The Economic Journal, **113** (*April*), 390–411. Published by Blackwell Publishing, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA.

IS STERILISED FOREIGN EXCHANGE INTERVENTION EFFECTIVE AFTER ALL? AN EVENT STUDY APPROACH*

Rasmus Fatum and Michael M. Hutchison

This study provides evidence supporting the effectiveness of sterilised foreign exchange market intervention by central banks using an event study approach. An event study framework is better suited to the study of sporadic and intense periods of official intervention, juxtaposed with continuously changing exchange rates, than standard time-series studies. Focusing on daily Bundesbank and US official intervention operations, we identify separate intervention 'episodes' and analyse the subsequent effect on the exchange rate. Using the non-parametric sign test and matched-sample test, we find strong evidence that sterilised intervention systemically affects the exchange rate in the short run. This result is robust to changes in event window definitions over the short run and to controlling for central bank interest rate changes during events.

The effectiveness of sterilised foreign exchange intervention has been the focus of an ongoing and unresolved dispute since the so-called Jurgensen report (Jurgensen, 1983).[1] While empirical research often finds only weak or no evidence in favour of a link between sterilised intervention and associated movements of exchange rates, policy makers nevertheless seem to view sterilised intervention as an instrument for policy and, from time to time, make use of this instrument.[2]

The theoretical justification offered by the 'portfolio balance' channel, through which sterilised intervention changes the currency denomination of relative asset supplies and thereby the exchange risk premium if assets are imperfect substitutes, has received mixed empirical support (Dominguez and Frankel, 1993*a*,*b*; Edison, 1993; Rogoff, 1984).

Evidence in favour of a 'signalling' channel, through which sterilised intervention is effective in providing new information about policy intentions and, if credible, thereby future fundamentals, is similarly mixed. Kaminsky and Lewis (1996) find that US intervention sometimes signals monetary policy indicators in the opposite direction of that predicted by the conventional signalling hypothesis. Fatum and Hutchison (1999), using daily data and a GARCH specification, find

* We thank the Bundesbank, the Board of Governors of the Federal Reserve System and the Federal Reserve Bank of San Francisco for providing data. This research was begun while Fatum was at the Danish Ministry of Economic Affairs and continued at the European Central Bank. Hutchison is also a Research Fellow at the Economic Policy Research Unit (University of Copenhagen) and a Visiting Scholar at the Center for Pacific Basin Monetary and Economics Studies at the Federal Reserve Bank of San Francisco. We thank two anonymous referees and the managing editor of this JOURNAL, Mike Wickens, for helpful comments. The views expressed are ours alone.

[1] It is well established that both Bundesbank and Fed intervention operations are sterilised, at least in the short run, see, for example, Dominguez and Frankel (1993*a*) and Weber (1994). Even though full sterilisation is unlikely to occur instantaneously (as both the Bundesbank and the Fed use reserve requirements with averaging provisions over several days), an immediate effect on the money supply is likely to be of little importance as the financial markets can expect it be off-set by the end of the averaging period.

[2] 'In any event, governments plainly believe that sterilised intervention has its uses, for they continue to practice it despite the lack of any hard evidence that it is consistently and predictably effective', Obstfeld and Rogoff (1996).

that intervention does not systematically signal future monetary policy (proxied by changes in the federal funds future's rate), but instead increases the uncertainty over the direction of the policy.

These findings are in line with Bonser-Neal and Tanner (1996), who use data on implied volatility from the options market and find that intervention increased exchange rate volatility over certain periods. Recent work by Galati and Melick (1999) finds no evidence on a (simultaneous) effect on the exchange rate level, but that, on average, (perceived) intervention increases uncertainty about future exchange rate movements.

Some empirical studies are more supportive of the effectiveness of sterilised intervention. In a descriptive study by Catte *et al.* (1994), 17 episodes of concerted intervention are extracted, all of which are deemed either 'definitely' or 'temporarily' successful.[3] Humpage (1999), using binary choice models on daily data from February 1987 to February 1990 and a 'smoothing' criterion for success, finds that intervention is systematically associated with exchange rate movements.

In order to address the issue of effectiveness, the methodological starting point of this paper is to recognise that standard time-series techniques may not be well suited when dealing with the analysis of intervention *vis-à-vis* the behaviour of exchange rates. Exchange rates are typically highly volatile on a day-to-day basis, intervention tends to come in sporadic clusters – viewed in this light it may seem less surprising that time-series based studies tend not to find strong evidence for a systematic link between exchange rate movements and intervention operations.

Although standard time-series techniques are somewhat problematic when dealing with data on exchange rates and intervention, the event study approach used in the finance literature seems to fit well. Specifically, a cluster of intervention operations constitutes a natural candidate for identification as a single event.

In this paper we apply the event study methodology to data on Bundesbank and Fed intervention in the DEM/USD exchange rate market since the Plaza Agreement. By construction, an event study is a very general test of a specific hypothesis and does not have to rely on a structural model of exchange rate determination. This is a desirable feature given the lack of consensus over the appropriate structural exchange rate model. We follow Dominguez and Frankel (1993*a*) and Catte *et al.* (1994) by carefully identifying events as clusters of intervention activity, and extend these studies by undertaking formal statistical tests using event study methods. By taking into account the market conditions prior to the time of intervention, i.e. if the US Dollar (USD) is appreciating or depreciating prior to the intervention activity, we introduce a 'reversal' criterion for success that allows us to analyse whether intervention is seemingly aimed at breaking an ongoing exchange rate movement.

Using the non-parametric sign test and the matched sample test, evidence in favour of short-term effectiveness is presented.[4] In order to check the robustness of

[3] As pointed out by Dominguez and Frankel (1993*a*), the variable length of the 'success criterion' seems problematic and it seems plausible that sterilised intervention is less potent than suggested by the three authors.

[4] Short-term refers to the two, five, ten and fifteen day post-event periods during which the exchange rate movement is examined.

the findings, different criteria for success, event definitions and event windows are investigated. The findings are not sensitive to these alterations, except when the event window length is extended to 30 days.

Two other limitations of our event study methodology are noteworthy. First, the event study methodology does not control for the effect of changes in other variables, e.g. arrival of news regarding changes in policies. This issue is addressed by conducting a robustness test on a sub-sample of events during which central bank intervention did not coincide with interest rate changes by either the Fed or Bundesbank. Second, the issue of endogeneity arises in our study (and every intervention study) since the central bank usually takes its cue to intervene on the basis of observed exchange rate movements. We define intervention events as a 'cluster' of related days of intervention activity, the final date of which is essentially the manifestation of when the central bank chooses to stop intervening. This 'endogeneity' may make intervention appear more effective. However, we argue that the appropriate measure of successful intervention is not the daily instantaneous impact on the exchange rate while the intervention activity is ongoing, but the cumulative effect after its completion.

The rest of the article is organised as follows. Section 1 discusses the data, and Section 2 explains the identification of intervention episodes and the event study methodology in detail. Section 3 presents the event study results. Section 4 presents the event study results based on the sub-sample of events during which central bank intervention did not coincide with interest rate changes. Section 5 reports on several extensions to the study, including an investigation of quantitative links between intervention and exchange rate movements and addresses the issue of long-run effects. Section 6 concludes the paper.

1. Data Description

The total intervention variable is the sum of the Bundesbank intervention and the Fed intervention variable. The Bundesbank intervention variable is daily Bundesbank sales (negative values) and purchases (positive values) of USD (millions) against DEM in the foreign exchange market.[5] The Fed intervention variable is daily Federal Reserve System sales (negative values) and purchases (positive values) of USD (millions) against DEM in the foreign exchange market.[6] Both variables are official foreign exchange market intervention data, provided by the Deutsche Bundesbank and the Board of Governors of the Federal Reserve System, respectively.

Table 1 shows that during the sample period, 1 September 1985 to 31 December 1995, the Bundesbank intervened in the DEM/USD exchange rate market on a total of 234 days. The Bundesbank sold USD against DEM on 169 days and purchased USD against DEM on 65 days. On most days the magnitude of intervention was fairly small, with trades of less than USD 100 million as compared to an average

[5] The Bundesbank intervention operation variable excludes operations due to portfolio management.

[6] Customer transactions, which consist of Fed sales or purchases of foreign exchange directly with customers that would otherwise need to transact in the foreign exchange market, are excluded. This is in line with previous research in this area.

Table 1

Intervention, Sept. 1, 1985–Dec. 31, 1995

	Number of Days	Cumulated Amount USD mn.
Bundesbank intervention		
Purchases of DEM		
>250	23	−8,640
>150	17	−3,437
>100	17	−2,059
>0	112	−3,956
Total Purchases	169	−18,092
Sales of DEM		
>250	13	4,835
>150	10	1,746
>100	13	1,493
>0	29	1,479
Total Sales	65	9,554
Fed Intervention		
Purchases of DEM		
>250	24	−8812
>150	16	−3,123
>100	16	−2,210
>0	74	−5,294
Total Purchases	130	−19,439
Sales of DEM		
>250	20	8,953
>150	8	1,663
>100	5	675
>0	43	2,601
Total Sales	76	13,892
Combined Total of Bundesbank and Fed Intervention		
Purchases of DEM		
>250	49	−22,758
>150	31	−6,243
>100	31	−3,951
>0	108	−4,578
Total Purchases	219	−37,531
Sales of DEM		
>250	33	16,982
>150	13	2,581
>100	12	1,461
>0	46	2,422
Total Sales	104	23,446

>250 Daily intervention operations of USD 250 million or greater.
>150 Daily intervention operations of USD 150 million or greater, but less than USD 250 million.
>100 Daily intervention operations of USD 100 million or greater, but less than USD 150 million.
>0 Daily intervention operations of less than USD 100 million.

(reported) daily trading in the DEM/USD exchange rate market of 290.5 billion USD in April 1998 (BIS, 1999). The Fed intervened in the DEM/USD exchange rate market on a total of 206 days. The Fed sold USD against DEM on 130 days and purchased USD against DEM on 76 days. As in the case of the Bundesbank, most

Fed interventions were small scale. During the sample period, at least one of the two central banks intervened on a total of 323 days. The Bundesbank (the Fed) was alone in the market on 117 (89) days.

Figures 1 and 2 illustrate the episodic occurrence of Fed and Bundesbank interventions in the DEM/USD exchange rate market, respectively, where long periods of consecutive days with no intervention are separated by clusters of relatively short periods of days where intervention took place. Figure 3 shows the evolution of the total intervention variable.

The exchange rate variable is the daily noon DEM/USD spot (bid) rate in New York City for cable transfers. Figure 4 shows the day-to-day percentage change in the DEM/USD exchange rate.

2. The Event Study Methodology

The starting point for an event study is to define the event of interest and to identify the period over which the security price is examined. This period is

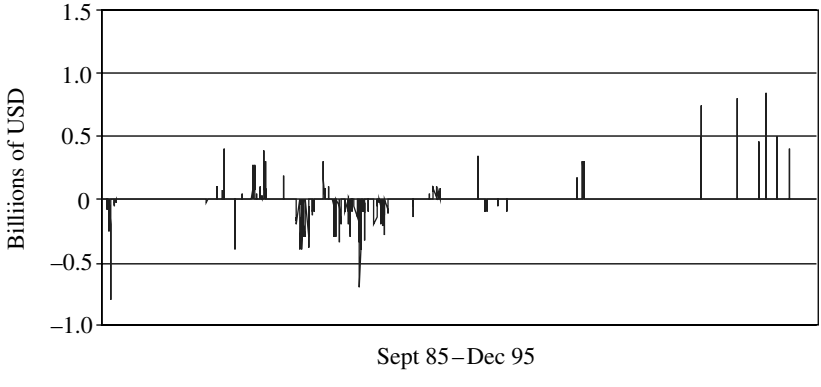

Fig. 1. *FED Intervention*

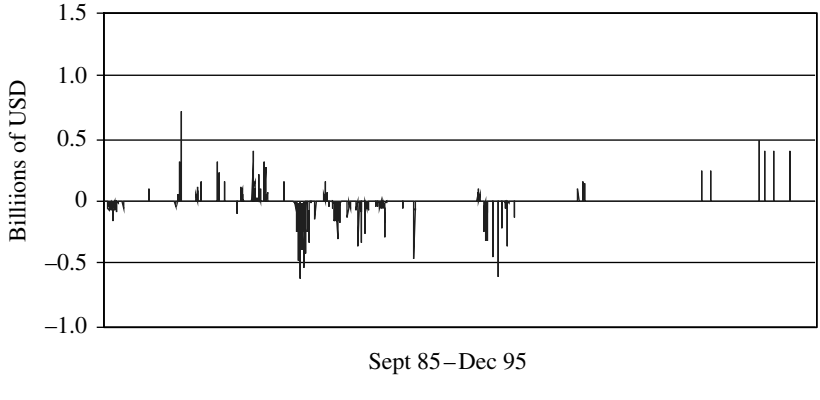

Fig. 2. *Bundesbank Intervention*

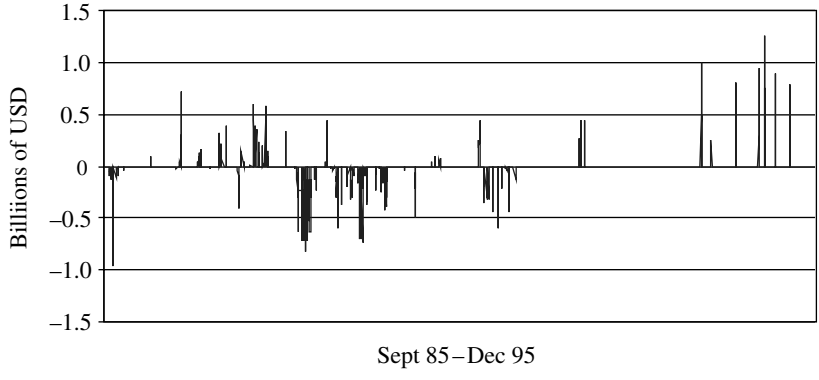

Fig. 3. *Total Bundesbank and Fed Intervention*

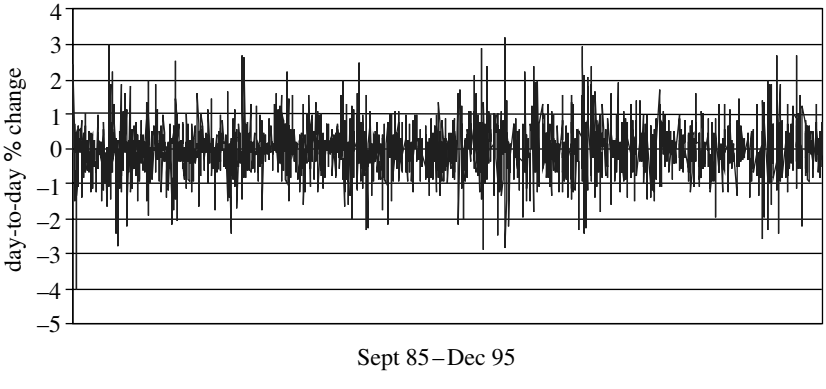

Fig. 4. *Changes in the DEM/USD exchange rate*

referred to as the event window and it is comprised of the pre-event days (sometimes referred to as the estimation window), the event day (or days), and the post-event days.[7]

In this context, the purpose of the study is assessing the success of intervention in affecting exchange rates. The task is, therefore, to define and identify the events of intervention and to define and identify the number of days before and after the event, respectively, over which the pattern of exchange rate movements is analysed. Finally, a carefully defined measure of success needs to be established.

2.1. *Defining the Events*

Most events in finance – mergers and acquisitions, earning announcements, issues of new debt etc. – occur only once over a given period of time. In other words, the

[7] See MacKinlay (1997) for a survey on event study methodology.

event takes place on a single day. Defining each day that the Bundesbank, the Fed, or both were active in the DEM/USD exchange rate market as a separate event, however, is problematic.

The pre- and post-event windows allow for a comparison of the exchange rate movements around the defined event. Since central banks often intervene for consecutive days, a one-day event definition would lead to several instances of pre- and post-event windows around one-day events, during which other one-day events occurred (regardless of the length of the pre- and post-event windows). A seemingly systematic exchange rate movement around one-day events could thus be caused by other one-day events occurring during the pre- and post-event windows, thereby making the event study of little use.

Furthermore, a one-day event definition does not help in structuring the data set, nor does it help illuminate the policy intent of intervention at a particular time.

For example, the five continuous days of either Bundesbank or Fed intervention in August 1987 (when both central banks attempted to sustain the DEM – the Bundesbank sold USD 276 million against DEM between August 5 and August 10, the Fed sold USD 631 million against DEM between August 4 and August 10) are naturally viewed as a single event.

A general consideration when defining events is that, if the event period is set too short, then what is actually one policy episode of intervention may be incorrectly identified as two (or more) events (and potentially leading to a number of overlapping event windows). On the other hand, if the event period is set too long, then what are actually two policy episodes – separate policy decisions to intervene in the foreign exchange market – may be incorrectly identified as a single event.

In this context, an event is defined as a period of days with official intervention in the DEM/USD exchange rate market in one direction (in terms of purchases or sales), conducted by either the Bundesbank, the Fed, or both, and possibly including a number of days with no intervention. This leaves the choice of how many consecutive days of no intervention that can be allowed for while still considering the surrounding days of intervention to be part of one and the same event.

Although this decision seems somewhat arbitrary in principle, a careful investigation of the intervention time series, shown in Figures 1, 2 and 3, shows that there are either few days, generally less than fifteen, or several days, generally more than thirty, between days of central bank presence in the DEM/USD exchange rate market.

Several event definitions were considered, distinguished by the maximum number of consecutive days of no intervention between days of intervention allowed for. Event definitions based on a maximum of two, five, ten and fifteen consecutive days of no intervention were considered and the maximum fifteen-day period was accepted. Choosing a period with more than fifteen consecutive days of no intervention seems unappealing, losing the intuition that a particular cluster of days of intervention constitutes a separate event. On the other hand, shorter periods created a number of instances of overlap of pre- and post-event windows.

Thirty-two events were identified of which one event covered a period of the maximum consecutive days of no intervention, two events covered a period of thirteen consecutive days, while the remaining 29 events covered less than ten consecutive days of no intervention. Put differently, allowing for, say, ten consecutive days of no intervention rather than fifteen only affects three of the identified events. The vast majority of the events had less than five consecutive days of no intervention and the results are not sensitive to the choice of a maximum of fifteen days.

2.2. *Defining the Pre- and Post-Event Windows*

The length of the pre-event and post-event periods, respectively, needs to be set long enough to capture a 'normal' no intervention performance of the exchange rate. If the length of the periods is set too long, however, a number of instances of overlap of pre- and post-event windows are created.

Pre- and post-event window lengths of two, five, ten and fifteen days were applied and the results were found to be robust to either window length. As an illustration, with the two-day window definition as the reference point, the direction of the change is the same for at least two of the other three pre-event (post-event) window definitions in 28 (25) of the 32 events. (Tables showing pre- and post-event exchange rate changes for different window lengths are available from the authors upon request.)

For reasons of space, the paper focuses on the results based on pre- and post-event windows of two days. The two-day window definition is chosen as the baseline since it ensures no overlap of pre- and post-event windows. Moreover, the shorter is the window length, the less is the risk of other financial news arriving. (The qualitatively similar results based on five, ten and fifteen day window definitions, summarised in Table 5, are briefly discussed at the end of Section 3.)

2.3. *Defining a Successful Event*

There is no convention on the definition of a successful intervention episode and rather than relying on a single definition, this study applies two previously suggested criteria as well as introduces a new 'reversal' criterion.

Frankel (1994) suggests that the proper criterion for judging whether the subsequent movement in the exchange rate is as desired by the central bank is simply whether the direction of the movement is the same as the direction in which the central bank was intervening, e.g. does the value of the DEM relative to the USD increase after DEM are purchased? This measure of successfulness is referred to as the 'direction' criterion and is formally expressed as follows: An event is a success if either

$$(E_i > 0 \text{ and } \Delta s_{i+} > 0) \text{ or } (E_i < 0 \text{ and } \Delta s_{i+} < 0)$$

where E_i is the total amount of central bank intervention (positive values represent purchases of USD, negative values represent sales of USD) during event i and s_{i+} is the DEM/USD exchange rate change during the associated post-event window.

The second criterion defines a successful event as one where intervention is associated with a smoothing of the exchange rate movement; see for example Humpage (1999). This criterion is formally expressed as follows: An event is a success according to the 'smoothing' criterion if either (the event is a success according to the 'direction' criterion) or

$$(E_i > 0 \text{ and } \Delta s_{i+} > \Delta s_{i-}) \text{ or } (E_i < 0 \text{ and } \Delta s_{i+} < \Delta s_{i-})$$

where s_{i-} is the DEM/USD exchange rate change during the associated pre-event window.

The meaningfulness of both criteria, however, can be questioned if the central banks were to follow a 'leaning with the wind' policy, i.e. if the central banks were to intervene in support of an ongoing exchange rate trend (formally expressed as either ($E_i > 0$ and $\Delta s_{i-} > 0$) or ($E_i < 0$ and $\Delta s_{i-} < 0$)) as opposed to 'leaning against the wind' when the central banks are trying to slow or reverse the trend (formally expressed as either ($E_i > 0$ and $\Delta s_{i-} < 0$) or ($E_i < 0$ and $\Delta s_{i-} > 0$)).[8] For example, if the DEM is appreciating during both the pre- and the post-event window, an associated purchase of DEM – even if in reality completely ineffective – is deemed a success according to the 'direction' as well as the 'smoothing' criterion. Using the same example, suppose the rate of change is actually smaller after the intervention event, i.e. the exchange rate still moves in the intended direction but at a lower pace than before the intervention occurred, it seems counterintuitive to denote such an event successful.

In order to accommodate these potential shortcomings of the applied definitions the analysis also distinguishes between 'leaning with the wind' and 'leaning against the wind' events by conditioning each event on the exchange rate movement of the associated pre-event window.

When the 'direction' criterion is applied to 'leaning against the wind' events only, the resulting measure of success has a clear meaning in terms of reversing the exchange rate trend that prevailed up until intervention occurred. This particular measure is denoted the 'reversal' criteria.

By construction of the event study and the suggested criteria for success, effectiveness of intervention is determined by the direction and/or the pace of the exchange rate change after the intervention operations have occurred. As noted in the introduction, the final date of each event, and thereby the starting date for the post-event window in the event study context, is essentially the manifestation of when the central bank chooses to stop intervening. Since the central bank may only stop intervention operations when either the exchange rate goal is (perceived to be) reached or the event is viewed as unsuccessful, it is possible that this 'endogeneity' makes intervention appear more effective. From the perspective of the central bank, however, it is reasonable to expect that the ultimate effect of an intervention event on the exchange rate is more important than daily instantaneous movements of the exchange rate. This is the underly-

[8] Since the motivation for central bank intervention is rarely announced, the policy criteria 'leaning against' and 'leaning with' the wind are only indicative of actual policy intentions.

ing logic of defining an event as related days, or 'clusters', of intervention purchases/sales, and measuring success after the central bank withdraws from the market.

2.4. *The Non-Parametric Sign Test and the Matched Sample Test*

Two statistical tests are employed. The first test is the non-parametric sign test for the median. This statistic verifies whether the 'directions' or the 'reversals' in the direction of the exchange rate change following intervention events (e.g. from appreciation during the pre-event window to depreciation during the post-event window), or 'smoothing' of the exchange rate change following intervention events (e.g. smaller appreciation) are random or systematic. The sign test for the median is applicable to any continuous distribution and the null hypothesis is that the population corresponding to the sample has a median value equal to zero against the alternative that the median is larger than zero.

With reference to the 'direction' and 'reversal' criteria for success, if the hypothesis is true, the probability ρ of observing a positive value ('success') is the same as that of observing a negative value ('no-success'), hence $\mu = 0.5$.[9] Then the random variable

X = the number of positive values ('successes') among n sample observations

has a binomial distribution with $\mu = 0.5$. A significant sign test indicates that the observed number of successes is not a random finding attributable to the equal probability of appreciation or depreciation. For details on this test in event studies, see MacKinlay (1997).[10]

The second test is the matched sample test; see, for example, Ben-Horim and Levy (1984, p. 458). This one verifies whether there is a significant shift in the exchange rate change between the pre- and the post-event periods. Since it is straightforward to match the observations of one sample (before) with the observations of the second sample (after), the matched sample test can be applied to the event study set-up. For each observation of the first sample, the associated or matched value of the second sample is obtained and the difference, D_i, is calculated. The sample mean, D, and standard deviation, S_D, are calculated as usual. Assuming that values (exchange rate changes) from both samples are normally distributed, the test statistic is t-distributed with $n - 1$ degrees of freedom, where n is the number of paired observations. The test statistic is then given by

$$\frac{D - \mu_D}{S_D} \sim \mathrm{t}(n-1)$$

where μ_D is the mean value of the difference under the null, and allows for testing whether the mean change has shifted between the two samples. The matched

[9] Using the sub-sample consisting of observations that were not part of any of the events as a control period, the probability of observing a change in the direction of the exchange rate trend is 51.3% while the probability of observing a smoothing is 75.4%.

[10] Despite the usefulness of the non-parametric rank test in event studies, see MacKinley (1997) and Campbell and Wasley (1993) for details, the number of events in our samples precludes this test.

sample test is identified with the 'smoothing' criterion since it indicates, at the minimum, smaller DEM appreciation or depreciation.

3. The Results of the Event Study

Focusing first on the two-day pre- and post-event window definitions, Table 2 presents the events that were identified according to the discussed methodology.

Table 2

Total Intervention in the DEM/USD Exchange Rate Market

Date of event*	Avg. daily % change in the DEM/USD exchange rate over preceding two days†	Total amount of intervention‡ (million USD)	Number of days of intervention during event	Avg. daily % change in the DEM/USD exchange rate over subsequent two days§
Sep 23, 85–Nov 12, 85 (35)	−1.017	−2,944	27	−0.143
Dec 11, 85 (1)	0.287	−51	1	−0.411
Apr 28, 86 (1)	−0.454	102	1	0.013
Sep 12, 86 (1)	0.775	−31	1	−0.291
Sep 29, 86–Oct 14, 86 (11)	−0.049	1,197	6	0.013
Jan 5, 87–Jan 27, 87 (16)	−0.734	568	6	−0.513
Mar 11, 87 (1)	0.467	−30	1	−0.482
Apr 24, 87–Jun 3, 87 (28)	−0.109	1,527	9	0.181
Aug 4, 87–Aug 10, 87 (5)	0.229	−908	5	−0.045
Aug 28, 87–Sep 9, 87 (8)	−0.260	391	5	0.079
Oct 20, 87–Jan 13, 88 (58)	−0.647	5,915	29	1.411
Apr 14, 88–Apr 15, 88 (2)	0.207	391	2	0.061
May 31, 88–Oct 7, 88 (94)	0.372	−12,905	62	−0.695
Nov 11, 88–Dec 2, 88 (16)	−0.896	988	6	0.047
Dec 8, 88–Feb 7, 89 (42)	1.040	−4,083	29	−0.219
Mar 7, 89–Jun 30, 89 (83)	0.307	−7,942	44	−1.663
Aug 11, 89–Oct 11, 89 (42)	0.033	−3,619	25	−0.685
Dec 21, 89–Jan 4, 90 (9)	0.428	−57	2	−0.437
Mar 2, 90–Mar 7, 90 (4)	0.886	−890	4	−0.058
May 29, 90–Jul 17, 90 (35)	0.299	1,000	17	−0.061
Feb 4, 91–Feb 12, 91 (7)	−0.841	1,606	7	0.446
Mar 11, 91–Mar 27, 91 (13)	0.679	−1,710	7	−0.243
Apr 23, 91–Jul 16, 91 (59)	2.300	−2,240	10	−0.795
Aug 19, 91 (1)	0.750	−122	1	−1.758
Jul 20, 92–Aug 24, 92 (26)	−0.610	1,783	5	0.125
Apr 29, 94–May 4, 94 (4)	−0.340	1,500	2	0.121
Jun 24, 94 (1)	0.246	253	1	−0.173
Nov 2, 94–Nov 3, 94 (2)	−0.438	1,300	2	−0.338
Mar 2, 95–Mar 3, 95 (2)	0.275	1,245	2	−2.158
Apr 3, 95–Apr 5, 95 (3)	−0.175	2,001	2	0.128
May 31, 95 (1)	−0.572	889	1	0.166
Aug 15, 95 (1)	0.190	789	1	0.057

*Total number of days (excluding weekends and holidays) during each event is listed in parenthesis.
†Average daily percentage change in the DEM/USD exchange rate over the two business days prior to first day of the event.
‡Positive values represent intervention in support of the USD, i.e. purchase of USD, while negative values represent intervention aimed at reducing the value of the USD, i.e. sale of USD.
§Average daily percentage change in the DEM/USD exchange rate over the two business days succeeding the last day of the event.

The Table provides a detailed description of the behaviour of the DEM/USD exchange rate during the pre- and post-event windows, the total amount (and direction) of the intervention for each event, and the number of days of intervention during the events.

The Bundesbank, the Fed, or both intervened in the DEM/USD exchange rate market in 32 separate events, and 24 of these cases consisted of multiple days of intervention operations. Comparing the direction of intervention during the event with the change in the exchange rate over the preceding period, the two-day pre-event window, 26 events appear consistent with a 'leaning against the wind' intervention policy and, accordingly, six events appear in line with 'leaning with the wind'.

Turning to the successfulness of the defined events, it is immediately apparent that the direction of the change in the exchange rate during the post-event window was consistent with the direction of the associated intervention in 27 events. In other words, 27 of the 32 events were successful according to the 'direction' criterion. Furthermore, 24 of the 26 'leaning against the wind' events were successful according to the 'reversal' criterion while all 26 'leaning against the wind' events were successful according to the 'smoothing' criterion.

3.1. *Sign Test Results*

Table 3 displays the results from the sign test based on the 'direction', the 'reversal', and the 'smoothing' criterion for successfulness of an event. For the case of

Table 3

Total Intervention in the DEM/USD Exchange Rate Market

	Number of events	Number of successes	p-value[†] (%)
*Non-parametric sign test of 'direction'**			
DEM purchases	14	14	0.01
DEM sales	18	13	4.81
Total purchases and sales	32	27	0.01
*Non-parametric sign test of 'reversal'**			
DEM purchases when DEM depreciates[‡]	13	13	0.01
DEM sales when DEM appreciates[‡]	13	11	1.12
Total DEM sales and purchases[‡]	26	24	0.00
Non-parametric sign test of 'smoothing'[§]			
DEM purchases when DEM depreciates[‡]	13	13	2.38[‖]
DEM sales when DEM appreciates[‡]	13	13	2.38[‖]
Total DEM sales and purchases[‡]	26	26	0.06[‖]

*Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) measured as the average of the exchange rate changes over subsequent 2-day period.
[†]Based on a binomial probability distribution with the probability of an individual success of 50%.
[‡]The Bundesbank and the Fed pursuing a 'leaning against the wind' intervention policy.
[§]Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) or slowing of DEM appreciation (depreciation).
[‖]Based on a binomial probability distribution with the probability of an individual success of 75%.

the 'direction' criterion, the Table divides the 32 events into DEM purchases (14 events) and sales (18 events). All 14 events of DEM purchases were successful thus rejecting randomness at the 99% significance level, while 13 of the 18 events of DEM sales were successful thus rejecting randomness at the 95% significance level. Without distinguishing between purchases and sales of DEM, 27 of the 32 events were successful, rejecting randomness at the 99% significance level.

Based on the 'reversal' criterion, and thus the sub-set of events associated with a 'leaning against the wind' policy, 13 of the 13 events of DEM purchases were successful, rejecting randomness at the 99% significance level. 11 of the 13 events of DEM sales were successful, rejecting randomness at the 95% significance level. Accordingly, 24 of the 26 events of either DEM sales or purchases were successful thus rejecting randomness at the 99% significance level.

Finally, the sign test based on successfulness according to the 'smoothing' definition finds that 13 (13) of the 13 (13) events of DEM purchases (sales) associated with a 'leaning against the wind' policy were successful, rejecting randomness at the 95 (95)% significance level. It follows that all 26 'leaning against the wind' events were successful and that randomness is rejected at the 99% significance level.

3.2. *Matched Sample Test Results*

Table 4 presents the results of the matched sample test. Before (after) the intervention events when the two central banks purchased DEM in the foreign

Table 4

Total Intervention in the DEM/USD Exchange Rate Market

	Number of events		t-statistic*
Matched sample test of 'smoothing'			
DEM purchases	14		
Difference in means		−1.10	−15.66
DEM purchases when DEM depreciates‡	13		
Prior event average percentage change‡		0.66	
Post event average percentage change‡		−0.60	
Difference in means		−1.26	−19.78
DEM sales	18		
Difference in means		0.25	4.87
DEM sales when DEM appreciates‡	13		
Prior event average percentage change‡		−0.47	
Post event average percentage change‡		0.14	
Difference in means		0.62	13.81

*Matched sample (paired comparison) of exchange rate growth rate changes prior and post each event, assuming both series are normally distributed.
†The Bundesbank and the Fed pursuing a 'leaning against the wind' intervention policy.
‡The average of the average daily percentage change in the exchange rate over preceding and subsequent 2 days, respectively.

exchange market the average exchange rate change was 0.66 (−0.60).[11] Before (after) the intervention events when the two central banks sold DEM in the foreign exchange market the average exchange rate change was −0.47 (0.14). Events of 'leaning against the wind' intervention in the DEM/USD exchange rate were, on average, associated with a reversal of the preceding trend. Formally, both cases strongly reject (at the 99% significance level) the null hypothesis of no difference in means – that is, intervention appears to have had at least a smoothing effect on exchange rate changes.

The applied matched sample test, as already noted, assumes normality in the underlying distribution of pre- and post-event window exchange rate changes. There is substantial evidence, however, that exchange rates exhibit a high degree of kurtosis ('fat tails'). This implies that the normality assumption would lead to a bias towards rejecting the null hypothesis of no difference in mean values. To address this concern, we regress our sample of leaning against the window 'matched pair' differences (for both DEM Sales and DEM Purchases) on a constant term using White's (1980) heteroscedasticity-consistent (robust) standard errors. The estimated constant term for the differences in matched pairs DEM Sales (DEM Purchases) regression is the same as the mean values reported in Table 4, of course, and the p-value is 0.2% (0.01%). These results are thus consistent with the matched sample tests reported in Table 4.

3.3. *Robustness Checks and Summary of Event Study Results*

As an illustration of the findings being robust to pre- and post-event window lengths other than two days, Table 5 provides an overview of the sign test results based on window lengths of 5, 10 and 15 days. With respect to the 'direction' criterion, randomness was rejected at the 90% significance level or better for all three of the window definitions while randomness was rejected at the 95% significance level or better when focusing on the 'reversal' as well as the 'smoothing' criterion.

Summarising the findings of this part of the analysis, the null hypothesis of no link between the intervention events and the subsequent short run exchange rate movements is rejected for all the criteria for success applied. These results are robust to changes in the length of the pre- and post-event windows and thereby the criteria for success applied as well as to exclusion of 'leaning with the wind' observations from the sample.

4. Intervention and Interest Rate Changes

Up to this point, exchange rate movements during the post-event windows are implicitly attributed to central bank intervention and no controls are made for the arrival of other economic news or policies. That is, the event study

[11] Focusing on the events associated with a 'leaning against the wind' policy.

Table 5

Total Intervention in the DEM/USD Exchange Rate Market

Sign test based on different window definitions	Number of events	Number of successes	p-value[†] (%)
*Non-parametric sign test of 'direction'**			
5-day window definition	32	25	0.11
10-day window definition	32	21	5.51
15-day window definition	32	24	0.35
*Non-parametric sign test of 'reversal'**			
5-day window definition[‡]	25	20	0.20
10-day window definition[‡]	26	18	3.78
15-day window definition[‡]	24	19	0.33
Non-parametric sign test of 'smoothing'[§]			
5-day window definition[‡]	25	24	0.70[‖]
10-day window definition[‡]	26	24	2.58[‖]
15-day window definition[‡]	24	24	0.10[‖]

*Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) measured as the average of the exchange rate changes over subsequent period.
[†]Based on a binomial probability distribution with the probability of an individual success of 50%.
[‡]The Bundesbank and the Fed pursuing a 'leaning against the wind' intervention policy.
[§]Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) or slowing of DEM appreciation (depreciation).
[‖]Based on a binomial probability distribution with the probability of an individual success of 75%.

methodology assumes that intervention defines the event and is not systematically linked to other relevant economic news or developments such as monetary policy shifts. In principle, this is an issue arising in all event studies but is a greater concern in cases such as ours where the event may be drawn out over several days.

In this context, changes in interest rate policy would seemingly be the most likely economic development systemically related to intervention policy. To address this point, we investigate in Table 6 the way short-term interest rates controlled by the Fed and Bundesbank are correlated with our intervention events. 11 events in our combined intervention (Fed and Bundesbank) sample were also associated with interest rate changes (oftentimes several changes) by either the Fed or the Bundesbank at some point during the sample period. The second column shows the interest rate changes during each event (*DISC/LOMB* indicates discount rate and Lombard rate changes by the Bundesbank; *FF* denotes Federal Funds rate changes by the Federal Reserve). The third column shows the amount (positive values indicate purchases of USD against DEM by either the Fed or Bundesbank). The fourth column shows the date of the interest rate change and the last column indicates whether the interest rate change is in a direction consistent with the intervention operation during the event. For example, during the January 5–27 1987 event listed, the Fed and Bundesbank together purchased 568 million USD against DEM and at the same time the Bundesbank lowered interest rates by 0.5 percentage points. This dollar support intervention was consistent, as noted in the last column of Table 6, with the decline in German interest rates at the time.

Table 6

Interest Rate Changes During Events

Date of event	Interest rate change	Total intervention*	Date of change	Consistency†
Jan 5, 87–Jan 27, 87	−0.5 (*DISC/LOMB*)	568	Jan 23, 87	Yes
Apr 24, 87–Jun 3, 87	+0.5 (*FF*)	1527	Apr 30, 87	Yes
	+0.25 (*FF*)		May 21, 87	Yes
Aug 28, 87–Sep 9, 87	+0.5 (*FF*)	391	Sep 4, 87	Yes
Oct 20, 87–Jan 13, 88	+0.5 (*FF*)	5915	Nov 5, 87	Yes
	−0.5 (*LOMB*)		Nov 6, 87	Yes
	−0.5 (*DISC*)		Dec 4, 87	Yes
May 31, 88–Oct 7, 88	+0.25 (*FF*)	−12905	Jun 22, 88	No
	+0.5 (*DISC*)		Jul 1, 88	Yes
	+0.25 (*FF*)		Jul 19, 88	No
	+0.5 (*LOMB*)		Jul 29, 88	Yes
	+0.5 (*FF*)		Aug 9, 88	No
	+0.5 (*DISC*)		Aug 26, 88	Yes
Nov 11, 88–Dec 2, 88	+0.125 (*FF*)	988	Nov 17, 88	Yes
Dec 8, 88–Feb 7, 89	+0.375 (*FF*)	−4083	Dec 15, 88	No
	+0.5 (*LOMB*)		Dec 16, 88	Yes
	+0.25 (*FF*)		Jan 5, 89	No
	+0.5 (*DISC/LOMB*)		Jan 20, 89	Yes
Mar 7, 89–Jun 30, 89	+0.5 (*DISC/LOMB*)	−7942	Apr 21, 89	Yes
	+0.125 (*FF*)		May 4, 89	No
	−0.25 (*FF*)		Jun 6, 89	Yes
	+0.5 (*DISC/LOMB*)		Jun 30, 89	Yes
Aug 11, 89–Oct 11, 89	+1.0 (*DISC/LOMB*)	−3619	Oct 6, 89	Yes
May 29, 90–Jul 17, 90	−0.25 (*FF*)	1000	Jul 13, 90	No
Apr 23, 91–Jul 16, 91	−0.25 (*FF*)	−2240	Apr 30, 91	Yes

*Positive values represent intervention in support of the USD, i.e. purchase of USD, while negative values represent intervention aimed at reducing the USD, i.e. sale of USD.
†The direction of the intervention operation is consistent with the direction of the interest rate change, e.g. a purchase of USD is consistent with a rise in the *FF* target rate and/or a fall in the German discount and Lombard rates.

This analysis indicates that most interest rate changes are consistent with the intervention operations during the event period. This complicates our task of interpreting whether 'success' is attributable to intervention or the interest rate change. To isolate the effect of intervention alone, we separate out those events during which no interest rate changes took place, i.e. a sub-sample of 'pure' intervention policy events.

These results, reported in Table 7, also support the hypothesis that intervention events are associated with significant exchange rate changes. Not surprisingly, including events where intervention is combined with central bank interest rate moves has a larger impact than intervention alone. Nonetheless, intervention is significant at conventional levels in every case except those employing the 10-day window definition (i.e. significance in 9 of 12 cases).

Some events coincided with announcements of other financial news such as exchange rate policy news (e.g. US officials expressing commitment to a stronger USD). Based on the exchange rate policy news found in Dominguez and Frankel (1993*a*), covering the years 1983 to 1990, and the updates from Fatum (2000), covering the years 1991 to 1995, 14 of the 32 events coincided

Table 7

Total Intervention in the DEM/USD Exchange Rate Market: Events During Which No Interest Rate Changes Occurred

	Number of events	Number of successes	p-value[†] (%)
*Non-parametric sign test of 'direction'**			
2-day window definition	21	18	0.07
5-day window definition	21	17	0.36
10-day window definition	21	12	33.18
15-day window definition	21	14	9.46
*Non-parametric sign test of 'reversal'**			
2-day window definition	16	15	0.03
5-day window definition[‡]	16	12	3.84
10-day window definition[‡]	16	9	40.18
15-day window definition[‡]	16	11	10.51
Non-parametric sign test of 'smoothing'[§]			
2-day window definition	16	16	1.00[‖]
5-day window definition[‡]	16	15	6.35[‖]
10-day window definition[‡]	16	14	19.71[‖]
15-day window definition[‡]	16	16	1.00[‖]

*Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) measured as the average of the exchange rate changes over subsequent period.
[†]Based on a binomial probability distribution with the probability of an individual success of 50%.
[‡]The Bundesbank and the Fed pursuing a 'leaning against the wind' intervention policy.
[§]Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) or slowing of DEM appreciation depreciation).
[‖]Based on a binomial probability distribution with the probability of an individual success of 75%.

with the arrival of such news.[12] Of the 14 events coinciding with exchange rate policy news, 8 events are also associated with interest rate changes by either the Fed or the Bundesbank.

5. Extensions

In this Section we extend our analysis in several dimensions. First, we investigate the quantitative links between the volume of intervention, the likelihood of a successful event, and the magnitude of the subsequent exchange rate change. Second, we address the issue of coordination and whether intervention events are more or less likely to appear successful if both the Fed and the Bundesbank are active during the event. Third, we consider the link between the duration of the event – in terms of the length of the period that the central banks were active in the market – and the subsequent likelihood of a successful intervention (and magnitude of the exchange rate change). Fourth, we investigate whether the success of an event is related to the duration of central bank 'inactivity' (no intervention spells) prior to the event. Is an intervention event that follows an extended period of 'inactivity' more likely to

[12] The news variable is based on all reports of official exchange rate policy that is published in at least one of the following three newspapers: *Wall Street Journal, New York Times* and *Financial Times*.

surprise the market and thus prove more effective? Fifth, we address the issue of a long run effect, if any, of intervention operations.

It might be argued that many of the small-scale interventions in our sample are so small relative to market transactions that they should not be considered as a serious attempt by central banks to move the exchange rate. In order to address this concern, Table 8 displays the results of the sign tests (with two-day windows) excluding 'small' intervention events (less than USD 100 million). The number of events falls, of course, but the p-values are very similar to the analogous results reported for the full sample of events in Table 3. The only substantive change is that the number of successes according to the smoothing criterion for the case of DEM sales consistent with the central banks pursuing a leaning against the wind policy becomes significant at the 90% level as opposed to the 95% level for the full sample.[13]

A number of studies find intervention operations more likely to be effective when more than one central bank is active in the foreign exchange market. Results of the sign tests (with two-day windows) including only the 21 events where both the Fed and the Bundesbank undertook intervention operations during each event, respectively, are similar to those reported in Table 3 (and Table 8) and available from the authors upon request. The number of successes according to the direction and the reversal criteria are all significant at the 99% level, while the

Table 8

Total Intervention in the DEM/USD Exchange Rate Market: Sub-Sample of Events with Volume Larger than 100 Mill. USD

	Number of events	Number of successes	p-value[†] (%)
*Non-parametric sign test of 'direction'**			
DEM purchases	10	10	0.10
DEM sales	18	13	4.81
Total purchases and sales	28	23	0.05
*Non-parametric sign test of 'reversal'**			
DEM purchases when DEM depreciates[‡]	9	9	0.20
DEM sales when DEM appreciates[‡]	13	11	1.12
Total DEM sales and purchases[‡]	22	20	0.01
Non-parametric sign test of 'smoothing'[§]			
DEM purchases when DEM depreciates[‡]	9	9	7.51[‖]
DEM sales when DEM appreciates[‡]	13	13	2.38[‖]
Total DEM sales and purchases[‡]	22	22	0.18[‖]

*Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) measured as the average of the exchange rate changes over subsequent 2-day period.
[†]Based on a binomial probability distribution with the probability of an individual success of 50%.
[‡]The Bundesbank and the Fed pursuing a 'leaning against the wind' intervention policy.
[§]Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) or slowing of DEM appreciation (depreciation).
[‖]Based on a binomial probability distribution with the probability of an individual success of 75%.

[13] Results based on window lengths of 5, 10 and 15 days support the findings of Table 8. These results are not reported for brevity but are available from the authors upon request.

number of successes according to the smoothing criterion is significant at the 90% level. Based on these numbers alone, events associated with coordination are as likely to appear successful as events characterised by a single central bank intervening.[14]

The link between intervention amounts and exchange rate changes are shown in Figure 5. The Figure compares the size of the intervention events (in USD 100 million) with the subsequent exchange rate change (positive values denote dollar appreciation against DEM). The categorisation of events is based on two-day windows and the measure of success is the direction criterion analogous to Tables 2 and 5. Both successful (denoted by triangle symbol) and unsuccessful (denoted by dot symbol) events are shown in the Figure.

Events in the first (third) quadrant of Figure 5 indicate dollar purchases (sales) against the DEM associated with dollar appreciation (depreciation). The Figure indicates that large-scale intervention events appear associated with relatively large exchange rate movements. Most of the events are small in magnitude and are associated with relatively small, but successful, outcomes (shown as clustered in the first and third quadrants near the origin). But the few large interventions (e.g. over USD 25 billion) were all successful and associated with substantial subsequent moves in the exchange rate.

Turning to the duration, the dating of the events (column 1 of Table 2) implies that most occurrences – 26 of the 32 events – are characterised by central banks being active over a period of less than 40 days. For these events (less than 40 days), no clear correlation is evident between duration and the magnitude of exchange rate changes. Furthermore, for this group of events no correlation appears between duration and whether intervention is successful or not. With the exception of two very short-lasting events (one successful and one unsuccessful, both associated with large subsequent exchange rate changes), the remaining 24 shorter lasting events were all associated with moderate exchange rate changes (average daily % changes of less than 0.5 in absolute value). However, it is interesting to notice that all six longer-lasting events (i.e. greater

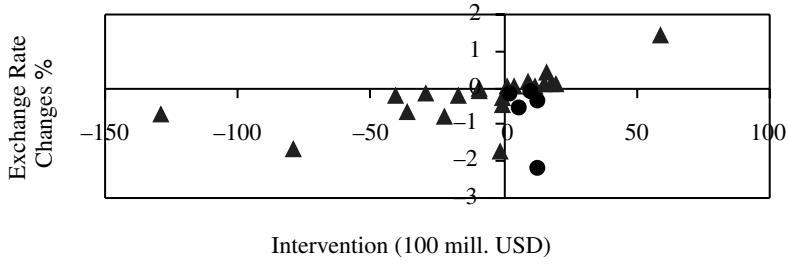

Fig. 5. *Volume and Exchange Rate Changes*

[14] It is not possible to extend the analysis of coordination to include intervention operations undertaken by other central banks, such as the Bank of Japan and the Swiss National Bank, due to unavailability of official and comparable data.

than 40 days) were successful and, with one exception, associated with substantial exchange rate movements. If one interprets the duration spell of intervention events as indicative of a central bank's resolve, then it appears that either the Fed or Bundesbank is likely to be successful if it is persistently in the market for a prolonged period. This is consistent with the aforementioned volume result since prolonged periods of intervention are generally characterised as high-volume events.

We also consider the link between the spell of central bank 'inactivity' (i.e. period of no intervention) prior to the event and the ultimate success of intervention. Again referring to column 1 of Table 2, we find that all of the intervention events preceded by at least 100 days of 'inactivity' are successful.[15] Beyond this observation, however, we do not find any discernible relationship between spell of 'inactivity' and the likelihood of a successful intervention event.

Our criteria for a successful event focus on the short run, i.e. the two to fifteen day-windows before and after each event. We have found that interventions, using these criteria, are largely successful. But is there any lasting effect? In order to address this question, we extend the pre- and post event windows of our event study set-up to span 30 days. 'Long run' success is thus defined as an average exchange rate movement over a period of 30-days following, and consistent with, the associated intervention event. Extending the analysis to encompass this long of an event window comes at a cost, however, since a number of the intervention events are necessarily excluded due to the overlap of post-event windows and subsequent events. Furthermore, the longer the event window the more likely that other news may influence exchange rate developments. Nonetheless, using the 30-day window and again applying the sign test to the three criteria of success (direction, reversal or smoothing), we can not reject the null hypothesis (no effect). In particular, the number of successful events does not exceed the 90% confidence level for 8 of the 9 tests (the only exception is the direction criterion for DEM purchases with a p-value of 6.25%). Although these 'long run' results should be interpreted with some caution due to the limited sample size, it is clear that evidence in support of effective intervention diminishes when the window-lengths are extended to 30 days.

6. Conclusion

Using an event study methodology, we find evidence that intervention affects the exchange rate in the short run. Though simple methodologically, looking at intervention operations in this way provides some support of the view that sterilised intervention may play a role in moving the exchange rate. This finding is consistent with the related work of Catte *et al.* (1994) and Humpage (1999) and the time-series based study of Dominguez and Frankel (1993*a*).

Our results may shed light on why central banks continue to pursue sterilised intervention despite widespread academic scepticism over its effectiveness. Intervention events – when viewed as a related set of daily intervention operations –

[15] The results on 'inactivity' and the results on 'long run' effects are not reported for brevity but are available from the authors upon request.

appear to influence the exchange rates in the short-run. These effects are likely to be missed in the standard time-series analysis generally used previously in this context. Our results are robust to changes in event and event window definitions, and after taking into account central bank interest rate changes. We also report evidence suggesting a link between the likely success of intervention and both its volume and duration of the event.

The event-study methodology does not allow identification of the particular channel through which intervention works. However, our findings are consistent with recent literature interpreting intervention as a means to 'signal' not only future policy but also the central bank's views on the fundamental/equilibrium value of the exchange rate.

We only find support for short-run effectiveness of intervention, however. Accordingly, our results should not be interpreted as a rationale for the longer-term management of exchange rates in the absence of more fundamental policy actions.

University of Alberta School of Business
University of California, Santa Cruz

Date of receipt of first submission: July 2000
Date of receipt of final typescript: July 2002

References

Bank for International Settlements (1999). *Central Bank Survey of Foreign Exchange and Derivatives Market Activity 1998*, Basle.

Ben-Horim, M. and Levy, H. (1984). *Statistics: Decisions and Applications in Business and Economics*, Second Edition, New York: Random House.

Bonser-Neal, C. and Tanner, G. (1996). 'Central bank intervention and the volatility of foreign exchange rates: evidence from the options market', *Journal of International Money and Finance*, vol. 15, no 6, pp. 853–78.

Campbell, C. J. and Wasley C. (1993). 'Measuring security price performance using daily NASDAQ returns', *Journal of Financial Economics*, vol. 33, no. 1, pp. 73–92.

Catte, P., Galli, G. and Rebecchini, S. (1994). 'Concerted interventions and the dollar: an analysis of daily data', in (P. Kenen, Papadia and Saccomanni, eds.), *The International Monetary System*, Cambridge: Cambridge University Press.

Dominguez, K. M. and Frankel A.J. (1993*a*): *Does Foreign Exchange Intervention Work?* Washington D.C.: Institute for International Economics.

Dominguez, K. M. and Frankel, A.J. (1993*b*). 'Does foreign-exchange intervention matter? The portfolio effect', *American Economic Review*, vol. 83, no. 5, pp. 1356–69.

Edison, H.J. (1993). *The Effectiveness of Central-Bank Intervention: A Survey of The Literature After 1982*, Princeton: Princeton University International Finance Section (Special Papers In International Economics no. 18).

Fatum, R. (2000). 'On the effectiveness of sterilized foreign exchange intervention', ECB Working Paper no. 10.

Fatum, R. and Hutchison, M.M. (1999). 'Is intervention a signal of future monetary policy? Evidence from the federal funds futures market', *Journal of Money, Credit and Banking*, vol. 31 (1), pp. 54–69.

Frankel, J. A. (1994). Discussion on P. Catte, G. Galli and S. Rebecchini: 'Concerted interventions and the dollar: an analysis of daily data', in (P. Kenen, Papadia and Saccomanni, eds.) *The International Monetary System*, Cambridge: Cambridge University Press.

Galati, G. and Melick, M. (1999). 'Central bank intervention and market expectations: an empirical study of the yen/dollar, 1993–96', BIS Working Paper no. 77.

Humpage, O. F. (1999). 'US intervention: assessing the probability of success', *Journal of Money, Credit and Banking*, vol. 31, pp. 732–47.

Jurgensen, P. (1983). *Report of the Working Group on Exchange Market Intervention* (Jurgensen Report), Washington: Treasury Department.

Kaminsky, G. L. and Lewis, K. K. (1996) 'Does foreign exchange intervention signal future monetary policy?', *Journal of Monetary Economics*, vol. 37, pp. 285–312.
MacKinlay, A. C. (1997). 'Event studies in economics and finance', *Journal of Economic Literature*, vol. 35, pp. 13–39.
Obstfeld, M. and Rogoff, K. (1996). *Foundations of International Macroeconomics,* Cambridge, MA: MIT Press.
Rogoff, K. (1984). 'On the effects of sterilized intervention: an analysis of weekly data', *Journal of Monetary Economics*, vol. 14, pp. 133–50.
Weber, A. A. (1994). 'Foreign exchange intervention and international policy coordination: comparing the G-3 and EMS experience', Centre for Economic Policy Research Discussion Paper, no. 1038.
White, H. (1980). 'A heteroskedasticity-consistent covariance matrix and a direct test for heteroskedasticity', *Econometrica*, vol. 48, pp. 817–38.