficent	0.858	0.574	0.670	0.728	0.766	1.529	0.540	-0.243
$Adj.R^2$	0.967	0.773	0.889	0.893	0.917	0.938	0.924	0.868
t_{BDM}	-3.917**	-4.107**	-3.059	-4.633***	-3.909*	-2.322	-5.676***	0.590
F_{PSS}	6.472***	6.139***	3.591	6.566***	5.427**	2.078	11.785***	3.298
SR symmetry	0.329	0.824	0.688	0.733	0.605	0.043	0.950	0.005***
LR symmetry	0.000***	0.166	0.058*	0.000***	0.000***	0.013**	0.000***	0.563

Note: (a) */**/*** denote significance at 10%, 5%, and 1%, respectively. (b) The LR^{+} and LR^{-} coefficients represent the long-run PTM coefficients in the exchange rate depreciation and appreciation periods, respectively. (c) t_{BDM} and F_{PPS} are the bounds *t*- and *F*-statistics, respectively, for long-run cointegrating relationships, where critical values for $k = 3$ are invoked. (d) *p*-values are reported for the SR symmetry tests for the hypothesis that additive short-run PTM coefficients are different between yen depreciation and appreciation periods. (e) *p*-values are reported for the LR symmetry tests for the hypothesis that long-run PTM coefficients are different between yen depreciation and appreciation periods.

Appendix Table A5: PTM coefficient estimates in the ARDL model

Industry	**Whole Sample (1997-2015)**				**First Sub-sample (1997-2006)**				**Second Sub-sample (2007-2015)**			
	SR Coefficient	LR Coefficient	Contegration Test		SR Coefficient	LR Coefficient	Cointegration Test		SR Coefficient	LR Coefficient	Cointegration Test	
			t_{BDM}	F_{PSS}			t_{BDM}	F_{PSS}			t_{BDM}	F_{PSS}
All	0.922 ***	0.326			0.913 ***	-0.002			0.911 ***	0.703 **		**
Textile	0.923 ***	0.473 ***	***	***	0.819 ***	0.320			1.014 ***	0.500 ***	**	***
Chemical	0.814 ***	0.307			0.727 ***	0.028	*		0.846 ***	0.480 **		*
Metal	0.746 ***	0.296			0.769 ***	0.078			0.701 ***	0.393 **		
Machinery	1.020 ***	0.744 **		**	0.970 ***	-0.034		**	1.070 ***	0.848 *		
Electric	0.937 ***	0.505			0.899 ***	-0.098			0.990 ***	1.163		
Transport	1.003 ***	0.682 **			0.984 ***	0.885* ***	*	*	1.035 ***	0.692 ***	*	***
Others	0.986 ***	-0.373			0.947 ***	-0.446			1.028 ***	-5.035		

Note: (a) SR and LR denote the short-run and long-run PTM coefficients, respectively. (b) */**/*** denote significance at 10%, 5%, and 1%, respectively. For cointegration testing, the significance is based on both t_{BDM} and F_{PPS} bounds tests for $k = 3$.