

## NOTES AND COMMUNICATIONS

### HAVE SEQUENTIAL INTERVENTIONS OF CENTRAL BANKS IN FOREIGN EXCHANGE BEEN EFFECTIVE?

#### 1 INTRODUCTION

Central bank interventions (CBI's) in foreign exchange markets have a long tradition and the effectiveness of CBI's has been studied extensively, both from a theoretical and an empirical point of view. This is not surprising as exchange rates affect the international competitiveness and economic performance of business firms and countries. With the international liberalisation of markets and the globalisation of economic activity, exchange rates have become a crucial parameter in economic decision making in business and in public policy.

Much of the literature assumes that exchange rates are determined either by the international exchange of goods and services or assets. It then studies ways in which a CBI affects the price formation on these good and asset markets. More recently the emphasis has shifted towards studying the microstructure of foreign exchange markets by adopting insights from information economics to explain the role of the spread (difference between bid and ask quotes) and order flows in the determination of foreign exchange rates.

Lyons (2001) adopts the latter approach. He devotes a full chapter to applying microstructure tools to CBI's. A synthesis of the broader literature on CBI's is presented in the recent survey by Sarno and Taylor (2000). Edison (1993) reviews the literature since 1982. The interested reader is referred to these publications for a detailed review.

Extensive empirical work within a microstructure framework has been done by Dominguez (1999, 2003). For instance, Dominguez (2003) studies the relationship between the effectiveness of a CBI<sup>1</sup> and the state of the market when the intervention is made public. Using 5-minute return series for the G3 exchange rates for the period 1987-1995, she concludes that the U.S. Federal Reserve Bank (Fed) interventions significantly affected USD/DM and USD/YEN in-

1 Dominguez (2003, p. 29) reports four reasons given by the Fed for its interventions in foreign exchange markets: to influence the trend movement in exchange rates, to calm disorderly markets, to rebalance its foreign reserve holdings and to support other central banks in their exchange rate operations.

tradaily returns and volatility (captured by squared returns) and that these effects persist to at least the end of the day. There is also evidence of mean reversion, possibly resulting from an overreaction. Fed interventions which occurred when US and European markets were open, when important macroeconomic announcements had been made or that were coordinated with other central banks appeared to have had a larger impact than those which took place under other conditions. From an analysis of G3 intervention policies using daily data for the period 1977-1994, Dominguez (1998) concludes that secret interventions generally increase foreign exchange rate volatility. Overt interventions appear to have reduced exchange rate volatility in the mid-1980's but not for the full sample. Baillie and Osterberg (1997) and Beine et al. (2002) also provide evidence of increased exchange rate volatility as a result of a CBI. Similar results are reported by Bonser-Neal and Tanner (1996) and Galati and Melick (1999) when volatility is measured by the implied volatility extracted from currency option prices.

In a recent study, Beine et al. (2003) assess the effectiveness of G3 CBI's using realized moments and cross-moments obtained from intradaily data for the period 1989-2001. Their analysis confirms previous findings that coordinated CBI's affect exchange rate volatility. Unilateral CBI's appear to be much less effective. Their study highlights new findings on the timing and the temporary feature of persistence of the effects of coordinated CBI's on volatility and volatility spillovers, on covariances and correlations between exchange rates and on exchange rate skewness measures.

In this communication we address the issue whether the effectiveness of CBI's can be improved by sequential interventions instead of isolated ones. This question is of importance for policy-making as the evidence in the literature suggests that the impact of CBI's on mean return is at most modest and not persistent. Furthermore, this impact is usually found to be adverse with respect to return volatility. Rather than calming markets, CBI's appear to increase volatility and thereby risk. Of course, these unsatisfactory findings could have resulted from adopting an insufficiently refined classification of types of CBI's leaving too much intraclass heterogeneity in the classified data. As central banks have the discretion to go for an isolated intervention or to intervene over a period of several days (especially when the operations are unconcerted), it is sensible to refine the policy evaluation by distinguishing between isolated and sequences of interventions. In this respect, the recent evidence concerning the intervention policy of the Bank of Japan<sup>2</sup> on the USD/YEN seems to emphasize the use of a long sequence of unilateral interventions. This contrasts with the usual policies followed by the Fed and the Bundesbank in the eighties and early nineties.

We study the impact of interventions on exchange rate mean return and volatility using realized moments, i.e. realized mean and variance, as advocated by

2 The Japanese data were also recently released by the Ministry of Finance of Japan but are available only for the period posterior to May 1991.

Andersen et al. (2001). In section 2, we describe the data and the method to compute realized moments and to analyze them in an event study. The findings are reported in section 3. An interpretation of the results in terms of economic theory and a discussion of their significance for exchange rate policy by central banks are provided as well. Section 4 concludes.

## 2 DATA AND METHOD

During the sample period from January 1989 to February 2001, 155 interventions took place in the USD/DM market (since 1999 the USD/Euro market). The data used are official data of central bank interventions in the foreign exchange market. For the Fed, all data have been transmitted by the Federal Reserve. For the Bundesbank, all data have been transmitted by the Bundesbank; the data since 1999 are reported interventions by the ECB, which nevertheless confirmed the 4 interventions carried out in September and November 2000 (but did not release the amounts). All interventions have been sterilized, according to the statements of the central banks.

Among the 155 interventions taking place on the USD/DM 64 were unilateral interventions by the Federal Reserve Bank (26 and 38 involving purchases and sales of US dollars, respectively), 33 unilateral interventions involving sales of US dollars by the Bundesbank/European Central Bank (none involving purchases of US dollars) and 58 coordinated interventions (respectively 14 and 44 involving purchases and sales of US dollars).

A sequential intervention is defined as a sequence of consecutive days on which interventions of a particular type have occurred. The 14 coordinated US dollar purchase CBI's consist of 12 isolated and one two-day sequence of interventions. The 44 coordinated US dollar sales CBI's consist of 25 isolated, 2 two-day sequences, 2 three-day sequences, 1 four-day sequence and 1 five-day sequence of interventions.

The 26 unilateral dollar purchase CBI's by the Fed consist of 7 single-day, 3 two-day sequences, 1 five-day sequence and 1 eight-day sequence of interventions. Among the 38 unilateral dollar sales CBI's by the Fed, there are 20 single-day interventions, 7 two-day sequences and 1 four-day sequence of interventions. Finally, the 33 unilateral dollar sales CBI's by the Bundesbank consist of 26 isolated interventions, 2 two-day sequences and 1 three-day sequence of interventions.

Given the small number of observations for some types of interventions, we restrict the analysis to unilateral interventions by the Fed and coordinated interventions involving sales of US dollars only when analyzing mean returns as the impact of dollar sales on mean returns is expected to be different from that of purchases on mean returns. When studying volatility, we limit the analysis to unilateral interventions by the Federal Reserve Bank and to coordinated interventions by the Bundesbank and the Fed respectively involving purchases and sales

of US dollars. A priori there is less reason to distinguish between sales and purchases of US dollars as we want to test the hypothesis often put forward that both types of interventions calm turbulent markets.

Our data set consists of hourly observations for the USD/DM (Euro since 1999) rate from January 1989 to February 2001. The raw data consist of all interbank USD/DM bid-ask quotes displayed on the Reuters FX screen during this period. As is standard in the literature, hourly logarithmic exchange rates are computed by linearly interpolating the averages of the logarithms of bid and ask quotes for the two ticks immediately before and after the hourly time stamps throughout the global 24-hour trading day. Finally, returns are obtained as 100 times the first difference of the equally time-spaced logarithmic rates.

Next realized (mean) return of day  $t$  at hour  $h$  ( $h = 0, 1, \dots, 23$ ) denoted by  $y_{t,h}$  is computed as the sum from  $j = 0, 1, \dots, 23$  of the intraday hourly return  $r_{t,h-j}$  of day  $t$  between time  $j-1$  and  $j$  (by convention  $r_{t,-j} = r_{t-1,24-j}$  for  $j = 1, 2, \dots, 23$ ). Similarly, realized volatility of day  $t$  at hour  $h$ , denoted as  $v_{t,h}$ , is computed as the sum from  $j = 0, 1, \dots, 23$  of squared intraday hourly returns. The realized volatility has been advocated and used recently by Andersen *et al.* (2001) as it is much less noisy and more efficient than for instance a single squared return as an estimate of instantaneous volatility. Moreover, under certain conditions it is a model-free (and therefore not affected by model specification errors) and unbiased estimate of the integrated volatility as the intraday frequency of observation is increased. Finally, as the realized moments are moving averages over the last twenty four hourly observations we have not to worry about the intradaily seasonality.

To study the impact of CBI's we carry out event studies. For a 7-day window consisting of the two days preceding an intervention day, the intervention day itself and four days following an intervention day we plot the trajectories of realized mean return and return volatility. The trajectories should exhibit any immediate and persistent short-run impact of the intervention. Also, we plot the quartiles (median and endpoints of the interquartile range) of the realized moments over the 7-days window defined above for a given type of intervention. These graphs should allow us to see the impact on the distribution of realized moments of various types of interventions.

### 3 THE FINDINGS AND THEIR INTERPRETATION

To get some insight into the behaviour of exchange rates before, during and after an intervention, in Figures 1 and 2 the trajectories of the realized mean hourly returns for the 25 single-day coordinated interventions and the 6 several-day sequences of coordinated interventions of the Fed and the Bundesbank involving sales of USD are presented for a window covering the two days preceding an intervention, the intervention day and the four days following an intervention.

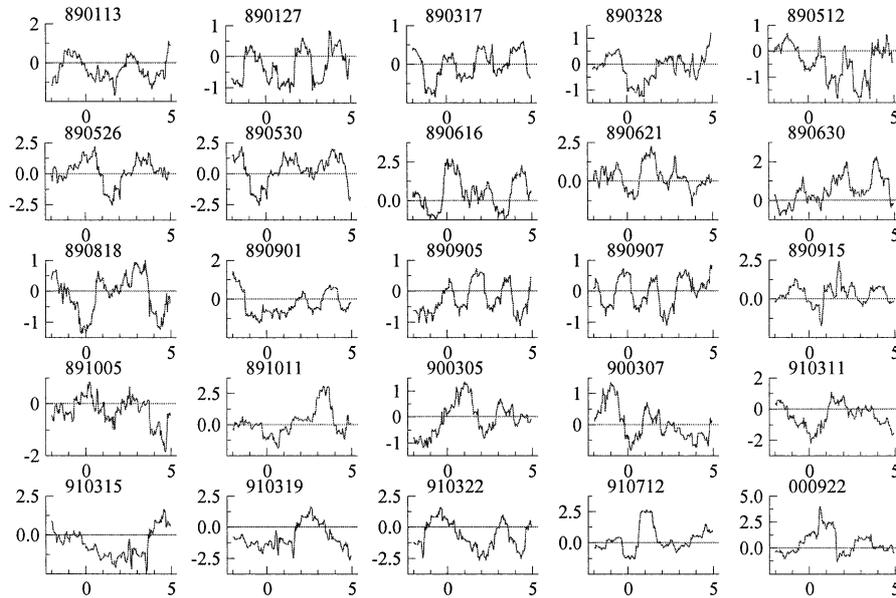


Figure 1 – Trajectories of the realized mean return of the USD/DM exchange rate for single-day coordinated sales of USD by the Fed and the Bundesbank; Note: the intervention date is reported above each graph. For example, 890113 corresponds to the 13 January 1989.

The origin of the time axis in the graphs (0) corresponds to the beginning of the intervention (mid-night in Frankfurt, GMT+1).

Since we rely on official intervention data transmitted by the central banks after the event, the intervention day is known. By contrast, the exact point in time of the intervention is not known.<sup>3</sup> Based on reported rather than official data (see Dominguez (2003), p. 29), the Fed generally intervenes between 8 am and 5 pm Eastern Standard Time. On average the Fed intervenes at 14.57 GMT (10 am EST) and the Bundesbank intervenes at 11.30 GMT (or at 12.30 pm in Frankfurt). Realized mean returns fluctuate around zero in the graphs. While one would expect a depreciation of the USD as a result of sales of USD by the two central banks, in several instances mean returns decrease, that is the USD appreciates with respect to the DM. The effects are not persistent. Notice that any effect is carried on for at least 24 hours as realized mean return is a moving average of hourly returns.

Usually there is mean reversion in the realized returns. Four days after an intervention realized (mean) return is again at approximately the same level as prior to the intervention. Similar results were found for the trajectories of realized re-

3 Most central banks including the Fed and the Bundesbank did not keep the time stamps for their operations.

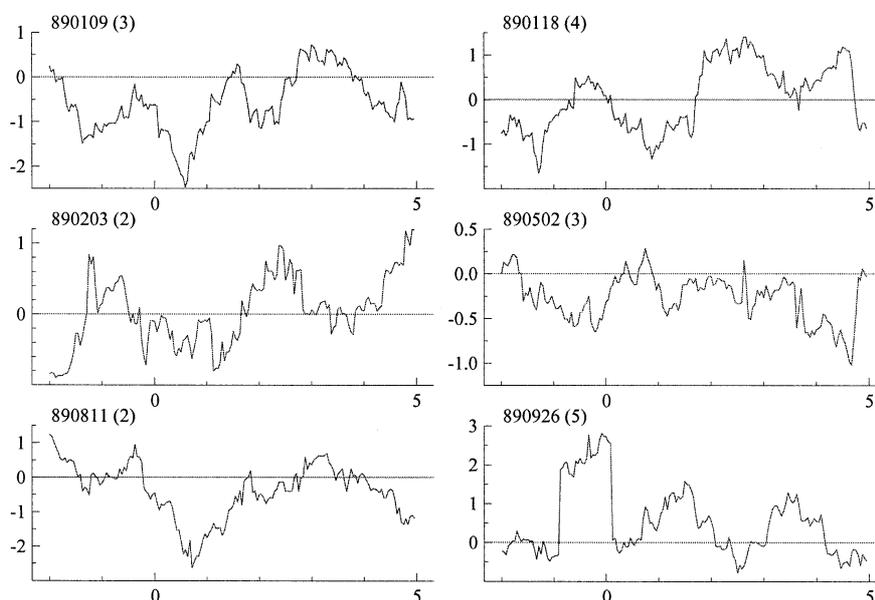


Figure 2 – Trajectories of the realized mean return of the USD/DM exchange rate for several-day sequences of coordinated sales of USD by the Fed and the Bundesbank; Note: the number of successive interventions is reported between brackets (next to the date of the first intervention).

turns for unilateral sales of USD by the Bundesbank. The trajectories of realized volatility for unilateral and coordinated isolated interventions or sequences of interventions by the Fed and the Bundesbank exhibit a transitory effect as well. The results have not been included but can be obtained from the authors upon request.

While studying the impact of the individual interventions is informative, it is useful to study the distribution of the impact for a given type of intervention. In the Figures 3 and 4 the graphs of so-called boxplots are presented. In Figure 3 the median and the lower and upper quartiles of the distribution of realized (mean) return are given for the seven-day window described above and for four types of interventions: unilateral isolated and unilateral several-day sequences of sales of USD by the Fed and isolated and several-day sequences of coordinated sales of USD by the Fed and the Bundesbank. In Figure 4 the median and lower and upper quartiles of the distributions of realized volatility of return are plotted for four types of interventions: unilateral isolated and several-day sequences of interventions (sales and purchases of USD) by the Fed and isolated and several-day sequences of coordinated interventions (sales and purchases of USD) by the Fed and the Bundesbank.

It is interesting to notice that the median of the realized returns fluctuates around zero. Hardly any effect of a unilateral sale of USD by the Fed on the

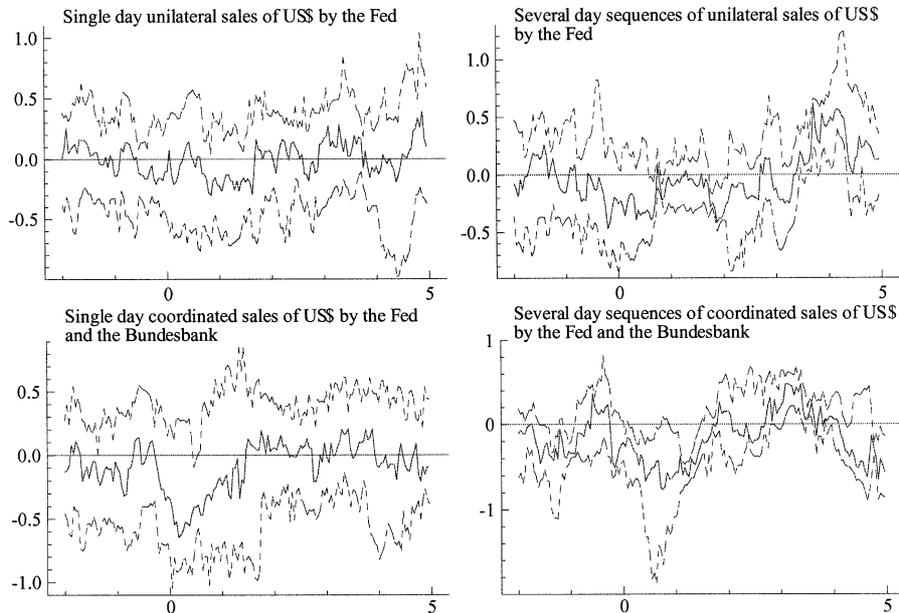


Figure 3 – Boxplot of realized mean return of the US\$/DM exchange rate for four types of interventions.

median is seen to occur during the intervention day. For several-day sequences of unilateral sales of the USD by the Fed some effects show up during the fourth and the fifth day after the intervention. When the Fed and the Bundesbank coordinate their sales of USD an important positive but temporary impact is found on the median and quartiles. That is to say, unilateral and coordinated sales of USD lead to a (transitory) depreciation of USD both in regimes when the USD is appreciating and when it is depreciating. For several-day sequences of coordinated sales (panel 4 of Figure 3) a temporary dip is found in the lowest (negative) quartile during the intervention day. This dip corresponds to a further appreciation of the USD in a regime of an appreciating USD after a sale of USD by the Fed and the Bundesbank.

For the realized volatility different patterns emerge. All four types of interventions lead to slightly persistent and sizeable increases in volatility in turbulent markets (the upper quartile corresponds to high volatility regimes). The impact on the median is smaller and the impact on the various types of interventions on volatility in tranquil markets is even less noticeable, except when the interventions are coordinated. While unilateral isolated and several-day sequences of interventions by the Fed and single-day coordinated interventions appear to lead to a slightly persistent increase of realized volatility, once the Fed and the Bundesbank coordinate their interventions the impact appears to be important though

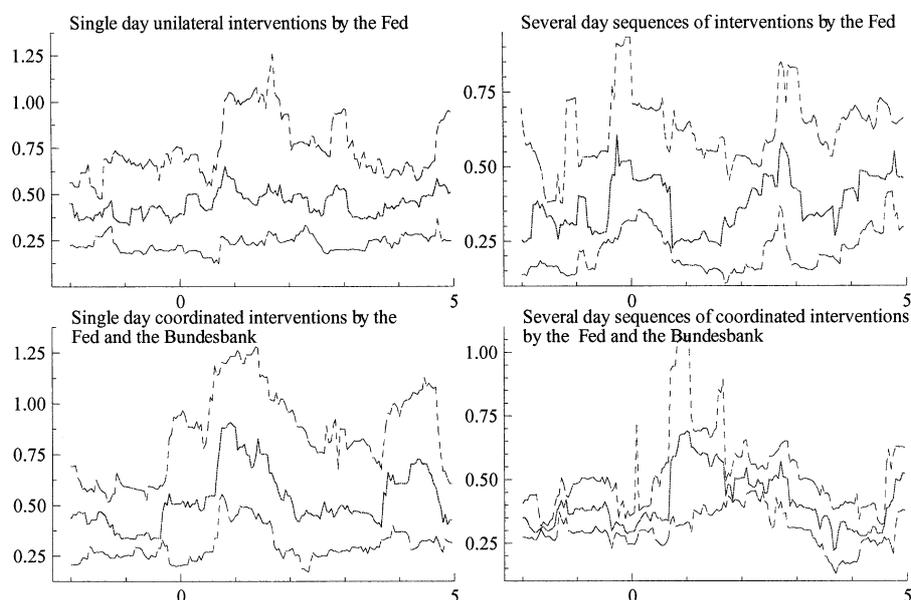


Figure 4 – Boxplot of realized volatility of the USD/DM exchange rate for four types of interventions.

transitory. It is worthwhile to notice that when uncertainty in the market measured by a large pre-intervention realized volatility is high, the impact of CBI's is large as well. Rather than calming turbulent markets interventions appear to temporarily increase uncertainty. This finding indicates an adverse effect of CBI's. After a few days tranquil markets reach the pre-intervention uncertainty levels, but more turbulent markets still suffer from increased volatility.

How can these results be interpreted? One could raise the question how a sterilized intervention works. As shown in Lyons (2001), a sterilized intervention does not alter the money supply and the interest rate. Therefore, the fundamentals in the flexible-price monetary model (see e.g. Frenkel (1976), Mussa (1976)) and the sticky-price monetary model (see Dornbusch (1976)) do not change and these models do not predict a change of the exchange rate.

Sarno and Taylor (2001) as well as Lyons (2001, chap. 8) summarize two theoretical channels from macroeconomics through which a sterilized CBI affects the exchange rate. Through the signalling channel<sup>4</sup> (Mussa (1981)) a sterilized intervention signals future money supply and interest changes to the market, thereby affecting the current exchange rate. Through the portfolio-balance channel, a ster-

<sup>4</sup> The signalling hypothesis has been tested by Payne and Vitale (2003) who studied the effects of sterilized operations executed on behalf of the Swiss National Bank (SNB) using tick by tick transactions data between 1986 and 1995. Using an event study approach they find that the interventions have important short-run effects on exchange rate returns in the Swiss Franc/USD market. The CBI is

alized intervention can affect exchange rates as it modifies the currency denomination of assets held by the public, especially if these assets are imperfect substitutes. The impact of a sale of USD would then have to be a (lasting) depreciation of the USD, which could be achieved by a transitory positive impact on the return provided the latter one is not undone by subsequent negative changes in the return (The change of the exchange rate over a given period could be computed as an average of intra-period exchange rate returns weighted by the intra-period exchange rates).

The interquartile range for (mean) returns contains the value zero for the seven-day window for single-day sales of USD (Figure 3, left panels). For several-day sequences of interventions this is the case as well for the major part of the seven-day window (Figure 3, right panels). This indicates that the impact of interventions on the mean return is not statistically significant at a 50 % level except for a significant positive effect (i.e. a depreciation of the USD) of several-day sequences of sales of USD three to four days after the intervention. This result has nevertheless to be taken with caution since there are few occurrences of several-day sequences on this market. Moreover, one should notice that the “mean” returns are measured as the cumulated sum of intradaily returns. To obtain truly mean returns one has to divide them by 24 and one would indeed obtain small numbers in absolute value. Most monetary models of exchange rates have little to tell about the impact of an intervention on volatility as volatility is often assumed to be constant in these models.

From the microstructure approach of financial assets implications for the impact of interventions on the exchange rate and on market volatility have been derived. The microstructure literature traditionally distinguishes between two approaches, the inventory-based approach and the information-based approach respectively (see O’Hara (1995), Lyons (2001)). The inventory-approach emphasizes the balancing problem faced by foreign exchange markets resulting from deviations between inflows and outflows of currencies. These deviations could be caused by a CBI. In general, these deviations are assumed to be unrelated to future values of the assets traded but they can affect the short-run behavior of the market in terms of order flows, bid-ask spreads, transactions and prices. For the long run, assuming market participants can adjust their positions, the deviations between inflows and outflows are irrelevant. Our findings of a temporary impact of CBI’s on exchange rates are consistent with predictions from the inventory approach stressing the rebalancing in the market after a CBI (see also Dominguez (2003)).

Our findings appear to be in line with the predictions from the theoretical model by Evans and Lyons (2001), that the predicted price effect resulting from

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found to be stronger when the SNB moves with-the-market and when its activity is concerted with that of other central banks. Exchange rate returns are found to move in the 15 minutes interval prior to a CBI.

portfolio rebalancing, turns out to be small if the order flow following a CBI is expected to be reversed as central banks sterilize their intervention whereby key fundamentals such as the money supply and interest rates remain unaffected.

The informational approach to market microstructure focuses on price formation and learning about the market. This approach predicts an increase in transaction volume, prices and price volatility following a CBI. Once the intervention news has been revealed, transaction volume and price volatility and prices should revert to pre-intervention levels. A full reversion however is not observed by the end of the four days period after an intervention when the market was turbulent (see Figure 4). Somewhat surprisingly, the impact on volatility of isolated interventions four days after the intervention seems to be more pronounced than that of sequences of interventions. Also, the finding in Figure 4 that a CBI impact on volatility in high volatility periods is more pronounced than in low volatility regimes is in line with the information-based approach that longer-run effects are related to factors such as information processing. Turbulent market conditions require more time to revert to initial levels. The effects of sequences of coordinated interventions on volatility in high volatility regimes (panel 4 of Figure 4) are more extreme but more short-lived than the effects of other types of interventions. Notice however, that the pre-intervention volatility level (measured by the upper quartile) is much lower in panel four than in the panels 1-3 of Figure 4. Four days after a several-day sequence of coordinated interventions, volatility is brought back to pre-intervention levels even when pre-intervention markets were turbulent. The increase in volatility at the end of the day four after the intervention has to be interpreted as an artefact due to the presence of a single five-day sequence of coordinated interventions in the data.<sup>5</sup>

#### 4 CONCLUSIONS

In this contribution we carried out an event study analysis of the impact on the exchange rate and exchange rate volatility of various types of central bank interventions in the USD/DM foreign exchange market. The intervention effects were measured by realized moments, which are model-free, easy-to-compute, unbiased, intraday-seasonality-free and fairly efficient estimates of the intradaily effects on the exchange rate and market volatility. Four types of interventions were considered in this policy evaluation: we distinguished between unilateral and coordinated interventions and between isolated and several-day sequences of interventions. The main conclusions confirm results from previous studies. All four types of interventions seem to have little significant effect on exchange rate returns. Volatility is found to be more heavily affected by all four types of interventions.

<sup>5</sup> On the whole, sequences of interventions have occurred more frequently in the USD /YEN market. Nevertheless, even in this case, there is a small number of several-days sequences of coordinated interventions.

In the presence of coordinated sequential interventions, four days after the first intervention volatility is brought back to almost pre-intervention levels. This holds even when markets are highly turbulent. On the basis of these results, central banks could be advised to coordinate their interventions in the form of a several-day sequence of actions and thereby in the end convince the market that their policy intentions ought to be taken seriously.

Michel Beine, Sébastien Laurent  
and Franz C. Palm\*

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\* These authors are affiliated with CADRE, University of Lille 2, France and Free University of Brussels, Belgium, CeReFim, University of Namur and CORE, Université Catholique de Louvain, Belgium, and Maastricht University, The Netherlands, respectively. Corresponding author: F.C. Palm, Maastricht University, Faculty of Economics and Business Administration, P.O. Box. 616, 6200 MD Maastricht, The Netherlands; e-mail: F.Palm@ke.unimaas.nl. These authors gratefully acknowledge the financial support from the European Science Foundation and the Netherlands Organisation for Scientific Research (NWO) and the comments by M.M.G. Fase.

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