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Exchange rate rebounds after foreign exchange market interventions☆

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HIGHLIGHTS

- There are the rebounds in the exchange rate after foreign exchange intervention.
- When intervention is strongly effective, the exchange rate rebounds at next day.
- The effect of intervention is reduced slightly by the rebounds.

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ABSTRACT

This study examined the rebounds in the exchange rate after foreign exchange intervention. When intervention is strongly effective, the exchange rate rebounds at next day. The effect of intervention is reduced slightly by the rebound after the intervention. The exchange rate might have been 67.12–77.47 yen to a US dollar without yen-selling/dollar-purchasing intervention of 74,691,100 million yen implemented by the Japanese government since 1991, in comparison to the actual exchange rate was 103.19 yen to the US dollar at the end of March 2014.

1. Introduction

This study examined the effects of exchange-rate rebounds after foreign exchange intervention. Exchange rates fluctuate because of changes in the supply–demand balance of currencies. If government or central bank intervenes in the foreign exchange market without prior announcement, the exchange rate will be moved by the intervention. Subsequently, market participants who have observed the authorities' intervention will react and the exchange rates will fluctuate according to the information related to the intervention. Fig. 1 presents trends in the Japanese yen per US dollar exchange rate around September 15, 2010. The Japanese government intervened in the foreign exchange market on September 15, 2010 by buying US dollars for 2124.9 billion yen.[1] Fig. 1 shows that the yen-selling/dollar-purchasing intervention depreciated the yen. When the exchange market is given a shock by such an intervention, verifying the effect of the intervention is important. It is also important to observe how the exchange rate changes after the intervention. Fig. 2 is a conceptual diagram of a case in which the exchange rate has fluctuated as a result of a foreign exchange intervention. We consider that the yen-selling/dollar-purchasing intervention at the time t has weakened the yen rapidly. In the left diagram of Fig. 2, the exchange rate just shifted, as shown by Path A. Path B in the right diagram, however, shows a rebound in the exchange rate to a

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1 See Ref. [1] for details of this intervention.

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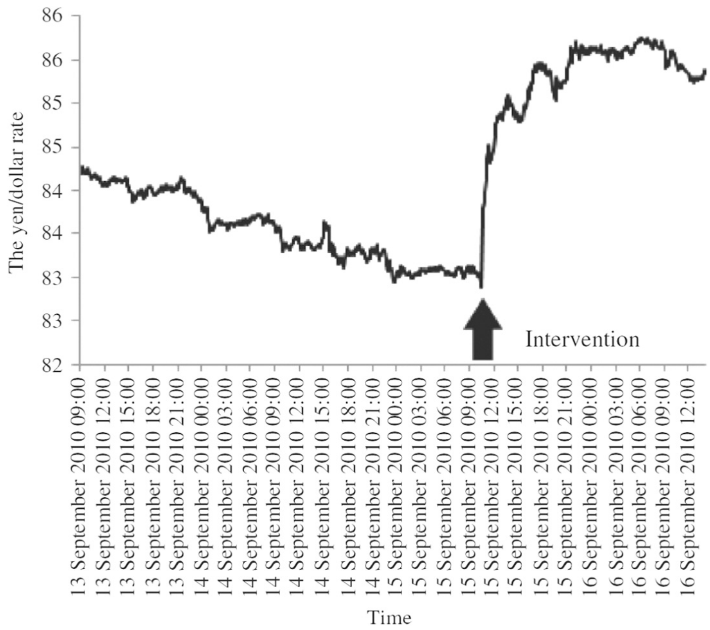

Fig. 1. Yen–dollar rates and intervention. The intervention conducted on September 15, 2010. The horizontal axis shows Japan time. The vertical axis shows the yen–dollar exchange rate (Bid, 5 min).
Source: Hoshikawa and Yamaguchi [1].

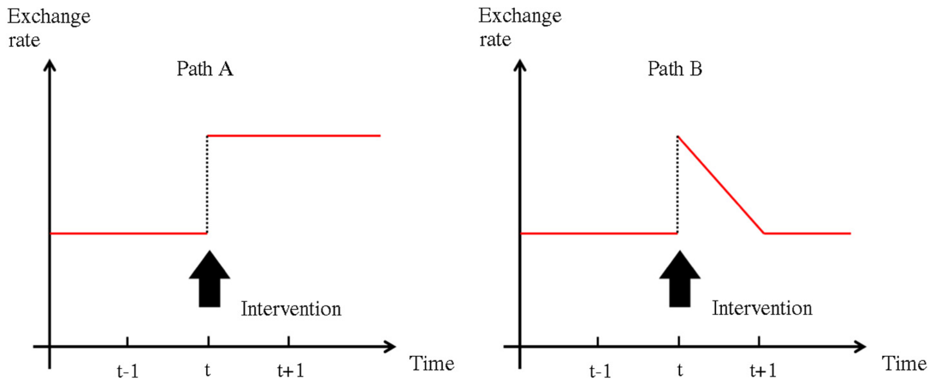

Fig. 2. Foreign exchange intervention at time t and exchange rate trend.

stronger yen after the intervention. Whether a rebound in the exchange rate like Path B on the right of Fig. 2 follows a foreign exchange intervention is important when examining the intervention effects because such a rebound seemingly reduces the importance of the intervention. Examples of survey-based studies of foreign exchange intervention include Sarno and Taylor [2] and Takagi [3]. Studies of exchange-rate rebounds are not common despite numerous studies done on foreign exchange intervention.

The following reviews a scatter diagram of data related to exchange-rate rebounds after intervention. Fig. 3 presents the amounts of intervention (horizontal axis, in hundred million yen) and rates of foreign exchange fluctuations (vertical axis, logarithmic difference). The amount of intervention is a positive value when a yen-selling/dollar-purchasing intervention is implemented and a negative value when a yen-buying/dollar-selling intervention is implemented. Data for days on which no intervention took place were excluded. When the amount of intervention is a positive value, the exchange rate appears likely to move to the positive side i.e., a weaker yen, because of the yen-selling/dollar-purchasing intervention. Fig. 4 is a graph of exchange rate fluctuations on the days following a foreign exchange intervention and the amounts of intervention on the respective preceding days. The exchange rates on the days following a positive intervention, i.e., a yen-selling/dollar-purchasing operation, appear to move somewhat to the negative direction in comparison to Fig. 3. Figs. 3 and 4, however, reveal no clear relation.

In this study, we modified the methods presented by Hoshikawa and Yamaguchi [1] and examined the extent of exchange-rate rebounds after foreign exchange interventions. The preceding study investigated the extent of exchange rate fluctuations attributable to foreign exchange intervention and the virtual exchange rate that would have resulted without

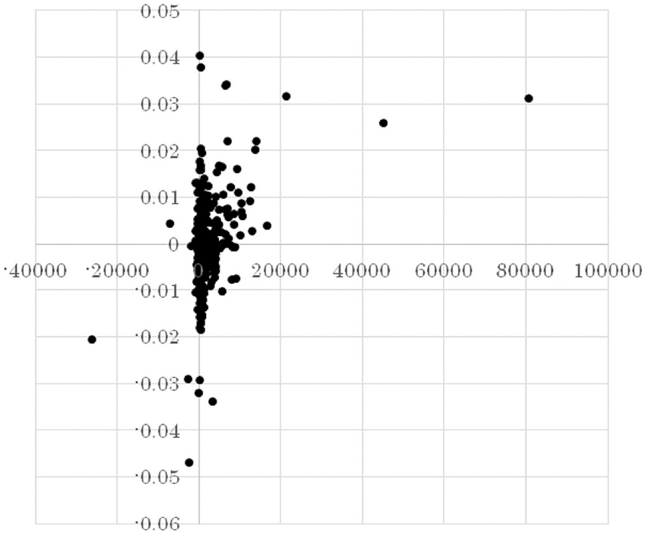

Fig. 3. Foreign exchange interventions and changes in the exchange rate. Note: The horizontal axis shows the amounts of foreign exchange interventions (in 100 million yen). The vertical axis shows the logarithmic difference $\Delta s_t \equiv s_t - s_{t-1}$ of the exchange rate on the day of intervention. Yen-selling/dollar-purchasing interventions are in the positive area, and dollar-selling/yen-buying interventions are in the negative area. The period is April 1, 1991–March 31, 2014.

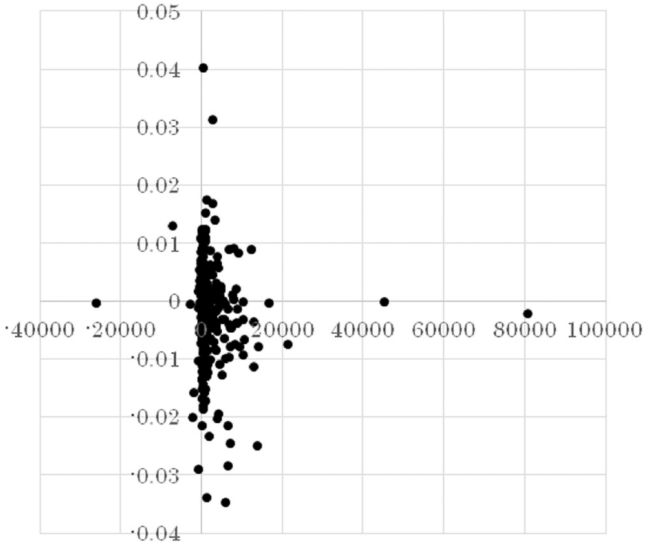

Fig. 4. Foreign exchange interventions and changes in the exchange rate after one period. Note: The horizontal axis shows the amounts of foreign exchange interventions (in 100 million yen); the vertical axis shows the logarithmic differences of the exchange rate on the day of intervention. Yen-selling/dollar-purchasing interventions are placed in the positive area; dollar-selling/yen-buying interventions are placed in the negative area. The period is April 1, 1991–March 31, 2014.

the intervention. This study also analyzed how the virtual exchange rate indicted by the previous study would be revised if a rebound existed. The main findings are the following: The effect of foreign exchange intervention varies depending on the period. The effect of intervention is large at some periods and smaller at others. It was particularly effective during the 1990s, but has gradually become less effective after the 2000s. When foreign exchange intervention proves to be effective, an exchange-rate rebound is observed on the day following an intervention. When intervention is less effective, however, the rebound cannot be large because the exchange rate has not reacted much to the intervention. Rebounds therefore tend not to be observed in such cases.

This article is structured as follows: Section 2 in the following presents details of the previous study, which has become the basis of the present study. Section 3 explains the results of estimation. Section 4 concludes the discussion.

2. Estimation model

2.1. Model of Hoshikawa and Yamaguchi [1]

The questions include how much exchange rates fluctuate as a result of foreign exchange intervention and what levels of exchange rates would prevail if no intervention had taken place. The following first describes the study conducted by Hoshikawa and Yamaguchi [1]. Firstly, we explain their assumptions that are used to calculate the virtual exchange rate without intervention in Ref. [1]. The log of exchange rate denotes $s_t = \ln(S_t)$, and period t denotes $t = 0, 1, 2, \ldots, T$ where s_0 is an initial value and s_T is the log exchange rate of the last period. They assumed the following three assumptions.

Assumption 1. The log exchange rate s_t follows the random walk process.

$$s_t = s_{t-1} + u_t. \tag{1}$$

Here, u_t is the error term. The exchange rate has a unit root. The equation can be written

$$s_T = s_0 + \sum_{t=1}^{T} u_t. \tag{2}$$

Assumption 2. The innovation u_t consists of intervention shock x_t and other shock ε_t, and we assume a linear relation with $\beta \neq 0$:

$$u_t = \beta x_t + \varepsilon_t. \tag{3}$$

Assumption 3. Intervention is an exogenous variable. It indicates

$$E(x_t \varepsilon_t) = 0. \tag{4}$$

Assumption 1 indicates that intervention shock is included in u_t ($\beta \neq 0$). This indicates that intervention is effective and has a constant effect in the sample period. In other words, the shock u_t includes information about intervention or news of it. They assume that intervention is exogenous in short-run intervals such as daily data in Assumption 3. From Eqs. (2) and (3), the level of the exchange rate at time T is expressed as the following equation:

$$s_T = s_0 + \beta \sum_{t=1}^{T} x_t + \sum_{t=1}^{T} \varepsilon_t. \tag{5}$$

Eq. (5) shows the exchange rate on date T is composed by the initial value, accumulated intervention and other accumulated shock. They define the virtual exchange rate $\tilde{s}$, which is Eq. (5) without the intervention term, as

$$\tilde{s}_T \equiv s_0 + \sum_{t=1}^{T} \varepsilon_t, \tag{6}$$

or

$$\tilde{s}_T \equiv s_T - \beta \sum_{t=1}^{T} x_t. \tag{7}$$

Hoshikawa and Yamaguchi [1] calculated Eq. (7) with the estimated parameter β. For example, the simple estimation equation is

$$\Delta s_t = \alpha + \beta x_t + \varepsilon_t, \tag{8}$$

where $\Delta s_t \equiv s_t - s_{t-1}$ is the first difference in the log exchange rate, x_t is the intervention and ε_t is the disturbance term. The estimated parameter by OLS is $\hat{\beta} = 0.000000776$, and the total intervention quantity is $\sum_{t=1}^{T} x_t = 610865$. They calculated the virtual exchange rate $\tilde{s}$, which is Eq. (7) with an estimated $\hat{\beta}$. The level of the exchange rate without intervention can be calculated

$$\tilde{S}_T = \exp(\tilde{s}_T) = \exp\left(s_T - \hat{\beta} \sum_{t=1}^{T} x_t\right) = \exp\left(4.38506 - 0.000000776 \times 610865\right) = 50.12.$$

They show that if the Japanese government did not intervene in the market after 1991, then the virtual yen/dollar rate would have been 50.12 instead of the actual rate of 80.52 on 30 June 2011. However, their model leaves many points to be improved. Their plain model also does not considerate the rebound of the exchange rate after intervention.

2.2. Modified model

This section presents development of a model of post-intervention exchange-rate rebounds based on the study of Hoshikawa and Yamaguchi [1]. A foreign exchange intervention is seemingly less effective when a rebound, such as that shown by Path B on the right of Fig. 2, occurs. Whether a rebound occurs is therefore important when examining the effect of foreign exchange intervention. In Eq. (5), the exchange rate at the final time T is expressed by the total of the initial rate, past intervention shocks, and other accumulated shocks, which assumes an extreme case in which the effect of foreign exchange intervention continues perpetually. This variable corresponds to the shift-type of fluctuation on the left of Fig. 2. However, the impact of intervention on the exchange rate is expected to decline if the exchange-rate rebounds to a stronger yen on the day following a yen-selling/dollar-purchasing intervention that moved the exchange rate to a weaker yen. Estimation of Eq. (8) is therefore revised as shown below to determine the occurrence of such a rebound:

$$\Delta s_t = \alpha + \beta x_t + \phi x_{t-1} + \varepsilon_t, \tag{9}$$

where $\Delta s_t \equiv s_t - s_{t-1}$ stands for the logarithmic difference of the exchange rate, x_t signifies the amount of intervention, and ε_t is the error term. The coefficient ϕ of the amount of intervention x_{t-1} in one time earlier that has been newly added is the parameter that expresses a rebound in the exchange rate. The coefficient is a negative value when the exchange-rate rebounds to the opposite direction on the day following a fluctuation in the rate attributable to intervention. We replace the Eq. (3) in Assumption 3 for $u_t = \beta x_t + \phi x_{t-1} + \varepsilon_t$. The exchange rate at time T is expressed as exhibited below when the amount of the rebound is adjusted.

$$s_T = s_0 + \beta \sum_{t=1}^{T} x_t + \phi \sum_{t=1}^{T} x_{t-1} + \sum_{t=1}^{T} \varepsilon_t. \tag{10}$$

In Eq. (10), the exchange rate at time T is the addition to Eq. (5) of the term expressing the swing back because of a past rebound in the third term of right-hand side. Coefficient ϕ expressing the exchange-rate rebound is assumed to be a negative value. Therefore, the impact of the foreign exchange intervention on the exchange rate is small. If $\beta + \phi = 0$, even if the intervention is effective and $\beta > 0$, then the rebound on the following day offsets the effect of the intervention. The virtual exchange rate at which no intervention takes place is modified and defined as presented below.

$$\tilde{s}_T^m \equiv s_0 + \sum_{t=1}^{T} \varepsilon_t, \tag{11}$$

or

$$\tilde{s}_T^m \equiv s_T - \beta \sum_{t=1}^{T} x_t - \phi \sum_{t=1}^{T} x_{t-1}. \tag{12}$$

This study estimates Eq. (9) and calculates the modified virtual exchange rate $\tilde{s}_T^m$ in the case without intervention using the estimated parameters and Eq. (11) or Eq. (12).

3. Results of estimation

The data period of the sample used for the estimation is April 1, 1991–March 31, 2014 because of data availability and the sample size of 5995. Table 1 exhibits the results of estimation. The column at the left end of Table 1 presents the parameters. The second column from the left labeled "OLS" indicates the results of estimation based on ordinary least squares of Estimation equation (8). In other words, if the estimation equation

$$\Delta s_t = \alpha + \beta x_t + \varepsilon_t,$$

is estimated, then β representing the effect of intervention is 5.56E−07, which is positively significant at the 1% significance level. Newey–West HAC (heteroskedasticity and autocorrelation consistent) standard errors for OLS estimation are reported in parentheses. Therefore, the yen-selling/dollar-purchasing intervention is moving the exchange rate to the direction of a weaker yen. The constant term α is not significant. Several regression diagnostics are reported at the bottom of the table: ln L denotes the value of the log-likelihood; $Q(5)$ and $Q^2(5)$ are the Ljung–Box statistics, with five lags for the standardized residuals and their squares; the associated p-values are in brackets.

The next column "OLS" lists the results of estimation based on ordinary least squares by adding the variable for the rebound effect to Estimation equation (9). In other words, the results of estimating the equation

$$\Delta s_t = \alpha + \beta x_t + \phi x_{t-1} + \varepsilon_t,$$

are indicated. The value of β representing the effect of intervention is 5.69E−07, which is also positively significant. Coefficient ϕ representing the exchange-rate rebound is −1.31E−07, which suggests that the exchange-rate rebounds to the direction of a stronger yen on the day following the intervention. The coefficient, however, is significant at the 10% level but not at the 5% level, which might be regarded as *not* being a rebound.

Table 1
Results of estimation.

Variable	OLS	OLS	GARCH	EGARCH
α	−0.000119	−0.000105	−6.26E−05	−0.000127
	(8.91E−05)	(8.62E−05)	(7.98E−05)	(8.07E−05)
β	5.56E−07***	5.69E−07***	4.80E−07***	4.67E−07***
	(5.91E−08)	(1.07E−07)	(6.45E−08)	(5.59E−08)
ϕ	–	−1.31E−07*	−7.37E−08	−8.31E−08
		(7.71E−08)	(5.00E−08)	(5.76E−08)
γ_0	–	–	6.44E−07***	−0.289176***
			(1.69E−07)	(0.057266)
γ_1	–	–	0.938349***	0.980685***
			(0.009095)	(0.00497)
γ_2	–	–	0.047991***	0.125695***
			(0.007484)	(0.017737)
γ_3	–	–	–	−0.026899**
				(0.010458)
Q(5)	1.99[0.85]	2.35[0.80]	1.21[0.94]	0.81[0.98]
Q^2(5)	322.43[0.00]	322.50[0.00]	8.13[0.15]	845[0.13]

Notes: Standard errors are in parentheses.
* Denotes significant at the 10% level.
** Denotes significant at the 5% level.
*** Denotes significant at the 1% level.

The second column from the right labeled "GARCH" presents the results of estimation performed using the generalized autoregressive conditional heteroskedasticity (GARCH) model shown below. We assume that the error term of estimation equation (9) is $\varepsilon_t = \nu_t\sqrt{h_t}$ and that

$$h_t = \gamma_0 + \gamma_1 h_{t-1} + \gamma_2 \varepsilon_{t-1}^2. \tag{13}$$

The column at the right end of the table lists the results of estimation based on the EGARCH (exponential GARCH) model.[2] This case uses a model to determine the variance of estimation equation (9), as presented below.

$$\ln(h_t) = \gamma_0 + \gamma_1 \ln(h_{t-1}) + \gamma_2|\nu_{t-1}| + \gamma_3 \nu_{t-1}. \tag{14}$$

The estimation results do not vary substantially when using the GARCH model and using the EGARCH model. The value of β expressing the impact of intervention is indicated as 4.80E−07 by the GARCH model and as 4.67E−07 by the EGARCH model. Heteroskedasticity consistent covariance standard errors[3] for GARCH and EGARCH models are reported in parentheses. The coefficient ϕ indicating the exchange-rate rebound is −7.37E−08 in the GARCH model and −8.31E−08 in the EGARCH model, which are both negative, but not significant. The results presented up to this point can be roughly summarized as the following: the effect of intervention β is positively significant, the effect of exchange-rate rebound ϕ is negative and not significant, and the parameter size is $\beta + \phi > 0$.

Although rebounds might appear to be non-existent from these results, the parameters vary depending on the sample period.[4] Figs. 5 and 6 exhibit the trends of β (Fig. 5), expressing the intervention effect, and ϕ (Fig. 6), the coefficient expressing exchange-rate rebounds when the sample period of estimation equation (9), that is,

$$\Delta s_t = \alpha + \beta x_t + \phi x_{t-1} + \varepsilon_t,$$

is set to 2000 business days in a rolling estimation that shifts the sample periods by one each. The estimation used the ordinary least-squares method. The upper and lower dotted lines represent standard errors of ±2. The time on the horizontal axis denotes the start of each sample period, which is shifted by one day each in the estimation. For instance, the date April 1, 1991 on the horizontal axis represents the sample period for 2000 business days from April 1, 1991 to December 4, 1998. The following day April 2, 1991, represents the 2000-business-day period from April 2, 1991 to December 7, 1998. The trends in the estimated values are indicated in the graphs. The reason for the selection of 2000 business days as the sample periods is that the longest period in which no intervention took place in the past was 1695 business days (between March 17, 2003, and September 14, 2010). The period of 2000 business days (approximately eight years) has therefore been selected because there would be times when the effect of intervention could not be estimated if the estimation were based on 1000-business-day periods.

Fig. 5 reveals the effect of intervention that varies depending on the timing. Whereas the interventions in the first half of the 1990s were able to move the exchange rate sharply, the impact decreased in the 2000s. In all 2000-business-day

2 See Ref. [4] for a description of the EGARCH model.

3 See Ref. [5].

4 Hoshikawa [6] pointed out that the effect of foreign exchange intervention varies depending on the timing of intervention.

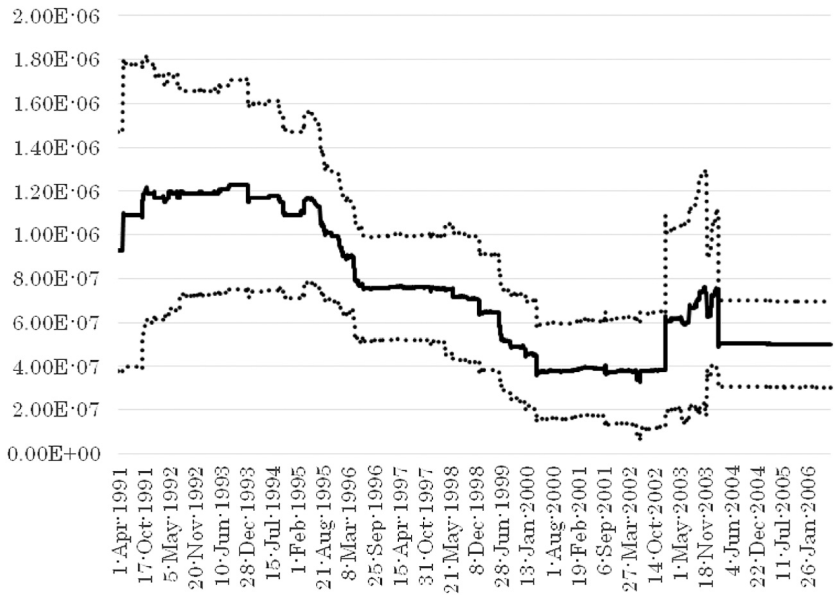

Fig. 5. Effect of intervention through rolling estimation. Note: Dates show the starts of respective sample periods. One sample period is 2000 business days.

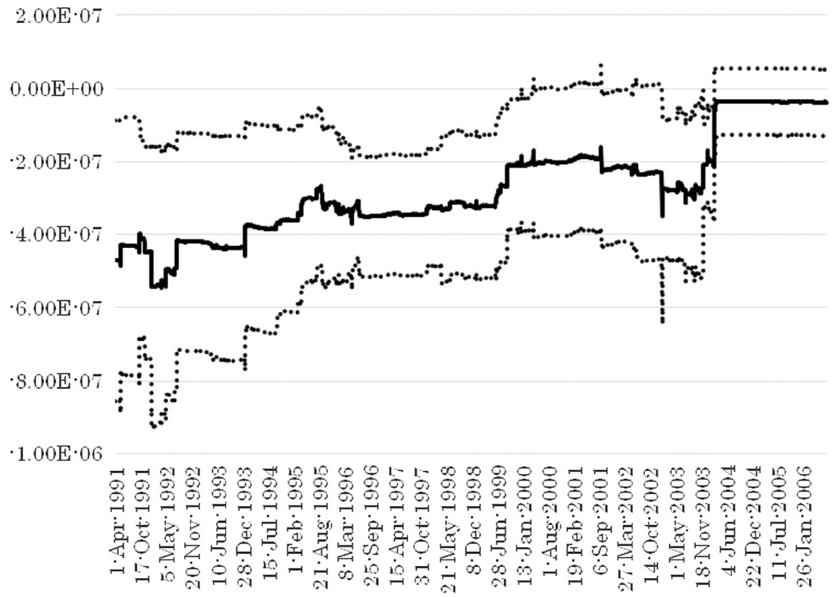

Fig. 6. Effects of rebounds based on rolling estimation.

periods, however, the yen-selling/dollar-purchasing intervention had a positively significant effect to move the exchange rate in the direction of a weaker yen. Fig. 6 presents the trend of ϕ, the coefficient expressing the exchange-rate rebounds in the rolling estimation that shifts the sample period by one day each using estimation equation (9). In the 1990s, when the effects of foreign exchange intervention were large, rebounds also tended to have a large impact. Since the 2000s, during which the effect of intervention decreased, the band of standard errors, or the dotted lines, between -2 and $+2$ crossed zero, which is not considered significantly different from zero, suggesting that the impact of rebounds increases when the effect of intervention is large. Conversely, rebounds have less effect when intervention is less effective.

The following estimates the virtual exchange rate assuming that no foreign exchange intervention took place in Japan since 1991 when the effect of rebounds is non-existent. Using the estimated $\hat{\beta} = 0.000000556$ in OLS of Table 1 and the

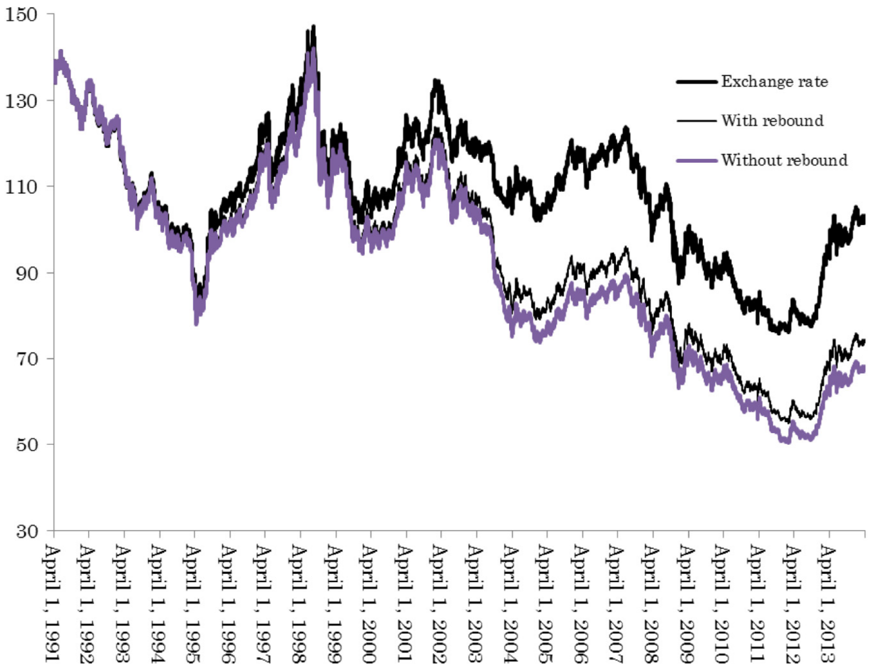

Fig. 7. Yen–Dollar rates excluding exchange rate rebounds and intervention shocks. Note: Horizontal axis shows dates.

total amount of intervention accumulated between April 1, 1991 and March 31, 2014, which is

$$\sum_{t=1}^{T} x_t = 746911. \tag{15}$$

The logarithm $\tilde{s}$ of the virtual exchange rate assuming no intervention taking place is derived from Eq. (7). Therefore, the level of the virtual exchange rate $\tilde{S}_T = \exp\left(\tilde{s}_T\right)$ is the following.

$$\tilde{S}_T = \exp\left(s_T - \hat{\beta}\sum_{t=1}^{T} x_t\right) = \exp\left(\ln(103.19) - 0.000000556 \times 746911\right) = 68.12. \tag{16}$$

The actual exchange rate on March 31, 2014 was 103.19 yen per US dollar. The virtually estimated exchange rate without the intervention since 1991 was 68.12 yen per US dollar.

If a rebound affects the exchange rate, then the modified virtual exchange rate $\tilde{S}_T^m = \exp\left(\tilde{s}_T^m\right)$ is 74.40 yen per US dollar. The estimated $\hat{\beta} = 0.000000569$, $\hat{\phi} = -0.000000131$, and the accumulated amount of intervention are substituted for Eq. (12).

$$\begin{aligned}\tilde{S}_T^m &= \exp\left(s_T - \hat{\beta}\sum_{t=1}^{T} x_t - \hat{\phi}\sum_{t=1}^{T} x_{t-1}\right)\\ &= \exp\left(\ln(103.19) - 0.000000569 \times 746911 + 0.000000131 \times 746911\right) = 74.398.\end{aligned} \tag{17}$$

Fig. 7 shows the yen/dollar rate and virtual rates $\tilde{S}_T$ and $\tilde{S}_T^m$.

Using estimation results from the EGARCH model, the virtual exchange rate $\tilde{S}_T^m$ with rebounds becomes 77.47 yen to the US dollar, which implies that, in comparison to 103.19 yen to the US dollar at the end of March 2014, the exchange rate would be 74.40–77.47 yen to the US dollar without the yen-selling/dollar-purchasing intervention of the Japanese government amounting to 74,691,100 million yen since 1991. The accumulated total of intervention of Eq. (15) indicates an important part of an increase in foreign exchange reserves, which therefore suggests how much of an effect the sale of the foreign exchange reserves added through the intervention can be expected to have on the exchange rate.[5]

In addition, Fig. 8 shows the virtual exchange rate based on the rolling estimation. The exchange rate at time T is expressed as following equation.

$$s_T = s_0 + \sum_{t=1}^{T} \beta_t x_t + \sum_{t=1}^{T} \phi_t x_{t-1} + \sum_{t=1}^{T} \varepsilon_t. \tag{18}$$

5 Dominguez et al. [7] examine the implications of reserve sales.

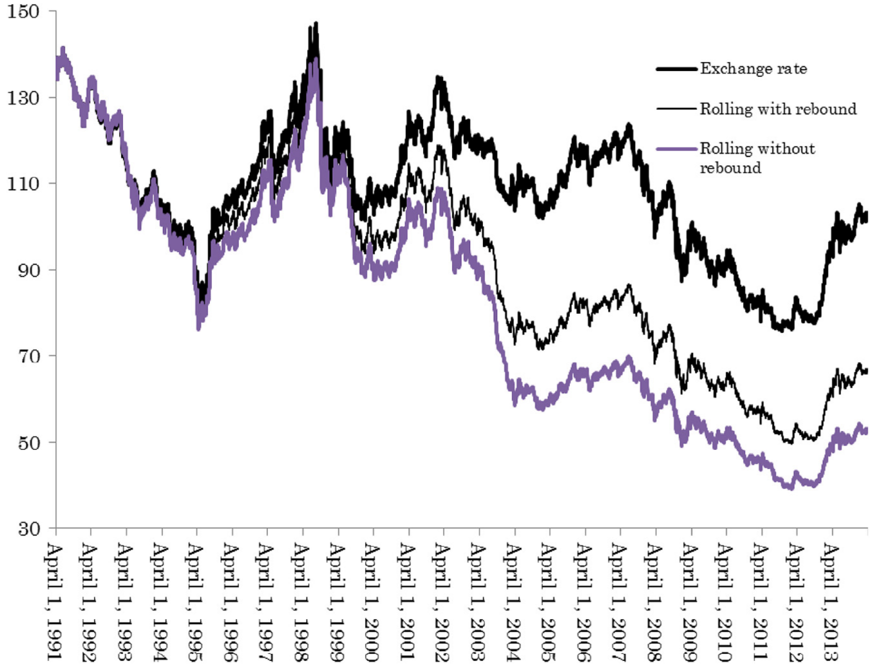

Fig. 8. Yen–Dollar rates excluding rebounds and interventions based on rolling estimation. Note: Horizontal axis shows dates. Parameters are based on Figs. 5 and 6.

The time varying parameters β_t and ϕ_t are shown in Figs. 5 and 6. The virtual exchange rate based on the rolling estimation is calculated from following equation.

$$\tilde{s}_{T^R} \equiv s_T - \sum_{t=1}^{T} \beta_t x_t - \sum_{t=1}^{T} \phi_t x_{t-1}. \tag{19}$$

Using results from the rolling estimation, the virtual exchange rate with rebound is 67.12 yen to the US dollar, and the virtual exchange rate without rebound is 53.15 yen to the US dollar.[6] It indicates that it is important to consider the rebound effect.

4. Conclusion

This study examined the rebounds in the exchange rate after foreign exchange intervention. When intervention is strongly effective, the exchange rate rebounds at next day. The effect of intervention is reduced slightly by the rebound after the intervention. The exchange rate might have been 67.12–77.47 yen to a US dollar without yen-selling/dollar-purchasing intervention of 74,691,100 million yen implemented by the Japanese government since 1991 (the actual exchange rate was 103.19 yen to the US dollar). Such results present important implications for considering the relation between the exchange rate and rapidly increasing foreign exchange reserves in East Asia.

Although this study has suggested the potential level of the exchange rate with the effect of rebounds and without the intervention, note should be taken of the fact that several unrealistic assumptions were made in the process. Future studies must address problems of endogeneity: foreign exchange intervention is implemented while observing the exchange rates and market participants engagement in transactions, considering whether intervention is taking place; the exchange rate and intervention are thereby determined endogenously.

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[6] Parameters are same value in the first 2000 business days. The virtual exchange rate with rebound is calculated as $\phi_t = 0$ when ϕ_t is not significant.