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Foreign Exchange Intervention When Interest Rates Are Zero: Does the Portfolio Balance Channel Matter After All?

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Foreign Exchange Intervention When Interest Rates Are Zero: Does the Portfolio Balance Channel Matter After All?

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Abstract: The Japanese zero-interest rate period provides a "natural experiment" for investigating the effectiveness and transmission channels of sterilized intervention when traditional monetary policy options are constrained. This paper takes advantage of the fact that all interventions in the JPY/USD market during the zero-interest rate period are sterilized sales of JPY and, therefore, none of these interventions can signal a future interest rate decrease. In order to further assess through which transmission channel these interventions work, the analysis integrates official daily Japanese intervention data with a comprehensive set of rumors data that capture interventions of which the market is aware. Market awareness is a necessary condition for intervention to disseminate information and work through channels other than the portfolio balance channel. The results of the time series analysis show that intervention, on average, induces a statistically and economically significant same-day depreciation of the JPY. Market awareness is shown to be unimportant. Consequently, the effects of Japanese interventions during the zero-interest rate period are consistent only with the portfolio balance channel. This is a remarkable finding, demonstrating that sterilized intervention is, in principle, an independent policy instrument.

Key words: Exchange Rates; Foreign Exchange Market Intervention; Channels of Transmission.

JEL Classifications: E52, F31, G14.

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1. Introduction

No previous study has taken advantage of the "natural experiment" provided by the Japanese zero-interest rate period to analyze the exchange rate effects of intervention when intervention is disconnected from traditional monetary policy moves.[1] The contribution of this paper is to assess whether sterilized intervention is effective when interest rates are zero and intervention cannot signal future monetary policy changes, and to determine through which channel of transmission intervention during this particular macroeconomic environment works.[2]

The Japanese zero-interest rate period began in January 1999 when money market rates effectively hit the lower bound (see Figure 1). At the outset of this period, the Japanese monetary authorities, i.e. the Bank of Japan acting as the agent for the Japanese Ministry of Finance, entered an intervention regime of unprecedented proportions, selling an astonishing total of USD 0.5 trillion worth of JPY against purchases of USD, roughly equivalent to 10% of Japan's yearly GDP, over a period of little more than five years. With Japanese interest rates remaining at the lower bound throughout this prolonged period of frequent and often large-scale interventions, and all interventions in the JPY/USD market carried out as unilateral sales of JPY by the Japanese monetary authorities, it is not possible for the interventions to send a signal of a future decrease in interest rates, thus effectiveness of intervention through the signaling transmission channel of future monetary policy is ruled out a-priori.[3] The Japanese zero-interest rate period,

[1] See, for example, Ito (2003) for a study of Japanese intervention during the 1991 to 2001 period, and Fatum and Hutchison (2005) and Ito (2005) for studies focusing on the 2003 to 2004 period. Humpage (2003), Neely (2005), Sarno and Taylor (2001) and others provide surveys of the intervention literature.

[2] Few studies investigate the transmission channels of intervention. Exceptions include empirical studies by Dominguez and Frankel (1993a), Fatum and Hutchison (1999), and Lewis (1995). Kumhof (2010) provides a theoretical model of the portfolio balance channel effects of intervention.

[3] Moreover, as discussed in Ito (2005), the Japanese institutional framework for intervention, where government bonds with 3-month maturity (so-called Fiscal Bills) are issued first in order to obtain the JPY necessary for carrying out interventions, guarantees that all interventions are sterilized, i.e. there is no institutional link between Japanese interventions and the monetary base. Furthermore, Fatum and Hutchison (2005) show that the Japanese

therefore, provides a "natural experiment" for investigating the effectiveness of sterilized intervention when traditional monetary policy options are constrained and, as a consequence, the signaling channel of intervention, often viewed as a particularly important transmission channel, is not functioning.

The traditional view of the intervention literature is that if intervention works, intervention is effective through signaling (by carrying out intervention the central bank informs the market about its future monetary policy intentions) or through portfolio balance effects (by carrying out intervention the central bank changes the relative demand and supply of imperfectly substitutable foreign and domestic assets). More recently, an additional transmission channel, deemed the coordination channel, has been proposed (by carrying out publicly announced intervention when individual market participants are hesitant to risk betting on a reversal of the exchange rate towards its equilibrium because of substantial exchange rate misalignment and coordination failure the central bank takes on a coordinating role that organizes "smart money" to enter the market at the same time, thereby causing the exchange rate to reverse).[4]

A necessary condition for intervention to disseminate information and be effective through channels such as the signaling or the coordination channel, is that the market is aware of intervention being carried out (otherwise a signal about future monetary policy intentions or current exchange rate misalignments will go unnoticed, in which case it is not possible for these channels to function).[5] By contrast, the portfolio balance channel does not require market awareness for intervention to work. Instead, this channel can only work if intervention is actually

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interventions are not significantly linked to changes in the monetary base, i.e. the sterilized interventions of the zero-interest rate period are not connected to the coinciding path of quantitative monetary easing.

[4] See Edison (1993) for a thorough exposition of the signaling and the portfolio balance channels, and Sarno and Taylor (2001) for details regarding the coordination channel and a discussion of the relative importance of the transmission channels of intervention.

[5] While Sarno and Taylor (2001) suggest that intervention must be publicly announced in order for the coordination channel to function, market awareness based on rumors of intervention might be sufficient.

carried out (otherwise the relative demand and supply of foreign and domestic assets do not change), and the larger the intervention volume the larger the portfolio balance effects.

To address the possibility that market awareness of intervention matters, the analysis integrates the official Japanese intervention data with a comprehensive set of newswire reports capturing days on which there is a rumor of intervention – distinguishing between rumors of intervention on days when intervention occur and rumors of intervention on days when no intervention occur - as well as days with official statements pertaining to intervention and the exchange rate. This is important, not only because other studies have found that "oral intervention" can influence the exchange rate (see Fratzcher 2008 and others), but because if market awareness matters, effectiveness of intervention cannot be explained by portfolio balance effects alone.

The existing literature combining intervention data with newswire reports of intervention generally uses newswire reports of intervention to indicate whether the market is aware of an intervention or whether an intervention is carried out in secrecy.[6] However, a report of intervention is typically on the newswire the day after the intervention the report refers to is carried out. For example, a firm report of the 12 January 1999 official Japanese intervention operation is reported on the newswire on 13 January 1999. Therefore, whether or not an intervention is reported is generally a matter of "after-the-fact" information that can play no role in the contemporaneous exchange rate response to intervention. By contrast, rumors and speculation of intervention are generally picked up by the newswire the same day they occur. Accordingly, the analysis of this paper uses rumors or speculation of intervention rather than reports of intervention to indicate market awareness as well as market perception of intervention.

[6] See Dominguez and Frankel (1993a and 1993b, chapter 7) for influential studies that use news reports of intervention to classify whether an intervention is secret or reported.

The analysis of the paper employs GARCH time series models for the baseline analysis, includes macro surprises in the estimations, tests for delayed effects, controls for endogeneity, and carries out a variety of robustness checks. In addition, the analysis pays careful attention to the possibility that institutional changes are associated with parameter instability and, as a result, carries out the analysis on the full zero-interest rate intervention period as well as separately on well-defined sub-samples. The results show that intervention, on average, exerts a significant same-day influence on the JPY/USD exchange rate during the zero-interest rate period. Regardless of whether or not the market is aware of intervention. The paper rejects the hypothesis of a systematic and significant link between days when there is a rumor of intervention but no intervention occurs, and the JPY/USD exchange rate. Similarly, the paper shows that official statements are insignificant and do not influence the exchange rate.

With market awareness shown not to be important and constrained monetary policy preventing the signaling channel from functioning, the effects of Japanese interventions during the zero-interest rate period are consistent only with the workings of the portfolio balance channel. This is a remarkable finding, demonstrating that the portfolio balance channel matters more than most studies seem to suggest and, therefore, that sterilized intervention is, in principle, an independent policy instrument.

The rest of the paper is organized as follows. Section 2 details the data. Section 3 presents the empirical analysis. Section 4 discusses the empirical results, model extensions, and robustness checks. Section 5 assesses the economic importance of the Japanese intervention policy. Section 6 concludes.

2. Data

The official Japanese intervention data consists of daily volumes of intervention operations in the JPY/USD foreign exchange market. During the zero-interest rate intervention period under study, 1 January 1999 to 31 March 2004, all official interventions in the JPY/USD market are sales of JPY against purchases of USD.[7]

Table 1 shows intervention data summary statistics. The table shows that Japan intervenes in the JPY/USD exchange rate market on a total of 159 days over the full sample period. Only 30 of the intervention days occur between 1 January 1999 and 13 January 2003, 78 intervention days occur between 14 January 2003 and 25 December 2003, while 51 intervention days occur between 26 December 2003 and 31 March 2004.

The cumulated intervention amount across the entire zero-interest rate period is nearly USD 0.5 trillion. The average daily amount of intervention ranges from nearly USD 5 billion during the 1 January 1999 to 13 January 2003 period to USD 2.2 billion during the 14 January 2003 to 25 December 2003 period. The average daily intervention amount relative to average daily market turnover is 1.3% across the full sample period, and ranges from roughly 2% during the first sub-period to roughly 1% during the second and third sub-periods.

The Factiva search engine and a comprehensive combination of various search words (e.g. Bank of Japan, intervention etc.) are used to find the days with a rumor of intervention. The second row of Table 2 shows that a total of 269 days across the full sample are associated with a rumor of intervention. Row three of Table 2 reports that 92 of the rumor days are also intervention days, i.e. 92 of the 269 rumors are "true". Row four shows that, accordingly, the remaining 67 of the 159 intervention days in the full sample do not coincide with a rumor of

[7] The U.S. government did not intervene in the JPY/USD exchange rate market during the zero-interest rate period.

intervention. For the full sample, as many as 177 rumor days are, in fact, "false". The number of days associated with false rumors is reported in row five. [8]

Factiva is also used to find newswire reports of official statements in support of intervention and/or a weaker JPY ("positive statements"), and newswire reports of official statements suggesting that further intervention in the JPY/USD rate is not recommended or unlikely ("negative statements"). Rows six and seven of Table 2, respectively, report a total of 108 positive and 17 negative statements for the full sample period.[9]

The analysis follows Ito (2003) and others in using New York close quotes of the daily JPY/USD exchange rate. The exchange rate data are obtained from Global Financial Data (GFD).

A comprehensive list of macro news control variables capture the surprise component of Japanese news regarding CPI, GDP, Industrial Production, Trade Balance, Unemployment and the surprise component of US news regarding CPI, GDP, Industrial Production, Trade Balance, (Non-Farm Payroll) Employment, and Monetary Policy. For each of these macro news control variables, the surprise measure is the difference between official announcements and results of surveys of expectations of these announcements conducted by Bloomberg during the days preceding the announcements. The official value of a news variable is announced once a month, or at a lower frequency. The news control variables capture the associated surprise element on announcement dates, thus these variables are non-zero only on announcement dates and only when the announcement differs from market expectations.

[8] It is not surprising to find a large number of false rumors of intervention. For example, Chang (2006) reports a total of 282 JiJi News (local Japanese newswire) and Wall Street Journal reports of rumors and speculation of Japanese intervention over the January 2000 to March 2003 time period when only 101 actual interventions occur. Other studies also question the accuracy of newswire reports of intervention (see Fischer 2006 and others).

[9] For completeness, Factiva is also gleaned for "firm" reports of intervention. Row eight of Table 2 shows that for the full sample, a total of 31 firm reports of intervention are found. This seems broadly consistent with Chang (2006) who finds 27 "firm" reports of intervention in the Wall Street Journal between January 2000 and March 2003.

Summary statistics for the JPY/USD exchange rate and the macro news surprises are displayed in Table 3.

3. Empirical Analysis

The empirical analysis follows Baillie and Bollerslev (1989) in estimating a regression equation with residuals modeled as a GARCH process. The basic empirical relationship of the analysis is given by the GARCH(p,q) specification:

$$(1) \quad \Delta s_t = a + b_1 \Delta s_{t-1} + b_2 INT_t + b_3 INT_t^{RUMOR} + b_4 INT^{JAN03} + b_5 INT^{DEC03} + b_6 RUMOR_t^{NoINT} + b_7 POSSTAT_t + b_8 NEGSTAT_t + CZ_t + \varepsilon_t$$

$$(2) \quad \varepsilon_t \sim N(0, h_t)$$

$$(3) \quad h_t = \alpha_0 + \sum_{j=1}^{q} \alpha_j \varepsilon^2{}_{t-j} + \sum_{j=1}^{p} \beta_j h_{t-j}$$

where a is a constant; Δs_t is the first-difference in the log of the spot JPY/USD exchange rate; INT is official intervention (millions of USD); INT^{RUMOR} is an interaction variable ("slope shifter") containing intervention (millions of USD) on days when there is a rumor of intervention (i.e. INT^{RUMOR} contains actual interventions of which the market is aware); INT^{JAN03} is an interaction variable containing interventions (millions of USD) carried out between 14 January 2003 and 25 December 2003; INT^{DEC03} is an interaction variable containing interventions (millions of USD) carried out between 26 December 2003 and 31 March 2004; $RUMOR^{NoINT}$ is an indicator variable that takes on the value one when a rumor of intervention is reported but no actual intervention takes place, and zero otherwise (i.e. $RUMOR^{NoINT}$ captures the days where

the market suspects an intervention taking place but no actual intervention occurs); POSSTAT is an indicator variable that takes on the value one on a day when there is an official statement in support of intervention and/or a weaker JPY, and zero otherwise; NEGSTAT is an indicator variable that takes on the value one on a day when there is an official statement suggesting that further intervention in the JPY/USD rate is not recommended or unlikely, and zero otherwise; C is the coefficient vector associated with the control variables contained in Z_t. The control variable matrix Z_t contains the unexpected component of Japanese news regarding CPI (JPCPI), GDP (JPGDP), Industrial Production (JPIP), Trade Balance (JPTB), Unemployment (JPUNEMP), and the surprise component of US news regarding CPI (USCPI), GDP (USGDP), Industrial Production (USIP), Trade Balance (USTB), Employment (USNFPR), and Monetary Policy (USFOMC).[10]

Equation (2) states that the error term is normally distributed with zero mean and time-dependant (conditional) variance h_t. Equation (3) shows that the variance depends on the squared error of the past q periods (the ARCH terms) and the conditional variance of the past p periods.

The estimation strategy is as follows. First, simultaneous estimations of equations (1) through (3) are carried out across the full sample. Next, insignificant variables are dropped one variable at a time, starting with the most insignificant variable, and the full sample model re-estimated until only significant variables remain. This procedure is repeated separately across

[10] Ito (2003 and 2005) suggests that a new intervention policy regime began on 14 January 2003 when Mr. Mizoguchi replaced Mr. Kuroda as Vice Minister for International Affairs at the Japanese Ministry of Finance whereas Mr. Kuroda's replacement of Mr. Sakikabara in July 1999 did not mark a change in policy. The inclusion of the interactive dummy INT^{JAN03} tests whether this regime change affects the effectiveness of intervention. Moreover, towards the end of 2003, the intervention frequency increased noticeably to intervention occurring every week. This increase in frequency continued until interventions seized in March 2004. Inclusion of the interactive dummy INT^{DEC04} formally tests whether this change in intervention frequency further affects the effectiveness of intervention.

sub-samples. For each of the estimations, the most parsimonious GARCH specification possible, that still allows for acceptance of the null hypothesis of no ARCH in the standardized residuals, is selected. As it turns out, GARCH(1,1) models give the better fit in all cases.

4. Results

Table 4 shows the GARCH(1,1) baseline estimations across the full sample. The first column displays the results pertaining to the model with all variables included. The basic intervention variable INT is highly significant (at 99%) and of the correct (positive) sign, thus the (alternative) hypothesis that intervention sales of JPY during the zero-interest rate period are, on average, effective and systematically associated with JPY depreciation is accepted. By contrast, the INT^{RUMOR} slope shifter variable is highly insignificant, thereby rejecting the hypothesis that intervention of which the market is aware (i.e. intervention that coincides with a rumor of intervention) influences the exchange rate differently. Similarly, the $RUMOR^{NoINT}$ indicator variable is highly insignificant, thus rejecting the hypothesis that a rumor of intervention is in itself sufficient to elicit a detectable exchange rate movement.

Both the sub-sample slope shifter variables, INT^{JAN03} and INT^{DEC03}, are significant, at 95% and 99%, respectively. Both are negative, thereby implying that the average effect of intervention is markedly smaller from 14 January 2003 and onwards and, furthermore, that the average effect of intervention is even smaller towards the very end of the sample. The highly insignificant POSSTAT and NEGSTAT variables show that official statements ("oral intervention") do not impact the exchange rate during this particular macroeconomic environment. Finally, some significant effects of Japanese macro surprises are detected, while none of the US macro surprise variables are significant.

The second column of Table 4 shows the estimation results of the full sample baseline model with only significant variables included. The coefficient estimates of the significant explanatory variables are practically the same (pair-wise) across the two models, and the previously described results are repeated.

The conditional variance equation estimates confirm the presence of ARCH effects in the exchange rate time series. The ARCH-F and Q^2 tests indicate that both full sample models are free of any ARCH effects left in the standardized residuals. Moreover, the standard F-test cannot reject the models.[11]

Since the interaction variable INT^{JAN03} clearly belongs in the full sample specification, the rest of the analysis of the paper is carried out separately across two sub-samples, the 1 January 1999 to 13 January 2003 sample ("the Sakikabara/Kuroda intervention period") and the 14 January 2003 to 31 March 2004 sample ("the Mizoguchi intervention period").[12]

The results of the baseline estimations carried out separately on the two sub-samples are displayed in Table 5. The first column of Table 5 shows the results of the baseline estimations on the 1 January 1999 to 13 January 2003 sample, and the second column shows the 14 January 2003 to 31 March 2004 results. For both sub-samples, the intervention variable INT is, once again, highly significant (at 99%) and of the correct sign.[13] Moreover, the slope shifter variable INT^{04} included in the second sub-sample is significant (at 95%) and negative, thereby confirming the full sample finding that intervention is significantly less effective during the latter part of the Mizoguchi intervention period. Consistent with the full sample findings, neither INT^{RUMOR} nor

[11] This also holds true for the estimations reported in Tables 5 through 7.
[12] The time-period associated with the INT^{DEC03} slope shifter variable is too short to facilitate a separate meaningful estimation. Instead, INT^{DEC03} is also included in the 14 January 2003 to 31 March 2004 sub-sample estimations.
[13] Interestingly, the coefficient estimate associated with INT during the Sakikabara/Kuroda period is about twice as large as during the Mizoguchi intervention period. Furthermore, a standard Wald test strongly rejects equality of the two coefficient estimates. Ito (2005) conjectures that interventions during the Mitzoguchi period are less effective due to increased uncertainty among financial market participants in regards to when interventions are carried out and what the interventions are meant to achieve.

$RUMOR^{NoInt}$ are significant, and none of the statement variables is significant. This is the case for both sub-samples.

To summarize the findings of the baseline estimations, intervention during the zero-interest rate period is, on average, effective in influencing the level of the exchange rate. The average effect of interventions carried out during the Sakikabara/Kuroda period is significantly stronger than the average effect of interventions carried out during the subsequent Mitzoguchi intervention period. Whether or not there is a coincident rumor of intervention, i.e. whether or not the market is aware of the intervention operation, is unimportant and does not help explain the associated exchange rate movement. A related finding is that neither a statement regarding exchange rate or intervention policy nor rumors of intervention on days with no intervention play a significant role in explaining day-to-day exchange rate movements.

Overall, the findings clearly show that intervention carried out during the zero-interest rate period is effective and, by elimination of other possible transmission channels, that intervention works through the portfolio-balance channel. This is a remarkable finding, considering that portfolio effects are oftentimes viewed as small and unimportant. However, while the importance of the portfolio balance channel might reasonably be dismissed in the context of small intervention volumes relative to large daily market turnover, the Japanese interventions during the zero-interest rate regime are anything but small. Instead, the average daily intervention amount during the Sakikabara/Kuroda zero-interest rate period accounts for more than 2% of the average total daily market turnover, and roughly 1% during the Mitzoguchi intervention period (details provided in Table 1). In other words, the Japanese interventions under study are, on average, of such a magnitude that it would seem surprising not to find evidence of detectable portfolio balance effects.

4.1 Delayed Effects

Exchange rate markets are generally perceived to be highly efficient and characterized by same-day processing of news, but in the context of unannounced interventions that often occur with the market seemingly unaware, it is necessary to test for delayed effects to ensure that the contemporaneous coefficient estimates fully capture the exchange rate effects.

In order to account for the possibility of delayed exchange rate effects, Equation (1) of the baseline model is augmented to include five lags of the explanatory intervention and statement variables:

$$\Delta s_t = a + \sum_{i=0}^{5} b_{2,i} INT_{t-i} + \sum_{i=0}^{5} b_{3,i} INT^{RUMOR}_{t-i} + \sum_{i=0}^{5} b_{5,i} INT^{DEC03}_{t-i} + \sum_{i=0}^{5} b_{6,i} RUMOR^{NoINT}_{t-i} + \sum_{i=0}^{5} b_{7,i} POSSTAT_{t-i} + \sum_{i=0}^{5} b_{8,i} NEGSTAT_{t-i} + CZ_t + \varepsilon_t \quad (4)$$

Table 6 shows the results of simultaneous estimations of Equations (2) through (4), carried out separately across the two sub-samples. As the table shows, none of the lags of INT is significant. As before, the coefficient estimates associated with the contemporaneous effects of intervention are highly significant (at 99%) as well as of the same sign and virtually the same magnitude as in the baseline estimations. Moreover, all lags of the slope shifter variables and the indicator variables are insignificant.[14] The complete absence of delayed effects implies that the estimated contemporaneous exchange rate effect of intervention fully describes how the exchange rate responds to intervention.

[14] For ease of exposition, only lags of the intervention variable are reported. The unreported results are available upon request.

4.2 Endogeneity

To control for endogeneity, the analysis of this section follows the daily data studies by Humpage (1999) and Namalendran and Naranjo (2000) in first estimating Japanese intervention reaction functions in order to capture the expected component of the intervention variable and, subsequently, use the residuals from the reaction function estimation as a measure of unexpected interventions (i.e. the expected component of intervention is subtracted from the actual intervention on days when interventions occur). Doing so produces more precise estimates of the influence of interventions on the JPY/USD exchange rate that are less affected by simultaneity bias.

Following Ito (2003) and Ito and Yabu (2007), the reaction functions are specified as:

$$(5) \qquad INT_t = \beta_0 + \beta_1 \Delta s_{t-1} + \beta_2 TARGET_{t-1} + \beta_3 MADAY_{t-1} + \beta_4 MAYEAR_{t-1} + \beta_6 INT_{t-1} + \varepsilon_t$$

where TARGET is the first-difference of the log of the JPY/USD deviation from an exchange rate target of 125 JPY/USD, MADAY is the 21-day moving average of the log of the JPY/USD exchange rate, and MAYEAR is the one-year moving average of the log of the JPY/USD exchange rate.[15] The reaction function estimations are carried out separately across the 1 January 1999 to 13 January 2003 period (the Sakikabara/Kuroda zero-interest rate period) and the 14 January 2003 to 25 December 2003 period (the first year of the Mitzoguchi period),

[15] The variable TARGET is included (and significant) in the reaction function estimations displayed in Ito (2003), but not included in Ito and Yabu (2007). Inclusion of TARGET is possibly problematic due to a high degree of collinearity with the JPY/USD exchange rate. As it turns out, TARGET is insignificant in all the estimations and, therefore, subsequently excluded from the analysis. The reaction function estimation results are not shown for brevity but available upon request.

respectively.[16] It should be noted that while the reaction function estimates are free of simultaneity bias due to the exclusion of contemporaneous exchange rate changes as explanatory variables, the cost of avoiding endogeneity is that there is no account for the possibility of within-day exchange rate movements triggering and/or determining the size of some interventions. In other words, the estimated reaction function parameters possibly suffer from omitted variable bias instead of endogeneity.

The results of the re-estimation of the model described in Equations (1) through (3) using unexpected intervention in place of actual intervention are shown in Table 7. While these results are qualitatively identical to those pertaining to the baseline analysis without controlling for endogeneity, it is interesting to notice that the coefficient estimate associated with intervention during the Sakikabara/Kuroda period (first column of Table 7) has increased by almost 20% (1.42E06 versus 1.21E06, the latter estimate displayed in the first column of Table 5), consistent with the idea that not controlling for endogeneity leads to a downward simultaneity bias in the estimated effect of intervention.[17]

4.3 Robustness

In order to check the robustness of the results, the analysis is also carried out using a different estimation technique, a different conditional mean specification, different sub-sample demarcation points, and the intervention reaction functions used to isolate the unexpected element of intervention are re-estimated using contemporaneous macro surprises as additional

[16] The increased intervention frequency between 26 December 2003 and 31 March 2004 implies a change in intervention policy and thus a separate intervention regime. Since this sub-period is too short for a meaningful separate reaction function estimation, it is simply excluded from the reaction function estimations and from the associated re-estimation of the baseline model using unexpected intervention in place of actual intervention.

[17] Since the 26 December 2003 to 31 March 2004 sub-period is excluded from the estimations that control for endogeneity, the estimations displayed in the second column of Table 7 refer to a different sub-sample than those displayed in the second column of Table 5. Therefore, a similar comparison of coefficient estimates associated with the Mitzoguchi intervention period is not applicable.

explanatory variables. The robustness results are not reported for brevity but available from the author upon request.

First, all estimations are carried out using OLS estimation techniques with robust heteroskedasticity- and serial-correlation consistent (HAC) standard errors instead of GARCH. All the previously described baseline results reported in Tables 4 and 5 regarding the intervention and the statement variables are completely unchanged across both the full sample and the two sub-samples. In addition, the augmented delayed effects model as well as the models addressing endogeneity are re-estimated using OLS and HAC standard errors, yielding identical results to those reported in Tables 6 and 7.

Second, the interventions are separated into two separate variables containing intervention (in millions of USD) on days when there is a rumor of intervention, and intervention (in millions of USD) on days when there is no rumor of intervention, respectively. INT is dropped from the conditional mean model (Equation 1) and, instead, a new variable, $INT^{NoRUMOR}$, containing intervention (in millions of USD) on days when there is no rumor of intervention (i.e. $INT^{NoRUMOR}$ contains actual interventions of which the market is unaware) is included alongside the variable INT^{RUMOR} (thus the sum of $INT^{NoRUMOR}$ and INT^{RUMOR} equals INT). The baseline model is re-estimated, and both $INT^{NoRUMOR}$ and INT^{RUMOR} are highly significant and of the correct (positive) sign. Moreover, a standard coefficient test (Wald test) cannot reject equality of the coefficient estimates associated with $INT^{NoRUMOR}$ and INT^{RUMOR}, thereby confirming the baseline finding that while intervention is, on average, effective during the zero-interest rate period under study, rumors, or market awareness, of intervention is unimportant.

Third, the first six months of the sample, encompassing the last 6 months of Mr. Sakakibara's tenure as Vice Minister for International Affairs at the Japanese Ministry of Finance, are dropped from the analysis. The baseline model is re-estimated across the adjusted full sample period (1 July 1999 to 31 March 2004) and across the adjusted first sub-sample period (1 July 1999 to 13 January 2003, i.e. "the Kuroda period"). Not surprisingly, given that only four interventions occur between 1 January 1999 and 30 June 1999, the previously described results are repeated.[18]

Fourth, the intervention reaction function models are extended to include Japanese macro surprises that could influence the decision to intervene. As noted earlier, previous studies have documented that macro surprises influence day-to-day exchange rate changes. These surprises, therefore, can be interpreted as proxies for contemporaneous movements in the exchange rate.[19] As it turns out, (positive) GDP surprises and (positive) CPI surprises help explain intervention, and inclusion of these significant macro surprise variables improve the fit of the reaction function models slightly. Re-estimation of the baseline models using unexpected intervention derived from the news augmented reaction function models leads to qualitatively identical results as those reported in Table 7.

5. Economic Effects

It is standard in the literature on foreign exchange intervention to translate coefficient estimates associated with the effects of intervention into measures of the exchange rate effect of a USD 100 million intervention operation. The second row of Table 8 shows that the estimates translate

[18] The four intervention days are 12 January 1999, 10 June 1999, 14 June 1999, and 21 June 1999.
[19] See Fatum and Hutchison (2010).

into exchange rate effects of a USD 100 million intervention ranging from a JPY depreciation of 0.014% to a JPY depreciation of 0.0015%.[20]

At a first glance, these economic effects seem negligible compared to, for example, an oft-cited point of reference, Dominguez and Frankel (1993a), who show that their estimated coefficients correspond to an exchange rate effect of 1.5% of a USD 100 million intervention. The average daily intervention amounts during the more recent zero-interest rate period are, however, dramatically different from those pertaining to the older studies of exchange rate markets and intervention, rendering a benchmark based on the economic effects of a USD 100 million intervention operation misleading.[21] A better way to get a sense of the economic importance of intervention is to measure the exchange rate effect of the average daily intervention amount. The third row of Table 8 shows that the exchange rate effect of average daily intervention ranges from an average 0.7% depreciation of the JPY during the first 4 years of the zero-interest rate regime to an average 0.11% and 0.04% depreciation during the first year and during the last three months, respectively, of the Mitzoguchi intervention period.

While these numbers certainly show that the average economic effects of intervention are not negligible, by construction they do not shed light on the total exchange rate effect of all the interventions carried out during the zero-interest rate period. The fifth row of Table 8 shows that interventions carried out during the 4-year Sakikabara/Kuroda period depreciated the JPY by roughly 20%, and the interventions carried out during the 5-quarter Mitzoguchi intervention

[20] Alternatively, the three coefficient estimates translate into an exchange rate effect associated with a JPY 1 trillion intervention ranging from 1.21% to 0.45% to 0.14%, as displayed in the third row of Table 8. These effects are quite similar to Ito (2005), who reports the effect of a JPY 1 trillion intervention across the 1995 to early 2003 period to be 2.1%, and 0.45% across the early 2003 to March 2004 period.

[21] To illustrate, the average amount of the 27 Japanese interventions carried out between 1991 to 1992 (the first two years of the now publicly available daily Japanese intervention data, a period included in the analysis of Dominguez and Frankel 1993) is roughly USD 220 million, while the average amount of the 159 Japanese interventions carried out during the 1999 to 2004 zero-interest rate period is roughly USD 3 billion (third row of Table 1), i.e. almost 15 times higher. An exchange rate effect of 1.5% per USD 100 million during the zero-interest rate period would thus imply an improbable JPY depreciation of more than 20% per average daily intervention amount.

period depreciated the JPY by more than 10%, respectively.[22] In other words, the combined economic effect of all the JPY intervention sales during the zero-interest rate period is, ceteris paribus, a very substantial JPY depreciation of roughly 30%.

A straightforward counterfactual assessment of what might have been the JPY/USD rate at the time the active Japanese intervention regime ended in March 2004 *had these interventions not occurred* suggests that the rate would have been in the mid- or high 70s (second-last row of Table 8). This would constitute a massive deviation from the actual rate in the mid-100s (last row of Table 8). The macroeconomic implications of such a strong JPY would likely have been devastating for the Japanese economy. Clearly, the economic effects of the interventions carried out during the zero-interest rate regime are of immense importance to the JPY/USD rate and the Japanese economy.[23]

6. Conclusion

During the first little more than five years of the Japanese zero-interest rate period, the Japanese monetary authorities sold an unprecedented total of USD 0.5 trillion worth of JPY in the JPY/USD foreign exchange market. The unusual combination of a prolonged macroeconomic period of constrained monetary policy and frequent as well as oftentimes large-scale interventions provides a "natural experiment" for investigating whether interventions that cannot work through the standard signaling channel of future monetary policy can still be effective in

[22] These exchange rate effect estimates are broadly consistent with Ito (2005), who calculates the combined exchange rate effect of the five quarters of intervention during the Mitzoguchi period to a JPY depreciation of 13%.

[23] In light of the substantial effects of these interventions, it is not surprising that the US and some European countries grew increasingly concerned with the active Japanese intervention policy during the zero-interest rate period. The concern culminated in a fairly critical statement issued by the G7 Finance Ministers and Central Meeting Governors Meeting in September 2003 in which the desirability of exchange rate flexibility was proponed (without any mentioning of which country or countries the statement was aimed at). See Ito (2005) for additional details. See also Taylor (2006) for an interesting discussion of the exchange rate policy of the Bush administration and why the Japanese intervention policy was met with relative acceptance.

influencing the level of the exchange rate. Since market awareness of intervention is a necessary condition for intervention to work through transmission channels other than the portfolio balance channel, the analysis also tests if market awareness plays a role in explaining the link between intervention and exchange rate movements when interest rates are at the lower bound.

Using a GARCH time series methodology for the baseline analysis, the paper shows that official intervention, whether or not the market is aware of the intervention, exerts a statistically significant same-day influence on the JPY/USD exchange rate. Considering that market awareness is shown to be unimportant and, moreover, the macroeconomic and institutional environment prevents the signaling channel from functioning, this is a remarkable finding that demonstrates that the portfolio balance channel matters after all.

The economic effects implied by the estimates of the exchange rate effects of intervention when taking into account the total intervention volumes spent by the Japanese monetary authorities during the zero-interest rate period are very substantial. During the first 4 years of the zero-interest rate period, the total of USD 0.15 trillion worth of JPY sold against USD is associated with a 20% depreciation of the JPY, and during the subsequent 5-quarters, the total of USD 0.35 trillion worth of JPY sold is associated with a JPY depreciation of more than 10%. In other words, the combined economic effect of all the Japanese interventions carried out during the zero-interest rate period add up to a JPY depreciation of roughly 30%, implying a counterfactual JPY/USD rate in the mid- or high-70s at the time the active Japanese intervention regime ended in March 2004 *had these interventions not occurred*. The macroeconomic implications of such a strong JPY would likely have been devastating for the Japanese economy, thus the economic importance of the active Japanese intervention policy during the first little more than five years of the zero-interest rate regime can hardly be understated.

Clearly, the substantial economic effects of intervention are achieved only because of the unprecedented intervention volumes involved. However, the finding that sterilized intervention significantly influences the exchange rate level and works through the portfolio channel, even when intervention is disconnected from monetary policy, shows that sterilized intervention is, in principle, an independent policy instrument.

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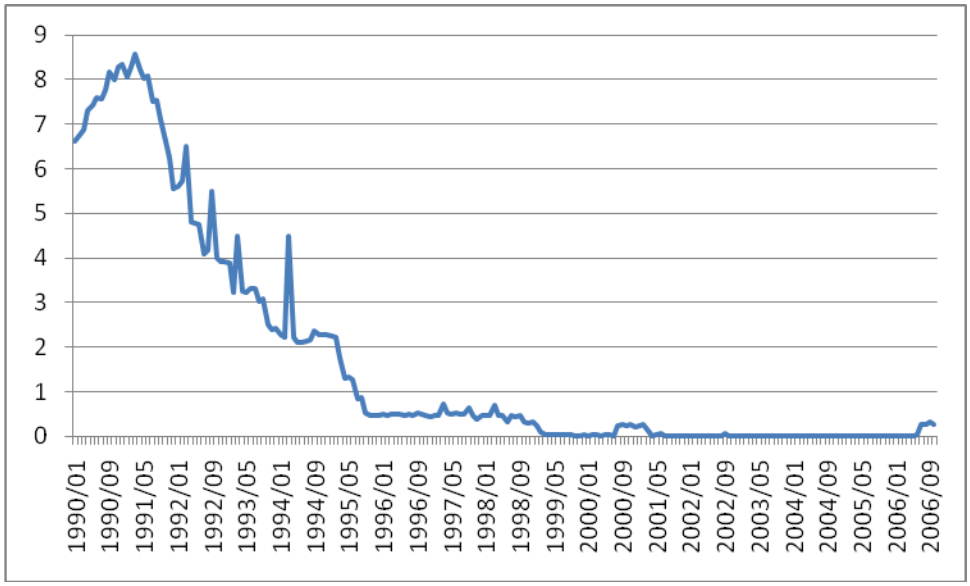
Figure 1: **Japanese Money Market Rate 1990 to 2006**



NOTES:

(a) End of month uncollateralized overnight call rate.
(b) Source: Bank of Japan.

Table 1	**Official Japanese Intervention 1999 to 2004**			
	1 January 1999 to 31 March 2004	1 January 1999 to 13 January 2003	14 January 2003 to 25 December 2003	26 December 2003 to 31 March 2004
Intervention Days	159	30	78	51
Cumulated Amount	464,251	149,428	171,886	142,937
Average Daily Amount	2,920	4,981	2,204	2,803
Standard Deviation	2,974	3,117	2,397	3,178
Average Daily Intervention Amount Relative to Average Daily Market Turnover	1.30%	2.15%	0.75%	1.07%

NOTES:

(a) Daily Bank of Japan intervention data obtained from the Japanese Ministry of Finance data bank.
(b) All Japanese interventions during the 1999 to 2004 period are sales of JPY against purchases of USD. All amounts are in millions of USD. Average Daily Amount and Standard Deviation refer to intervention days only.
(c) The April 2001 BIS statistic is used for calculating the average daily intervention amount relative to average daily market turnover for the 1 January 1993 to 13 January 2003 period while the April 2004 BIS statistic is used for the calculations pertaining to the two most recent sub-periods. A weighted average calculation is used for the full period. Average daily turnover in the JPY/USD market was USD 231 billion in April 2001 and USD 296 billion in April 2004. Source: BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity in 2001 and 2004, http://www.bis.org/publ/rpfxf02t.htm and http://www.bis.org/publ/rpfx05t.htm, Statistical Annex Tables E.2.

Table 2	**Summary Statistics: Days with Intervention, Rumors, Statements and Reports**			
	1 January 1999 to 31 March 2004	1 January 1999 to 13 January 2003	14 January 2003 to 25 December 2003	26 December 2003 to 31 March 2004
Intervention (INT)	159	30	78	51
Rumors of intervention (RUMOR)	269	136	98	35
Intervention on days with a rumor of intervention (INT^{RUMOR})	92	11	54	27
Intervention on days with no rumor of intervention ($INT^{NoRUMOR}$)	67	19	24	24
Rumor of intervention on days with no intervention ($RUMOR^{NoINT}$)	177	125	44	8
Positive statements (POSSTAT)	108	70	28	10
Negative statements (NEGSTAT)	17	17	0	0
Reports of Intervention (REP)	31	27	3	1

NOTES:

(a) INT is official intervention; RUMOR is a rumor of intervention; INT^{RUMOR} is intervention on days with a rumor of intervention; $INT^{NoRUMOR}$ is intervention on days with no rumor of intervention; $RUMOR^{NoINT}$ is a rumor of intervention when no intervention occurs; POSSTAT is an official statement in support of intervention and/or a weaker JPY; NEGSTAT is an official statement suggesting that further intervention in the JPY/USD rate is not recommended or unlikely; REP is a firm report of intervention.

TABLE 3 **Summary Statistics: The JPY/USD Exchange Rate and the Macro News Surprises**

	Mean	**Std. Dev.**	**Maximum**	**Minimum**	**Non-Zero Observations**
JPY/USD	116.3350	7.81857	134.73	101.56	1364
JP CPI	0.00394	0.001456	0.003	-0.002	33
JP GDP	0.001148	0.005362	0.018	-0.009	27
JP Industrial Production	-0.00232	0.007961	0.015	-0.017	44
JP Trade Balance	-6.6374	171.3451	367.10	-363.40	46
JP Unemployment Rate	-0.0004	0.00161	0.002	-0.004	30
US CPI	-0.00004	0.001536	0.003	-0.003	26
US GDP	0.00175	0.006151	0.0120	-0.0110	12
US Industrial Production	-0.00006	0.002936	0.0070	-0.0050	54
US Trade Balance	-0.4917	2.3448	3.1000	-5.5000	24
US Non-Farm Payroll Employment	-38.9032	101.6827	178.0000	-318.000	62
US FOMC	-0.00083	0.002887	0.0025	-0.0025	3

NOTES:

(a) All data series run from January 1, 1999 to March 31, 2004. All data are five days a week (Monday to Friday).
(b) Data Sources: The Exchange Rate Series is from Global Financial Data (New York close quotes). The Macro News Surprises are from Bloomberg (difference between actual announcement and median survey value).

TABLE 4 **JPY/USD Exchange Rate and Intervention: Baseline Estimations on Full Sample**		
GARCH Models Daily Data: 1 January 1999 to 31 March 2004 (Full Sample)		
	1 January 1999 to 31 March 2004: All Variables	1 January 1999 to 31 March 2004: Significant Variables Only
Constant	-0.235 (0.194)	-0.300 (0.174)
$\Delta s(-1)$	-0.022 (0.029)	-
INT	1.240*** (0.333)	1.211*** (0.186)
INT^{RUMOR}	-0.079 (0.356)	-
INT^{03}	-0.676** (0.311)	-0.705** (0.296)
INT^{04}	-1.060*** (0.286)	-1.092*** (0.273)
$RUMOR^{NoINT}$	-0.340 (0.503)	-
POSSTAT	0.003 (0.683)	-
NEGSTAT	-0.724 (1.282)	-
JPCPI	-0.149 (0.594)	-
JPGDP	-0.179 (0.186)	-
JPIP	0.079 (0.123)	-
JPTB	-0.014** (0.006)	-0.012** (0.006)
JPUNEMP	-1.0543* (0.545)	-0.920* (0.526)
USCPI	0.558 (0.921)	-
USGDP	0.466 (0.734)	-
USIP	0.053 (0.277)	-
USTB	-0.001 (0.001)	-
USNFPR	0.001 (0.011)	-
USFOMC	0.220 (2.793)	-
Variance Equation		
Constant	0.759*** (0.249)	0.697*** (0.221)
ARCH(-1)	0.0199*** (0.006)	0.019*** (0.006)
GARCH(-1)	0.959*** (0.010)	0.962*** (0.009)
Observations	1364	1364
R-squared	0.043	0.039
S.E. of regression	0.006	0.006
Durbin-Watson	1.981	2.020
ARCH-F (Q^2)	0.53[0.47]	0.89[0.35]
Q^2 (2)	0.58[0.75]	0.92[0.63]
F-Stat	2.74***[0.00]	6.96***[0.00]

NOTES:

(a) * Denotes significance at 90%, ** Denotes significance at 95%, *** Denotes significance at 99%.
(b) Standard Errors (S.E.) in ( ) below the point estimates; p values in [ ]; lags in ( ) in Variable Names.

(c) GARCH estimations are defined in Equations (1) (2) and (3) in the text.
(d) The dependent variable (Δs) is the first difference of the log of the daily JPY/USD spot exchange rate.
(e) The independent variables: INT is the daily intervention volume; INT^{RUMOR} is the intervention volume on days with no rumor of intervention; INT^{03} is the daily intervention volume during the 14 January 2003 to 25 December 2003 period; INT^{04} is the daily intervention volume during the 26 December 2003 to 31 March 2004 period; $RUMOR^{NoINT}$ is an indicator variable that takes on the value 1 on days when there is a rumor of intervention but no intervention occurs, and 0 otherwise; POSSTAT is an indicator variable that takes on the value 1 on days when there is an official statement in support of intervention and/or a weaker JPY, and 0 otherwise; NEGSTAT is an indicator variable that takes on the value 1 on days when there is an official statement suggesting that further intervention in the JPY/USD rate is unlikely or not recommended, and 0 otherwise.
(f) Control Variables are measuring macro news surprises (difference between actual announcement and survey expectations extracted from Bloomberg) regarding Japanese CPI (JPCPI), GDP (JPGDP), Industrial Production (JPIP), Trade Balance (JPTB), and Unemployment (JPUNEMP), and US CPI (USCPI), GDP (USGDP), Industrial Production (USIP), Trade Balance (USTB), Non-Farm Payroll Employment (USNFPR), and Interest Rate Changes (USFOMC).
(g) The conditional mean constant, $RUMOR^{NoINT}$, POSSTAT, NEGSTAT, JPTB, and USNFPR are multiplied by 10^3; and INT, INT^{RUMOR}, INT^{03}, INT^{04}, and the constant associated with the variance equation, are multiplied by 10^6 for readability.

TABLE 5 **JPY/USD Exchange Rate and Intervention: Baseline Estimations on Sub-Samples**		
GARCH Models Daily Data: 1 January 1999 to 31 March 2004		
	1 January 1999 to 13 January 2003: Significant Intervention Variables	14 January 2003 to 31 March 2004: Significant Intervention Variables
Constant	-0.111 (0.208)	-0.873*** (0.319)
INT	1.210*** (0.194)	0.649*** (0.203)
INT^{04}	-	-0.496** (0.250)
Variance Equation		
Constant	1.112*** (0.400)	2.100 (1.442)
ARCH(-1)	0.014** (0.007)	0.054* (0.029)
GARCH(-1)	0.959*** (0.013)	0.864*** (0.074)
Observations	1048	316
R-squared	0.038	0.053
S.E. of regression	0.007	0.005
Durbin-Watson	2.019	1.976
ARCH-F (Q^2)	0.15[0.70]	0.04[0.84]
Q^2 (2)	0.63[0.73]	3.80[0.15]
F-Stat	7.05***[0.00]	2.91[0.01]

NOTES:

(a) * Denotes significance at 90%, ** Denotes significance at 95%, *** Denotes significance at 99%.
(b) Standard Errors (S.E.) in ( ) below the point estimates; p values in [ ]; lags in ( ) in Variable Names.
(c) GARCH estimations are defined in Equations (1) (2) and (3) in the text.
(d) The dependent variable (Δs) is the first difference of the log of the daily JPY/USD spot exchange rate.
(e) The independent variables: INT is the daily intervention volume; INT^{04} is the daily intervention volume during the 26 December 2003 to 31 March 2004 period;
(f) Significant control variables measuring macro news surprises are included but not shown for ease of exposition.
(g) The conditional mean constant is multiplied by 10^3; and INT, INT^{04}, and the constant associated with the variance equation, are multiplied by 10^6 for readability.

TABLE 6 **JPY/USD Exchange Rate and Intervention: Delayed Effects**

GARCH Models
Daily Data: 1 January 1999 to 31 March 2004

	1 January 1999 to 13 January 2003	14 January 2003 to 31 March 2004
Constant	-0.154 (0.214)	-0.809** (0.366)
INT	1.173*** (0.212)	0.675*** (0.216)
INT(-1)	-0.252 (0.232)	-0.080 (0.182)
INT(-2)	0.066 (0.298)	-0.020 (0.166)
INT(-3)	-0.113 (0.342)	0.052 (0.226)
INT(-4)	0.231 (0.263)	-0.039 (0.201)
INT(-5)	0.289 (0.262)	-0.017 (0.149)
INT^{04}	- 	-0.472* (0.274)
Variance Equation		
Constant	2.061*** (0.546)	2.140 (1.600)
ARCH(-1)	0.015* (0.008)	0.051* (0.030)
GARCH(-1)	0.935*** (0.015)	0.864*** (0.080)
Observations	1048	316
R-squared	0.041	0.056
S.E. of regression	0.007	0.008
Durbin-Watson	2.01	1.97
ARCH-F (Q^2)	0.70[0.40]	0.05[0.83]
Q^2 (2)	0.72[0.70]	3.47[0.18]
F-Stat	4.46***[0.00]	1.67*[0.08]

NOTES:

(a) See notes to Table 5.

TABLE 7 **JPY/USD Exchange Rate and Intervention: Controlling for Endogeneity**

GARCH Models
Daily Data: 1 January 1999 to 31 March 2004

	1 January 1999 to 13 January 2003	14 January 2003 to 25 December 2003
Constant	-0.119 (0.208)	-0.461 (0.316)
INT^{UNEXP}	1.42*** (0.237)	0.522*** (0.183)
Variance Equation		
Constant	1.572*** (0.475)	2.381 (3.352)
ARCH(1)	0.014** (0.007)	0.040 (0.036)
GARCH(1)	0.947*** (0.014)	0.861*** (0.160)
Observations	1048	316
R-squared	0.041	0.047
S.E. of regression	0.007	0.005
Durbin-Watson	2.01	2.13
ARCH-F (Q^2)	0.14[0.71]	0.57[0.45]
Q^2 (2)	0.59[0.75]	1.79[0.41]
F-Stat	7.51***[0.00]	2.42**[0.04]

NOTES:

(a) The independent variable INT^{UNEXP} is the residual of the Bank of Japan intervention reaction function (defined in Equation 5 in the text) multiplied by an intervention indicator variable. The intervention indicator variable takes on the value 1 when intervention occurs and 0 otherwise.
(b) For all other notes see notes to Table 5.

Table 8	**Economic Effects of Intervention**		
	1 January 1999 to 13 January 2003	14 January 2003 to 25 December 2003	26 December 2003 to 31 March 2004
Coefficient Estimate	0.00000142	0.00000052	0.00000015
Exchange Rate Effect of a USD 100 Million Intervention	0.0142%	0.0052%	0.0015%
Exchange Rate Effect of a JPY 1 Trillion Intervention	1.21%	0.45%	0.14%
Exchange Rate Effect of average daily Intervention	0.71%	0.11%	0.04%
Exchange Rate Effect of Total Within-Period Intervention	20.81%	8.82%	2.15%
Counterfactual End-of-Period JPY/USD Exchange Rate	98	80	76
Actual End-of-Period JPY/USD Exchange Rate	118.89	107.22	104.28

NOTES:

(a) The coefficient estimates for the 1 January 1999 to 13 January 2003 period and the 14 January to 25 December 2003 period are from the models that control for endogeneity (results displayed in Table 7); the coefficient estimate for the 26 December 2003 to 31 March 2004 period is the sum of the coefficient estimates associated with INT and INT^{04} from the baseline estimations (results displayed in Table 5). Coefficient estimates are associated with a USD 1 million intervention.

(b) The exchange rate effect of a JPY 1 trillion intervention is calculated using JPY/USD exchange rate averages. The average JPY/USD exchange rates across the three sub-periods are 117.04, 115.86, and 107.22, respectively.

(c) The average daily intervention amounts (in billions of USD) across the three sub-periods are 4.9, 2.2 and 2.8, respectively.

(c) The exchange rate effect of the total amount of intervention is the total within-period intervention in trillions of JPY times the associated exchange rate effect of a JPY 1 trillion intervention.

(d) The counterfactual end-of-period exchange rate is the start-of-period rate net of the actual within-period percentage rate change minus the effect of total within-period intervention. The start-of-period rate for the first sub-period is 111.85 (the actual JPY/USD rate primo 1999), the start-of-period rate for the subsequent periods is the counterfactual end-of-period rate of the immediately preceding sub-period (98 and 80, respectively).