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**A CRITICAL APPRAISAL OF RECENT  
DEVELOPMENTS IN THE ANALYSIS  
OF FOREIGN EXCHANGE  
INTERVENTION**

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***INTERNATIONAL MACROECONOMICS***



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# A CRITICAL APPRAISAL OF RECENT DEVELOPMENTS IN THE ANALYSIS OF FOREIGN EXCHANGE INTERVENTION

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## **ABSTRACT**

### **A Critical Appraisal of Recent Developments in the Analysis of Foreign Exchange Intervention\***

We offer a critical review of recent developments in the study of foreign exchange intervention. In particular, we discuss some unresolved issues, such as the secrecy puzzle, the relevance of the signalling and portfolio-balance effect hypotheses, the identification of the impact of foreign exchange intervention on currency values. We suggest that: i) the unresolved nature of these issues is partly due to the absence of a market microstructure perspective in most of the existing analysis of foreign exchange intervention; and ii) that recent promising advances in this strand of research have not fully exploited the potential of such perspective.

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Keywords: exchange rate dynamics, foreign exchange micro structure and official intervention

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# 1 Introduction

*Foreign exchange (FX) intervention* denotes the trading activity of central banks which purchase and sell foreign currencies in spot FX markets with the intention of conditioning currency values. FX intervention activity is typically *sterilized*, in that when central banks buy and sell currencies the consequent change in the money supply is usually *offset* through an immediate open market operation. In effect, FX intervention represents an independent instrument of policy-making as long as it does not change the money supply, since otherwise it would be a different and less convenient way of implementing the monetary policy.

In the past twenty years a vast body of empirical research has sought to analyze the impact of FX intervention on currency values and on FX market conditions.<sup>1</sup> Whereas it is difficult to sum up in a nutshell the results of numerous contributions, we can confidently claim that little consensus has been reached among researchers on the effectiveness of FX intervention. Such lack of consensus is reflected in the opinion of practitioners and central bankers. Thus, in a survey by Neely (2000) most central bankers agreed with the thesis that FX intervention has an impact on FX markets, but could not agree on what it can achieve. In particular, 47 percent of the respondents claimed that FX intervention is aimed at resisting short term trends, 22 percent suggested that its main goal is to eliminate misalignments from fundamental values, while the rest indicated different, unspecified reasons for intervention.

At best partial agreement has been reached among researchers on few aspects of FX intervention. Indeed, some empirical evidence substantiates the theses that: i) FX intervention operations have at least a short-term impact on currency levels and on exchange rate volatility; ii) intervention operations which are coordinated among several central banks present a larger impact on currency values; and iii) the impact of *reported* FX intervention is larger than that of *secret* FX intervention. However, whether FX intervention is profitable or not, whether it is more effective when it tries to resist current trends or to sustain them, whether FX intervention actually increases or reduces exchange rate volatility, whether it signals future monetary policy and presents an informative content, whether it possesses a long-lasting impact on currency values, remain all unresolved issues.

Contributory factors to the unresolved nature of these issues are: i) a lack of adequate data on central bank intervention transactions; ii) the absence of a clear theoretical underpinning of

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<sup>1</sup>Edison (1993), Baillie, Humpage, and Osterberg (2000), Sarno and Taylor (2001) and Neely (2005) offer detailed accounts of this literature.

the link between FX intervention, currency values and market conditions; and iii) the reliance on non-structural analyses of the relation between currency values and FX intervention. Indeed, as pointed out elsewhere,<sup>2</sup> most empirical studies employ data sets in which intervention operations are aggregated to daily or lower frequencies and where no structural relation is employed to identify the effects of FX intervention on exchange rate dynamics. Within this context it is impossible to avoid simultaneity issues and identify properly the impact of FX intervention.

However, recently two new venues of research have been pursued in an attempt to shed more lights on the effectiveness of FX intervention. Thus, several researchers have turned their attention to high frequency data-sets, undertaking micro-structural investigations of the effects of FX intervention on exchange rates; whereas others have attempted to formulate and then estimate fully identified models of FX intervention and exchange rate dynamics. We believe that both venues of research have so far offered promising results. Though such results pertain only to very specific data-sets and countries.

Moreover, while none of the existing high frequency studies of FX intervention relies on proper structural models, all structural models of FX intervention contain no market microstructure component. This is quite extraordinary, given that the most popular explanation of the impact of FX intervention on currency values derives from market microstructure theory. We argue that it is exactly in the interplay between studies of FX intervention and market microstructure models of exchange rate determination which lie the most promising developments of this strand of international finance research.

Thus, in this article we briefly present (Section 2) the two main alternative theoretical explanations of the impact of FX intervention on currency values, discussing (Section 3) some empirical studies which have attempted to verify the informational role of FX intervention. We also comment on some apparently puzzles pertaining to exchange rate volatility and to the secrecy of intervention (Section 4) and on some recent developments in the empirical analysis of FX intervention (Section 5). Finally, we discuss further developments we should expect from this strand of research with a particular attention for the market microstructure approach to exchange rates (Section 6).

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<sup>2</sup>See Neely (2005).

## 2 Signalling versus Portfolio-Balance Effects

Theoretically it can be established that FX intervention may alter currency values via two distinct channels of transmission. Thus, according to the *portfolio-balance effect* hypothesis domestic and foreign assets are imperfect substitutes, since investors have a preference for assets denominated in their own currency. Therefore, under this hypothesis, a purchase (sale) of foreign currencies by a central bank, which reduces (augments) the ratio between domestic and foreign assets held by the private sector, induces a depreciation (appreciation) of the national currency, in that investors require a greater risk-premium to hold a larger quantity of this currency.

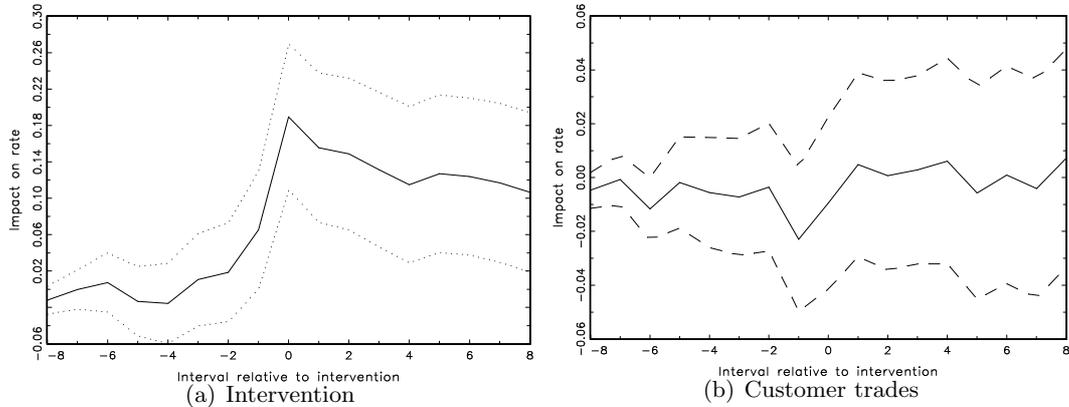
An alternative channel through which FX intervention may alter exchange rates has been popularized by Mussa (1981). According to his *signalling* hypothesis operations in FX markets by a central bank may signal changes in future monetary policy. Sales (purchases) of foreign exchange should signal a forthcoming monetary contraction (expansion) more effectively than a simple announcement, because the central bank stakes its own capital in support of the future policy and hence “buys credibility”. In fact, when a sale of foreign assets is followed by a monetary expansion, that forces a devaluation of the domestic currency, the central bank incurs in a net loss. Consequently, FX intervention affects market expectations on currency fundamentals and hence alters exchange rates.

During the last twenty years numerous empirical studies have sought to establish whether sterilized purchases and sales of foreign currencies by central banks influence exchange rates and whether this is the consequence of the portfolio-balance effect or of the information content of FX intervention. Starting with the seminal work of Dominguez and Frankel (1993b) several studies, among which Klein and Rosengren (1991), Watanabe (1992), Catte, Galli, and Rebecchini (1994), Ito (2002), Fatum and Hutchison (2003), Chaboud and Humpage (2005), Kearns and Rigobon (2005), have found that FX intervention does affect currency values. However, what explains its impact on exchange rates remains unclear.

### 2.1 The portfolio-balance effect hypothesis

Early studies, such as Frankel (1982), Frankel and Engle (1984), Jurgensen (1983), Loopesko (1984), Neumann (1984) and Rogoff (1984), concentrated on the portfolio-balance effect hypothesis. Their results indicated that either domestic and foreign assets are perfect substitutes

Figure 1: Basic effects of intervention and customer trades on the USD/CHF



**Notes:** Results are based on exchange rates and intervention events defined using a 15 minutes sampling frequency. Time is measured in 15 minute intervals relative to intervention. The dashed lines indicate the 95% confidence interval for the cumulative intervention effect.

or that at most the effect of FX intervention on risk-premia is minuscule. Other studies based on more recent and accurate data, notably Dominguez and Frankel (1993a) and Gosh (1992), concluded that FX intervention presents a *significant* short-term impact on risk-premia.

The small scale dimension of FX intervention relatively to the large volume of transactions in FX markets and the huge value of the stocks of international assets has in any case induced researchers in the 1990s to shift their attention to the signalling hypothesis. Indeed, even taking for granted the portfolio-balance effect, the limited dimension of FX intervention suggests that the signalling role of FX intervention is potentially more important. In other words, one might believe that FX intervention represents an effective instrument of policy-making insofar it influences currency values via its information content.

Payne and Vitale (2003) lends some support to this thesis, as they investigate data on the intervention operations of the Swiss National Bank (SNB) in the spot USD/CHF market between 1986 and 1995 and conduct an event study of the effects of FX intervention on exchange rates at high frequency. Crucially their data-set consists of all *customer* and *intervention* operations conducted by the SNB. The distinction between *customer* and *intervention* operations is fundamental, in that while the former are triggered by the need of the Swiss government for foreign currency, the latter are aimed at influencing the value of the Swiss franc.

In Figure 1 the cumulative impact on the USD/CHF rate of a purchase of US dollars on the part of the SNB is plotted. This purchase can be either on behalf of the Swiss government (right panel) or of its own initiative (left panel). We see that interventions appear to have a *significant* impact on exchange rate levels. Customer trades do not alter exchange rates, as at no point is the cumulative effect of a customer trade on the USD/CHF rate significantly different from zero. These results are clearly incompatible with the portfolio-balance effect hypothesis, as one should not see any significant difference between the two types of trades. On the contrary, assuming that only intervention operations carries information, Payne and Vitale's results may be consistent with the signalling hypothesis.

While the conclusions one derives from Figure 1 are quite stark, one should not necessarily write off the portfolio-balance effect. Indeed, the very recent experience of the intervention activity of the Bank of Japan (BoJ), and of other central banks in East Asia, should actually revamp the interest among researchers for the portfolio-balance effect. In fact, it might well be possible that the extremely large dimension of purchases of US dollars on the part of these central banks in the last few years has had a significant impact on risk-premia.<sup>3</sup> In this respect, it is quite surprising that no attempt to exploit these showcases to investigate the portfolio-balance effect has been made.

### 3 The Signalling Hypothesis

The first important empirical investigation which has given credit to the signalling hypothesis has been conducted by Dominguez and Frankel (1993c). In their study they investigate the impact of Fed and Bundesbank's FX intervention on market expectations of future exchange rates. Coherently with Mussa's hypothesis, purchases (sales) of US dollars on the part of the Fed should indicate an impending monetary contraction (easing), which should lead to an appreciation of the US currency. Purchases (sales) of US dollars on the part of the Bundesbank should have a similar effect, as they should signal a monetary expansion (contraction) in Germany. Hence, the impact of the intervention operations of these two central banks on the market expectations of future values of the USD/DEM rate should be clear: when the Bundesbank or the Fed purchases (sells) the US dollar market participants should expect an appreciation (depreciation) of the US currency.

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<sup>3</sup>Data released by the Japanese Minister of Finance indicate that between mid 1993 and early 2004 the BoJ has purchased more than \$500 billions. Similarly, official statistics indicate that the central banks of China, South Korea, Malaysia and Singapore have also accumulated several hundred billions of the US currency.

To test such an hypothesis Dominguez and Frankel employ Money Market Services' survey data on four-week-ahead market participants' forecasts of the USD/DEM rate and daily observations of the Fed and Bundesbank interventions in the USD/DEM market over the period October 1984 to December 1988. They run simple linear regressions of the innovation in the market participants' forecasts of future exchange rates over signed intervention indicators. Such indicators distinguish between interventions which were reported by the press and those which were unreported.

Interestingly, only the reported interventions appear to have a significant impact on exchange rate forecasts, with a sign compatible with Mussa's signalling hypothesis. The two authors suggest that such a finding is further evidence in favor of the signalling hypothesis, because only when market participants can observe FX intervention this can affect their expectations and currency values.<sup>4</sup>

Other tests of the signalling hypothesis have not followed Dominguez and Frankel's route of investigating the impact of FX intervention on market participants' forecasts. This is because it is difficult to obtain reliable survey data on market forecasts of future exchange rates. Researchers have hence pursued alternative directions of investigation, studying: i) the link between FX intervention and exchange rate fundamentals; ii) the profitability of FX intervention; iii) the probability of its success; and its impact on exchange rate volatility.

### **3.1 Exchange rate fundamentals and FX intervention**

A possible way to test the signalling hypothesis is that of analyzing its information content. More precisely, researchers have sought to establish whether FX intervention anticipates exchange rate fundamentals. Several difficulties emerge with this sort of studies. In fact, it is difficult to list precisely which macroeconomic aggregates represent exchange rate fundamentals, nor is it clear in which direction shifts in these fundamentals should move exchange rates. Furthermore, even if exchange rate fundamentals can be identified, often they can only be observed at relatively low frequency (monthly or quarterly). This represents a strong impediment to an econometric analysis of their link with FX intervention, which is instead typically observed at higher frequency and over short intervals of time.

In practice, most of the studies which have investigated the information content of FX intervention, notably Klein and Rosengren (1991), Watanabe (1992), Lewis (1995), Kamin-

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<sup>4</sup>We discuss in detail in Section 4 the issue of the secrecy of intervention.

sky and Lewis (1996), Bonser-Neal, Roley, and Sellon (1998), Fatum and Hutchinson (1999, 2003) and Sapp (2003), have concentrated on the analysis of the interdependence between FX intervention and monetary policy variables, such as short term interest rates and monetary aggregates.

In particular, Lewis (1995) examines the relation between US monetary policy variables, such as the monetary base, non-borrowed reserves, M1 and the Fed funds rate, and the intervention activity of the Fed over the period between 1985 and 1990. She runs Granger-causality tests of FX intervention upon monetary policy variables.

Over weekly and bi-weekly horizons her Granger-causality tests strongly reject the hypothesis that FX intervention does not help predicting future monetary policy variables.<sup>5</sup> However, while these results are clearly compatible with the signalling hypothesis, delays in the sterilization of the Fed operations may also explain why its intervention activity Granger causes monetary policy variables. In this respect, it is reassuring that Lewis still finds that FX intervention helps predicting future monetary policy when lags of the intervention variable are employed in the Granger-causality tests.<sup>6</sup>

In a follow-up study Kaminsky and Lewis (1996) employ the same data-set to estimate a regime-switching model for the US monetary policy and to check whether the Fed intervention activity in FX markets conveys any signal on its future monetary policy. According to their model the US monetary policy switched between a contractionary and an expansionary regime during the 1980s. Then, Kaminsky and Lewis examine whether Fed intervention activity provided signals on its future monetary policy, i.e. whether lagged FX intervention helped predicting the prevailing monetary regime and whether the sign of the intervention operations was coherent with the monetary policy stance.

Once more Kaminsky and Lewis strongly reject the hypothesis that FX intervention does not convey any information on future monetary policy, comforting the signalling hypothesis.<sup>7</sup> On the other hand, their results are puzzling, as they find that over prolonged intervals of time FX intervention systematically delivered the wrong signal on the prevailing monetary policy regime.

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<sup>5</sup>Interestingly, the opposite causality seems to hold as well. In fact, Lewis finds that over the bi-weekly horizon monetary policy variables helps predicting FX intervention.

<sup>6</sup>Notice also that she checks that monetary aggregates condition exchange rate levels, in this way confirming that FX intervention contains fundamental information on currency values.

<sup>7</sup>More precisely they strongly reject the hypothesis that FX intervention switches randomly between the *correct signal mode* and the *wrong signal mode* one.

Indeed, at times in the late 1980s the US monetary policy and Fed intervention activity seemed to point in opposite directions. For instance, starting in mid 1988 and continuing well into 1989 the Fed systematically sold US dollars in FX markets, whereas its monetary policy remained relatively tight. Minutes of the FOMC meetings indicate that governors were well aware of such inconsistency.

Interestingly, however, Kaminsky and Lewis's analysis of the reaction of exchange rates to FX intervention suggests that market participants were able to interpret ambiguous signals provided by the US monetary authorities in the FX markets. They find, in fact, that when FX intervention was of the *wrong signal* type, then exchange rates moved in the opposite direction to that indicated by the intervention operation. On the contrary, when FX intervention was followed by consistent movements in monetary policy variables, ie. when it was of the *correct signal* type, exchange rates tended to move in the direction indicated by the intervention operation.

The results of other more recent studies, such as Bonser-Neal, Roley, and Sellon (1998), Fatum and Hutchinson (1999, 2003) and Sapp (2003), which have extended Kaminsky and Lewis' analysis considering different, and usually longer, data-sets, are not univocal. Depending on the set of monetary policy variables, the period and the econometric technique employed, these studies propose different conclusions on the ability of FX intervention to anticipate shifts in monetary policy.

This indicates that it cannot be legitimately claimed that these studies have reached some common ground on the information content of FX intervention. In addition, one should also outline a fundamental limit of most of these studies. They in fact investigate whether FX intervention anticipates future monetary policy. However, according to the efficient markets hypothesis, what one should investigate is whether FX intervention contains information on the *unexpected* component of the monetary policy variables. Only in this case FX intervention would possess a genuine signalling role.

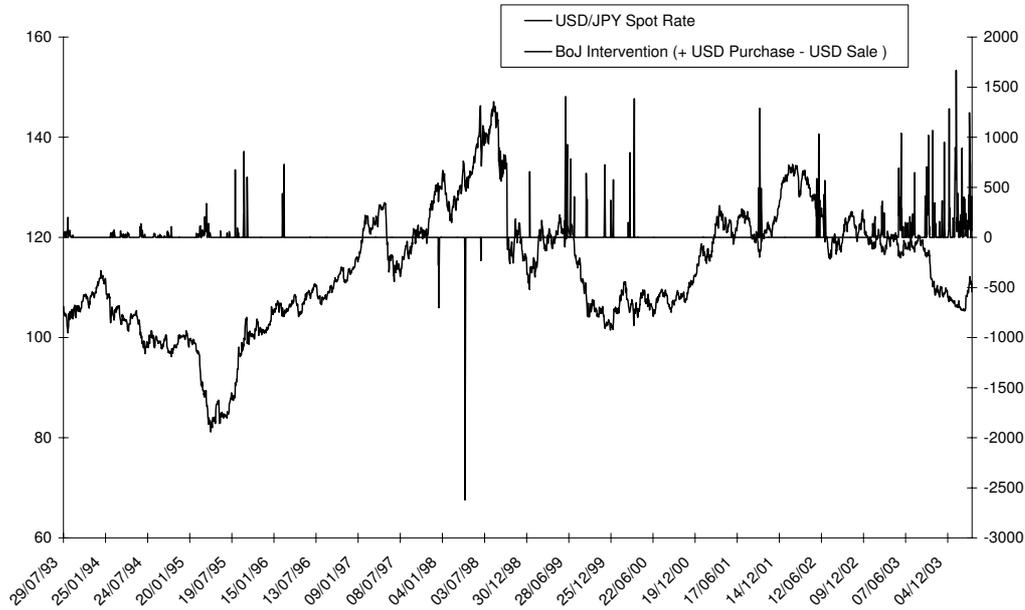
### **3.2 The profitability of FX intervention and of technical analysis**

Leahy (1995), Sweeney (2000) Sjöo and Sweeney (2000), Ito (2002) and Saache (2002) have followed an alternative route to investigate the signalling hypothesis.<sup>8</sup> They have examined whether FX intervention generates systematic profits for central banks. Such an analysis offers

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<sup>8</sup>See Sweeney (1997) for a detailed presentation of these studies on the profitability of FX intervention.

Figure 2: Bank of Japan FX Intervention and USD/JPY Rate



**Notes:** Daily observations of the USD/JPY rate, left scale, and BoJ intervention operations in the USD/JPY market (in millions of USD), right scale, for the period 27/07/93 – 16/03/04.

a less stringent way to test the signalling hypothesis. In fact, one does not need to identify exchange rate fundamentals, nor is it required to specify in which directions shifts in these variables should move currency values. On the other hand, verifying whether central banks make *excessive* profits can indicate whether they exploit their informational advantage, that is whether their intervention operations reflect their superior information and hence whether FX intervention presents an informational content.

Typically, these studies find that central banks gain large profits from their intervention activity in FX markets. Thus, Leahy (1995), using daily data on the Fed trading activity between March 1973 and December 1992 in the USD/DEM and USD/JPY markets, estimates in \$16.5 billions the cumulative profits gained from FX intervention by the Fed during this period. Similarly, Saacke (2002) extends Leahy’s results considering a longer period and the activity of both the Fed and the Bundesbank. He estimates in respectively \$14.8 and \$38.5 billions the cumulative profits the two central banks have earned in the FX markets between January 1979 and July 1994.

While such results are quite striking, two important points deserve some consideration. On the one hand, the profits central banks obtain from trading foreign currencies may derive from the income foreign assets generate. In other words, one needs to check whether central banks earn excessive profits on their FX intervention activity.

Thus, Sweeney (2000) calculates several measures of risk-adjusted profits for the intervention activity of the Fed in the USD/JPY and USD/DEM markets in the years between January 1985 and December 1991. He concludes that irrespective of the method employed to calculate risk-premia, the Fed gained significantly positive excess returns from its intervention activity. A similar conclusion is drawn by Söo and Sweeney (2000), which consider the intervention activity of the Sverige Riskbank in the USD/SEK market.

On the other hand, the excessive profits gained by central banks may not be the consequence of their superior information, but rather of the excessive volatility of FX markets. Thus, Ito (2002) calculates the cumulative profits earned by the BoJ in the ten years between April 1991 and March 2001. These amount to ¥8.6 trillions, i.e roughly \$75 billions. Ito interprets his result as indicating that during this decade the BoJ bought (sold) the US dollar when the US currency was undervalued (overvalued), operating *de facto* as a stabilizing speculator. Figure 2, which represents the USD/JPY rate alongside the amount of US dollars bought and sold by the BoJ in the period between July 1993 and March 2004, comforts Ito's interpretation.

A counterargument in defence of the signalling hypothesis relies on the profitability of technical trading rules around periods of FX intervention. In fact, when a central bank purchases (sells) a foreign currency to provide market participants with a signal on exchange rate fundamentals, it can generate serial correlation in exchange rate returns, which technical trading rules may pick up and exploit.<sup>9</sup>

Thus, Szakmary and Mathur (1997) investigate the monthly returns generated by moving average trading rules in various markets, comprising the USD/DEM, USD/JPY, GBP/USD, USD/CHF and USD/CAD markets between January 1978 and June 1991 and find that these returns are correlated with changes in the official reserves of the respective central banks. LeBaron (1999) and Saacke (2002) instead analyze the daily returns generated by technical trading rules.

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<sup>9</sup>Vitale (1997) shows, within a multi-period micro-structure model of the FX market, that the intervention operations of a superiorly informed central bank generate exchange rate returns which are *ex-post* serially correlated. Vitale (2000) shows how uninformed traders can exploit such serial correlation to gain speculative profits.

LeBaron employs data from January 1979 to December 1992 and investigates the significance of returns generated by a simple moving average trading rule in the USD/JPY and USD/DEM markets. LeBaron shows that this trading rule gains significantly positive profits, but that when days of Fed intervention are removed such profitability disappears. Saacke extends LeBaron's analysis, considering Bundesbank FX intervention as well and investigating the profitability of a wider range of technical trading rules in the USD/DEM market between January 1979 and June 1995.

An important result of LeBaron and Saacke's analysis is that technical trading rules generate excessive profits on the days that *precede* FX intervention,<sup>10</sup> so that it can be argued that the logical causality between FX intervention and technical trading profitability must be reversed: it is not the case that FX intervention brings about predictable patterns in exchange rate returns, from which technical trading rules profit; on the contrary, it is the case that sustained trends in currency values bring about technical trading profitability and induce central banks to intervene in FX markets.

Such thesis is reinforced by Neely (2002), who conducts a high frequency study of technical trading rule profitability in correspondence of FX intervention in several countries, including Australia, Germany, Switzerland and the US. More precisely, he investigates daily returns obtained from LeBaron's moving average trading rule in the USD/DEM, USD/JPY, USD/CHF and USD/AUS markets. Neely replicates LeBaron's analysis, but employs several observations per day for the four exchange rates he investigates. This allows him to calculate the excess returns generated by LeBaron's trading rule in the hours around FX intervention.

Neely finds that, with the exception of Australian intervention, most of the profitability of LeBaron's trading rule materializes in the hours which precede intervention activity. While fairly intriguing, Neely's results must be taken with a word of caution, as he does not have access to data on the precise timing of FX intervention. The recent availability of transaction data on the intervention operations of the Swiss National Bank (SNB) in the USD/CHF market should allow to shed more light on this issue.

### 3.3 The success of FX intervention

Another route followed by several researchers to assess whether FX intervention presents an information content is that of evaluating the probability of its *success*. The basic argument

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<sup>10</sup>Neely and Weller (2001) obtain a similar conclusion from trading rules generated by genetic algorithms.

behind this type of studies is that if central banks are informed traders on average their intervention operations should be in line with future changes in currency values, so that FX intervention should on average be successful in moving exchange rates in the desired direction.

Humpage (1999, 2000), Fatum and Hutchison (2003) and Chaboud and Humpage (2005) have all tried to assess the probability of success of the intervention activity of the Fed and the BoJ in FX markets. Success of intervention is anyhow an ambiguous concept, so that many different methods can be used to assess it.<sup>11</sup> It is therefore not surprising that on balance these studies do not provide clear-cut results on the successfulness of FX intervention.

Thus, Humpage (1999) analyzes the intervention activity of the Fed between February 1987 and February 1990 and argues that such activity had limited success in altering the USD/DEM and USD/JPY rates, except under a weak smoothing criterion. In his follow-up study, which extends his analysis to five different intervals of time between September 1985 and March 1997, Humpage obtains similar conclusions, but also argues that the probability of success increases during periods of acute uncertainty in the market place over future monetary policy.

Fatum and Hutchison (2003), focusing on the activity of both the Fed and the Bundesbank in the USD/DEM market between 1985 and 1995, obtain fairly different conclusions, as they provide evidence that the *post*-intervention distribution of the innovation in the USD/DEM rate was significantly different from the *pre*-intervention one. Finally, Chaboud and Humpage (2005), analyzing the intervention activity of the BoJ in the USD/JPY market between March 1991 and December 2002, also provide mixed results, as they conclude that depending on the style of intervention this was more or less successful in altering the course of the USD/JPY rate.

### 3.4 FX intervention and exchange rate volatility

A large part of the empirical literature on the effects of FX intervention has sought to establish its impact on exchange rate volatility. Such an analysis may be relevant for the signalling hypothesis, in that it could be argued that any information on future monetary policy FX intervention releases should reduce market uncertainty and exchange rate volatility.

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<sup>11</sup>Typically these studies define an *ad hoc* success criterion, which then they try to verify with some non-parametric methodology. While there are plentiful success criterions, they usually fall under two broad categories: on the one hand, according to the *direction criterion* FX intervention is successful if after a central bank purchases (sells) a foreign currency this appreciates (depreciates) during a reference period; on the other hand, according to the *smoothing criterion* FX intervention is successful if it manages to resist the current trend.

Unfortunately, very little consensus has been reached on the impact of FX intervention on the second moment of the exchange rate innovation. Thus, depending on the currency pair employed, the central bank whose FX intervention is analyzed, the frequency of the observations and the volatility model estimated completely different results are reached. We do not attempt here to mention all the studies of the effects of FX intervention on exchange rate volatility.<sup>12</sup> But we can legitimately claim that no consensus on the thesis that FX intervention reduces exchange rate volatility has so far been reached. On the contrary, on balance this literature offers more support to the thesis that FX intervention actually augments exchange rate volatility, particularly over shorter horizons.<sup>13</sup>

Notice that an increase in exchange rate volatility associated with FX intervention contradicts both the thesis that: i) FX intervention is useful in calming disordered markets; and ii) that FX intervention reduces market uncertainty on future exchange rates, as it signals future monetary policy. On the second point some words of caution must anyhow be spent.

In fact, FX intervention may increase exchange rate volatility via an adverse selection mechanism: in the face of informed orders from a central bank FX dealers widen their bid-ask spreads to cover their adverse selection costs and hence increase exchange rate volatility in the aftermath of an intervention operation, even if this carries information. In this respect moves the empirical evidence provided by Naranjo and Nimalendran (2000) on the positive impact on quoted spreads in the USD/DEM market of the unexpected interventions of the Fed and the Bundesbank in the period between January 1976 and December 1994.

In addition, when FX intervention presents an information content not necessarily this reduces market uncertainty on future exchange rates. In particular, consider a very simple model of exchange rate determination, where a risk-neutral FX dealer fixes the bid and ask prices for a foreign currency according to a semi-strong form efficiency condition. This means that in equilibrium the spot rate at which the foreign currency is traded corresponds to the conditional expectation of the fundamental value of the foreign currency,  $\tilde{f}$ . Hence, assume that unconditionally  $\tilde{f}$  can be either 1 or zero with respectively probability  $p$  and  $1 - p$  and that the FX dealer receives a market order from a central bank with probability  $\alpha$  and from an uninformed trader with probability  $1 - \alpha$ . Such an uninformed trader buys and sells the foreign currency with the same probability,  $1/2$ . On the contrary, the central bank knows  $\tilde{f}$  and trades accordingly, so that it buys if  $\tilde{f} = 1$  and sells otherwise.

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<sup>12</sup>See Baillie, Humpage, and Osterberg (2000) for a presentation of some of these contributions.

<sup>13</sup>See Dominguez (2005).

Finally, suppose that the dealer cannot discern the identity of her clients, that  $p = 1/4$ ,  $\alpha = 1/10$ . If the central bank submits a buy order, one can show that the volatility of  $\tilde{f}$  conditional on the information the FX dealer extracts from this order is *larger* than the unconditional one, so that FX intervention actually increases market uncertainty, even if it provides the correct signal on the fundamental value of the foreign currency. Indeed, one can show that it would actually take several consecutive buy orders by the central bank to obtain a reduction in market uncertainty.

## 4 The Secrecy Puzzle

The practice of intervention in FX markets of most central banks has been that of *not* publicly announcing the direction and size of their intervention operations. Whereas several explanations for the secrecy of FX intervention have been put forward,<sup>14</sup> this practice seems incompatible with the signalling hypothesis, in that it has been argued that only visible intervention activity can convey a meaningful signal on future values of exchange rate fundamentals.

On the other hand, very often when central banks trade in FX markets their presence is reported by newswire services and by financial newspapers. As shown by Klein (1993), who analyzes the reports by the financial press of the intervention operations of the Fed between January 1985 and December 1989, these reports are fairly accurate, in that they usually indicate the correct direction of intervention when central banks trade foreign currencies. However, these reports are much less precise in indicating the size of the intervention activity.

In fact, when central banks choose to intervene in FX markets they typically contact several FX dealers and place a number of small orders. In these instances the central banks' trading desks would mention that the individual orders are part of an intervention operation.<sup>15</sup> News of the operation would then be disseminated through the inter-dealer market before reaching the financial press.

In sum, partial transparency on FX intervention exists in FX markets, in that central banks do not announce the direction, size and objective of their intervention operations, but rather leave market participants to learn them via the trading process. Bhattacharya and

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<sup>14</sup>See Dominguez and Frankel (1993b) and Beine and Bernal (2005).

<sup>15</sup>The increasing relevance of centralized electronic limit order platforms, such as EBS and Reuters Dealing System 2000-2, in FX markets has recently slightly modified the practice of FX intervention. Thus, in the last instance in which the Fed intervened, in September 2000, it decided to conduct half of its intervention operation via EBS and the rest through the more traditional route.

Weller (1997) and Vitale (1999) provide theoretical explanations of way this strategy may be optimal.<sup>16</sup>

Both contributions formulate a microstructure model of the market for a foreign currency, where the monetary authorities exploit the signalling role of their intervention operations. However, the interpretation of the signalling role of FX intervention these researchers propose differs from Mussa's. In fact, while according to Mussa FX intervention should be aimed at revealing impending changes in the monetary policy, Bhattacharya and Weller and Vitale argue that its objectives might be incoherent with exchange rate fundamentals. Under this assumption their models offer a rationalization of several features of FX intervention.

Thus, Vitale shows that when FX intervention is not aimed at revealing exchange rate fundamentals, but rather at targeting the currency value, in the event of an intervention operation the monetary authorities cannot credibly announce either the objectives of the operation, nor its size and direction. However, it still carries an information content, and hence influences market expectations and the exchange rate, in that the monetary authorities cannot fail to take into account the cost of its intervention activity.

In fact, in his formulation the central bank's objective function weights the cost of its intervention operations and the deviation of the exchange rate from a target level. Then, assuming that in the market for the foreign currency the exchange rate is set by a FX dealer according to a semi-strong form efficiency condition, it is shown that the central bank places with the FX dealer an anonymous market order which comprise two components: the former signals the correct fundamental value of the foreign currency; the latter pushes the currency value toward the target level.

Within this scenario the central bank cannot announce the size and direction of its intervention operation.<sup>17</sup> However, in the face of rational expectations, even if secret, this operation still influences the FX dealer's expectation and the currency value. In this way, Vitale offers

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<sup>16</sup>At times purchases and sales of foreign currency by central banks are not reported by either newswire services or the financial press. Intervention operations might remain unreported as central banks might prefer to keep market participants completely unaware of their intervention activity. This is possible if their orders are filed through a broker, which keeps the identity of its client anonymous. Some studies, notably Dominguez (1998) and Beine, Bénassy-Quéré, and Lecourt (2002), have found that usually reported FX intervention presents a different impact from unreported one. However, one may wonder whether unreported intervention operations are actually conducted with the intention of altering currency values and hence whether they correspond to genuine FX intervention.

<sup>17</sup>Beine and Bernal (2005) have investigated the motives which might induce the monetary authorities to keep secret their intervention operations. Interestingly, they find that the probability that an intervention operation remains unreported by newswire services increases when the operation is aimed at targeting the exchange rate at a value which is inconsistent with exchange rate fundamentals.

a simple explanation of the secrecy puzzle. In addition, he shows that: i) the direction of the intervention operation is not necessarily coherent with future shifts in exchange rate fundamentals, in line with the empirical finding of Kaminsky and Lewis on the inconsistency of the signals provided by the Fed in the late 1980s; and ii) on average the monetary authorities gain profits from their intervention activity, consistently with the empirical results of Sweeney and others.

## 5 Some Recent Developments

A crucial criticism which has been moved against most of the existing empirical analysis of FX intervention is that it has not been able to deal with the simultaneity of the determination of FX intervention and currency values.<sup>18</sup> In a nutshell, when exchange rates and FX intervention are determined simultaneously, a simple linear regression of the exchange rate innovation on contemporaneous FX intervention typically produces spurious estimates for the impact of the latter on the former.

Standard methods to deal with simultaneity issues are usually inapplicable, in that instrumental variables for FX intervention are very hard to come by. Recently researchers have followed two alternative strategies to deal with this problem. On the one hand, some studies have considered high-frequency analyses of FX intervention and exchange rates; on the other hand, fully identified models of FX intervention and exchange rate dynamics have been formulated and tested.

### 5.1 High-frequency analysis of FX intervention

Relying on intra-daily observations of exchange rates and FX intervention allows to impose the useful restriction that the latter is not influenced by the contemporaneous exchange rate innovation and hence to properly estimate the contemporaneous impact of an intervention operation on the currency level via straightforward linear regressions.

Indeed, Payne and Vitale (2003) can correctly claim that even if intervention operations may be triggered by past exchange rate movements, the decision to intervene by central banks takes time and that hence the impact of exchange rate movements on FX intervention is not so

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<sup>18</sup>Neeley (2005) extensively discusses the identification problem that plagues standard event studies of FX intervention.

immediate as to be felt within the 15 minutes which elapse between two subsequent observations in their data-set. Then, using transaction data on SNB intervention activity in the USD/CHF market between 1986 and 1995, they run linear regressions of the 15 minute innovation in the USD/CHF rate on leads and lags of a signed intervention indicator and measure the actual impact of FX intervention on exchange rates.<sup>19</sup>

High frequency studies like those conducted by Payne and Vitale are anyhow not devoid of problems. Firstly, data limitation has impeded to extend Payne and Vitale's approach to the intervention activity of more important central banks. Thus, Dominguez (2003) has conducted a high frequency study of the intervention activity of the Fed, the BoJ and the Bundesbank in the USD/JPY and USD/DEM markets employing newswire reports of FX intervention in lieu of actual transaction data. However, as observed by Fischer (2004), newswire reports of FX intervention are published with a significant delay. This implies that one cannot be sure that Payne and Vitale's restriction is warranted here as well.

Secondly, simple linear regressions as those estimated by Payne and Vitale do not isolate the *unexpected* component of an intervention operation when estimating the impact of FX intervention on exchange rate innovations. This shows clearly in the impulse response function of the USD/CHF rate to SNB intervention Payne and Vitale estimate, as reported in panel (a) of Figure 1. We see that the exchange rate jumps *before* intervention takes place.

Such an *anticipation* effect is difficult to reconcile with the efficient markets hypothesis, unless it is assumed that SNB intervention operations are timed to follow movements in the exchange rate in the direction favored by the Swiss monetary authorities. To shed more light on this anticipation effect and more generally to study the long-run impact of FX intervention on currency values one needs to isolate the effects of the unexpected component of FX intervention. This clearly requires a fully identified model of FX intervention and exchange rate dynamics.

## 5.2 Models of FX intervention and exchange rate dynamics

Kim (2003), Kearns and Rigobon (2005) and Neely (2005b) all develop complex dynamic models of FX intervention and exchange rate dynamics, where the interrelations between the interventional variables and exchange rate innovations are explicitly modelled. While we do not discuss in detail these models it can be said that, when properly identified, they allow to

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<sup>19</sup>Fischer and Zurlinden (1999) have investigated the SNB transaction data before Payne and Vitale, but due to limited access to exchange rate quotes they have not been able to run a proper event-study.

overcome the simultaneity issue which plagues standard event studies and to isolate the impact of the unexpected component of FX intervention on exchange rates.

However, we should underline two important limitations. On the one hand, none of these specifications presents a precise theoretical underpinning. In particular, these models do not represent clearly either the portfolio-balance effect or the information content of FX intervention. Thus, Kim (2003) builds a structural VAR model where FX intervention and exchange rates depend on a number of macroeconomic variables, while Kearns and Rigobon (2005) construct a model of the impact of FX intervention on exchange rates with structural breaks in the reaction function of the central bank. Similarly, Neely (2005b) develops a friction model of FX intervention.

On the other hand, while these models are inspired by econometric requirements, they do not present any market microstructure component. This is both surprising and unfortunate. In fact, a new approach to exchange rate determination based on the study of the microstructure of FX markets has provided useful hindsight on exchange rate dynamics. In particular, widespread empirical evidence outlining a very strong and significant contemporaneous correlation between trade innovations and exchange rate returns has induced several researchers to formulate models of exchange rate determination which contain a significant market microstructure component, ie. where the interplay between the microstructure of FX markets and its macro-level implications is explicitly modelled.

We then suggest that progress in the analysis of FX intervention can be made exactly following the lead of the market microstructure approach to exchange rate determination. In next Section we try to give substance to such a thesis.

## 6 The Way Forward

The principal result of the new market microstructure approach to exchange rate determination is that order flow, ie. the imbalance between buyer-initiated and seller-initiated transactions, is an important determinant of exchange rate dynamics in the short and possibly even in the medium term. Indeed, empirical studies of the impact of order flow on exchange rates, notably Lyons (1995), Evans and Lyons (2002), Payne (2003) and Bionnes and Rime (2005), suggest that in FX markets order flow possesses an information content, as the impact of trade

Table 1: Correlations for FX intervention, exchange rates and interest rates.

**Notes:** Table shows correlations on daily observations for a number of series during the period 13/10/99 – 16/03/04. The intervention variable  $I_t$  is defined as the amount (millions) of USD dollars bought (sold) in day  $t$  by the BoJ. Returns are the percentage change in the USD/JPY exchange rate observed over period  $t$ ,  $r_t \equiv 100(\log(S_t) - \log(S_{t-1}))$ . Interest rates are the percentage point change in the Japan-US target interest rate differential,  $\Delta(i_t - i_t^*) \equiv 100[(i_t - i_t^*) - (i_{t-1} - i_{t-1}^*)]$ .

	$\Delta(i_t - i_t^*)$	$\Delta(i_{t-1} - i_{t-1}^*)$	$r_t$	$r_{t-1}$	$I_t$	$I_{t-1}$
$\Delta(i_t - i_t^*)$	1.0000	-0.0301	-0.0209	-0.0498	0.0139	-0.0187
$\Delta(i_{t-1} - i_{t-1}^*)$		1.0000	-0.0024	-0.0210	-0.0187	0.0139
$r_t$			1.0000	-0.0168	0.0388	0.0637
$r_{t-1}$				1.0000	-0.1024	0.0395
$I_t$					1.0000	0.3421
$I_{t-1}$						1.0000

innovation on exchange rate is large, significant and persistent. There is also evidence, Evans and Lyons (2005), that order flow anticipates shifts in foreign exchange fundamentals.

Theoretical underpinnings of this empirical result associate the explanatory power of order flow with two different channels of transmission, due respectively to portfolio-balance and information effects. However, we can also link this empirical evidence to FX intervention, as this component of order flow can signal shifts in monetary policy variables. To understand how FX intervention conditions currency values one can rely on one of several market microstructure models of exchange rate determination, including Breedon and Vitale (2004), Evans and Lyons (2004) and Bacchetta and van Wincoop (2006), where order flow affects exchange rates via both the portfolio-balance and the information effects.

## 6.1 A market microstructure model of FX intervention

To see how we can formulate a proper market microstructure model of exchange rate determination where FX intervention affects currency values via these two effects, let us concentrate

on the intervention activity of the BoJ between September 1999 and January 2004. This has been an unprecedented period of heavy and insisted intervention operations by a major central bank. Hence, consider Table 1, which reports the contemporaneous and first-lag correlations between: i) the innovation in the interest rate differential between Japan and the United States,  $\Delta(i_t - i_t^*)$ ; ii) the percentage innovation in the USD/JPY rate,  $r_t$ ; and iii) signed BoJ intervention in the USD/JPY market.

Table 1 shows that the intervention variable,  $I_t$ , and the exchange rate innovation,  $r_t$ , present positive contemporaneous correlation, so that a purchase of USD on the part of the BoJ tends to appreciate the US currency. In addition, the first *lag* of the intervention variable,  $I_{t-1}$ , is negatively correlated with the innovation in the interest rate differential,  $\Delta(i_t - i_t^*)$ .

These correlations may be read according to an signaling-based interpretation of FX intervention. Indeed, when BoJ sells the US currency,  $I_{t-1} > 0$ , it *signals* an impending increase in the interest rate differential between Japan and the United States,  $\Delta(i_t - i_t^*) > 0$ , that leads to a depreciation of the US currency,  $r_t < 0$ , as shown by the negative contemporaneous correlation between the exchange rate return,  $r_t$ , and the innovation in the interest rate differential,  $\Delta(i_t - i_t^*)$ .

Then, we can follow Breedon and Vitale (2004) in formulating a microstructure model of FX intervention. Their model presents three important features: i) it captures both the information and portfolio-balance effects of order flow on exchange rates; ii) it allows identifying a clear *link* between the intervention operations of a central bank, the expectations of FX markets' participants and the exchange rate; iii) it can be directly estimated and tested using standard econometric techniques, such as instrumental variables or GMM.

While we refer to the original paper here we offer a brief presentation of a simplified version of Breedon and Vitale's model. Thus, in the FX market a single foreign currency (the US dollar) is traded for a domestic currency (the Japanese yen). In this market two classes of traders coexist: FX dealers and customers. FX dealers are risk-averse agents who select optimal portfolios of domestic and foreign assets. They are supposed to be short-sighted in that their investment horizon is just one period long.

All FX dealers share the same CARA utility function of their end-of-period wealth. At time  $t$  they can invest in three different assets: domestic (Japanese) bonds that pay period-by-period interest rate  $i_t$  and foreign (US) bonds that pay period-by-period interest rate  $i_t^*$ , plus a domestic production technology, which depends on the amount of real balances possessed.

In equilibrium the total demand for foreign currency on the part of the population of FX dealers,  $y_t$ , equals the total amount of foreign currency supplied by their customers,  $z_t$ . These customers comprise a population of liquidity traders and a central bank (the BoJ). The amount of foreign currency they supply changes over time in order to meet their liquidity needs and/or exploit their private information. If  $o_t$  represents the amount of foreign currency the liquidity traders and the central bank collectively desire to sell at time  $t$ , the total supply of foreign currency changes according to the following expression

$$z_t = z_{t-1} + o_t. \quad (1)$$

*Signed* order flow,  $o_t$ , can be decomposed into the number of units of foreign currency traded respectively by the central bank,  $cb_t$ , and non-official customers,  $c_t$ ,

$$o_t = cb_t + c_t. \quad (2)$$

We assume that the central bank knows the future shifts in interest rates and that intervenes in the FX market to signal them. Coherently with the evidence reported in Table 1 the number of units of foreign currency offered for sale by the domestic central bank in day  $t$  respects the following formulation,

$$cb_t = -\theta_b \epsilon_{t+1}^m + \epsilon_t^b, \quad (3)$$

where  $\epsilon_{t+1}^m$  is a monetary shock which will be publicly released in day  $t + 1$ ,  $\theta_b$  is a positive constant that measures the intensity of the informative trading activity of the central bank, while  $\epsilon_t^b$  is a random component which captures all other motives behind official intervention.

Then, Breedon and Vitale: i) show how FX dealers extract a signal on future shifts in interest rates from the flow of transactions which are completed in the FX market and which include the central bank operations; and ii) solve for the equilibrium exchange rate, which respects the following linear relation

$$s_t = \lambda_f f_t + \lambda_z z_t + \lambda_o o_t + \lambda_v v_t, \quad (4)$$

where  $f_t$  is a composite variable which summarizes all monetary and real variables which represent exchange rate fundamentals,  $v_t$  is a news variable representing all macroeconomic announcements which reach financial markets in day  $t$  and condition FX dealers' expectations of future exchange rate fundamentals, while the coefficients  $\lambda$ 's depend on the deep parameters of the model.

The linear relation (4) allows: i) to isolate, via the dependence of its coefficients  $\lambda$ 's on the model parameters, the information and portfolio-balance effects of order flow and FX intervention on the exchange rate; and ii) to define a series of moment conditions which, given the appropriate transaction data, can be used to estimate and test the model. Such an empirical exercise would permit to assess the relevance of Mussa's signalling hypothesis and to evaluate the effectiveness of FX intervention.

Clearly, Breedon and Vitale's model might be considered fairly simple and applicable only to the Japanese scenario, where the monetary authorities have operated in FX markets quite steadily in the recent past. Nevertheless, we believe that it follows the correct approach, in that it is based on the formulation of a microstructural model which permits direct testing of the signalling and portfolio-balance hypotheses. In sum, we strongly advocate a similar line of research for future studies of FX intervention.

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