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What determines firms' predicted exchange rates? Empirical evidence from Japanese firm survey data*

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Abstract

This study uses the Bank of Japan's *Tankan* survey data for 12 manufacturing industries to examine the determinants of firms' prediction errors, defined as the difference between realized and predicted exchange rates. Using a fixed-effect panel estimation, we find that Japanese exporting firms, particularly large firms with higher profit margins, are less likely to quickly update their exchange rate predictions. The prediction errors decrease (increase) as the yen depreciates (appreciates) in nominal effective terms, using invoice-currency weights. Considering both the level of the invoice-currency-weighted NEER and its volatility, the reduction in prediction errors from NEER depreciation is partially offset during periods of yen depreciation. In addition, the more (less) volatile the invoice-currency-weighted NEER is, the smaller (larger) the prediction errors. Thus, firms with a higher (lower) yen-invoiced export ratio tend to have greater (smaller) prediction errors.

JEL Classification: D22, D84, F31, G13

Keywords: Predicted exchange rates, invoice currency, nominal effective exchange rate (NEER), yen appreciation and depreciation,

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1. Introduction

Exchange rate expectations have attracted considerable attention in international finance. However, only a few studies have empirically examined how market participants expect the future level of exchange rates, because obtaining data on expected future exchange rates is very hard. Previous studies, such as Ito (1989) and Takagi (1991), empirically examined how market participants expect the future level of exchange rates using the survey data. Such survey data are not readily available, which prevents rigorous empirical investigation of this research question.

The Bank of Japan (BOJ) publishes firms' predictions of the nominal exchange rate of the yen vis-à-vis the US dollar (henceforth, the predicted yen/USD exchange rate) by firm size and industry, as part of the "Short-Term Economic Survey of Enterprises in Japan," abbreviated as Tankan.[1] The survey is conducted four times per year (March, June, September, and December) and covers about 9,000 Japanese firms. Specifically, in March and September, Tankan collects firms' predicted yen/USD exchange rates for the next six months. In June and December, Tankan collects updates on predicted yen/USD exchange rates for the remaining three months. Using these updated predictions, we can construct a quarterly series of the predicted yen/USD exchange rates.

Figure 1 presents the monthly series of the nominal yen/USD exchange rate and two types of predicted exchange rates: one is the large-sized firms' predicted exchange rates, and the other is the small-sized firms' predicted exchange rates.[2] First, during the rapid yen depreciation period from 2013 to 2015 and from 2021 to 2025, the actual yen/USD exchange rate is generally above the predicted exchange rates, which suggests that firms' response to the yen depreciation trend tends to be slow, especially in the case of large-sized firms. Second, during the yen appreciation period from around 2007 to 2012, the actual yen/USD exchange rate was typically lower than the predicted exchange rates. In contrast to the period of yen depreciation, large-sized firms tend to respond more quickly to actual yen appreciation than small-sized firms. Thus, questions to be examined are (1) what determines firms' predicted exchange rates and the prediction errors between

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[1] The response rate for the Tankan survey is typically above 99 percent. The BOJ's Tankan provides survey data on firms categorized by capital: large (1 billion yen or more), medium (100 million yen or more and less than 1 billion yen), and small (20 million yen or more and less than 100 million yen).

[2] As explained earlier, we can construct at most a quarterly series of the predicted yen/USD exchange rate. We converted the quarterly series to a monthly series, assuming that firms' predictions would not change over the next three months.

the actual and predicted exchange rates; (2) why the predicted exchange rates tend to respond slowly to the rapid yen appreciation and depreciation; and (3) why the predicted exchange rates respond differently between yen appreciation and depreciation periods.

The fixed-effect panel estimation yields three main findings. First, large Japanese exporting firms with higher profit margins are less likely to update their exchange rate predictions. Second, prediction errors decrease (increase) as the yen depreciates (appreciates) in nominal effective terms, using invoice-currency weights. Third, when both the level of Invoice-NEER and its volatility are considered, the reduction effect of Invoice-NEER depreciation is mitigated to some extent during the yen depreciation period. In addition, the more (less) volatile the Invoice-NEER is, the smaller (larger) the prediction errors are for large-sized firms. Thus, firms with a lower (higher) yen-invoiced export ratio tend to update their forecasts quickly (slowly).

The fixed-effect panel estimation shows that Japanese exporting firms are less likely to quickly update their exchange rate prediction errors if they are large firms with higher profit margins. The prediction errors decrease (increase) as the yen depreciates (appreciates) in nominal effective terms, using invoice-currency weights. Considering both the level of the Invoice-NEER and its volatility, the reduction in prediction errors from Invoice-NEER depreciation is partially offset during periods of yen depreciation. In addition, the more (less) volatile the Invoice-NEER is, the smaller (larger) the prediction errors. Thus, firms with a higher (lower) yen-invoiced export ratio tend to have greater (smaller) prediction errors.

The paper is organized as follows. Section 2 shows the empirical strategy and presents a data description. Section 3 discusses the estimated results and their implications. Finally, Section 4 concludes the paper.

2. Empirical Strategy

2.1 Prediction Errors

The firm's prediction error ($error_t$) between the actual nominal exchange rate and the predicted exchange rate is shown as:

$$error_t = \ln S_t - \ln E_{t-1} S_t , \qquad (1)$$

where S denotes the nominal yen/USD exchange rate, and E_{t-1} denotes the expectation operator based on the information available at $(t-1)$. Thus, the second term on the right-

hand side indicates that the firm predicted the future exchange rate at (t – 1). The BOJ's Tankan publishes the predicted exchange rates, as explained above, although it does not provide firm-level information; instead, it provides aggregated industry-level information. We follow Nguyen and Sato (2019, 2020) and Liu and Sato (2024) to construct the quarterly series of predicted exchange rates, as described below.

We generate the quarterly series of prediction errors ($error_t$) using equation (1). Because the BOJ's Tankan survey is conducted in March, June, September, and December, we use three-month-ahead forecasts from those periods. For instance, the prediction error in June 2025 is the difference between the three-month-ahead exchange rate forecast in March 2025 and the realized nominal exchange rate in June 2025.

Since the prediction errors equal the log-differences between the realized and predicted exchange rates, we can derive the following:

$$error_t = \ln S_t - \ln E_{t-1} S_t = \ln\left(\frac{S_t}{\ln E_{t-1} S_t}\right) \approx \frac{S_t - \ln E_{t-1} S_t}{\ln E_{t-1} S_t} \tag{2}$$

Multiplying by 100 converts the prediction errors into percentage terms for empirical estimation. We computed the prediction errors across 12 manufacturing industries.[3]

2.2 Determinants of Prediction Errors

We set up the following fixed-effect panel specification to examine what determines the absolute value of a firm's prediction errors:

$$\begin{aligned} \left|error_{i,t}\right| = {} & \beta_1 \left(\frac{Exports}{D.Sales}\right)_{i,t-1} + \beta_2 \left(\frac{Curr.profit}{TotalSales}\right)_{i,t-1} + \beta_3 \ln(InvoiceNEER)_{i,t-1} \\ & + \beta_4 Volatility(InvoiceNEER)_{i,t-1} + \beta_5 Yen.Dep.Dummy_t + \gamma_i + \varepsilon_{i,t} \end{aligned} \tag{3}$$

where (*Exports*/*D.Sales*) denotes the ratio of exports to domestic sales, a proxy for foreign market dependence. Both exports and domestic sales are obtained from the BOJ's Tankan

[3] The BOJ's Tankan provides survey data for 19 industries (including sub-sectors), all industries, and all manufacturing. We selected 12 industries and excluded the aggregated data for all industries and all manufacturing. The 12 industries include (1) Textiles, (2) Pulp & Paper, (3) Chemicals, (4) Petroleum & Coal products, (5) Ceramics, Stone & Clay, (6) Iron & Steel, (7) Nonferrous metals, (8) Processed metals, (9) General-purpose, Production & Business-oriented machinery, (10) Electrical machinery, (11) Motor vehicles, and (12) Shipbuilding, Heavy machinery & Other transportation machinery.

survey, making them one-quarter-ahead forecast variables. (*Curr.profit*/*TotalSales*) denotes the ratio of current profits to total sales, the recurring profit margin. Both current profit and total sales are also taken from the BOJ's Tankan survey, so they are one-quarter-ahead forecast variables. *InvoiceNEER* and its volatility denote the invoice-currency-weighted nominal effective exchange rate (henceforth, Invoice-NEER) and the standard deviation of the Invoice-NEER over the last twelve months. We construct the monthly Invoice-NEER series for each industry, *i*, and convert it to an end-quarter series. To calculate its standard deviation, we use the monthly Invoice-NEER series for the last twelve months, including the current month. The yen depreciation dummy (*Yen.Dep.Dummy*) takes 1 during the yen depreciation trend and 0 otherwise.[4] As shown in Figure 1, we have an obvious yen depreciation trend from 2013 to 2015 and from 2021 to 2025. Although somewhat arbitrary, this division of the sample period enables us to analyze likely asymmetric revisions to exchange rate predictions between yen-appreciation and yen-depreciation periods. γ_i denotes the industry fixed effect, and $\varepsilon_{i,t}$ denotes an error term. The sample period ranges from 2004Q1 to 2025Q4.

2.3 Invoice Currency Weighted NEER

The BOJ publishes two types of price indices for Japanese exports: (1) a *yen*-based export price index and (2) a *contract-currency*-based export price index. The BOJ collects export price data by contract (invoice) currency from sample firms and then calculates the yen-based export price using the yen's monthly average bilateral nominal exchange rate vis-à-vis each contract currency.

Let us assume that Japanese exporters use only three currencies: yen, US dollars (USD), and euros (EUR), in their exports, and also that the BOJ constructs the yen-invoiced export price (P_{yen}), USD-invoiced export price ($P_{\$}$), and EUR-invoiced export price (P_{eur}).[5] Then, we can define the yen-based export price index (P^x_{yen}) as follows:

$$P^x_{yen} = (P_{yen} \cdot S_{yen/yen})^{\alpha} (P_{\$} \cdot S_{yen/\$})^{\beta} (P_{eur} \cdot S_{yen/eur})^{\gamma} \qquad (4)$$

where α, β, and γ denote the shares of exports invoiced in yen, USD, and EUR,

[4] Based on visual inspections of Figure 1, the yen depreciation period is assumed to be 2005Q3–2007Q2, 2013Q1–2015Q4, and 2021Q1–2025Q4.

[5] This is not an extreme assumption. In the second half of 2015, these three currencies accounted for 96.3 percent of the invoice currencies of Japanese total exports (see Ito *et al*. (2018), Table 2.2).

respectively, and $\alpha+\beta+\gamma=1$. $S_{yen/\$}$ and $S_{yen/eur}$ denote the yen's bilateral nominal exchange rates vis-à-vis the USD and EUR, respectively. We assume $S_{yen/yen}=1$. The export price in contract currencies (P_c^x) is defined as $P_c^x=(P_{yen})^{\alpha}(P_{\$})^{\beta}(P_{eur})^{\gamma}$. Thus, the yen-based export price index (P_{yen}^x) can be reformulated as:

$$\begin{aligned} P_{yen}^x &= (P_{yen})^{\alpha}(P_{\$})^{\beta}(P_{eur})^{\gamma}(S_{yen/yen})^{\alpha}(S_{yen/\$})^{\beta}(S_{yen/eur})^{\gamma} \\ &= P_c^x(S_{yen/yen})^{\alpha}(S_{yen/\$})^{\beta}(S_{yen/eur})^{\gamma} \end{aligned} \tag{5}$$

By dividing both sides of equation (5) by P_c^x, we obtain the following NEER with invoice-currency weights:

$$P_{yen}^x \Big/ P_c^x = (S_{yen/yen})^{\alpha}(S_{yen/\$})^{\beta}(S_{yen/eur})^{\gamma} \tag{6}$$

An increase (decrease) in the Invoice-NEER reflects yen depreciation (appreciation). For example, if all Japanese exports are invoiced in USD, the Invoice-NEER equals the yen/USD exchange rate. If all Japanese exports are invoiced in yen, the Invoice-NEER equals unity, indicating that Japanese exporters are immune to foreign exchange risk at least in the short run. Thus, a change in Invoice-NEER has different implications depending on whether the yen appreciates or depreciates: an increase (decrease) in the Invoice-NEER leads to foreign exchange gains (losses).

3. Empirical Results

We conducted a fixed-effect panel estimation with seasonal dummies because we use quarterly data from 2004Q1 to 2025Q4. All explanatory variables in equation (3) are lagged by one quarter. The BOJ's Tankan provides survey data for three firm-size categories: large, medium, and small. The estimated results for each firm size group are presented in Tables 1 and 2.

First, the yen depreciation dummy is significantly positive across all columns in Tables 1 and 2, indicating that prediction errors are larger during the yen depreciation period. The estimated coefficient for large-sized firms' prediction errors is larger than that for medium-sized firms and much larger than that for small-sized firms.

Second, only in large firms is the estimated coefficient for the recurring profit margin significantly positive (Tables 1 and 2). This suggests that large firms with higher profit margins update their exchange rate forecasts slowly.

Third, the estimated coefficient for Invoice-NEER is significantly negative across most cases in the three firm-size groups, indicating that prediction errors decrease as the yen depreciates in nominal effective terms, as measured by invoice-currency weights (Table 1). The interaction term between Invoice-NEER and the yen depreciation dummy is significantly negative in the large- and medium-sized firm groups, indicating that these firms accelerate the decline in prediction errors during the yen depreciation period.

Fourth, in Table 2, we include both the level and the volatility of the Invoice-NEER because they are weakly correlated and less likely to cause multicollinearity. In column (4) of Table 2, including both the level and the volatility of the Invoice-NEER changes the sign of the interaction term between the Invoice-NEER and the yen depreciation dummy from negative to positive. During the yen depreciation period, the reduction in prediction errors is partially offset.

Fifth, Invoice-NEER volatility has a significantly negative effect on prediction errors for large-sized firms in columns (1) and (2) of Table 2, whereas this effect is not significant for medium- and small-sized firms. In other words, the more (less) volatile the Invoice-NEER, the smaller (larger) the prediction errors for large-sized firms. This result suggests that large-sized firms with a lower (higher) yen-invoiced export ratio tend to have smaller (greater) prediction errors. In addition, Invoice-NEER volatility has asymmetric effects on prediction errors: positive during the yen appreciation period and negative during the yen depreciation period. For medium- and small-sized firms, these effects offset each other, but the negative effect likely dominates the positive effect for large-sized firms.

4. Concluding Remarks

Using the BOJ's Tankan survey data, we have empirically examined the determinants of Japanese firms' prediction errors. The findings are threefold. First, large Japanese exporting firms with higher profit margins are less likely to update their exchange rate predictions. Second, prediction errors decrease (increase) as the yen depreciates (appreciates) in nominal effective terms, using invoice-currency weights. Third, when both the level of Invoice-NEER and its volatility are considered, the reduction effect of Invoice-NEER depreciation is mitigated to some extent during the yen depreciation period. In addition, the more (less) volatile the Invoice-NEER is, the smaller (larger) the prediction errors are for large-sized firms. Thus, firms with a lower (higher)

yen-invoiced export ratio tend to update their forecasts quickly (slowly). These empirical findings will motivate further research on firm-level predictions of future exchange rates.

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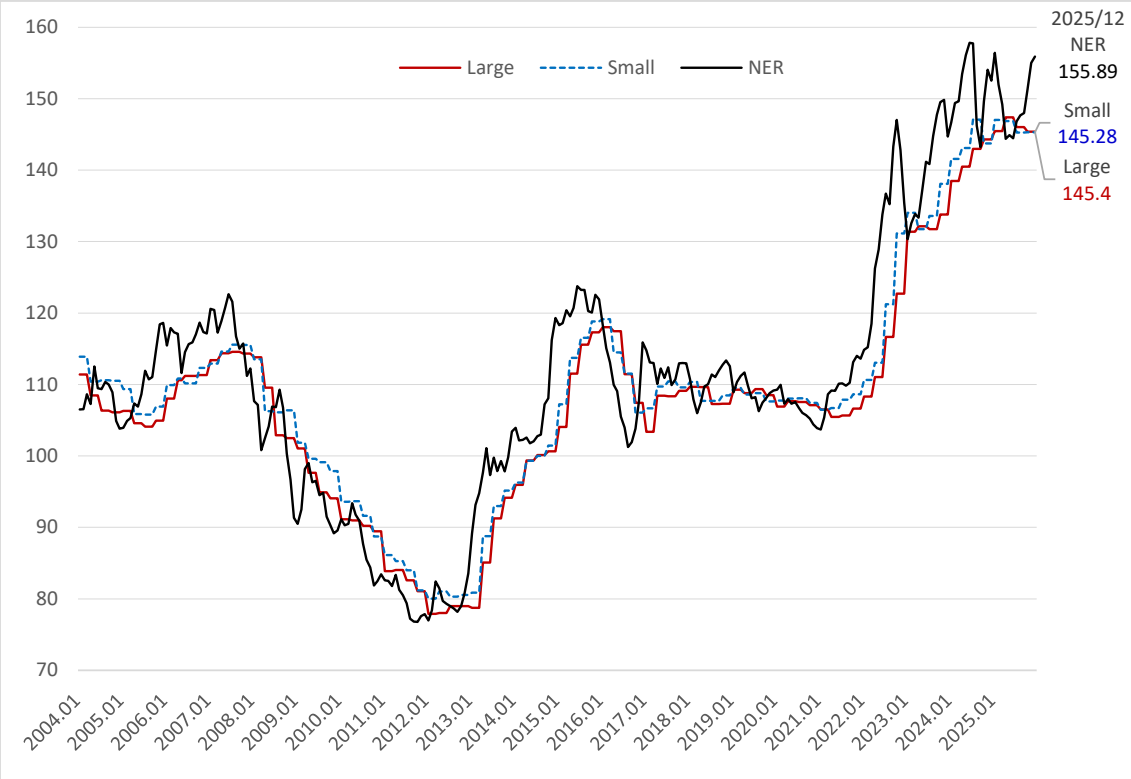
Figure 1. Nominal Exchange Rate (NER) of the Yen vis-à-vis the US Dollar and the Predicted Exchange Rate (January 2004–December 2025)



Note: Predicted exchange rates for large-sized and small-sized firms are presented.

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

Table 1. Results of Panel Estimation

Dependent Variable: Absolute value of exchange rate prediction error

	Large				Medium				Small			
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
L.ExpDSales	0.0148	0.00937	0.0148	0.0151	-0.00386	-0.00507	-0.00355	-0.00340	0.00593	0.00608	0.00489	0.00650
	(0.0111)	(0.00997)	(0.0114)	(0.0114)	(0.0117)	(0.0101)	(0.0115)	(0.0119)	(0.0166)	(0.0166)	(0.0166)	(0.0171)
L.ProfitSales	0.154***	0.135***	0.154***	0.157***	0.0589	0.0572	0.0869	0.0603	-0.0815	-0.0825	-0.110	-0.0804
	(0.0401)	(0.0399)	(0.0420)	(0.0405)	(0.113)	(0.114)	(0.126)	(0.116)	(0.0928)	(0.0930)	(0.0995)	(0.0937)
L.Invoice-NEER	-9.367***	-9.624***	-9.364***	-8.926***	-6.293***	-6.403***	-6.106***	-5.854***	-5.070**	-5.014**	-5.270**	-4.841*
	(0.944)	(0.859)	(0.988)	(0.925)	(1.816)	(1.727)	(1.698)	(1.882)	(2.237)	(2.249)	(2.165)	(2.395)
L.(DepDum × ExpDSales)		0.0123*				0.00892				-0.0125		
		(0.00641)				(0.0112)				(0.0149)		
L.(DepDum × ProfitSales)			-0.000994				-0.0837				0.0858	
			(0.0513)				(0.111)				(0.0952)	
L.(DepDum × InvoiceNEER)				-0.121**				-0.113*				-0.0578
				(0.0445)				(0.0608)				(0.0733)
Depreciation Dummy	4.650***	4.274***	4.654***	5.088***	4.303***	4.193***	4.600***	4.714***	3.144***	3.236***	2.893***	3.354***
	(0.287)	(0.368)	(0.439)	(0.362)	(0.410)	(0.523)	(0.643)	(0.407)	(0.279)	(0.336)	(0.467)	(0.368)
Constant	45.49***	46.96***	45.48***	43.46***	32.20***	32.73***	31.23***	30.19***	27.16**	26.91**	28.18**	26.12**
	(4.462)	(4.019)	(4.745)	(4.401)	(8.179)	(7.761)	(7.543)	(8.492)	(10.37)	(10.42)	(10.01)	(11.12)
Industry FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036	1,036
R-squared	0.187	0.189	0.187	0.188	0.157	0.158	0.158	0.158	0.095	0.095	0.095	0.095
Number of ID	12	12	12	12	12	12	12	12	12	12	12	12

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: All explanatory variables, except the yen depreciation dummy, are one-quarter lagged.

Table 2. Results of Panel Estimation with the Invoice-NEER and its Volatility

Dependent Variable: Absolute value of exchange rate prediction error

	Large				Medium				Small			
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
L.ExpDSales	0.0138	0.0142	0.0175	0.0176	-0.00287	-0.00251	-0.00636	-0.00726	0.00561	0.00610	0.00435	0.00127
	(0.0109)	(0.0112)	(0.0126)	(0.0126)	(0.0123)	(0.0125)	(0.0132)	(0.0131)	(0.0165)	(0.0170)	(0.0186)	(0.0195)
L.ProfitSales	0.147***	0.152***	0.175***	0.173**	0.0461	0.0501	0.0914	0.0929	-0.0933	-0.0911	-0.0250	-0.0216
	(0.0407)	(0.0411)	(0.0543)	(0.0558)	(0.115)	(0.118)	(0.129)	(0.128)	(0.0967)	(0.0985)	(0.104)	(0.103)
L.Invoice-NEER	-9.487***	-9.001***	-8.175***	-8.682***	-6.420***	-5.947***	-5.280**	-5.677**	-5.212**	-4.997*	-3.789	-4.683*
	(0.891)	(0.900)	(1.014)	(1.004)	(1.833)	(1.879)	(1.860)	(1.879)	(2.208)	(2.365)	(2.291)	(2.418)
L.Volatility(InvoiceNEER)	-0.0881*	-0.0772*	0.334***	0.380***	-0.0828	-0.0733	0.262***	0.298***	-0.106	-0.102	0.336***	0.413***
	(0.0412)	(0.0412)	(0.0380)	(0.0475)	(0.0762)	(0.0759)	(0.0707)	(0.0751)	(0.0786)	(0.0770)	(0.0707)	(0.0749)
L.(DepDum × InvoiceNEER)		-0.135***		0.193***		-0.122**		0.142*		-0.0550		0.312***
		(0.0319)		(0.0601)		(0.0522)		(0.0727)		(0.0759)		(0.0992)
L.(DepDum × Volatility)			-0.693***	-0.793***			-0.556***	-0.632***			-0.717***	-0.882***
			(0.0477)	(0.0665)			(0.0328)	(0.0553)			(0.0758)	(0.0808)
Depreciation Dummy	4.748***	5.233***	6.194***	5.708***	4.391***	4.832***	5.560***	5.205***	3.233***	3.431***	4.740***	3.960***
	(0.245)	(0.240)	(0.232)	(0.221)	(0.386)	(0.353)	(0.363)	(0.338)	(0.272)	(0.370)	(0.201)	(0.331)
Constant	46.29***	44.02***	39.07***	41.28***	33.02***	30.82***	26.90***	28.63***	28.11**	27.11**	20.39*	24.30*
	(4.258)	(4.314)	(4.855)	(4.767)	(8.338)	(8.553)	(8.421)	(8.533)	(10.27)	(11.02)	(10.66)	(11.23)
Industry FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028
R-squared	0.191	0.192	0.207	0.208	0.160	0.161	0.171	0.171	0.097	0.097	0.116	0.119
Number of ID	12	12	12	12	12	12	12	12	12	12	12	12

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: All explanatory variables, except the yen depreciation dummy, are one-quarter lagged.