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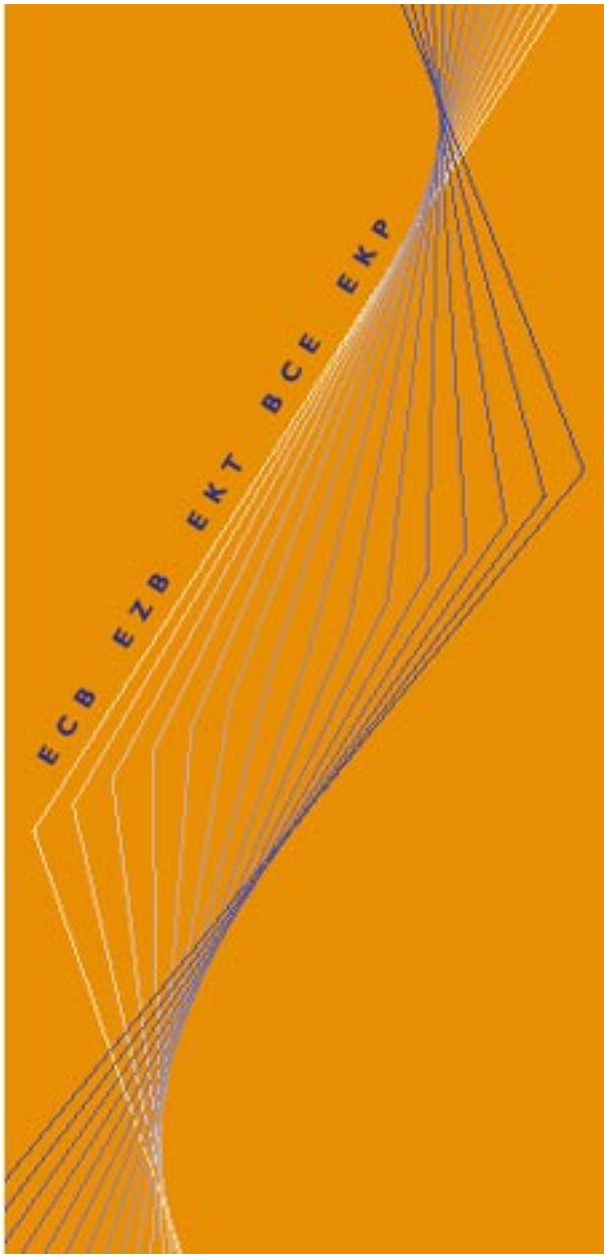

WORKING PAPER NO. 10

ON THE EFFECTIVENESS OF STERILIZED FOREIGN EXCHANGE INTERVENTION

BY RASMUS FATUM

February 2000

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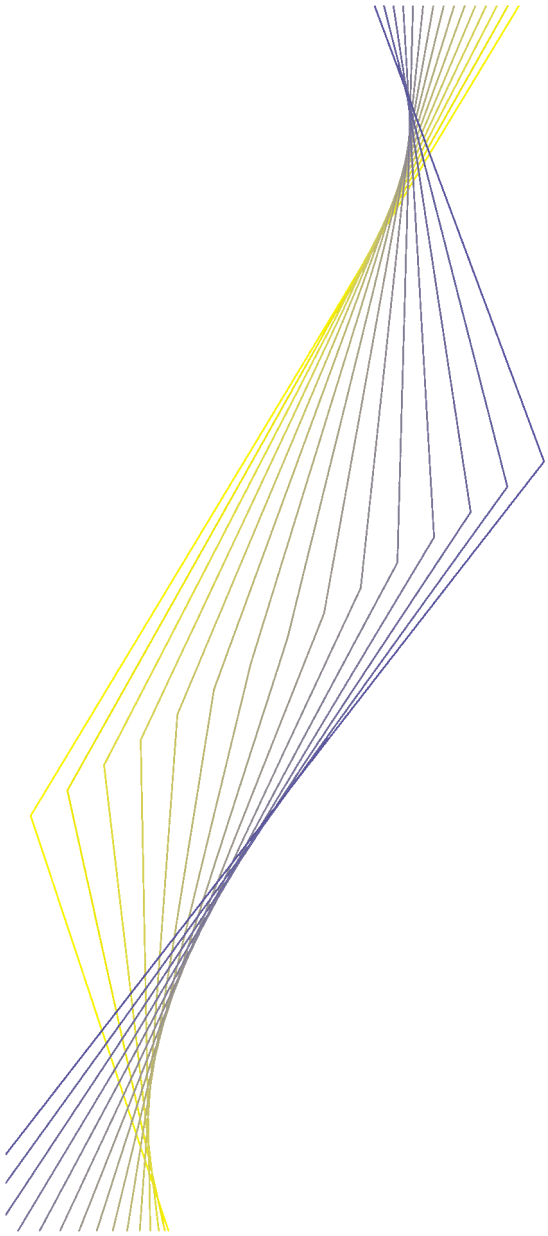

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February 2000

I thank the Bundesbank and the Board of Governors of the Federal Reserve System for providing data, Philipp Hartmann, Michel Hutchison, Oreste Tristani, and participants at a seminar at the European Central Bank for detailed comments. I also thank Vitor Gaspar and the Editorial Board of the ECB Working Paper Series, an anonymous referee with the ECB Working Paper Series, and Ulrich Grorsch, Heinz Herrmann, Joachim Keller and Rasmus Rüffer of the Bundesbank for very helpful comments. The views expressed do not necessarily represent those of the ECB, the Bundesbank or the Board of Governors of the Federal Reserve System.

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Abstract

This paper addresses the question of whether sterilized central bank intervention systematically affects exchange rates. Furthermore, the paper analyzes whether a central bank can conduct its intervention operations in a specific manner, in order to increase the likelihood of achieving its objectives.

The methodological starting point of the paper is to recognize that standard time-series techniques may not be well suited when dealing with the analysis of intervention vis-à-vis the behavior of exchange rates as the latter are typically highly volatile on a day-to-day basis while intervention tends to come in sporadic clusters.

Therefore, the question is addressed by applying the event study methodology, typically found in the finance literature, to daily data on Bundesbank and Fed post-Plaza intervention. Using the non-parametric sign test and the matched sample test, evidence of effectiveness in terms of a systematic association between exchange rate levels and intervention is found.

The second issue is addressed by estimating binary choice models of the conditional probabilities of observing a successful intervention operation over the sub-sample of observations when at least one of the two central banks were intervening. The results suggest that central banks can in fact improve the likelihood of success primarily through coordination and, in particular, if intervention is relatively infrequent.

The results presented are based on short-term criteria for success and, therefore, do not question the limitations of sterilized intervention on its own as a policy instrument for achieving long-term effects on exchange rates.

1 Introduction

The effectiveness of sterilized 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 favor of a link between sterilized intervention and associated movements of exchange rates, policy makers nevertheless seem to view sterilized 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 sterilized 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 (Edison (1993), Rogoff (1984)).[3]

Evidence in favor of a "signaling" channel, through which sterilized intervention is effective in providing new information about policy intentions and, if credible, thereby future fundamentals, is similarly mixed.[4] Kaminsky and Lewis (1996) find that US intervention sometimes signals monetary policy indicators in the opposite direction of that predicted by the conventional signaling hypothesis. Fatum and Hutchison (1999a), using daily data and a GARCH specification, find that intervention does not systematically signal future monetary policy (proxied by changes in the federal funds future's rate), instead it increases the uncertainty over the direction of the policy.

These findings are in line with Bonser-Neal and Tanner (1995), 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 sterilized intervention. In a descriptive study by Catte, Galli and Rebecchini (1994), 17 episodes of concerted intervention are extracted, all of which are deemed either "definitely" or "temporarily" successful.[5] Humpage (1996), 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 recognize that standard time-series techniques may not be well suited when dealing with the analysis of intervention vis-à-vis the behavior 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

1 *It is well established that both Bundesbank and Fed intervention operations are sterilized, at least in the short run, see, for example, Dominguez and Frankel (1993) and Weber (1994). Even though full sterilization 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 sterilized 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).*

3 *According to portfolio-balance models, an investor's holdings of domestic and foreign assets depend on the expected returns and the variance of returns. If a central bank intervenes in the foreign exchange market by, say, selling domestic assets, the supply of domestic relative to foreign assets held by the market increases, thereby making the investor require a higher expected return on domestic assets for holding the larger outstanding stock. In turn, this will lead to a fall in the price of the domestic currency, i.e. the domestic currency depreciates.*

4 *According to the signaling channel hypothesis, the current exchange rate is a function of current and (discounted) expected future fundamentals. By intervening in the foreign exchange market, a central bank can convey information about future fundamentals, thereby changing the expected future fundamentals and, in turn, the current exchange rate. See Watanabe (1994) for a detailed exposition of the signaling channel hypothesis.*

5 *As pointed out by Dominguez and Frankel (1993), the variable length of the "success criterion" seems problematic and it seems plausible that sterilized intervention is less potent than suggested by the three authors.*

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.[6] This paper applies the event study methodology, along with carefully defined criteria for what constitutes a successful event, to data on Bundesbank and Fed intervention in the DEM/USD exchange rate market since the Plaza Agreement.[7] Using the non-parametric sign test and the matched sample test, evidence in favor of short-term effectiveness is presented.[8] In order to check the robustness of the findings, different criteria for success and different sample periods are investigated. The findings are insensitive to these alterations.

The second step of the analysis acknowledges that exchange rate movements appear systematically associated with intervention episodes and turns to the issue of whether a suitable management of intervention operations can increase the likelihood of success. Adjusting the event study criteria for success to fit the focus of individual intervention operations, the methodology of this part of the paper combines the event study approach with the binary choice models applied by Humpage (1996).

The findings emphasize the importance of coordinated and relatively infrequent intervention, suggesting that a central bank could in fact improve the likelihood of observing a success by conducting its intervention operations in a certain manner.

The rest of the paper is organized as follows: Section 2 provides a description of the data set. Section 3 introduces the event study approach, carefully defines the events and the criteria for success and presents the results. Section 4 presents the methodology and the results when focussing on the successfulness of individual intervention operations. Section 5 summarizes the findings and discusses the policy implications.

2 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.[9] 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.[10] 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.

6 *Fatum and Hutchison (1999b) introduce the event study approach to data on Fed intervention. The identification itself of separate intervention episodes is readily found in for example Dominguez and Frankel (1993), Catte, Galli and Rebbechini (1994) and Lewis (1996).*

7 *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. Given the lack of consensus over the appropriate exchange rate model, this is seen as an advantage. A limitation of the event study methodology, however, is that it does not control for the effect of changes in other variables, e.g. arrival of news regarding changes in policies. This issue is addressed in the second part of the paper.*

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

9 *The Bundesbank intervention operation variable excludes operations due to portfolio management.*

10 *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.*

No official distinction is available regarding intervention operations being either announced or non-announced.[11]

Table 1 shows that during the sample period, September 1, 1985 to December 31, 1995, the Bundesbank intervened in the DEM/USD exchange rate market on a total of 234 days.[12] 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 (reported) daily trading in the DEM/USD exchange rate market of 290.5 billion USD in April 1998 (BIS (1998)). 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.

Figure 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 and 5 show the level and the day-to-day percentage change in the DEM/USD exchange rate, respectively.

3 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 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.[13]

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 analyzed. Finally, a carefully defined measure of success needs to be established.

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

11 In line with previous research, the logit models of this study uses newspaper reports to distinguish announced ("reported") intervention from unannounced ("secret") intervention. According to Dominguez and Frankel (1993) some 80 percent of Fed intervention is reported while the distinction between reported and secret intervention is less relevant for the case of the Bundesbank, where the argument is that Bundesbank intervention is for all practical purposes always discernable.

12 The sample period is September 1, 1985 to December 31, 1995. The first intervention operation in the sample occurred after the Plaza Meeting. Neither Bundesbank nor the Fed has intervened in the DEM/USD exchange rate market since 1995.

13 See MacKinlay (1997) for a recent survey on event study methodology.

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.

32 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.[14]

[14] *Table A1 of the appendix shows the details of each of the events.*

3.2 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, table A2 (A3) of the appendix compares the direction of the pre-event (post-event) change in the DEM/USD exchange rate for each of the suggested window lengths. 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 window definitions in 28 (25) of the 32 events.

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. (The qualitatively similar results based on five, ten and fifteen day window definitions, summarized in table 5, are discussed at the end of section 3.5).

3.3 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? In this paper, 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 1996). This criterion is formally expressed as follows: An event is a success according to the "smoothing" criterion if either

$$\{\text{ the event is a success according to the "direction" criterion}\} \text{ or}$$
$$\{E_i > 0 \text{ and } \Delta s_{i+} > \Delta s_{i-}\} \text{ or } \{E_i < 0 \text{ and } \Delta s_{i+} < \Delta s_{i-}\}$$

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 $\{E_i > 0 \text{ and } \Delta s_{i-} > 0\}$ or $\{E_i < 0 \text{ and } \Delta s_{i-} < 0\}$) as opposed to "leaning against the wind"

when the central banks are trying to slow or reverse the trend (formally expressed as either $\{E_i > 0 \text{ and } \Delta s_{i-} < 0\}$ or $\{E_i < 0 \text{ and } \Delta s_{i-} > 0\}$).[15] 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.[16]

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. 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 the central banks choosing to stop intervening. Since central banks will stop intervening when either the exchange rate goal is (perceived to be) reached or the event is viewed as unsuccessful, and the latter outcome may be avoided as long as there is still some possibility of reaching the goal, it is possible that this "endogeneity" makes intervention appear more effective.

However, using the intra-event exchange rate change as the foundation for an alternative measure of success is unappealing. First, it would introduce a criterion with a variable length (namely the length of the event itself). More importantly, since central banks intervene when and for as long as an exchange rate goal is not yet reached, an intra-event criterion would be subject to a more severe "endogeneity" problem, as the very reason for intervening would also label the event successful or not, i.e. the results could be strongly biased towards ineffectiveness.[17]

3.4 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

15 *Since the motivation for central bank intervention is rarely announced, the policy criteria "leaning against the wind" and "leaning with the wind" are only indicative of actual policy intentions.*

16 *Notice again that the direction of the exchange rate change preceding the events, and thus whether the associated intervention policy is characterized as leaning with or against the wind, is very robust to the chosen length of the pre-event, see table A2 of the appendix.*

17 *Table A4 of the appendix shows the intra-event DEM/USD exchange rate changes. The table shows that 17 of the 24 events that lasted more than a single day were characterized by an intra-event exchange rate change in the opposite direction of the associated intervention operations.*

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 $\mu = 0.5$.[18] 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).[19]

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

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

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

3.5 The Results of the Event Study

Focussing first on the two-day pre- and post-event window definitions, table 2 presents the events that were identified according to the discussed methodology. The table provides a detailed description of the behavior 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.[20]

The Bundesbank, the Fed, or both intervened in the DEM/USD exchange rate market on 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

18 *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 %.*

19 *Despite the usefulness of the non-parametric rank test in event studies of finance, see MacKinlay (1997), Campbell and Wasley (1993) and Corrado (1989) for details and applications, the number of events during the sample period seems too small for applying this test procedure.*

20 *By construction of the event study, there are no "prescriptive" implications of an event's accumulated amount of intervention and the size of the associated post-event window exchange rate change.*

"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.[21]

3.5.1 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 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 percent significance level, while 13 of the 18 events of DEM sales were successful thus rejecting randomness at the 95 percent significance level. Without distinguishing between purchases and sales of DEM, 27 of the 32 events were successful, rejecting randomness at the 99 percent 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 percent significance level. 11 of the 13 events of DEM sales were successful, rejecting randomness at the 95 percent significance level. Accordingly, 24 of the 26 events of either DEM sales or purchases were successful thus rejecting randomness at the 99 percent 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) percent significance level. It follows that all 26 "leaning against the wind" events were successful and that randomness is rejected at the 99 percent significance level.

3.5.2 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 exchange market the average exchange rate change was 0.66 (-0.60).[22] 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 percent 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.

3.5.3 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 five,

21 *Of the 32 events, eight events consisted of intervention operations conducted by the Bundesbank only. Seven "Bundesbank only" events were consistent with a "leaning against the wind" policy and six of these events were successful according to the "reversal" criterion. Five of the eight "Bundesbank only" events occurred between late 1985 and early 1987 when the Fed did not intervene at all.*

22 *Focusing on the events associated with a "leaning against the wind" policy.*

ten and fifteen days. With respect to the "direction" criterion, randomness was rejected at the 90 percent significance level or better for all three window definitions while randomness was rejected at the 95 percent significance level or better when focussing on the "reversal" as well as the "smoothing" criterion.

Summarizing the findings of the first 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 applied criteria for success. These results are robust to changes in the length of the pre- and post-event windows and thereby the applied criteria for success as well as to exclusion of "leaning with the wind" observations from the sample.

4. The Successfulness of an Individual Intervention Operation

While the first part of the analysis was concerned with the pattern of exchange rate changes around the 32 defined events, addressing the question of whether the events of intervention were successful, the focus of this part of the analysis is on each of the daily intervention operations separately. In particular, it is of interest to investigate if – given that at least one of the two central banks decides on intervening - the central banks can improve the chances for successfulness of an individual daily intervention operation by conducting or timing intervention in a certain way.

Ideally, this part of the analysis would employ the exact same event definition as in the first part. However, estimating any econometric model using the event study definition of the first part is less appealing as the number of observations (32 events) is quite small. Therefore, the applied methodology is such that key features of the event study are maintained, while an event itself no longer refers to a period of days but rather a single day when intervention occurred.[23]

The measures of success in terms of either the "direction" or the "smoothing" criteria are applied as before.[24] Apart from being as consistent as possible with respect to the first part of the analysis, there are convincing reasons for measuring success over subsequent exchange rate movements as opposed to measuring success as a current day exchange rate change. Even though exchange rate markets are typically viewed as being highly efficient, full incorporation of new information into exchange rate quotations is unlikely to happen instantaneously, especially when the new information is unannounced and typically kept "secret".[25]

Since the exchange rate change associated with each intervention operation is deemed either successful or unsuccessful, a binary choice model such as the logit model seems a natural choice when investigating the factors affecting the probability of success of an individual intervention operation.

23 *In order to ensure complete consistency between the two parts of the analysis, the event study presented in the first part of the paper could be based on a single-day event definition. As previously noted, such a definition, however, would make the event study approach less meaningful, as it would not help structuring the data, nor would it help illuminate the policy intent of intervention at a particular time.*

24 *The "smoothing" criterion is adjusted to relate the subsequent two-day exchange rate change to the change over the two days preceding the day of intervention. "Leaning against the wind" intervention policy is adjusted to relate the direction of the daily intervention operation to the direction of the exchange rate change on the preceding day.*

25 *See Osterberg and Wetmore Humes (1993) on the inaccuracy of news reports of US intervention and Vitale (1999) for a theoretical framework justifying the secrecy of intervention operations.*

4.1 The Logit Model Framework

It is assumed that the probability of observing a success (i.e. the binary dependent variable y_i takes the value one) is given by a symmetric distribution F:

$$P(y_i = 1|X_i) = F(\beta' X_i) = 1 - F(-\beta' X_i) \qquad (i = 1,\ldots, n)$$

where X_i is a (k x 1) vector of variables (i.e. the conditioning variables) that affect the probability of observing a successful intervention operation, β is the (k x 1) vector of parameters. Let F denote the logistic probability distribution such that:

$$P(y_i = 1|X_i) = \frac{\exp(\beta' X_i)}{1+\exp(\beta' X_i)} = \frac{1}{1+\exp(-\beta' X_i)},$$

then the odds $\frac{P(y_i = 1|X_i)}{1 - P(y_i = 1|X_i)}$ can be written as $\exp(\beta' X_i)$ or, alternatively, as:

$$L_i = \ln\left(\frac{\hat{P}(y_i = 1|X_i)}{1 - \hat{P}(y_i = 1|X_i)}\right) = b' X_i + u_i$$

where the logit function L_i is estimated using maximum likelihood techniques. $\hat{P}_i$ is the estimated probability of observing a success, b is the estimated parameters, and u_i is the error-term.[26]

4.2 The Conditioning Variables

The conditioning variables are constructed as dummy variables and are chosen with reference to what the literature on intervention has previously distinguished as possible candidates for influencing the effectiveness of sterilized intervention.[27] Four categories of conditioning variables are considered: "Coordination", "pattern", "monetary and exchange rate policy" and "magnitude" variables. In order to avoid multicollinearity in the estimated models, no two variables from the same category are included as simultaneous regressors, as the variables within the same category are highly linearly correlated.

4.2.1 "Coordination" Variables

The idea that coordinated intervention has a different effect than non-coordinated is old, yet the results in the previous literature have been mixed.[28] The issue is addressed by inclusion of the variable COORD, which equals one on days when both the Bundesbank and the Fed intervene, and BUBA (FED) which equals one on days when only Bundesbank (the Fed) intervenes.

Although most intervention operations are not publicly announced, the foreign exchange market is often aware of a central bank's presence. Intervention operations of which the market is aware can have both a supply as well as a signaling effect, whereas intervention operations of which the

26 *The maximum likelihood is estimated by quadratic hill dimbing. The log-likelihood can be written as ln L = Σi ln F((2yi – 1)β'Xi), using that the logistic distribution, F, is symmetric (see Greene (1997)).*

27 *Several other candidates have also been suggested, e.g. announcements of macro-economic variables such as consumer prices, unemployment figures etc., but generally little empirical support have been found (see, for example, Humpage (1996)).*

28 *"About half of the studies find that coordinated intervention is more effective than noncoordinated intervention; the other half find no special significance to the difference between regimes", Edison (1993), p. 35.*

market is unaware can have a supply effect only. Thus it is possible that market awareness of intervention matters for its effectiveness. Market awareness is proxied by the variable REPINT, which equals one when intervention by either the Fed, the Bundesbank, or both, is reported in at least one of the three newspapers Wall Street Journal, New York Times and London Financial Times.[29] [30]

4.2.2 "Pattern" Variables

The "pattern" variables are included to test for certain day effects. As already noted, typically long periods of consecutive days with no intervention are separated by clusters of relatively short periods of days where intervention took place. If sterilized intervention is a way for central banks to purposely reveal "private" information regarding the "true" fundamentals or the direction of future monetary policy, it is likely that the first day in an intervention cluster provides more new information than subsequent days of intervention.[31] This hypothesis is tested through inclusion of the variables FDE and B2B. The first variable equals one on the first day of an event (using the event definition suggested by section 3) and the second variable equals one when the intervention operation immediately succeeds an intervention operation of the previous day.

4.2.3 "Monetary and Exchange Rate Policy" Variables

Although intervention is fully sterilized at least in the short run, an (unexpected) change in German or US monetary policies coinciding with intervention operations could increase the chance of deeming the intervention operation successful (or unsuccessful, if the direction of the policy change is inconsistent with the direction of intervention), i.e. the associated change in the exchange rate could be due to the change in monetary policy rather than intervention. To account for this possibility, the analysis includes the monetary policy variables DEDISC, DELOMB, DEREPO and FFTARG. DEDISC equals one when the German discount rate changes in the direction consistent with the associated intervention operation. Similarly, DELOMBARD (DEREPO) equals one when the German Lombard rate (repurchase rate) changes in the direction consistent with the associated intervention operation, and FFTARG equals one when the federal funds target rate changes in the direction consistent with the associated intervention operation.[32]

To account for the possibility of intervention operations coinciding with announcements of exchange rate policy news (e.g. US officials expressing commitment to a stronger USD on the same day of intervention operations in support of the USD, thereby potentially increasing the likelihood of effectiveness), the variable NEWS is included. NEWS is based on all reports of official exchange rate policy that is published in at least one of the three newspapers Wall Street Journal, New York Times and London Financial Times and equals one on days when exchange rate policy announcements consistent with the associated intervention operation were made.[33]

[29] *The listing of reported intervention found in Dominguez and Frankel (1993), covering the years 1983 through 1990, is updated with respect to intervention for the years 1991 through 1995 for the purpose of this study. The updates are available from the author upon request.*

[30] *Not surprisingly, REPINT appears linearly correlated with COORD and is, therefore, categorized with the "coordination" variables for convenience.*

[31] *Humpage (1988) found that the first intervention operation was more likely to be related with exchange rate changes than were the subsequent interventions, a result not supported by Humpage (1996).*

[32] *The included monetary policy variables are only indicative for the impact of monetary policy as no distinction is being made between expected an unexpected policy changes (see Hardy (1998) for an analysis of expected versus unexpected changes in official interest rates).*

[33] *The listing of exchange rate policy news found in Dominguez and Frankel (1993), covering the years 1983 through 1990, is updated with respect to intervention for the years 1991 through 1995 for the purpose of this study. The updates are available from the author upon request.*

4.2.4 "Magnitude" Variables

The size of the foreign exchange market is indeed very large relative to the magnitude of the central bank intervention operations in the DEM/USD exchange rate. Nevertheless, as other studies have pointed out, it is of interest to test if successfulness of an intervention operation is related to its magnitude. For instance, if the central banks possess superior information about the direction of future policy moves and thereby about future fundamentals, it is plausible that conveying such information through intervention need not require large amounts as it is primarily the direction of the intervention operation that is of interest.[34] This study employs the variables LARGE and SMALL, where the first is set to one on days when the total amount of Bundesbank and Fed intervention was at least USD 500 million and the latter equals one when the total amount was no larger than USD 100 million. The choice of cut-off amounts is consistent with other research in this area, see for example Dominguez and Frankel (1993). For completeness, the continuous variable MAGN is included to capture the actual sign and magnitude of each intervention operation.[35]

4.3 The Results of the Logit Model Analysis

Before presenting the estimation results, two implications of the applied methodology should be emphasized. First, the focus of this part of the analysis is "if intervention occurs, what are the chances of success" thus the relevant observations are constituted by the sub-sample of days when at least one of the two central banks were intervening. Second, the construction of the successfulness criteria has the convenient implication that none of the estimated models are subject to simultaneous equation bias - all the conditioning variables are pre-determined relative to the exchange rate movement over the subsequent days.

4.3.1 "Direction" Criterion Results

Table 6 shows the results of the logit models of successfulness according to the "direction" criterion, estimated over each of the conditioning variables separately.

The logit models using success according to the "direction" criterion as the dependent variable show significant (at the 90 percent level or higher) coefficient estimates for the coordination variables COORD and BUBA, with both estimates of the expected sign. When the two central banks intervene on the same day, the probability of success increases from 0.42 to 0.52, i.e. the marginal probability of coordination is 0.10. When Bundesbank is the only central bank in the market, the probability of success decreases from 0.50 to 0.39, i.e. the marginal probability of Bundesbank intervening alone is –0.11. (For comparison, the unconditional probability of success is 0.46.) Whether the Fed is acting alone in the market has no significant impact on the probability of success.

The variable REPINT is of the expected sign but insignificant, suggesting that the market's awareness of intervention does not increase the probability of success.

The "pattern" variable FDE is significant at the 95 percent significance level, indicating that the marginal probability of observing a success when intervention occurs on the first day of an event

34 See Dominguez and Frankel (1993), p. 88-89, for a discussion on how relatively modest amounts of intervention may have substantial influence on the foreign exchange market.

35 Ideally, each magnitude variable should be related to for instance the size of the DEM/USD foreign exchange market on the day in question. However, daily data on the size of the foreign exchange markets is unavailable.

is 0.23. None of the monetary and exchange rate policy variables are significant and none of the magnitude variables are significant.

Table 7 shows the results of the joint significance tests of the conditioning variables. For the models based on the "direction" criterion, four specifications seem plausible. The first specification has COORD and FDE as explanatory variables, producing marginal probabilities of 0.12 and 0.14, respectively. The second specification has COORD and B2B as explanatory variables and marginal probabilities of 0.13 and –0.11, respectively. The third specification has BUBA and FDE as explanatory variables, producing marginal probabilities of –0.12 and 0.24, respectively. Finally, the fourth specification has BUBA and B2B as explanatory variables and marginal probabilities of –0.13 and –0.11, respectively. All four models do well with respect to the Hosmer-Lemeshow test statistic (with p-values between 95 and 70 percent) and all four models mimic the indicative findings of the "one conditioning variable only" models.[36]

Table 8 presents the results of the broadest possible specifications, i.e. specifications simultaneously including conditioning variables from all four categories. The broad specifications support the findings of the models presented in tables 6 and 7, suggesting that conditioning variables from the categories "exchange rate and monetary policy" and "magnitude" are insignificant while the conditioning variables of importance come from the categories "coordination" and "pattern".

4.3.2 "Smoothing" Criterion Results

Table 9 shows the results of the logit models of successfulness according to the "smoothing" criterion, estimated over each of the conditioning variables separately.

The results based on the "smoothing" criterion are very similar to those in section 4.3.1, with the significant SMALL variable as the exception. When intervention is characterized as small scale, the probability of success decreases from 0.72 to 0.60, i.e. the marginal probability is –0.12. The unconditional probability of success is 0.67. The coordination variables COORD and BUBA are significant and indicate marginal probabilities of 0.16 and –0.12, respectively. The pattern variable FDE is significant with a marginal probability of 0.16. None of the monetary and exchange rate policy variables are significant.

Table 10 shows the results of the joint significance tests of the conditioning variables. The pattern regarding the COORD, BUBA and FDE variables is repeated (although the Hosmer-Lemeshow test statistics are less favorable). The specifications using COORD and FDE and BUBA and FDE, respectively, are suggested and the findings based on the "one conditioning variable only" models are supported. The specifications including B2B in place of FDE are no longer supported by the estimates.

The broad specifications shown in table 11 support the findings of the models presented in tables 9 and 10.

4.3.3 Robustness Checks and Summary of Logit Model Results

Tables A5 through A8 of the appendix display the results based on the "leaning against the wind" sub-sample. With respect to the "direction" criterion (i.e. the "reversal" criterion) the findings

[36] *The Hosmer-Lemeshow test is based on grouping of the values from the estimated probabilities into deciles of risk. For details on this statistic, see Hosmer and Lemeshow (1989), ch. 5.*

repeat the aforementioned results with two exceptions. The coefficient on BUBA is still negative but no longer significant, while the pattern variable B2B is significant (and negative). The marginal probability of the B2B variable is –0.12 when B2B is the only conditioning variable, and –0.15 when B2B is included with the COORD variable. With respect to the "smoothing" criterion, the coefficient on BUBA is still negative and insignificant, while FDE is the only significant pattern variable.[37]

As a further check for robustness of the presented findings, all the estimations were repeated using a post-Louvre sub-sample, i.e. a sample covering the period February 23, 1987 through December 31, 1995, thus excluding the first 15 months of steep USD depreciation; the results are robust to this change in sample size. For reasons of space, these estimations are not shown but available from the author upon request.

Summarizing the findings, the conditional probability of success varies significantly with the way in which intervention is conducted. Simultaneous intervention by Bundesbank and the Fed is more likely to be successful and so is the intervention operation of the first day of an event. Mirroring these results, it was found that Bundesbank intervention alone is less likely to be successful and this also applies to the intervention operation that is immediately subsequent to a day of intervention. Similar to the findings of the first part of the analysis, the findings of this section are insensitive to the criteria for success as well as to the exclusion of "leaning with the wind" observations from the sample.

5 Conclusion

This paper has addressed two issues regarding sterilized foreign exchange intervention. First, whether Bundesbank and Fed intervention is systematically associated with short-run movements in the DEM/USD exchange rate. The methodology applied, following event studies in the finance literature, is built around the distinction of separate intervention clusters as the events of interest.

Insensitive to the applied criteria for successfulness, the results clearly suggested that intervention is indeed effective in terms of influencing the evolution of exchange rates over the short-run, thereby questioning the view that sterilized intervention is central bank force of habit rather than rational policy conduct.

Second, the paper investigated whether there is a certain way for central banks to conduct intervention operations that will increase the likelihood of success of each intervention operation. Estimating logit functions over the sub-sample of days of intervention, clear evidence was presented that coordinated intervention is more likely to be associated with a success and that the first day of intervention in an event or cluster of daily interventions is more likely to be successful. Accordingly, evidence was found that intervention operations conducted by the Bundesbank alone are less likely to be successful. This was also found to be the case for intervention operations immediately following a day of intervention in the same direction. Finally, some evidence was found that small-scale intervention operations are less likely to be successful.

On a cautious note and as an attempt to put the strong findings in favor of sterilized intervention as being effective into perspective, the potency of sterilized intervention on its own should not be exaggerated. Although potentially effective in the short run, sterilized intervention is unlikely to have lasting effects on its own.

37 Results of the broad specifications based on the "leaning against the wind" sub-sample (not shown in the paper) support these findings.

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Tables

Table 1

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

Purchases of DEM (million USD)	Number of Days	Cumulated Amount
>250[b]	23	-8640
>150[c]	17	-3437
>100[d]	17	-2059
>0[e]	112	-3956
Total Purchases	169	-18092
Sales of DEM (million USD)		
>250[b]	13	4835
>150[c]	10	1746
>100[d]	13	1493
>0[e]	29	1479
Total Sales	**65**	**9554**

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

Purchases of DEM (million USD)	Number of Days	Cumulated Amount
>250[b]	24	-8812
>150[c]	16	-3123
>100[d]	16	-2210
>0[e]	74	-5294
Total Purchases	**130**	**-19439**
Sales of DEM (million USD)		
>250[b]	20	8953
>150[c]	8	1663
>100[d]	5	675
>0[e]	43	2601
Total Sales	**76**	**13892**

Total Bundesbank and Fed Intervention, Sept. 1, 1985 – Dec. 31, 1995.

Purchases of DEM (million USD)	Number of Days	Cumulated Amount
>250[b]	49	-22758
>150[c]	31	-6243
>100[d]	31	-3951
>0[e]	108	-4578
Total Purchases	**219**	**-37531**
Sales of DEM (million USD)		
>250[b]	33	16982
>150[c]	13	2581
>100[d]	12	1461
>0[e]	46	2422
Total Sales	**104**	**23446**

a) Daily intervention operations of USD 250 million or greater.
b) Daily intervention operations of USD 150 million or greater, but less than USD 250 million.
c) Daily intervention operations of USD 100 million or greater, but less than USD 150 million.
d) Daily intervention operations of less than USD 100 million.

Table 2 Total Intervention in the DEM/USD Exchange Rate Market

Date of event	Average daily percentage change in the DEM/USD exchange rate over preceding two days (a)	Total amount of intervention (b) (millions USD)	Number of days of intervention during event	Average daily percentage change in the DEM/USD exchange rate over subsequent two days (c)
Sep 23, 85 - Nov 12, 85	-1.017	-2944	27	-0.143
Dec 11, 85	0.287	-51	1	-0.411
Apr 28, 86	-0.454	102	1	0.013
Sep 12, 86	0.775	-31	1	-0.291
Sep 29, 86 – Oct 14, 86	-0.049	1197	6	0.013
Jan 5, 87 – Jan 27, 87	-0.734	568	6	-0.513
Mar 11, 87	0.467	-30	1	-0.482
Apr 24, 87 - Jun 3, 87	-0.109	1527	9	0.181
Aug 4, 87 – Aug 10, 87	0.229	-908	5	-0.045
Aug 28, 87 – Sep 9, 87	-0.260	391	5	0.079
Oct 20, 87 - Jan 13, 88	-0.647	5915	29	1.411
Apr 14, 88 – Apr 15, 88	0.207	391	2	0.061
May 31, 88 – Oct 7, 88	0.372	-12905	62	-0.695
Nov 11, 88 - Dec 2, 88	-0.896	988	6	0.047
Dec 8, 88 – Feb 7, 89	1.040	-4083	29	-0.219
Mar 7, 89 - Jun 30, 89	0.307	-7942	44	-1.663
Aug 11, 89 – Oct 11, 89	0.033	-3619	25	-0.685
Dec 21, 89 – Jan 4, 90	0.428	-57	2	-0.437
Mar 2, 90 – Mar 7, 90	0.886	-890	4	-0.058
May 29, 90 – Jul 17, 90	0.299	1000	17	-0.061
Feb 4, 91 – Feb 12, 91	-0.841	1606	7	0.446
Mar 11, 91 - Mar 27, 91	0.679	-1710	7	-0.243
Apr 23, 91 - Jul 16, 91	2.300	-2240	10	-0.795
Aug 19, 91	0.750	-122	1	-1.758
Jul 20, 92 – Aug 24, 92	-0.610	1783	5	0.125
Apr 29, 94 - May 4, 94	-0.340	1500	2	0.121
Jun 24, 94	0.246	253	1	-0.173
Nov 2, 94 – Nov 3, 94	-0.438	1300	2	-0.338
Mar 2, 95 - Mar 3, 95	0.275	1245	2	-2.158
Apr 3, 95 - Apr 5, 95	-0.175	2001	2	0.128
May 31, 95	-0.572	889	1	0.166
Aug 15, 95	0.190	789	1	0.057

a) *Average daily percentage change in the DEM/USD exchange rate over the two business days prior to first day of the event.*

b) *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.*

c) *Average daily percentage change in the DEM/USD exchange rate over the two business days succeeding the last day of the event.*

Table 3 Total Intervention in the DEM/USD Exchange Rate Market

Non-parametric sign test of "direction"

	Number of Events	Number of Successes (a)	P-value (b)
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"

	Number of Events	Number of Successes (a)	P-value (b)
DEM Purchases when DEM Depreciates (c)	13	13	0.01%
DEM Sales when DEM Appreciates (c)	13	11	1.12%
Total DEM Sales and Purchases (c)	26	24	0.00%

Non-parametric sign test of "smoothing"

	Number of Events	Number of Successes (d)	P-value (e)
DEM Purchases when DEM Depreciates (c)	13	13	2.38%
DEM Sales when DEM Appreciates (c)	13	13	2.38%
Total DEM Sales and Purchases (c)	26	26	0.06%

a) 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.

b) Based on a binomial probability distribution with the probability of an individual success of 50 %.

c.) The Bundesbank and the Fed pursuing a "leaning against the wind" intervention policy.

d) Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) or slowing of DEM appreciation (depreciation).

e) Based on a binomial probability distribution with the probability of an individual success of 75 %.

Table 4 Total Intervention in the DEM/USD Exchange Rate Market

Matched sample test of "smoothing"

	Number of Events		t-statistic (a)
DEM Purchases	14		
Difference in means		-1.10	-15.66
DEM Purchases when DEM Depreciates (b)	13		
Prior event average percentage change (c)		0.66	
Post event average percentage change (c)		-0.60	
Difference in means		-1.26	-19.78
DEM Sales	18		
Difference in means		0.25	4.87
DEM Sales when DEM Appreciates (b)	12		
Prior event average percentage change (c)		-0.47	
Post event average percentage change (c)		0.14	
Difference in means		0.62	13.81

a) Matched sample (paired comparison) of exchange rate growth rate changes prior and post each event, assuming both series are normally distributed.

b) The Bundesbank and the Fed pursuing a "leaning against the wind" intervention policy.

c.) The average of the average daily percentage change in the exchange rate over preceding and subsequent 2 days, respectively.

Table 5 **Total Intervention in the DEM/USD Exchange Rate Market: Sign test based on different window definitions**

Non-parametric sign test of "direction"

	Number of Events	Number of Successes (a)	P-value (b)
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"

	Number of Events	Number of Successes (a)	P-value (b)
5-day window definition (c)	25	20	0.20%
10-day window definition (c)	26	18	3.78%
15-day window definition (c)	24	19	0.33%

Non-parametric sign test of "smoothing"

	Number of Events	Number of Successes (d)	P-value (e)
5-day window definition (c)	25	24	0.70%
10-day window definition (c)	26	24	2.58%
15-day window definition (c)	24	24	0.10%

a) 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.

b) Based on a binomial probability distribution with the probability of an individual success of 50 %.

c) The Bundesbank and the Fed pursuing a "leaning against the wind" intervention policy.

d) Intervention is successful if the sale (purchase) of DEM is associated with DEM depreciation (appreciation) or slowing of DEM appreciation (depreciation).

e.) Based on a binomial probability distribution with the probability of an individual success of 75 %.

Table 6 Logit Models of Each Conditioning Variable Separately

Dependent variable: Success according to "direction" criterion
Sample: Total days of intervention from September 1, 1985 – December 31, 1995
(323 observations of which 147 were successful).

	Coefficient[a]	Constant[a]	LR statistic[b]
Coordination			
COORD	0.419 (0.233)	-0.333 (0.141)	3.244 **
BUBA	-0.451 (0.236)	-0.019 (0.139)	3.699 *
FED	0.031 (0.250)	-0.189 (0.131)	0.015
REPINT	0.050 (0.225)	-0.208 (0.167)	0.050
Pattern			
B2B	-0.358 (1.572)	0.030 (0.174)	2.477
FDE	0.916 (0.391)	-0.270 (0.118)	5.813 *
Monetary and Exchange Rate Policy			
DEDISC	-0.002 (0.616)	-0.180 (0.114)	0.000
DELOMB	-0.233 (0.655)	-0.173 (0.113)	0.127
DEREPO	0.073 (0.237)	-0.204 (0.137)	0.096
FFTARG	-0.518 (1.230)	-0.175 (0.112)	0.186
NEWS	0.635 (0.425)	-0.229 (0.117)	2.287
Magnitude			
LARGE	0.271 (0.378)	-0.206 (0.118)	0.513
SMALL	-0.059 (0.225)	-0.154 (0.149)	0.070
MAGN	0.000 (0.000)	-0.171 (0.113)	0.296

a) Standard errors in parentheses.
*b) Likelihood ratio test of the estimated model against the constant only model. Critical values for 95 and 90 percent significance levels for the LR test with one degree of freedom are 3.841 and 2.706, respectively. Significance at the 95 (90) percent level is indicated with a * (**).*

Marginal probabilities of the Models Not Rejected by the LR-Test

Cond. Variable (x_i)	$P(y=1 \mid x_i = 1)$[c]	$P(y=1 \mid x_i = 0)$[d]	Marg. Prob.	HL statistic[e]
COORD	0.52	0.42	0.10	5.69
BUBA	0.39	0.50	-0.11	13.29
FDE	0.66	0.43	0.23	15.14 **

c) Probability of observing a success when the conditioning variable equals one.
d) Probability of observing a success when the conditioning variable equals zero.
*e) Hosmer-Lemeshow test statistic for goodness-of-fit. The 95 (90) percent critical value for rejecting the null of a fitting model is 15.51 (13.36) (chi-square distribution with 8 degrees of freedom). Rejection at the 95 (90) percent level of significance is indicated with a * (**).*

Table 7 Joint Significance of Conditioning Variables in Logit Models

Dependent variable: Success according to "direction" criterion
Sample: Total days of intervention from September 1, 1985 – December 31, 1995
(323 observations of which 147 were successful).

	LR statistic 1[a]	LR statistic 2[b]
COORD		
and FDE	9.858 *	6.614 *
COORD, FDE		
and DEDISC	10.125 *	0.268
and DELOMB	10.250 *	0.393
and DEREPO	9.900 *	0.042
and FFTARG	10.734 *	0.879
and NEWS	11.793 *	1.935
and LARGE	9.858 *	0.000
and SMALL	10.758 *	0.900
and MAGN	9.936 *	0.078
COORD		
and B2B	7.146 *	3.902 *
COORD, B2B		
and DEDISC	7.214 **	0.068
and DELOMB	7.518 **	0.372
and DEREPO	7.193 **	0.047
and FFTARG	7.579 **	0.433
and NEWS	8.308 **	1.162
and LARGE	7.166 **	0.020
and SMALL	7.713 **	0.567
and MAGN	7.297 **	0.151
BUBA		
and FDE	10.598 *	6.898 *
BUBA, FDE		
and DEDISC	10.738 *	0.140
and DELOMB	10.844 *	0.247
and DEREPO	10.793 *	0.195
and FFTARG	11.522 *	0.924
and NEWS	12.649 *	2.051
and LARGE	10.610 *	0.013
and SMALL	11.119 *	0.522
and MAGN	10.610 *	0.012

BUBA		
and B2B	7.159 *	3.460 **
BUBA, B2B		
and DEDISC	7.167 **	0.008
and DELOMB	7.365 **	0.206
and DEREPO	7.372 **	0.213
and FFTARG	7.605 **	0.446
and NEWS	8.473 *	1.314
and LARGE	7.259 **	0.100
and SMALL	7.364 **	0.205
and MAGN	7.212 **	0.053

*a) Likelihood ratio test of estimated model against the constant only model. Significance at the 95 (90) percent level is indicated with a * (**).*
*b) Likelihood ratio test of adding the new variable to the variable/those variables listed at the top of each section. Significance at the 95 (90) percent level is indicated with a * (**).*

Marginal probabilities of the Models Not Rejected by the (Second) LR-Test

Cond. Variables (x_i)	$P(y=1 \mid x_i = 1)$[c]	$P(y=1 \mid x_i = 0)$[d]	Marg. Prob.	HL statistic[e]
COORD, FDE				**2.93**
COORD	0.53	0.41	0.12	
FDE	0.67	0.43	0.14	
COORD, B2B				**5.04**
COORD	0.54	0.41	0.13	
B2B	0.41	0.52	-0.11	
BUBA, FDE				**5.48**
BUBA	0.38	0.50	-0.12	
FDE	0.67	0.43	0.24	
BUBA, B2B				**7.05**
BUBA	0.37	0.50	-0.13	
B2B	0.41	0.52	-0.11	

c) Probability of observing a success when the conditioning variable equals one.
d) Probability of observing a success when the conditioning variable equals zero.
*e) Hosmer-Lemeshow test statistic for goodness-of-fit. Rejection at the 95 (90) percent level of significance is indicated with a * (**).*

Table 8 Broad Specifications of Logit Models[a]

Dependent variable: Success according to "direction" criterion
Sample: Total days of intervention from September 1, 1985 – December 31, 1995
(323 observations of which 147 were successful).

	Coefficient[b]	z-statistic[c]
Specification 1		
COORD	0.488 (0.238)	2.049 *
FDE	1.000 (0.407)	2.458 *
DEDISC	-0.346 (0.652)	-0.531
MAGN	0.000 (0.000)	0.758
Specification 2		
COORD	0.528 (0.242)	2.186 *
B2B	-0.451 (0.240)	-1.876 **
DEDISC	-0.182 (0.630)	-0.289
MAGN	0.000 (0.000)	0.406
Specification 3		
BUBA	-0.521 (0.241)	-2.162 *
FDE	1.027 (0.409)	2.514 *
DEDISC	-0.248 (0.657)	-0.378
MAGN	0.000 (0.000)	0.126
Specification 4		
BUBA	-0.515 (0.240)	-2.144 *
B2B	-0.421 (0.238)	-1.770 **
DEDISC	-0.066 (0.629)	-0.105
MAGN	0.000 (0.000)	0.236
Specification 5		
FED	0.034 (0.254)	0.132
FDE	0.939 (0.404)	2.325 *
DEDISC	-0.263 (0.645)	-0.408
MAGN	0.000 (0.000)	0.074
Specification 6		
FED	-0.002 (0.253)	-0.009
B2B	-0.350 (0.234)	-1.497
DEDISC	-0.097 (0.625)	-0.156
MAGN	0.000 (0.000)	0.231

a) Broad specifications using monetary and exchange rate policy variables other than DEDISC and/or magnitude variables other than MAGN produces qualitatively identical results, i.e. no monetary and exchange rate policy or magnitude variable is significant at the 90 percent level or higher.

b) All specifications include a constant term. Standard error in parentheses.

*c) Significance at the 95 (90) percent level is indicated with a * (**).*

Table 9 Logit Models of Each Conditioning Variable Separately

Dependent variable: Success according to "smoothing" criterion
Sample: Total days of intervention from September 1, 1985 – December 31, 1995
(323 observations of which 216 were successful).

	Coefficient[a]	Constant[a]	LR statistic[b]
Coordination			
COORD	0.750 (0.262)	0.454 (0.143)	8.632 *
BUBA	-0.550 (0.243)	0.913 (0.154)	5.103 *
FED	-0.174 (0.262)	0.751 (0.140)	0.440
REPINT	0.223 (0.237)	0.581 (0.173)	0.887
Pattern			
B2B	0.016 (0.240)	0.693 (0.185)	0.004
FDE	0.834 (0.469)	0.632 (0.123)	3.622 **
Monetary and Exchange Rate Policy			
DEDISC	0.288 (0.688)	0.693 (0.120)	0.182
DELOMB	0.703 (0.800)	0.684 (0.120)	0.874
DEREPO	0.419 (0.260)	0.571 (0.142)	2.670
FFTARG	-0.009 (1.230)	0.703 (0.119)	0.000
NEWS	0.056 (0.446)	0.698 (0.123)	0.016
Magnitude			
LARGE	0.580 (0.447)	0.652 (0.123)	1.828
SMALL	-0.526 (0.238)	0.943 (0.165)	4.887 *
MAGN	-0.000 (0.000)	0.687 (0.119)	0.851

a) Standard errors in parentheses.
*b) Likelihood ratio test of the estimated model against the constant only model. Critical values for 95 and 90 percent significance levels for the LR test with one degree of freedom are 3.841 and 2.706, respectively. Significance at the 95 (90) percent level is indicated with a * (**).*

Marginal probabilities of the Models Not Rejected by the LR-Test

Cond. Variable (x_i)	$P(y=1 \mid x_i = 1)$[c]	$P(y=1 \mid x_i = 0)$[d]	Marg. Prob.	HL statistic[e]
COORD	0.77	0.61	0.16	8.88
BUBA	0.59	0.71	-0.12	12.83
FDE	0.81	0.65	0.16	13.95 **
SMALL	0.60	0.72	-0.12	8.84

c) Probability of observing a success when the conditioning variable equals one.
d) Probability of observing a success when the conditioning variable equals zero.
*e) Hosmer-Lemeshow test statistic for goodness-of-fit. The 95 (90) percent critical value for rejecting the null of a fitting model is 15.51 (13.36) (chi-square distribution with 8 degrees of freedom). Rejection at the 95 (90) percent level of significance is indicated with a * (**).*

Table 10 Joint Significance of Conditioning Variables in Logit Models

Dependent variable: Success according to "smoothing" criterion
Sample: Total days of intervention from September 1, 1985 – December 31, 1995
(323 observations of which 216 were successful).

	LR statistic 1[a]	LR statistic 2[b]
COORD		
and FDE	13.226 *	4.593 *
COORD, FDE		
and DEDISC	13.226 *	0.000
and DELOMB	13.710 *	0.484
and DEREPO	15.164 *	1.938
and FFTARG	13.361 *	0.136
and NEWS	13.229 *	0.004
and LARGE	13.356 *	0.130
and SMALL	13.703 *	0.477
and MAGN	14.343 *	1.117
BUBA		
and FDE	9.670 *	4.567 *
BUBA, FDE		
and DEDISC	9.717 *	0.047
and DELOMB	10.419 *	0.749
and DEREPO	11.004 *	1.334
and FFTARG	9.869 *	0.200
and NEWS	9.671 *	0.001
and LARGE	10.267 *	0.597
and SMALL	11.381 *	1.711
and MAGN	11.308 *	1.638

*a) Likelihood ratio test of estimated model against the constant only model. Significance at the 95 (90) percent level is indicated with a * (**).*
*b) Likelihood ratio test of adding the new variable to the variable/those variables listed at the top of each section. Significance at the 95 (90) percent level is indicated with a * (**).*

Marginal probabilities of the Models Not Rejected by the (Second) LR-Test

Cond. Variables (x_i)	$P(y=1 \mid x_i = 1)$[c]	$P(y=1 \mid x_i = 0)$[d]	Marg. Prob.	HL statistic[e]
COORD, FDE				**5.10**
COORD	0.78	0.61	0.17	
FDE	0.83	0.66	0.17	
BUBA, FDE				**12.31**
BUBA	0.58	0.72	-0.14	
FDE	0.83	0.65	0.18	

c) Probability of observing a success when the conditioning variable equals one.
d) Probability of observing a success when the conditioning variable equals zero.
*e) Hosmer-Lemeshow test statistic for goodness-of-fit. Rejection at the 95 (90) percent level of significance is indicated with a * (**).*

Table 11 Broad Specifications of Logit Models[a]

Dependent variable: Success according to "smoothing" criterion
Sample: Total days of intervention from September 1, 1985 – December 31, 1995
(323 observations of which 216 were successful).

	Coefficient[b]	z-statistic[c]
Specification 1		
COORD	0.772 (0.265)	2.914 *
FDE	1.026 (0.486)	2.112 *
DEDISC	0.037 (0.716)	0.052
MAGN	-0.000 (0.000)	-1.062
Specification 2		
COORD	0.758 (0.267)	2.834 *
B2B	-0.153 (0.253)	-0.605
DEDISC	0.231 (0.702)	0.329
MAGN	-0.000 (0.000)	-0.763
Specification 3		
BUBA	-0.603 (0.247)	-2.443 *
FDE	1.025 (0.484)	2.116 *
DEDISC	0.182 (0.714)	0.254
MAGN	-0.001 (0.000)	-1.285
Specification 4		
BUBA	-0.563 (0.246)	-2.290 *
B2B	-0.097 (0.251)	-0.388
DEDISC	0.371 (0.695)	0.534
MAGN	-0.000 (0.000)	-0.969
Specification 5		
FED	-0.138 (0.265)	-0.521
FDE	0.935 (0.485)	1.928 **
DEDISC	0.092 (0.707)	0.131
MAGN	-0.001 (0.000)	-1.282
Specification 6		
FED	-0.147 (0.264)	-0.559
B2B	-0.031 (0.247)	-0.124
DEDISC	0.302 (0.695)	0.434
MAGN	-0.000 (0.000)	-0.915

a) Broad specifications using monetary and exchange rate policy variables other than DEDISC and/or magnitude variables other than MAGN produces qualitatively identical results, i.e. no monetary and exchange rate policy or magnitude variable is significant at the 90 percent level or higher.

b) All specifications include a constant term. Standard error in parentheses.

*c) Significance at the 95 (90) percent level is indicated with a * (**).*

Table A1 Event Details: Total Bundesbank and Fed Intervention in the DEM/USD Exchange Rate Market[a]

Date of event	Total amount of interventio n (b) (mil-lions USD)	Number of days during event	Number of days of interventi on during event	Number of days of no intervention during event	Maximum number of consecutive days of no intervention during event
Sep 23, 85 – Nov 12, 85	-2944	35	27	8	4
Dec 11, 85	-51	1	1	0	0
Apr 28, 86	102	1	1	0	0
Sep 12, 86	-31	1	1	0	0
Sep 29, 86 – Oct 14, 86	1197	11	6	5	3
Jan 5, 87 – Jan 27, 87	568	16	6	10	8
Mar 11, 87	-30	1	1	0	0
Apr 24, 87 – Jun 3, 87	1527	28	9	19	9
Aug 4, 87 – Aug 10, 87	-908	5	5	0	0
Aug 28, 87 – Sep 9, 87	391	8	5	3	2
Oct 20, 87 – Jan 13, 88	5915	58	29	29	7
Apr 14, 88 – Apr 15, 88	391	2	2	0	0
May 31, 88 – Oct 7, 88	-12905	94	62	32	6
Nov 11, 88 – Dec 2, 88	988	16	6	10	5
Dec 8, 88 – Feb 7, 89	-4083	42	28	14	7
Mar 7, 89 – Jun 30, 89	-7942	83	44	39	9
Aug 11, 89 – Oct 11, 89	-3619	42	25	17	5
Dec 21, 89 – Jan 4, 90	-57	9	2	7	7
Mar 2, 90 – Mar 7, 90	-890	4	4	0	0
May 29, 90 – Jul 17, 90	1000	35	17	18	13
Feb 4, 91 – Feb 12, 91	1606	7	7	0	0
Mar 11, 91 – Mar 27,	-1710	13	7	6	2
91	-2240	59	10	49	15
Apr 23, 91 – Jul 16, 91	-122	1	1	0	0
Aug 19, 91	1783	26	5	21	13
Jul 20, 92 – Aug 24, 92	1500	4	2	2	2
Apr 29, 94 – May 4, 94	253	1	1	0	0
Jun 24, 94	1300	2	2	0	0
Nov 2, 94 – Nov 3, 94	1245	2	2	0	0
Mar 2, 95 – Mar 3, 95	2001	3	2	1	1
Apr 3, 95 - Apr 5, 95	889	1	1	0	0
May 31, 95	789	1	1	0	0
Aug 15, 95					

a) An event is defined as a period of days of intervention in one direction including no more than fifteen consecutive days of no intervention.

b) 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.

Table A2 Direction of Pre-Event DEM/USD Exchange Rate Changes for Different Pre-Event Window Definitions[a]

Date of event[b,c]	2-day window	5-day window	10-day window	15-day window
* Sep 23, 85 – Nov 12, 85	-	-	-	+
Dec 11, 85	+	+	-	-
* Apr 28, 86	-	-	-	-
* Sep 12, 86	+	+	+	+
* Sep 29, 86 – Oct 14, 86	-	+	-	-
* Jan 5, 87 – Jan 27, 87	-	-	-	-
* Mar 11, 87	+	+	+	+
* Apr 24, 87 – Jun 3, 87	-	+	-	-
* Aug 4, 87 – Aug 10, 87	+	+	+	+
* Aug 28, 87 – Sep 9, 87	-	-	-	-
* Oct 20, 87 – Jan 13, 88	-	-	-	-
* Apr 14, 88 – Apr 15, 88	+	+	+	+
* May 31, 88 – Oct 7, 88	+	+	+	+
* Nov 11, 88 – Dec 2, 88	-	-	-	-
* Dec 8, 88 – Feb 7, 89	+	+	+	+
* Mar 7, 89 – Jun 30, 89	+	+	+	-
* Aug 11, 89 – Oct 11, 89	+	+	+	-
Dec 21, 89 – Jan 4, 90	+	+	-	-
* Mar 2, 90 – Mar 7, 90	+	+	+	+
* May 29, 90 – Jul 17, 90	+	+	+	+
* Feb 4, 91 – Feb 12, 91	-	-	-	-
* Mar 11, 91 - Mar 27, 91	+	+	+	+
* Apr 23, 91 – Jul 16, 91	+	+	+	+
* Aug 19, 91	+	+	+	+
* Jul 20, 92 – Aug 24, 92	-	-	-	-
* Apr 29, 94 – May 4, 94	-	-	-	-
Jun 24, 94	+	-	-	-
* Nov 2, 94 – Nov 3, 94	-	+	-	-
Mar 2, 95 – Mar 3, 95	+	-	-	-
* Apr 3, 95 – Apr 5, 95	-	-	-	-
* May 31, 95	-	-	-	+
* Aug 15, 95	+	+	+	+

a) Average daily percentage change in the DEM/USD exchange rate over the two, five, ten and fifteen business days preceding the first day of the event.

b) An event is defined as a period of days of intervention in one direction including no more than fifteen consecutive days of no intervention.

*c) With the two-day pre-event window as the reference point, * indicates same direction of the DEM/USD exchange rate change for at least two of the other three applied pre-event window definitions*

Table A3 Direction of Post-Event DEM/USD Exchange Rate Changes for Different Post-Event Window Definitions[a]

Date of event[b,c]	2-day window	5-day window	10-day window	15-day window
* Sep 23, 85 – Nov 12, 85	-	-	-	-
* Dec 11, 85	-	-	-	-
* Apr 28, 86	+	+	+	+
* Sep 12, 86	-	-	-	-
* Sep 29, 86 – Oct 14, 86	+	+	+	+
* Jan 5, 87 – Jan 27, 87	-	-	-	+
* Mar 11, 87	-	-	-	-
* Apr 24, 87 – Jun 3, 87	+	-	+	+
* Aug 4, 87 – Aug 10, 87	-	-	-	-
* Aug 28, 87 – Sep 9, 87	+	+	+	+
* Oct 20, 87 – Jan 13, 88	+	+	+	+
* Apr 14, 88 – Apr 15, 88	+	+	+	+
* May 31, 88 – Oct 7, 88	-	-	-	-
* Nov 11, 88 – Dec 2, 88	+	+	+	+
* Dec 8, 88 – Feb 7, 89	-	-	-	-
* Mar 7, 89 – Jun 30, 89	-	-	-	-
* Aug 11, 89 – Oct 11, 89	-	-	-	-
Dec 21, 89 – Jan 4, 90	-	-	+	+
Mar 2, 90 – Mar 7, 90	-	+	+	+
* May 29, 90 – Jul 17, 90	-	-	-	-
* Feb 4, 91 – Feb 12, 91	+	+	+	+
* Mar 11, 91 - Mar 27, 91	-	-	-	-
* Apr 23, 91 – Jul 16, 91	-	-	-	-
* Aug 19, 91	-	-	-	-
Jul 20, 92 – Aug 24, 92	+	-	-	+
Apr 29, 94 – May 4, 94	+	+	-	-
* Jun 24, 94	-	+	-	-
Nov 2, 94 – Nov 3, 94	-	+	+	+
* Mar 2, 95 – Mar 3, 95	-	-	-	-
Apr 3, 95 – Apr 5, 95	+	+	-	-
May 31, 95	+	-	-	-
* Aug 15, 95	+	+	-	+

a) Average daily percentage change in the DEM/USD exchange rate over the two, five, ten and fifteen business days subsequent to last day of the event.

b) An event is defined as a period of days of intervention in one direction including no more than fifteen consecutive days of no intervention.

*c) With the two-day post-event window as the reference point, * indicates same direction of the DEM/USD exchange rate change for at least two of the other three applied post-event window definitions.*

Table A4 Intra-Event DEM/USD Exchange Rate Changes

Date of event[a]	Total amount of intervention[b] (millions USD)	Level of DEM/USD exchange rate first day of event	Level of DEM/USD exchange rate last day of event	Average daily percentage change in the DEM/USD exchange rate during the event[c]
Sep 23, 85 – Nov 12, 85	-2944	2.732	2.624	-0.113
Dec 11, 85	-51	2.543	n.a.	n.a.
Apr 28, 86	102	2.165	n.a.	n.a.
Sep 12, 86	-31	2.061	n.a.	n.a.
Sep 29, 86 – Oct 14, 86	1197	2.026	1.975	-0.229
Jan 5, 87 – Jan 27, 87	568	1.931	1.806	-0.405
Mar 11, 87	-30	1.871	n.a.	n.a.
Apr 24, 87 – Jun 3, 87	1527	1.791	1.808	0.034
Aug 4, 87 – Aug 10, 87	-908	1.892	1.894	0.021
Aug 28, 87 – Sep 9, 87	391	1.810	1.797	-0.090
Oct 20, 87 – Jan 13, 88	5915	1.808	1.633	-0.167
Apr 14, 88 – Apr 15, 88	391	1.663	1.661	-0.060
May 31, 88 – Oct 7, 88	-12905	1.729	1.862	0.082
Nov 11, 88 – Dec 2, 88	988	1.758	1.731	-0.096
Dec 8, 88 – Feb 7, 89	-4083	1.742	1.868	0.172
Mar 7, 89 – Jun 30, 89	-7942	1.854	1.954	0.065
Aug 11, 89 – Oct 11, 89	-3619	1.939	1.917	-0.027
Dec 21, 89 – Jan 4, 90	-57	1.726	1.684	-0.270
Mar 2, 90 – Mar 7, 90	-890	1.720	1.707	-0.189
May 29, 90 – Jul 17, 90	1000	1.672	1.646	-0.044
Feb 4, 91 – Feb 12, 91	1606	1.465	1.453	-0.117
Mar 11, 91 – Mar 27, 91	-1710	1.580	1.706	0.613
Apr 23, 91 – Jul 16, 91	-2240	1.742	1.799	0.055
Aug 19, 91	-122	1.817	n.a.	n.a.
Jul 20, 92 – Aug 24, 92	1783	1.482	1.403	-0.205
Apr 29, 94 – May 4, 94	1500	1.661	1.659	-0.030
Jun 24, 94	253	1.587	n.a.	n.a.
Nov 2, 94 – Nov 3, 94	1300	1.504	1.524	0.665
Mar 2, 95 – Mar 3, 95	1245	1.459	1.435	-0.823
Apr 3, 95 - Apr 5, 95	2001	1.374	1.380	0.146
May 31, 95	889	1.414	n.a.	n.a.
Aug 15, 95	789	1.474	n.a.	n.a.

a) An event is defined as a period of days of intervention in one direction including no more than fifteen consecutive days of no intervention.
b) 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.
c) The reported average daily percentage changes in the DEM/USD exchange rate are associated with events of different lengths and are, therefore, not immediately comparable.

Table A5 Logit Models of Each Conditioning Variable Separately

Dependent variable: Success according to "reversal" criterion
Sample: Total days of "leaning against the wind" intervention from September 1, 1985 December 31, 1995 (204 observations of which 90 were successful).

	Coefficient[a]	Constant[a]	LR statistic[b]
Coordination			
COORD	0.505 (0.293)	-0.425 (0.180)	2.983 **
BUBA	-0.367 (0.298)	-0.107 (0.175)	1.540
FED	-0.171 (0.318)	-0.190 (0.165)	0.292
REPINT	0.173 (0.284)	-0.333 (0.213)	0.371
Pattern			
B2B	-0.488 (0.287)	0.048 (0.218)	2.896 **
FDE	1.127 (0.455)	-0.373 (0.152)	6.603 *
Monetary and Exchange Rate Policy			
DEDISC	0.658 (0.924)	-0.253 (0.143)	0.520
DELOMB	-1.407 (1.105)	-0.203 (0.143)	2.105
DEREPO	-0.154 (0.296)	-0.182 (0.175)	0.272
FFTARG	-0.463 (1.233)	-0.230 (0.142)	0.147
NEWS	0.628 (0.405)	-0.266 (0.143)	2.500
Magnitude			
LARGE	-0.029 (0.446)	-0.233 (0.150)	0.004
SMALL	-0.144 (0.289)	-0.179 (0.181)	0.250
MAGN	0.000 (0.000)	-0.220 (0.143)	0.606

a) Standard errors in parentheses.
*b) Likelihood ratio test of the estimated model against the constant only model. Critical values for 95 and 90 percent significance levels for the LR test with one degree of freedom are 3.841 and 2.706, respectively. Significance at the 95 (90) percent level is indicated with a * (**).*

Marginal probabilities of the Models Not Rejected by the LR-Test

Cond. Variable (x_i)	$P(y=1 \mid x_i = 1)$[c]	$P(y=1 \mid x_i = 0)$[d]	Marg. Prob.	HL statistic[e]
COORD	0.52	0.40	0.12	5.39
B2B	0.40	0.52	-0.12	8.34
FDE	0.68	0.41	0.27	5.63

c) Probability of observing a success when the conditioning variable equals one.
d) Probability of observing a success when the conditioning variable equals zero.
*e) Hosmer-Lemeshow test statistic for goodness-of-fit. The 95 (90) percent critical value for rejecting the null of a fitting model is 15.51 (13.36) (chi-square distribution with 8 degrees of freedom). Rejection at the 95 (90) percent level of significance is indicated with a * (**).*

Table A6 Logit Models of Each Conditioning Variable Separately

Dependent variable: Success according to "smoothing" criterion
Sample: Total days of "leaning against the wind" intervention from September 1, 1985 December 31, 1995 (204 observations of which 150 were successful).

	Coefficient[a]	Constant[a]	LR statistic[b]
Coordination			
COORD	1.068 (0.376)	0.693 (0.187)	9.039 *
BUBA	-0.500 (0.325)	1.214 (0.208)	2.354
FED	-0.506 (0.342)	1.172 (0.193)	2.138
REPINT	0.295 (0.318)	0.863 (0.229)	0.861
Pattern			
B2B	-0.024 (0.323)	1.036 (0.248)	0.006
FDE	1.072 (0.637)	0.920 (0.166)	3.528 **
Monetary and Exchange Rate Policy			
DEDISC	38.998 (100+)	0.988 (0.159)	0.077
DELOMB	0.603 (1.107)	1.006 (0.161)	0.335
DEREPO	0.466 (0.347)	0.869 (0.191)	1.863
FFTARG	-0.334 (1.235)	1.027 (0.160)	0.070
NEWS	0.252 (0.591)	1.001 (0.165)	0.189
Magnitude			
LARGE	0.022 (0.504)	1.019 (0.168)	0.002
SMALL	-0.472 (0.321)	1.222 (0.215)	2.162
MAGN	-0.001 (0.000)	1.004 (0.160)	0.903

a) Standard errors in parentheses.
b) Likelihood ratio test of the estimated model against the constant only model. Critical values for 95 and 90 percent significance levels for the LR test with one degree of freedom are 3.841 and 2.706, respectively. Significance at the 95 (90) percent level is indicated with a * (**).

Marginal probabilities of the Models Not Rejected by the LR-Test

Cond. Variable (x_i)	$P(y=1 \mid x_i = 1)$[c]	$P(y=1 \mid x_i = 0)$[d]	Marg. Prob.	HL statistic[e]
COORD	0.85	0.67	0.18	6.88
FDE	0.88	0.72	0.16	6.98

c) Probability of observing a success when the conditioning variable equals one.
d) Probability of observing a success when the conditioning variable equals zero.
*e) Hosmer-Lemeshow test statistic for goodness-of-fit. The 95 (90) percent critical value for rejecting the null of a fitting model is 15.51 (13.36) (chi-square distribution with 8 degrees of freedom). Rejection at the 95 (90) percent level of significance is indicated with a * (**).*

Table A7 Joint Significance of Conditioning Variables in Logit Models

Dependent variable: Success according to "reversal" criterion
Sample: Total days of "leaning against the wind" intervention from September 1, 1985 – December 31, 1995 (204 observations of which 90 were successful).

	LR statistic 1[a]	LR statistic 2[b]
COORD		
and FDE	11.872 *	8.889 *
COORD		
And B2B	7.491 *	4.508 *

*a) Likelihood ratio test of estimated model against the constant only model. Significance at the 95 (90) percent level is indicated with a * (**).*
*b) Likelihood ratio test of adding the new variable to the variable/those variables listed at the top of each section. Significance at the 95 (90) percent level is indicated with a * (**).*

Marginal probabilities of the Models Not Rejected by the (Second) LR-Test

Cond. Variables (x_i)	$P(y=1 \mid x_i = 1)$[c]	$P(y=1 \mid x_i = 0)$[d]	Marg. Prob.	HL statistic[e]
COORD, FDE				**10.74**
COORD	0.54	0.38	0.16	
FDE	0.72	0.40	0.32	
COORD, B2B				**6.21**
COORD	0.54	0.38	0.16	
B2B	0.38	0.53	-0.15	

c) Probability of observing a success when the conditioning variable equals one.
d) Probability of observing a success when the conditioning variable equals zero.
*e) Hosmer-Lemeshow test statistic for goodness-of-fit. Rejection at the 95 (90) percent level of significance is indicated with a * (**).*

Table A8 Joint Significance of Conditioning Variables in Logit Models

Dependent variable: Success according to "smoothing" criterion
Sample: Total days of "leaning against the wind" intervention from September 1, 1985 – December 31, 1995 (204 observations of which 150 were successful).

	LR statistic 1[a]	LR statistic 2[b]
COORD		
and FDE	14.991 *	5.952 *

*a) Likelihood ratio test of estimated model against the constant only model. Significance at the 95 (90) percent level is indicated with a * (**).*
*b) Likelihood ratio test of adding the new variable to the variable/those variables listed at the top of each section. Significance at the 95 (90) percent level is indicated with a * (**).*

Marginal probabilities of the Models Not Rejected by the (Second) LR-Test

Cond. Variables (x_i)	$P(y=1 \mid x_i = 1)$[c]	$P(y=1 \mid x_i = 0)$[d]	Marg. Prob.	HL statistic[e]
COORD, FDE				**8.82**
COORD	0.87	0.66	0.21	
FDE	0.91	0.72	0.19	

c) Probability of observing a success when the conditioning variable equals one.
Probability of observing a success when the conditioning variable equals zero.
*Hosmer-Lemeshow test statistic for goodness-of-fit. Rejection at the 95 (90) percent level of significance is indicated with a * (**).*

Charts

Fig. 1 FED Intervention

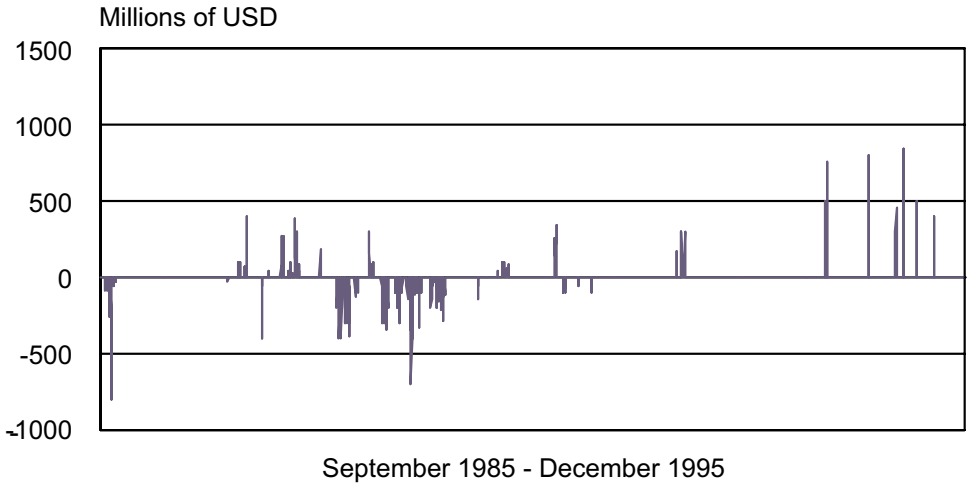


Fig. 2 Bundesbank Intervention

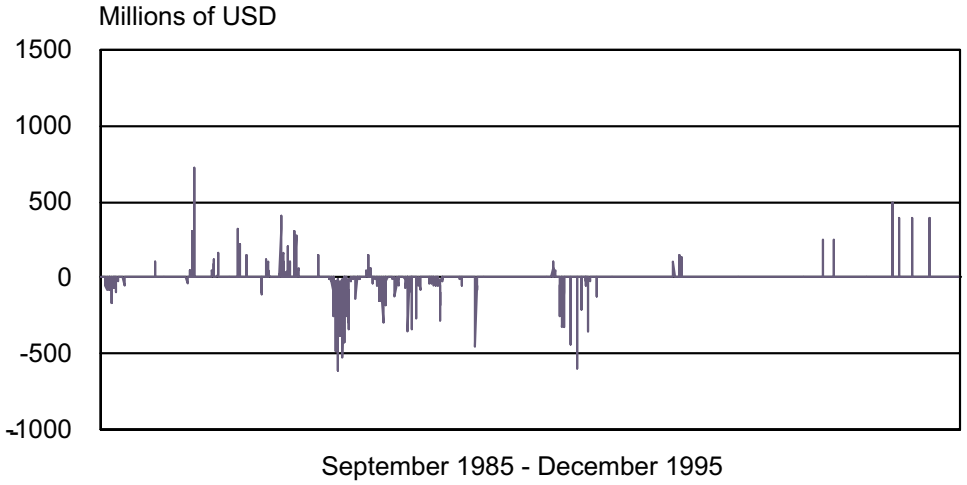


Fig. 3 Total Bundesbank and Fed Intervention

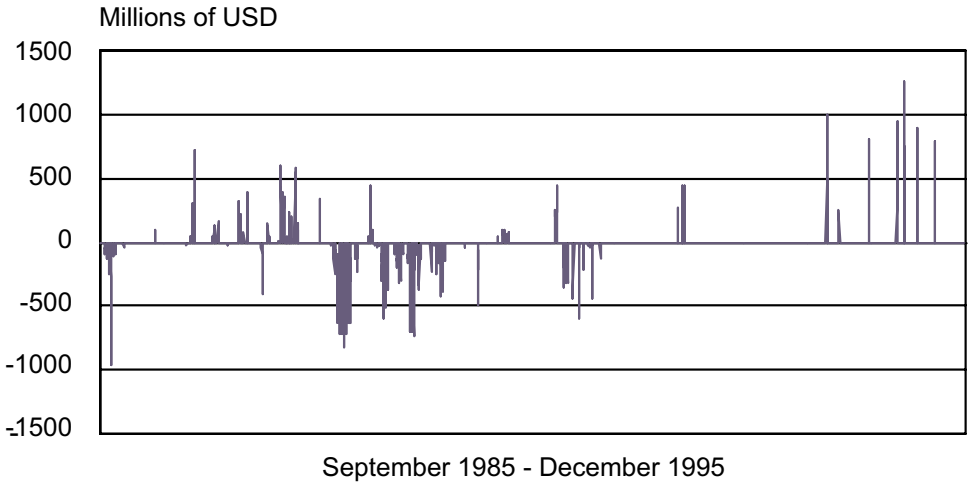


Fig. 4 DEM / USD exchange rate

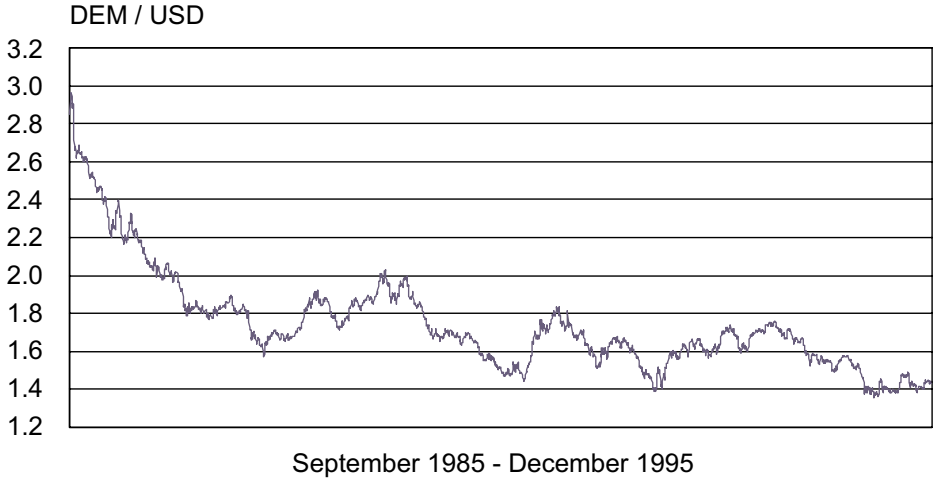
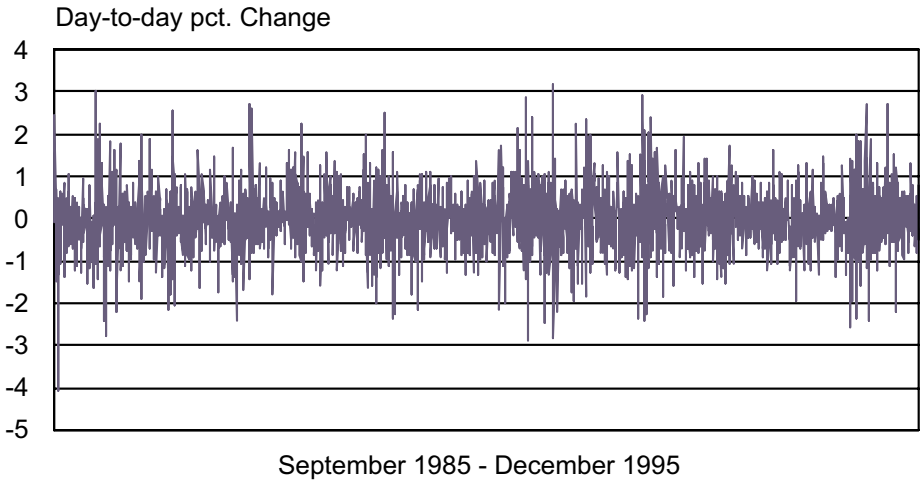


Fig. 5 Changes in the DEM / USD exchange rate



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