Order Flow and Central Bank Intervention: An Empirical Analysis of Recent Bank of Japan Actions in the Foreign Exchange Market

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Abstract:
This paper examines the behaviour of end-user order flows in the foreign exchange market around periods of intense and large-scale intervention activity by the Bank of Japan. First, we find very limited evidence that corporate customers are more than usually likely to be net sellers of yen on days when the Bank of Japan is intervening to sell yen. However, there is somewhat stronger evidence that financial customers are more likely to be net buyers of yen on the same days. Second, using a regression framework we again find evidence that corporate customers react in ways consistent with the presumed intentions of the Bank of Japan, while financial customers act in the opposite way. The aggregate impact of intervention to sell the yen is counterproductive in that it permanently increases net purchases of the yen by the customers of the bank we analyse. Finally, we find very clear evidence that intervention matters in a microstructure analysis. The strong contemporaneous correlation between order flows and exchange rate changes essentially disappears on days in which the Bank of Japan intervenes.

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This paper is a contribution to the extensive literature on whether central bank intervention in foreign exchange markets works. It is novel in that instead of analysing the effect of intervention on the value of the exchange rate, the volatility of the exchange rate, expectations of the level of the future exchange rate or even the full probability density function of the future exchange rate, it examines end-user (customer) order flows in the foreign exchange market.[1]

Why is this interesting? Decades of research have unearthed only one type of variable that appears correlated with exchange rate changes at high frequencies, namely order flow. Early work by Evans and Lyons (2002) showed that interbank order flows into a currency are highly correlated with the contemporaneous appreciation of that currency. However, interbank order flows primarily result from risk-sharing activities of banks in the face of inventory shocks caused by end-user order flows. Subsequent work shows that end-user order flows – private information observed only by the bank acting as counterparty – are also correlated with exchange rate changes (Evans and Lyons, 2004; Froot and Ramadorai, 2005; Marsh and O'Rourke, 2005). These end-user flows are the driving force behind turnover in the market. Even so, the nature of the correlation between flows and exchange rate changes is contentious. Since order flow data are usually only available at daily frequencies, the direction of causation is hard to prove. Feedback trading, where flows react to exchange rate changes, is arguably as plausible as flows causing exchange rate changes. However, to the extent that order flows lead to exchange rate changes (either within the day or over longer horizons), intervention activities that alter the behaviour of end-users will affect exchange rates. This paper initially focuses on the link between end-user order flows and intervention, before returning to the order flow-exchange rate link in the process.

We examine the Bank of Japan's recent attempts to manage the value of the yen. This intervention episode is itself the subject of several analyses and is of interest primarily because of the huge amount of yen sold by the central bank in an attempt to hold down the value of its currency. The analysis proceeds in three stages. First, we use a variety of

[1] Earlier drafts of this paper used the word "unique" rather than "novel" in this sentence. After drafts were circulated we located a copy of Girardin and Lyons (2006) who have also analysed order flow in a similar context.

metrics used previously in the literature to test the effectiveness of intervention on the level of the exchange rate to test instead whether intervention successfully altered the nature of customer order flows as observed by a major European commercial bank. We find very limited evidence that corporate customers are influenced to trade in the same direction as the intervention flows. However, there is somewhat stronger evidence that financial customers are inclined to accommodate the demand for dollars for the Bank of Japan.

Second, we test whether intervention affects net order flows in a regression framework, allowing the intervention to have both short-term and persistent effects on order flow. Again, we find evidence that corporate customers react in ways consistent with the presumed intentions of the Bank of Japan, while financial customers act in the opposite way. The aggregate impact of intervention to buy the dollar is, if anything, to permanently increase net purchases of the yen by the customers of the bank we analyse.

Finally, we find very clear evidence that intervention matters in a microstructure context. The strong contemporaneous correlation between order flows and exchange rate changes observed in many studies also holds for our data over the full sample. However, the relationship essentially disappears for the yen-dollar on days in which the Bank of Japan intervenes. Furthermore, the strong relationship between customer order flows and exchange rate changes in the (hugely liquid) euro-dollar market also disappears on days when the Bank of Japan intervenes in the yen-dollar market. While the nature of the relationship between flows and exchange rate changes is not unequivocally established in the literature yet, this relationship is clearly affected by the presence of a central bank in the foreign exchange market.

We briefly summarise the literature on intervention by the Japanese authorities in recent years in section 1, before describing the data used in our analysis in section 2. Section 3 contains the analysis outlined above and we end with some brief conclusions.

1. Intervention in the Japanese Yen Market

Government intervention to manage the exchange rate has a "bad press" in the academic literature. While several theoretical reasons can be found to explain why it could work, empirical analyses struggle to find much evidence of success (Sarno and Taylor, 2001)

While central banks in most developed countries have increasingly shied away from intervention, the Japanese authorities have been extremely active in their attempts to manage the value of the yen in recent years. Intervention is instigated by the Japanese Ministry of Finance and executed by the Bank of Japan as its agent. For simplicity, we will refer to it as intervention by the Bank of Japan below. As discussed in Ito (2002) and Chaboud and Humpage (2005), the intervention strategies employed by the Japanese authorities have altered over time, usually coinciding with new appointments as Director General of the International Bureau of the Ministry of Finance. Between 1991 and June 1995, intervention was small, frequent, persistent, and often coordinated with the United States. However, the strategy changed to one of large, infrequent interventions following the appointment of Eisuke Sakakibara as Director General in June 1995. This strategy was continued by his successor Haruhiko Kuroda. The appointment of Zembei Mizoguchi as Director General at the start of 2003 prompted a shift to very frequent but somewhat smaller uncoordinated interventions. The increased frequency of interventions more than compensated for the drop in values such that this is the largest intervention programme seen to date in the yen or any other currency. Since our order flow data are only available from August 2002, we focus on the Mizoguchi period in this paper.

Figure 1 plots the intraday low of the yen-dollar exchange rate and highlights intervention days around the period of intense Bank of Japan actions. The appointment of Mr Mizoguchi coincides with the commencement of intervention after several months of no inactivity. From his appointment until the G7 Dubai Summit in September 2003, intervention occurred on 55 days to a total value of ¥13.5 trillion, all seemingly aimed at preventing the value of the yen rising beyond ¥115 against the dollar (see Ito, 2004, for a full discussion of intervention during this period). These intervention episodes marked a

change in tactics with the Bank of Japan placing standing orders with a number of banks to sell yen for dollars (or sometimes euros) in the market under their own names at pre-determined levels. This more passive kind of intervention, when the Bank of Japan offers to supply large amounts of yen at a given price, was a shift from the Bank's previous approach of aggressively intervening by initiating transactions. The passive tactic was apparently favoured since the Japanese authorities wished to draw a "line in the sand" and prevent the yen appreciating beyond ¥115.

Conversations with dealers suggest that the line in the sand approach of this first phase of intervention created a one-way bet in the minds of many participants. The yen might not have appreciated much in the face of continuous intervention but equally it did not depreciating much either. With the yen seen as significantly undervalued, many participants were willing to accumulate long yen positions and await the day the Bank of Japan ceased intervening.

This appears to have happened at the G7 Summit in Dubai where the September 20th communiqué included a paragraph affirming the desirability of flexibility in exchange rates and emphasising that markets should determine the value of currencies. Following this, the yen was allowed to appreciate by around ¥5 before the second phase of intervention under Mr Mizoguchi's command (69 days of intervention with a total value of ¥21.8 trillion). This period saw a return to more aggressive intervention tactics with the Bank of Japan actively initiating deals. It is not apparent that the Bank was conducting a defence of a particular value of the yen, perhaps in response to the failure of the previous attempt to provide a ceiling to the value of the yen. The early days of this phase saw the Bank of Japan fighting against a strong trend appreciation of the yen, while in the later days intervention was able to push the yen down significantly.

Many studies have analysed the effect of Japanese intervention on the value of the yen. On balance, they appear to find rather more evidence supporting the effectiveness of intervention than would be expected from reading the extant literature. Ito (2002) finds that intervention in the latter half of the 1990s was relatively successful, producing the intended effect on the value of the yen. Fatum and Hutchinson (2003) present evidence

of short-term effectiveness over the period 1991-2000 using an event study approach. Chaboud and Humpage (2005) concur but also say that the behaviour of the exchange rate on intervention days during the period we analyse here was statistically hard to distinguish from that on non-intervention days using a variety of metrics. Hillebrand and Schnabl (2006) note that, from 2000 onwards, Bank of Japan intervention pushed the exchange rate in the desired direction and also reduced volatility. Galati, Melick and Micu (2005), however, detect no impact of (perceived) intervention on either the mean or the higher moments of the risk neutral distribution of future exchange rates derived from options prices over the period 1993-2000.

2. Data Sources and Descriptions

I. Order Flow Data

The order flow data used in this paper come from the Royal Bank of Scotland (RBS). Customer order flow data are obviously highly confidential and so the data description provided here is necessarily less detailed than usual. In particular, we cannot reveal the value of order flows. However, we hope that readers still get a feel for the nature of the flows across this bank's foreign exchange desks.

RBS is among the top twelve global foreign exchange banks by volume traded and maintains a 24-hour foreign exchange trading service for its customers. The end-user order flow data are aggregated over a 24-hour window from the opening of the Sydney market through the close of the US market. The data include all spot transactions entered into by customers against the bank. The data do not include forward deals or deals between RBS and other banks via the brokered inter-dealer markets. The data set begins on 1 August 2002 and ends 2 March 2006, a period of 890 trading days once holidays are excluded. We use this full period in our analysis even though the most recent intervention took place on 16 March 2004 since we wish to compare the behaviour of order flows on intervention days with those on non-intervention days. While it is feasible to use days that can be ex post identified as non intervention days but that nevertheless lie

within intervention episodes, we also wish to include days that are uncontroversially free from intervention.

The order flow is disaggregated according to the counterparty classification assigned by the bank. There are four categories of customer: non-financial corporates (denoted Corp), unleveraged financials such as mutual funds and other real money managers (Unlev), leveraged financials including hedge funds (Lev) and other financials (Other). The final category is rather heterogeneous but will include the trades of smaller banks that do not have access to the inter-dealer network (non-reciprocal banks), non-leveraged system accounts and central banks.

RBS data are provided on a gross basis. That is, we know the value of yen sales in exchange for dollars (denoted $Sell^Y$) and the value of dollar sales in exchange for yen (denoted Buy^Y) each day (with both series given in dollar terms and yen terms). From this we compute the net order flow in the yen-dollar market which is more typically used in microstructure analysis. This is denoted *OF* and is equal to $Sell^Y - Buy^Y$ such that a positive number indicates a net flow out of the yen and into the dollar.

II. Exchange and Interest Rate Data

Contemporaneous spot exchange rate data were also supplied by RBS, denoted *spot* and defined as the number of yen per US dollar. These data are for New York close and so match the timing of the daily order flows described above. We supplement this with data on the intraday high and low yen-dollar rate from Norgate Investor Services.

We use Federal Funds interest rates collected from the Federal Reserve Board website (http://www.federalreserve.gov/releases/h15/data/Business_day/H15_FF_O.txt), and overnight call rates from the Bank of Japan website (http://210.174.171.233/en/type/stat/dlong/etc/ehdaily.csv).

III. Intervention Data

The Japanese Ministry of Finance provides details of its intervention activities, with a significant delay, via its website (http://www.mof.go.jp/english/e1c021.htm). The Ministry's website gives the total yen value of all foreign exchange intervention operations each day, broken down according to the currency pairs used. In the episode examined in this paper, the vast majority of interventions were in the dollar but some euro interventions also occurred. We use both the total value of intervention (denoted *Intval*) and a simple indicator dummy, *Int*, that takes the value of 1 if intervention took place and zero otherwise.

The exact timing of the intervention is not given. It is thought that the majority of interventions took place during Tokyo trading hours (i.e. early in the 24 hour window over which order flows are aggregated) but at least one major intervention episode is known to have taken place in late New York trading (i.e. at the end of the order flow window).[2]

We examine whether the fact that intervention is detected or remains secret matters. Data on whether financial markets detected the activities of the Bank of Japan were generously provided by Michel Beine. Intervention is considered detected if news wire reports from either Reuters or Bloomberg clearly state that the Bank of Japan was seen to have intervened. Further details are available in Beine and Lecourt (2004). However we note that conversations with dealers and fund managers suggest that the Bank of Japan might not have been successful in hiding intervention despite the relatively rare reporting of their activities by the newswires. The (Japanese) commercial banks receiving either the standing order or the intervention transaction from the Bank of Japan reportedly passed them directly to the interbank market by placing large yen sale limit orders in the electronic broking market. While unfilled orders are anonymous, any dealer transacting against the order learns the counterparty. Participants claim that such large yen-sale

[2] These conclusions, gleaned from press reports of intervention, were confirmed by conversations with foreign exchange dealers. Dominguez (1999), while covering a completely different time period, notes that on average Bank of Japan intervention took place around the Tokyo lunch hour which is 4am GMT.

orders are rare and that the revelation of a Japanese counterparty in such large deals is a good indicator of intervention.

3. Analysis

We begin with a simple *t*-test of equal mean order flows in the yen-dollar market on intervention and non-intervention days, reported in Table 1. Mean aggregate gross order flows (the sum of all yen buy orders and yen sell orders) are significantly different across the two samples. The positive value of the *t*-test indicates that aggregate gross flows are higher on non-intervention days than on intervention days. This is mirrored by the flows from leveraged and other financial institutions, while gross flows from corporate customers are significantly higher on intervention days. Gross flows from unleveraged financial institutions are not significantly different. It appears from this preliminary analysis that both the scale and composition of customer trading volume differs from normal on intervention days.

The second panel suggests that aggregate net order flows are weakly significantly *into* the yen on intervention days (p-value is 0.124). This is driven by the actions of the unleveraged and, to a lesser extent, leveraged financial customer categories which show much more significant differences in mean net order flows across the two samples.

Finally, we test whether the spot exchange rate behaves differently on intervention days. A test of differences in mean (log) exchange rate changes across intervention and non-intervention days is insignificant (p-value is 0.42). However, the ratio of standard deviations of exchange rate changes is 2.14, which is significantly different from unity at the 0.04 level, and suggests that exchange rate changes are more volatile on intervention days. This is in line with much of the literature on intervention (Nagayasu, 2004).

We conclude that, if anything, intervention days are characterised by higher than average gross flows, higher than average spot volatility, and higher than average net flows into the yen. Net flows are therefore in the opposite direction to the trades of the Bank of Japan, suggesting that the private sector customers of RBS are willing to accommodate

the increased demand for dollars from the Bank of Japan and absorb the increased supply of yen. Nevertheless, this is quite a crude analysis of the effect of intervention and we now turn to more specific tests of the success, or failure, of the Bank of Japan's activities.

I. Success Criteria

The exact intentions of the Ministry of Finance in initiating intervention are not known. It is clear that the overall objective was to contribute to the recovery of the Japanese economy and it may be inferred that this entailed managing the appreciation of the yen to the benefit of the export sector. Whether this entailed driving the value of the yen down, targeting one or more specific values for the level of the yen, or simply slowing the appreciation of the yen is not known. Similarly, in the context of this paper, it is hard to give one specific development in the behaviour of customer order flows that could be used to judge the success or failure of intervention. Instead, we apply the battery of success criteria introduced by Humpage (1999), adopting them slightly for the context of judging the success (or otherwise) of intervention in affecting order flows rather than the exchange rate itself. Since the intervention we analyse is all in one direction – the Bank of Japan only acted to limit the appreciation of the yen in our sample – we dispense with the success criterion for purchases of yen in each case.

(i) Net flow out of yen

The first success criterion tests whether, when the Bank of Japan intervenes to sell yen, the net order flow seen by RBS is also out of the yen:

$$S1_t = \begin{cases} 1 \text{ if } Int_t = 1, \text{ and } OF_t > 0 \\ 0 \text{ otherwise} \end{cases}$$

(ii) Reversing the direction of net flows

The second criterion is a more stringent subset of the first. It tests whether intervention to sell yen changes the direction of net flows from 'into the yen' to 'out of the yen':

$$S2_t = \begin{cases} 1 \text{ if } Int_t = 1, \text{ and } OF_t > 0 \text{ and } OF_{t-1} < 0 \\ 0 \text{ otherwise} \end{cases}$$

(iii) Accentuating the net flow

The third criterion, also a subset of the first, considers intervention that 'leans with the wind'. Intervention would be deemed successful if it accelerated the net flow out of yen, such that intervention to sell the yen today increases the value of the net outflow from the yen:

$$S3_t = \begin{cases} 1 \text{ if } Int_t = 1, \text{ and } OF_t > OF_{t-1} \text{ and } OF_{t-1} > 0 \\ 0 \text{ otherwise} \end{cases}$$

(iv) Moderating the net flow

Criterion four takes the opposing view and considers intervention that 'leans against the wind'. To be deemed successful, yen sales by the Bank of Japan must reduce the value of net flows into yen, but not reverse them:

$$S4_t = \begin{cases} 1 \text{ if } Int_t = 1, \text{ and } OF_t > OF_{t-1} \text{ and } OF_t \leq 0 \text{ and } OF_{t-1} < 0 \\ 0 \text{ otherwise} \end{cases}$$

(v) General success criterion for net flows

The general success criterion takes the union of the previous criteria. Intervention to sell the yen is successful if order flows are also out of the yen or, if not, at least less into the yen than they were:

$$S5_t = \begin{cases} 1 \text{ if } Int_t = 1, \text{ and } OF_t > 0 \text{ or } OF_t > OF_{t-1} \\ 0 \text{ otherwise} \end{cases}$$

(vi) Increased yen sales

Yen sales by the Bank of Japan could be deemed successful if they increase the value of yen sales:

$$S6_t = \begin{cases} 1 \text{ if } Int_t = 1, \text{ and } Sell_t^Y > Sell_{t-1}^Y \\ 0 \text{ otherwise} \end{cases}$$

(vii) Decreased yen purchases

Yen sales by the Bank of Japan could be deemed successful if they decrease the value of yen purchases:

$$S7_t = \begin{cases} 1 \text{ if } Int_t = 1, \text{ and } Buy_t^Y < Buy_{t-1}^Y \\ 0 \text{ otherwise} \end{cases}$$

(viii) Success criterion for gross flows

The success criterion for gross flows is the intersection of the previous two criteria, such that yen sales by the Bank of Japan should both increase the value of yen sales and decrease the value of yen purchases:

$$S8_t = \begin{cases} 1 \text{ if } Int_t = 1, \text{ and } Sell_t^Y > Sell_{t-1}^Y \text{ and } Buy_t^Y < Buy_{t-1}^Y \\ 0 \text{ otherwise} \end{cases}$$

(ix) Success criterion for flow proportions

Since the values of gross and net flows are very volatile from day to day, the final success criterion judges the effect of intervention on yen sales as a proportion of total trading volume. Intervention is successful if the yen sales proportion increases from the previous day:

$$S9_t = \begin{cases} 1 \text{ if } Int_t = 1, \text{ and } Sell_t^Y / \left(Sell_t^Y + Buy_t^Y\right) > Sell_{t-1}^Y / \left(Sell_{t-1}^Y + Buy_{t-1}^Y\right) \\ 0 \text{ otherwise} \end{cases}$$

The benchmark against which performance under each criterion can be judged is, in each case, the unconditional performance. That is, does intervention in the market by the Bank of Japan raise the probability of success relative to the sample average success rate? As a first step, we can simply compare success rates on days in which the Bank of Japan intervenes with success rates over the whole sample. When the conditional success rates

are higher than the unconditional, some test of statistical significance is called for. We use the methodology introduced by Hendriksson and Merton (1981) and applied in similar analyses of central bank intervention by Humpage (1999, 2000) and Chaboud and Humpage (2005). The probability of observing a given number of successes is evaluated under the assumption that their occurrence is a hypergeometric random variable. This does not require events to be independent and does not depend upon the presumed probability of an individual success. The null hypothesis is that the actual number of successes equals the expected (unconditional) number of successes.

Table 2 summarises the values of these success criteria for the bilateral yen-dollar flows. Results are reported for aggregate flows and for flows broken down according to counterparty classification. The population is set to 889 days for each criterion (one day is lost due to comparing performance with the previous day for some criteria) and the sample size is 124. The first row of figures in each block gives the number of successes under each criterion (call this *X*). The second row expresses *X* as a proportion of the sample, which we will call the conditional success rate. The third row gives the success proportion based on the entire population, or the unconditional success rate (call this *Y*). When the conditional success rate exceeds the unconditional success rate, the former is made bold. The final row in each block gives the probability value of observing *X* successes in a sample of 124 when the success rate in a population of 889 is *Y*. Probability values less than 0.05 are made bold. For example, using aggregate flows and criterion S6 (increased yen sales), intervention was successful on 68 days or 54.84% of the sample. Yen sales increased relative to the previous day on 452 of the 889 days in the population, giving an unconditional proportion of 50.84%. While the conditional proportion is greater than the unconditional proportion, this is not a statistically significant improvement since the probability value is 0.146.

The conditional probability is greater than the unconditional probability for only 16 of the 45 tests. Statistical significance is only found three times. It appears that Bank of Japan intervention accentuated corporate net flows out of the yen, and moderated the net flow into the yen for both leveraged and unleveraged financials. However, in 29 cases the

conditional probability is less than expected. On balance, there is in Table 1 at least as much evidence that intervention worsened the situation as there is that it improved things.

In particular, we note that the probability that flows were out of the yen and into the dollar on days of Bank of Japan intervention (S1) is lower than the unconditional probability for each counterparty category. For leveraged and unleveraged financials, the number of successes is significantly *below* the expected level. This is itself an interesting result. It suggests that fund managers were taking advantage of the Bank of Japan's willingness to supply yen to build up long yen positions with minimal price impact.

As noted above, the Japanese authorities were reticent to confirm or deny intervention for much our sample. This made a break from previous policy when intervention was often either announced or at least confirmed within a few days or even hours of taking place. This, together with the change in operating procedure discussed earlier, suggests that the authorities were trying to keep intervention secret. We therefore split our sample according to whether the intervention was detected or not based the news wire reports described above. Of the 124 days of intervention, 25 were detected and 99 were not. Repeating the calculations using the 99 day sample of secret interventions slightly improves the probabilities of success in most cases. Of the 45 tests, 22 report higher conditional probabilities than unconditional probabilities, but only one is statistically significantly higher.

Interestingly, eight of the nine tests for corporate flows showed higher than expected success rates on intervention days. This compares to three, four and three for unleveraged, leveraged and other financial institutions, respectively. One of the mechanisms by which intervention is thought to work is the noise trader channel (Hung, 1997). Unsophisticated investors misinterpret the results of undetected central bank activities as new trends in the market and alter their behaviour to follow these trends. To the extent that corporate customers are unsophisticated, the results in this section give some support to this hypothesis.

We discussed earlier how the operating procedures of the Bank of Japan appeared to change between the fist phase of passive intervention (January 2003 – 20 September

2003) and the second more active phase (21 September 2003 onwards). Tables 4 and 5 repeat the analysis of success for these two sub-samples of the data. There are clear differences between the two samples. Most obviously, the suggestion from the full sample that leveraged and unleveraged financial customers were buying yen more often than would be expected on intervention days can be sharpened by splitting the intervention into two phases. The passive phase 1 sees many fewer success days under criterion S1 for profit maximising financials, while in phase 2 they behaved more in line with the population period. We can conclude that, in line with comments from participants, speculators took advantage of the first phase of passive intervention to acquire long yen positions. The actions of the Bank of Japan prevented the spot exchange rate from reflecting this pressure, but once intervention ceased following the G7 summit, the yen appreciated sharply, rewarding the speculators. Intervention in phase 2 was more successful where there are 25 cases of relatively high conditional probabilities, compared to just 11 in phase 1. Even so, statistical significance is hard to find.

II. Regression Analysis

We now focus on the determinants of net order flows.[3] The analysis in the previous section is suggestive of an impact of intervention on the behaviour of order flows of end-user groups, albeit not always in the direction hoped for by the Japanese authorities. In this section we use regression analysis to test whether intervention has significant effects when other determinants of order flow are included in the analysis. Further, this approach allows us to also test for long-lasting effects of intervention on private sector flows. Within the microstructure framework, some persistent impact on flows is necessary if flows are not to return to normal and cause adverse movements in the exchange rate once intervention stops. Whether this effect on flows is due to intervention providing new information to the market (the signalling channel), changing risk premia (the portfolio balance channel), altering the balance of the participants in the market

[3] We do not model gross order flows because of significant trends and structural changes in the customer base of RBS during our sample.

(noise trader channel) or otherwise is not explored. We simply attempt to quantify the effect of intervention on flows. We regress net order flows on the following variables:

(i) Lagged net flows from the same end-user category (OF_{t-i}).

These variables should mop up any autocorrelation in the net order flow series.

(ii) The lagged cumulative value of net flows for the same end-user category (ΣOF_{t-1}).

This variable will capture any mean reversion tendencies in the positions of participants.

(iii) The lagged change in the (log) spot exchange rate (Δs_{t-1}).

While the maintained thesis of this paper is that order flow causes exchange rate changes, it is probable that feedback trading also exists such that exchange rate changes cause order flow.

(iv) The lagged level in the (log) spot exchange rate (s_{t-1}).

On the assumption of a constant equilibrium or fair value for the yen over the relatively short window of our sample, the level of the exchange rate (in conjunction with the constant term) will capture deviations from fair value.

(v) The interest rate differential (i_{t-1}-i^*_{t-1}).

The interest differential (or, perhaps, the change in the interest differential) proxies as a high frequency summary statistic for the relative fundamentals of the two countries.

(vi) The contemporaneous value of intervention ($Intval_t$).

This variable captures the effect of intervention on day *t* on the order flows in day *t*. While potentially causing endogeneity problems, the timing difference between Japanese intervention (early morning) and the majority of order flows seen by RBS (European and US trading hours) mitigates this problem. We note in the text the results of replacing this and the following variables with their lagged counterparts.

(vii) The cumulative value of intervention ($\Sigma Intval_t$).

This variable cumulates all intervention since the start of our sample and will allow intervention to have a permanent impact on flows.

(viii) The number of business days since the last intervention day ($DayGap_t$).

This is our first proxy for expected intervention. If intervention was recent, then we assume more intervention could be expected. If there hasn't been intervention for some time, then the probability of further intervention is assumed to be low irrespective of the level of the yen.

(ix) The distance in yen since the lowest level to date at which the Bank of Japan had intervened ($LevelGap_t$).

The exact level at which intervention occurred is not known. However, we know the intraday low of the yen-dollar exchange rate (i.e. the highest value of the yen) on each intervention day. Given that the Bank of Japan has intervened on a day, it must have done so at the intraday low or at some level above it. For each day *t* in the sample, we take the lowest intraday low on intervention days up to and including day *t* and interpret this as the level of the exchange rate at which participants might reasonably expect the Bank of Japan to intervene again. Finally, we compute the difference between the day *t* close and this rolling intraday low in yen. The greater this distance, the further away is the lowest value of the exchange rate at which the Bank of Japan intervened and, we assume, the lower the probability of further intervention.

(x) The product of the previous two measures ($Distance_t$).

This variable will be small if the current spot rate is close to the lowest intervention level and intervention took place recently. Such a situation is one in which further intervention might be deemed likely. The variable will take a large value if the spot exchange rate is above historical intervention lows and intervention has not occurred for some time. In such a case further intervention might reasonably be deemed unlikely.

The results of the regressions are given in Table 6. Goodness of fit measures are not particularly high but as the net flow on any given day is the difference between two very large and volatile numbers this is perhaps not too surprising. Encouragingly, the probability values reported at the foot of the table show that the regressors are jointly significant ("joint p-val") and that, with the exception of other financials, the intervention

variables are jointly significant ("intervention p-val") for each end-user category and for aggregate flows.

The lagged change in the exchange rate has a positive coefficient for the financial end-users (although it is not significant for leveraged funds) while it has a negative but insignificant coefficient for corporates. We observe a similar heterogeneity when looking at the level of the exchange rate. The coefficient is significantly positive for corporates but significantly negative for leveraged and unleveraged financial customers. All customer categories show signs of mean reversion in their order flows (ΣOF_t). Lagged order flows and interest differentials (and the change in interest rate differentials) are all insignificant.

Turning to the intervention-related variables, the contemporaneous value of intervention ($Intval_t$) has a negative effect on flows for three of the four categories but is only significant for leveraged financials.[4] This reflects some of the earlier results, suggesting that when the Bank of Japan sells yen, the net flows of private sector participants are, if anything, into the yen thereby accommodating the Bank of Japan.

The persistent component of the effect on flows is perhaps more relevant for judging the long term success of intervention. Corporate customers of RBS respond positively as intervention accumulates ($\Sigma Intval_t$), such that they buy more dollars.[5] The average increment in the cumulative value of intervention is ¥284bn. Ten such intervention episodes would result in an increase in corporate net flows into the dollar of $7.25m, which is around 10% of the standard deviation of net flows from this customer group.[6] Although quite small, recall that this is a permanent impact on corporate flows. Similarly, corporates are more likely to be net buyers of dollars as the spot exchange rate approaches levels at which the Bank of Japan has intervened previously ($LevelGap_t$). A one yen shift in the value of the yen towards the expected intervention level prompts an increase of $10.5m in the net flow into the dollar. Again, this is a permanent shift in the

[4] Replacing this with lagged intervention because of worries about endogeneity reduces the significance of intervention values for each customer category but does not alter the sign of the coefficients. It also reduces the coefficient estimate for aggregate flows (to -0.07) but increases its significance (p-val is 0.023).
[5] Using a lagged value of accumulated intervention has no impact on the estimates).
[6] We do not wish to overemphasise these results since there is the possibility of simultaneity bias in the coefficient estimates. However we would reiterate that most interventions took place early in the daily window while the bulk of the flows occur later in the day, suggesting the bias should be small.

net flow of corporates. Corporate customers therefore appear to act in ways consistent with likely Bank of Japan intentions.

By contrast, leveraged and unleveraged financial institutions are more likely to be net buyers of yen as intervention takes place and as cumulated intervention rises. Similarly, net yen purchases rise when spot rates approach intervention levels. The magnitudes of the impacts on financial order flows more than offset the more positive impacts on corporate flows. The overall impact of cumulated intervention on total net order flows is significantly negative (i.e. ten average intervention days prompt permanent net flows into the yen of $16.2m), while a one yen shift in the value of the yen towards intervention levels prompts an increase of $22.9m in the total net flow into the yen. We conclude that intervention by the Bank of Japan has persistent effects on the flows of end-users, although in different and typically off-setting ways.

III. Order Flow and Exchange Rate Changes

We now turn to probably the most important set of findings. We motivated this paper's approach of looking at the impact of intervention on customer order flow through the results of the simple regression of exchange rate changes on contemporaneous customer order flow. These regressions show consistent results cross a variety of exchange rates, sample periods, sampling frequency and sources of data. Customer order flows are statistically significant in the regressions, R^2 are reasonably high by the standards of the finance literature and sometimes staggeringly high by the standards of the exchange rate literature, and consistent coefficient sign patterns emerge (corporate flows have a negative coefficient while profit maximising financial institution flows have positive coefficients). The RBS data analysed in this paper are no exception, either when considering several major exchange rates (see Marsh and O'Rourke, 2005) or when focusing on the yen.

However, consider the results given in Table 7. The top panel first reports the results of the standard regression of the daily change in the (log) yen-dollar exchange rate on contemporaneous aggregate order flow, then on disaggregated order flow separately and finally on disaggregated order flow simultaneously, using the full sample period. The

results are standard. The middle panel repeats these regressions using just the non-intervention days in the sample. Again the results are standard. The bottom panel uses the 124 observations in the intervention day sample. Now, there is absolutely no explanatory power in any regression.

To test whether this is simply due to the small sample we randomly draw 124 day samples without replacement from the full 889 day 'population', run the disaggregate order flow regression, collect the R^2 figure and repeat 1,000 times. The R^2 from the intervention day sample (0.0286) lies at the 4th percentile of the distribution. If we repeat the same exercise using only non-intervention days as the population, the observed R^2 lies below the 2nd percentile. The results are essentially unchanged if we use p-values from a test of joint significance of the regressors instead of R^2 values. We conclude that the explanatory power of flows on intervention days is unusually low even accounting for the relatively small sample size.

Girardin and Lyons (2006) note the time varying nature of the relationship between flows and exchange rate changes. To test whether the intervention episodes merely coincided with a period of unusually low correlation between the variables we run the regression using non-intervention days during the period in which the Bank of Japan was intervening (i.e. between January 2003 and March 2004). The R^2 is 0.1512, the p-value of the test of joint significance of the regressors is 0.0001, and coefficient estimates are little changed from the full sample of non-intervention days reported in the centre panel of Table 7.[7] We conclude that it is not the January 2003- March 2004 period that is special, but the specific days on which the intervention takes place.

To test whether the days on which the Bank of Japan intervened were special only for yen-dollar, we examine the relationship between exchange rate changes and customer order flow in the euro-dollar market for the 124 intervention days. The euro-dollar market is the most liquid foreign exchange market and is the most heavily traded currency pair in our sample. Intriguingly, we find almost exactly the same results. Days on which the Bank of Japan did not intervene show strong correlations between exchange

[7] We ran the regression using non-intervention days that immediately follow intervention days. This only provides a sample of 28 days but again, the coefficients are close to those for "normal" days, the R^2 is high (0.29) and the p-value low (0.093).

rate changes and order flows, but when intervention occurs in the yen-dollar market, the relationship between order flow and exchange rates in the euro-dollar market (and the yen-dollar market) disappears. Drawing random samples from the full data set using the procedure outlined above suggests that the observed R^2 on intervention days again lies in the left hand tail of the sampled distributions – below the 5th percentile for the full population and below the 2nd percentile for the non-intervention day population. Intervention in one market appears to have also affected the relationship between flows and exchange rate changes in another market.

While RBS is a large bank with a significant presence in the foreign exchange markets, it may be that our findings are specific only to them. Order flow data is particularly difficult to come by and so testing the robustness of our findings is complicated. In particular, we are unable to gain access to a flows data set with a daily frequency. However, we do have access to a weekly foreign exchange order flow data set provided by another large commercial bank with a significant presence in Asia, this time on an anonymous basis. It consists of net order flows from speculative customers of the bank in the yen-dollar market. The flows data have been re-scaled by the source bank such that the coefficients in any regression are meaningless. Nevertheless, the significance of any relationship between flows and exchange rate changes should not be affected by the scaling. A sub-sample of this data has been extracted that matches the RBS sample period, resulting in 207 observations. For this sample, net flows from this bank are again positively correlated with changes in the yen-dollar exchange rate. In a linear regression with robust standard errors, the coefficient on net flows is significant at the 0.084 level. However, in a regression using only those weeks in which the Bank of Japan intervened (42 observations), the marginal significance of the coefficient on net flows is 0.218, a significant decline. Since a week may contain both intervention and non-intervention days, using such low frequency data is not ideal. But this second data set also suggests a drop in the association between customer order flows and exchange rate changes around intervention periods. Furthermore, Girardin and Lyons (2006) also find that the correlation between order flows from Citibank and changes in the yen exchange rate are sensitive to intervention.

As Evans and Lyons (2005) note, interpreting the coefficients in a regression of exchange rate change on order flow from different end-user segments is difficult since it is essentially a misspecified reduced form regression.[8] However, whatever the nature of the relationship between order flow and changes in the exchange rate captured by the regression, it appears that intervention days are significantly different from normal.

Of course, it may not be that intervention itself causes the relationship between spot rate changes and flows to disappear. The possibility remains that there is a missing variable which triggers intervention and is responsible for the correlation breakdown. But if this is correct, it is a variable that must be very highly correlated with the tactical decision to intervene on a day by day basis. The p-value of the joint significance test on those non intervention days that immediately precede or immediately follow an intervention day (a sample of 47 observations) is 0.010. The results suggest that there is no correlation on intervention days but strong correlation on the days adjacent to interventions.[9]

What might explain our findings? Proponents of order flow analysis argue that end-user flows contain information that is dispersed across agents in the economy. Their trading activities reveal this information first to the bank with which they deal and finally to the market as a whole through interbank trading. Only when the market has deciphered the information is it priced into the exchange rate (Evans and Lyons, 2005).

There then appear to be at least three reasons why order flows on certain days might not be related to exchange rate changes:

1. The market is unable to decipher the content of the order flow because of the special factors at play on those days.
2. The special factors at play on those days themselves reveal the information content that order flow would otherwise have imparted.

[8] One source of misspecification is omitted variable bias. The most obvious omitted variable is the order flow from the Bank of Japan, however including the intervention flows makes no difference to any of our results.

[9] Unreported experimentation with the variables suggested by the literature on intervention reaction functions failed to locate anything capable of capturing the tactical decision to intervene (although as expected the policy of intervention appears related to deviations of the spot rate from target levels).

3. Order flow contains no information and the correlation found on "normal" days is not information-related.

Each of these can be used to rationalise our findings of no correlation on intervention days.

Perhaps the single most special factor relating to intervention days is the sheer magnitude of the transactions of the Bank of Japan. In our sample, the average intervention is a net order flow of $2.55 billion. Euromoney (2003) reports that Royal Bank of Scotland's average daily gross customer order flow, aggregating all currencies, was about $2 billion.[10] While foreign exchange volumes have risen substantially since the Euromoney survey, the magnitude of the intervention is clearly very high. Perhaps the magnitude of intervention simply swamped the market's ability to extract information from other customers' orders.

Evans and Lyons (2003) show that the importance of (interbank) order flow and exchange rate changes is higher in periods when new information is released. They argue that this is because the market needs the order flow to interpret properly the price implications of the new information. They contrast this with the macroeconomic view of exchange rates wherein the market instantaneously computes the implications of the new information and marks the price accordingly. Therefore, an alternative explanation for the lack of a relationship between order flow and exchange rate changes on intervention days is that the market did not need the order flow to work out what was happening. Instead market makers observed the news that intervention was happening (but did not tell the newswires) and priced it into the market. This element of news dominated all other news on those days, and therefore end-user order flow was not important.

Finally, some researchers contend that there is no information in order flow. Rather, the correlation between flows and exchange rate changes reflects variations in the liquidity premium charged by participants to absorb the inventory resulting from customer order flows (Breedon and Vitale, 2006). That is, excess buying pressure on the yen is reflected by net order flow into the yen which is accommodated by the yen rising in value. However, on intervention days, when we show higher than usual net order flow into the

[10] This is equivalent to approximately 3% of the total market, giving RBS the twelfth largest market share.

yen, the Bank of Japan is injecting large amounts of yen liquidity and hence the excess demand can be accommodated with minimal change in the value of the yen.

In an attempt to differentiate between these alternative arguments we ran further regressions that allow the coefficient on disaggregated order flows (which for brevity we term "price impact" from now) to differ across alternative dimensions. Two of the three arguments above suggest that the liquidity pumped into the market by the Bank of Japan is behind the lack of price impact on intervention days, either because it swamps the market and obscures the signal in private flows or because it removes the illiquidity premium. For both explanations then we might expect price impact to be detected on smaller scale intervention days, while no impact would be detected on large scale intervention days. We split the full sample into three – days with no intervention, days with low levels of intervention (intervention values less than the median value) and days with high levels of intervention. The coefficients on order flows are jointly insignificantly different from zero on both high and low value intervention days (p-values 0.965 and 0.455, respectively)[11] while coefficients on no intervention days are jointly significantly different from zero (p-value 0.000). The size of intervention does not seem to be important – private order flows lose their association with exchange rate changes irrespective of the scale of intervention.

Second, we split the intervention days according to whether they were detected by newswires. If the signalling explanation for the lack of price impact is correct, such that intervention reveals all the otherwise private information contained in order flow, then order flows on secret intervention days might still have a price impact. However, the p-values of the hypothesis test that price impacts are jointly zero are 0.106 and 0.447 for detected and secret intervention days, respectively.[12]

Finally, we examine whether different intervention styles affect price impact. Price impact coefficients during passive-style phase 1 intervention were jointly insignificant (p-value = 0.104), and they were also insignificant during the more aggressive phase 2 intervention period (p-value = 0.500). Neither the intervention style nor whether the

[11] Intervention day coefficients are also all individually insignificant for both size classes.
[12] Again, coefficients are also individually insignificant.

intervention was detected by newswires appears to matter, simply the fact that the Bank of Japan is intervening is sufficient to remove the relationship between private order flows and the spot rate.

In short, the regressions provide no clear support for any explanation for the correlation breakdown. On-going research examines whether this breakdown is specific to the Japanese interventions or whether it also applies to the actions of other central banks. It is hoped that this work will shed further light on the issue.

IV. Conclusions

Changes in the exchange rate are notoriously hard to explain. Therefore one of the most impressive recent findings in the empirical literature is the high correlation between order flows in the FX market and exchange rate movements. When (some) customers of (some) banks are net buyers of a currency, that currency tends to appreciate.

In this paper we first analyse whether the actions of the Bank of Japan to hold down the value of the yen in recent years affected the behaviour of customers of a major European commercial bank. We find relatively strong evidence that corporate customers tended to change their trading activities as reflected by their net order flows in ways consistent with the likely intentions of the Japanese authorities. That is, other things equal they bought more dollars than usual on days when the Bank of Japan was buying dollars. Financial customers, on the other hand, acted against the central bank, buying more yen on intervention days. The overall impact was for aggregate customer order flows to be into the yen more than expected on intervention days, thereby accommodating the demand for dollars from the Bank of Japan. Regression analysis also indicated that intervention had small but persistent effects on order flows. The overall impact was for customers demand a permanently higher amount of yen following intervention. In this regard, intervention could not be judged as being successful.

The second part of our analysis reveals that the striking correlation between order flows and exchange rate changes essentially disappears on intervention days. Even more intriguing, the relationship between order flows and exchange rate changes in the euro-dollar market also breaks down on days when the Bank of Japan is active in the yen-

dollar market. We have no convincing explanation for this, but whatever the nature of the link between flows and exchange rates, it appears to be very affected by the presence of central banks in the market.

References

Beine, Michel, and Christelle Lecourt (2004) "Reported and Secret Interventions in the Foreign Exchange Market", *Financial Research Letters* 1, 215-225.

Breedon, Francis and Paolo Vitale (2006) "An Empirical Study of Portfolio-Balance and Information Effects of Order Flow on Exchange Rates", *mimeo*.

Chaboud, Alain P., and Owen F. Humpage (2005) "An Assessment of the Impact of Japanese Foreign Exchange Intervention: 1991-2004", *International Finance Discussion Paper No 824*, Board of Governors of the Federal Reserve System.

Dominguez, Kathryn M., (1999) "The Market Microstructure of Central Bank Intervention", *NBER working paper 7337*.

Euromoney (2003) *FX Poll 2003*, www.euromoney.com

Evans, Martin D.D., and Richard Lyons (2002) "Order Flow and Exchange Rate Dynamics", *Journal of Political Economy* 113, 485-517.

Evans, Martin D.D., and Richard Lyons (2003) "How is Macro News Transmitted to Exchange Rates?" *mimeo*.

Evans, Martin D.D., and Richard Lyons (2004) "Exchange Rate Fundamentals and Order Flow", *mimeo.*

Evans, Martin D.D., and Richard Lyons (2005) "Understanding Order Flow", *mimeo*.

Fatum, Rasmus, and Michael M. Hutchinson (2006) "Effectiveness of Official Daily Foreign-Exchange-Market Intervention Operations in Japan", *Journal of International Money and Finance* 25, 199-219.

Froot, Kenneth, and Tarun Ramadorai (2005) "Currency Returns, Institutional Investor Flows, and Exchange Rate Fundamentals", *Journal of Finance* 14, 71-100.

Galati, Gabriele, William Melick and Marian Micu (2005) "Foreign Exchange Market Intervention and Expectations: The Yen/Dollar Exchange Rate", *Journal of International Money and Finance* 24, 982-1011.

Girardin, Eric and Richard Lyons (2006) "Does Intervention Alter Private Behaviour?" *mimeo*.

Hendriksson R.D., and Robert C. Merton (1981) "On Market Timing and Investment Performance II: Statistical Procedures for Evaluating Forecasting Skills", *Journal of Business* 54, 513-533.

Hillebrand, Eric, and Gunther Schnabl (2006) "Japanese Foreign Exchange Intervention and the Yen/Dollar Exchange Rate: A Simultaneous Approach Using Realized Volatility", *mimeo*.

Humpage, Owen F., (1999) "U.S. Intervention: Assessing the Probability of Success", *Journal of Money, Credit and Banking* 31, 731-747.

Humpage, Owen F., (2000) "The United States as an Informed Foreign-Exchange Speculator", *Journal of Financial Markets, Institutions and Money* 10, 287-302.

Hung, J.H., (1997) “Intervention Strategies and Exchange Rate Volatility: A Noise Trading Perspective”, *Journal of International Money and Finance* 16, 779-793.

Ito, Takatoshi (2002) “Is Foreign Exchange Intervention Effective? The Japanese Experiences in the 1990s”, *NBER working paper 8914*.

Ito, Takatoshi (2004) “Intervention and Japanese Economic Recovery”, *mimeo*.

Marsh, Ian W., and Ceire O’Rourke (2005) “Customer Order Flow and Exchange Rate Movements: Is There Really Information Content?” *mimeo*.

Nagayasu, Jun (2004) “The effectiveness of Japanese foreign exchange interventions during 1991–2001” *Economics Letters* 84, 377-381.

Sarno, Lucio, and Mark P. Taylor (2001) “Official Intervention in the Foreign Exchange Market: Is it Effective and, if so, How Does it Work?” *Journal of Economic Literature* 39, 839-868.

Table 1.

Tests of the equality of mean order flows on non-intervention and intervention days. The alternative hypothesis is that the means in the two samples are not equal.

	t-test	p-value
	Gross flows	
Aggregate	6.6919	0.0000
Corp	-3.6813	0.0003
Unl	-0.6755	0.5003
Lev	3.4447	0.0007
Oth	8.1491	0.0000
	Net Flows	
Aggregate	-1.5466	0.1238
Corp	-0.8494	0.3972
Unl	-2.5571	0.0104
Lev	-1.8812	0.0612
Oth	0.1181	0.9061

Table 2.

Success criteria performance, bilateral yen-dollar flows. Population size is 889 and sample size is 124 for each criterion. The first row in each panel gives the number of "successes" according to the nine success criteria. The second row expresses this as a percentage of the sample. The third row gives the unconditional (expected) success rate using the population and the final row gives the probability of observing the given number of successes given the sample size, population size and unconditional success rate using the hypergeometric function. Conditional success rates greater than the unconditional success rate are made bold for ease of identification.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
				Aggregate flows					
Success	51	28	11	20	71	68	62	15	55
Conditional	41.13%	22.58%	8.87%	**16.13%**	57.26%	**54.84%**	50.00%	**12.10%**	44.35%
Unconditional	47.47%	22.72%	11.70%	15.41%	62.88%	50.84%	50.96%	10.80%	50.06%
p-val	0.923	0.464	0.816	0.348	0.902	0.146	0.553	0.250	0.898
				Corporate flows					
Success	62	28	21	13	75	63	62	21	64
Conditional	50.00%	22.58%	**16.94%**	10.48%	60.48%	**50.81%**	**50.00%**	**16.94%**	**51.61%**
Unconditional	50.62%	24.86%	12.26%	10.57%	61.19%	49.49%	49.61%	16.09%	49.16%
p-val	0.521	0.695	**0.036**	0.440	0.532	0.340	0.424	0.335	0.246
				Unleveraged financial flows					
Success	48	27	13	25	73	64	62	20	61
Conditional	38.71%	21.77%	10.48%	**20.16%**	58.87%	**51.61%**	**50.00%**	16.13%	49.19%
Unconditional	47.81%	24.18%	12.49%	13.95%	61.75%	47.92%	49.38%	18.90%	49.61%
p-val	0.982	0.710	0.713	**0.014**	0.731	0.162	0.403	0.763	0.501
				Leveraged financial flows					
Success	53	28	13	23	76	65	61	24	57
Conditional	42.74%	22.58%	10.48%	**18.55%**	61.29%	**52.42%**	49.19%	19.35%	45.97%
Unconditional	52.08%	23.17%	13.95%	12.26%	64.34%	49.49%	49.94%	19.69%	49.83%
p-val	0.984	0.515	0.857	**0.010**	0.725	0.212	0.533	0.484	0.797
				Other financial flows					
Success	54	25	17	18	72	61	59	10	62
Conditional	43.55%	20.16%	**13.71%**	**14.52%**	58.06%	**49.19%**	47.58%	8.06%	50.00%
Unconditional	48.59%	24.52%	12.04%	13.50%	62.09%	49.16%	50.39%	10.35%	50.62%
p-val	0.867	0.866	0.218	0.302	0.815	0.458	0.719	0.766	0.521

Table 3.

Success criteria performance, bilateral yen-dollar flows on secret intervention days. Population size is 889 and sample size is 99 for each criterion. The first row in each panel gives the number of "successes" according to the nine success criteria. The second row expresses this as a percentage of the sample. The third row gives the unconditional (expected) success rate using the population and the final row gives the probability of observing the given number of successes given the sample size, population size and unconditional success rate using the hypergeometric function. Conditional success rates greater than the unconditional success rate are made bold for ease of identification.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
				Aggregate flows					
Success	42	24	9	15	57	54	49	12	46
Conditional	42.42%	**24.24%**	9.09%	15.15%	57.58%	**54.55%**	49.49%	**12.12%**	46.46%
Unconditional	47.47%	22.72%	11.70%	15.41%	62.88%	50.84%	50.96%	10.80%	50.06%
p-val	0.831	0.302	0.749	0.461	0.852	0.194	0.577	0.259	0.741
				Corporate flows					
Success	53	24	18	12	65	53	54	21	54
Conditional	**53.54%**	24.24%	**18.18%**	**12.12%**	**65.66%**	**53.54%**	**54.55%**	**21.21%**	**54.55%**
Unconditional	50.62%	24.86%	12.26%	10.57%	61.19%	49.49%	49.61%	16.09%	49.16%
p-val	0.233	0.504	**0.025**	0.238	0.147	0.179	0.118	0.051	0.099
				Unleveraged financial flows					
Success	42	22	13	16	58	52	46	14	45
Conditional	42.42%	22.22%	**13.13%**	**16.16%**	58.59%	**52.53%**	46.46%	14.14%	45.45%
Unconditional	47.81%	24.18%	12.49%	13.95%	61.75%	47.92%	49.38%	18.90%	49.61%
p-val	0.848	0.637	0.344	0.200	0.723	0.138	0.695	0.876	0.778
				Leveraged financial flows					
Success	47	24	12	15	62	54	46	20	46
Conditional	47.47%	**24.24%**	12.12%	**15.15%**	62.63%	**54.55%**	46.46%	**20.20%**	46.46%
Unconditional	52.08%	23.17%	13.95%	12.26%	64.34%	49.49%	49.94%	19.69%	49.83%
p-val	0.807	0.343	0.647	0.139	0.610	0.128	0.737	0.382	0.728
				Other financial flows					
Success	42	20	14	16	58	49	49	9	50
Conditional	42.42%	20.20%	**14.14%**	**16.16%**	58.59%	**49.49%**	49.49%	9.09%	**50.51%**
Unconditional	48.59%	24.52%	12.04%	13.50%	62.09%	49.16%	50.39%	10.35%	50.62%
p-val	0.885	0.825	0.192	0.162	0.746	0.425	0.537	0.589	0.466

Table 4.

Success criteria performance, bilateral yen-dollar flows on phase 1 intervention days (January 2003 – 20 Sept 2003). Population size is 889 and sample size is 55 for each criterion. The first row in each panel gives the number of "successes" according to the nine success criteria. The second row expresses this as a percentage of the sample. The third row gives the unconditional (expected) success rate using the population and the final row gives the probability of observing the given number of successes given the sample size, population size and unconditional success rate using the hypergeometric function. Conditional success rates greater than the unconditional success rate are made bold for ease of identification.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
				Aggregate flows					
Success	20	11	4	9	29	31	26	5	24
Conditional	36.36%	20.00%	7.27%	**16.36%**	52.73%	**56.36%**	47.27%	9.09%	43.64%
Unconditional	47.47%	22.72%	11.70%	15.41%	62.88%	50.84%	50.96%	10.80%	50.06%
p-val	0.942	0.621	0.795	0.335	0.927	0.166	0.663	0.558	0.800
				Corporate flows					
Success	27	15	7	3	30	24	29	7	26
Conditional	49.09%	**27.27%**	**12.73%**	5.45%	54.55%	43.64%	**52.73%**	12.73%	47.27%
Unconditional	50.62%	24.86%	12.26%	10.57%	61.19%	49.49%	49.61%	16.09%	49.16%
p-val	0.537	0.273	0.359	0.855	0.817	0.776	0.266	0.684	0.557
				Unleveraged financial flows					
Success	16	10	4	16	32	25	31	7	28
Conditional	29.09%	18.18%	7.27%	**29.09%**	58.18%	45.45%	**56.36%**	12.73%	**50.91%**
Unconditional	47.81%	24.18%	12.49%	13.95%	61.75%	47.92%	49.38%	18.90%	49.61%
p-val	0.997	0.818	0.841	**0.000**	0.668	0.593	0.115	0.849	0.365
				Leveraged financial flows					
Success	15	9	4	15	30	23	26	8	20
Conditional	27.27%	16.36%	7.27%	**27.27%**	54.55%	41.82%	47.27%	14.55%	36.36%
Unconditional	52.08%	23.17%	13.95%	12.26%	64.34%	49.49%	49.94%	19.69%	49.83%
p-val	0.999	0.859	0.905	**0.001**	0.921	0.851	0.608	0.789	0.973
				Other financial flows					
Success	24	12	6	6	30	29	23	4	28
Conditional	43.64%	21.82%	10.91%	10.91%	54.55%	**52.73%**	41.82%	7.27%	**50.91%**
Unconditional	48.59%	24.52%	12.04%	13.50%	62.09%	49.16%	50.39%	10.35%	50.62%
p-val	0.733	0.617	0.500	0.612	0.853	0.243	0.880	0.693	0.427

Table 5.

Success criteria performance, bilateral yen-dollar flows on phase 2 intervention days (21 Sept 2003 onwards). Population size is 889 and sample size is 69 for each criterion. The first row in each panel gives the number of "successes" according to the nine success criteria. The second row expresses this as a percentage of the sample. The third row gives the unconditional (expected) success rate using the population and the final row gives the probability of observing the given number of successes given the sample size, population size and unconditional success rate using the hypergeometric function. Conditional success rates greater than the unconditional success rate are made bold for ease of identification.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
				Aggregate flows					
Success	31	17	7	11	42	37	36	10	31
Conditional	44.93%	**24.64%**	10.14%	**15.94%**	60.87%	**53.62%**	**52.17%**	**14.49%**	44.93%
Unconditional	47.47%	22.72%	11.70%	15.41%	62.88%	50.84%	50.96%	10.80%	50.06%
p-val	0.622	0.289	0.572	0.370	0.594	0.276	0.365	0.111	0.776
Corporate flows									
Success	35	13	14	10	45	39	33	14	38
Conditional	**50.72%**	18.84%	**20.29%**	**14.49%**	**65.22%**	**56.52%**	47.83%	**20.29%**	**55.07%**
Unconditional	50.62%	24.86%	12.26%	10.57%	61.19%	49.49%	49.61%	16.09%	49.16%
p-val	0.442	0.856	**0.013**	0.102	0.204	0.095	0.570	0.121	0.121
Unleveraged financial flows									
Success	32	17	9	9	41	39	31	13	33
Conditional	46.38%	**24.64%**	**13.04%**	13.04%	59.42%	**56.52%**	44.93%	18.84%	47.83%
Unconditional	47.81%	24.18%	12.49%	13.95%	61.75%	47.92%	49.38%	18.90%	49.61%
p-val	0.546	0.400	0.353	0.502	0.619	0.052	0.741	0.430	0.570
Leveraged financial flows									
Success	38	19	9	8	46	42	35	16	37
Conditional	**55.07%**	**27.54%**	13.04%	11.59%	**66.67%**	**60.87%**	**50.72%**	**23.19%**	**53.62%**
Unconditional	52.08%	23.17%	13.95%	12.26%	64.34%	49.49%	49.94%	19.69%	49.83%
p-val	0.261	0.150	0.502	0.478	0.297	**0.023**	0.400	0.174	0.219
Other financial flows									
Success	30	13	11	12	42	32	36	6	34
Conditional	43.48%	18.84%	**15.94%**	**17.39%**	60.87%	46.38%	**52.17%**	8.70%	49.28%
Unconditional	48.59%	24.52%	12.04%	13.50%	62.09%	49.16%	50.39%	10.35%	50.62%
p-val	0.777	0.841	0.109	0.122	0.541	0.637	0.336	0.586	0.542

Table 6.

Results of the linear regression of the net order flow from each end-user category on determinants described in the text. Robust *t*-statistics are reported in parentheses below coefficient estimates. Coefficients significant at the five percent level are marked with *, and coefficients significant at the one percent level with **. The p-values at the bottom of the table give the probability values of the test of joint significance of all regressors ("joint p-val") and the intervention-related regressors ("intervention p-val").

	Aggregate	Corp	Unl	Lev	Oth
OF_{t-1}	0.072	0.058	0.012	-0.020	0.045
	(1.68)	(1.11)	(0.35)	(0.56)	(1.08)
OF_{t-2}	0.040	0.003	0.047	0.007	0.031
	(1.10)	(0.08)	(1.34)	(0.16)	(0.79)
OF_{t-3}	-0.043	0.026	0.059	-0.058	-0.041
	(1.18)	(0.73)	(1.83)	(1.49)	(1.07)
ΣOF_{t-1}	-0.037**	-0.038**	-0.046**	-0.017*	-0.026**
	(4.10)	(4.23)	(4.93)	(2.17)	(3.09)
Δs_{t-1}	3076.855*	-391.471	828.268**	282.012	2828.850*
	(2.20)	(0.93)	(2.78)	(0.82)	(2.25)
s_{t-1}	-792.173	1084.145**	-621.169**	-696.858**	-681.967
	(1.13)	(3.32)	(3.88)	(4.58)	(1.17)
$(i\text{-}i^{*})_{t-1}$	-66.207	13.104	-11.940	9.753	-64.761*
	(1.45)	(0.86)	(0.81)	(1.11)	(2.10)
$Intval_t$	-0.083	-0.068	-0.032	-0.026**	0.044
	(1.79)	(1.20)	(1.48)	(3.18)	(0.63)
$\Sigma Intval_t$	-0.006*	0.003*	-0.003**	-0.002**	-0.004*
	(2.32)	(2.46)	(4.45)	(3.48)	(1.98)
$DayGap_t$	0.025	0.093	0.176	0.053	-0.154
	(0.08)	(0.77)	(1.54)	(0.85)	(0.75)
$LevelGap_t$	22.904**	-10.487**	11.922**	8.670**	14.013*
	(2.91)	(3.19)	(5.61)	(4.36)	(2.02)
$Distance_t$	-0.004	0.001	-0.016**	-0.007	0.007
	(0.27)	(0.30)	(4.24)	(1.58)	(0.57)
R^2	0.070	0.063	0.097	0.031	0.052
Joint p-val	0.000	0.000	0.000	0.000	0.003
Intervention p-val	0.019	0.004	0.000	0.000	0.088

Table 7.

Each panel reports the results of a linear regression of the daily change in the log of the spot yen-dollar exchange rate on net order flow from each end-user category first aggregated, then singly and finally jointly. Robust standard errors are reported in parentheses below coefficient estimates. The top panel uses the full 889 day sample, the middle panel uses just the non-intervention day sample (765 observations), and the bottom panel uses just the 124 days on which the Bank of Japan intervened in the market. The column headed p-value gives the probability value of the test of (joint) significance of the regressor(s).

	Aggregate	Corp	Unl	Lev	Oth	R^2	p-value
Full sample	0.00498					0.0325	0.000
	(4.77)						
		-0.00879				0.0119	0.004
		(2.88)					
			0.01653			0.0231	0.000
			(4.39)				
				0.00758		0.0063	0.013
				(2.50)			
					0.00584	0.0330	0.000
					(4.86)		
		-0.00821	0.01588	0.00664	0.00545	0.0697	0.000
		(2.60)	(4.47)	(2.22)	(4.54)		
Non-intervention days only	0.00554					0.0396	0.000
	(5.14)						
		-0.01074				0.0128	0.005
		(2.83)					
			0.02123			0.0346	0.000
			(5.38)				
				0.00778		0.0070	0.013
				(2.50)			
					0.00614	0.0356	0.000
					(4.89)		
		-0.01054	0.01979	0.00705	0.00578	0.0847	0.000
		(2.85)	(5.32)	(2.27)	(4.71)		
Intervention days only	0.0007					0.0008	0.864
	(0.17)						
		-0.00556				0.0159	0.225
		(1.22)					
			-0.00520			0.0038	0.449
			(0.76)				
				0.00255		0.0004	0.858
				(0.18)			
					0.00383	0.0174	0.364
					(0.91)		
		-0.00411	-0.00392	0.00211	0.00301	0.0286	0.666
		(0.77)	(0.56)	(0.15)	(0.64)		

Figure 1

Spot exchange rates and Japanese intervention, August 2002 to June 2004. Vertical bars denote days on which Bank of Japan conducted intervention in either the dollar-yen or euro-yen market. Vertical dotted lines denote key event dates. The exchange rate plotted is the intraday low of the yen-dollar exchange rate.