INTERVENTION STRATEGIES AND EXCHANGE RATE VOLATILITY: A NOISE TRADING PERSPECTIVE

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Abstract

This paper estimates and explains the impact of U.S. sterilized intervention on exchange rate volatility. We find that U.S. intervention reduced both yen/dollar and DM/dollar exchange rate volatilities during 1985-86, but increased them during 1987-89. These results make sense in a noise trading framework where the effectiveness of sterilized intervention may depend critically on the shrewdness of intervention strategies. Depending on circumstances, central banks may use noise trading channels through covert intervention, or activate signalling channels through overt intervention. The intervention-exchange rate volatility relationship may change as intervention strategies adjust to differing circumstances.

Key words: Foreign Exchange Intervention, Exchange Rate Volatility, Noise Trading

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The debate on whether sterilized foreign exchange intervention can affect the exchange rate has generated a large volume of research.[1] Most research efforts have been devoted to testing the hypothetical channels through which sterilized intervention can affect the exchange rate **level,** most notably the portfolio balance channel and the signalling channel.[2] None of the prevailing hypotheses considers the possibility that central banks' strategies on when and how to enter the market may determine the effectiveness of sterilized intervention. Such a void in the literature is particular perplexing given the fact that central banks often intervene covertly in the foreign exchange market.

The literature also offers little theory regarding the impact of sterilized intervention on exchange rate volatility. Policy makers apparently hold the view that intervention can be used to lower volatility.[3] Some analysts, however, believe intervention will only have the undesirable effect of creating uncertainty and thus volatility.[4] Empirical research to ascertain the impact of sterilized intervention on exchange rate **volatility** barely existed until recent years. Baillie and Humpage (1992) find that the sum of U.S. and Japan intervention increased yen/dollar volatility in the post-Louvre Accord period. Dominguez (1993) finds that actual U.S. intervention reduced conditional daily and weekly exchange rate volatility, while secret intervention increased conditional volatility. (Both studies use GARCH models to estimate conditional exchange rate volatility.) Using volatilities implied by options prices as proxies of ex ante exchange rate volatilities, Bonser-Neal and Tanner (1994) find that U.S.

intervention in general either increased ex ante exchange rate volatility, or had no effect. For the most part, these authors do not have a satisfactory explanation for their empirical findings.

This paper extends Hung's (1991b) "noise trading channel hypothesis[5]" and proposes that sterilized intervention may be intended to increase or decrease exchange rate volatility to manage the exchange rate level. We argue that, if noise trading is active in the foreign exchange market, then the shrewdness of a intervention strategy may critically determine the effectiveness of sterilized intervention. In such a setting, when strategically necessary, authorities may use volatility-enhancing intervention to manage the exchange rate level, even though normally they may prefer to reduce exchange rate volatility.

The notion that central banks may use different intervention strategies under different circumstances is strongly supported by the high frequency with which central banks intervene covertly. Table 1 shows that, although intervention was reported on 185 days during 1985-89, intervention was correctly reported on only 130 days. That is, only 130 days out of 232 days of actual intervention -- less than 60 percent of actual intervention -- were **correctly** reported over the 1985-89 period.[6] These statistics suggest that about 40 percent of U.S. intervention in that period was conducted covertly.[7] However, neither the portfolio balance channel nor the signalling channel offers a satisfactory explanation as to why central banks need to intervene covertly.[8]

To ascertain whether this hypothesis can explain the relation between intervention and exchange rate volatility, we estimate the impact of U.S. intervention on dollar exchange rate volatility in two periods characterized by distinct policy and market conditions: the 1985-86 post-Plaza period and the 1987-89 post-Louvre period. We assess the independent effect of sterilized intervention on volatility by using implied volatility (backed up from currency option prices) to control for volatility already expected by the market, and "news" variables (deviations between actual and expected macroeconomic data) to control for the impact of new information on unexpected volatility. U.S. intervention is found to *reduce* both yen/dollar and DM/dollar volatilities during 1985-86 but *raise* them during 1987-89.

These findings clearly contradict views that intervention only has a one-way effect on exchange rate volatility. Nevertheless, they are readily explained in the noise trading channel framework, as illustrated in sections I.C and II.C. The ability to explain simultaneously the flipping of the signs in the intervention-volatility relation and the frequent use of covert intervention by central banks lends strong support to the noise trading channel hypothesis.

The remainder of this paper is organized as follows. Section I presents the noise trading channel hypothesis and discusses the relationship between intervention strategies and exchange rate volatility. Section II describes the empirical methods used in estimating the intervention-exchange rate volatility relationship, and interprets the estimation results. Section III summarizes the overall findings.

I. Conceptual Discussion

In this section, we first introduce noise trading terminologies and examine how noise trading operates in the foreign exchange market. We then explain the ways in which sterilized intervention may affect the exchange rate by manipulating trading rules commonly used by noise traders. Examples are used to illustrate how the relationship between intervention and exchange rate volatility varies as intervention strategies change.

I.A. Noise trading in the foreign exchange market

Noise traders are investors whose demand for currencies is affected by beliefs or sentiments that are not fully consistent with economic fundamentals. Many of them are so-called chartists (or technical analysts) who see the market price as embodying every aspect of the market, discounting all pertinent information. Consequently, they rely on analysis of past price patterns to predict the future direction of exchange rate movements.[9] In contrast to noise traders, *fundamentalists* are those who trade according to their best guesses of the equilibrium exchange rate based on economic fundamentals.

Unlike the efficient markets hypothesis, the noise trading hypothesis acknowledges that noise traders as a group can move asset prices away from their fundamental equilibrium values.[10] Many chartists subscribe to the notion of market momentum and rely on some sort of feedback rule (buying when the price is going up and selling when the price is going down). Some chartists use moving averages of exchange rates of different time lengths to generate buying or selling signals, while other chartists use trendlines to clarify the direction of market movements. Many chartists also use past price movements to identify technical levels (such as support and resistance levels); they then place stop-loss orders around these levels [see Edwards and Magee (1966); Pring (1985)]. Such practices tend to amplify exchange rate fluctuations.

Risk-averse fundamentalists may not fully exploit the gap between the actual exchange rate and their perceived equilibrium exchange rate for two reasons. First, fundamentalists might not know the exact fundamental value of a given currency.[11] Second, even if they know the true fundamental equilibrium value of that currency, the unpredictability of the future exchange rate in an environment with noise traders still presents a risk.[12] Consequently, fundamentalists' demand for underpriced currencies may be limited and not sufficient to bring undervalued currencies into line with their equilibrium values.

Fundamentalists may even, when induced by profit opportunities or compelled by risk management, engage in trading activities that further aggravate misaligned or disorderly market conditions. If it has become obvious that most chartists follow the strategy of buying an appreciating currency, then fundamentalists may jump on the bandwagon themselves, hoping to beat chartists by selling out the appreciating currency near the top. Alternatively, fundamentalists, in their effort to manage risk, may be compelled to sell an undervalued currency.[13] In both cases, fundamentalists temporarily become noise traders themselves and further destabilize the market.

In a noise trading paradigm, the exchange rate may thus deviate persistently from its fundamental equilibrium value because of two factors. First, noise trading activities are not random and do not necessarily cancel one another out, and thus can lead to aggregate shifts in demand for currencies.[14] Second, fundamentalists' demand for underpriced currencies may be limited because of risk considerations and thus cannot fully counter unjustified movements in exchange rates prompted by noise trading.

The hypothesis that noise trading affected dollar exchange rates gained growing acceptance during the 1980s. For example, Frankel and Froot (1986), using a model that features three classes of players (fundamentalists, chartists, and portfolio managers), find that the dollar's appreciation after mid-1984 can be explained by the endogenous takeoff of a speculative bubble. Allen and Taylor (1989), conducting a survey of chief dealers in the

London foreign exchange market, find that about 90 percent of respondents use some chartist input in forming their intraday or one-week ahead exchange rate forecasts. Levich and Thomas (1993), using a bootstrap approach, find that simple technical trading rules often lead to unusually high profits.

I.B. The noise trading channel hypothesis

The noise trading channel hypothesis makes two main assumptions. First, noise trading prevails in the foreign exchange market, at least some of the time. Second, on a minute-by-minute basis, the exchange rate is determined by marginal demand and supply flowing through the foreign exchange market. The hypothesis maintains that, under these two assumptions, central banks can use well-designed intervention strategies to induce noise traders to buy or sell a currency in such a way that the otherwise temporary effect of sterilized intervention is perpetuated.[15]

As already discussed in section I.A, support for the first assumption can be found in Frankel and Froot (1986), Allen and Taylor (1989), and Levich and Thomas (1993). The second assumption can be thought of as a corollary of the first assumption, since the adjustment toward stock equilibrium of all markets is unlikely to be completed instantaneously in a noise trading market. In an efficient foreign exchange market where market participants always have a long-run fundamental view, a flow demand for a currency reflects a fundamental shift in stock demand consistent with equilibrium conditions of all markets. In a noise trading market, however, partial equilibrium, not general equilibrium, is most likely to determine the exchange rate on a minute-by-minute basis.

If so, then a central bank -- like any other big player in the market -- can conceivably manipulate the exchange rate by entering a relatively *thin market*. To be sure, if everything else remains unchanged, the effect of sterilized intervention by disturbing the flow market equilibrium is most likely to be transitory. However, if the transitory effect of intervention causes chartists to perceive that the prevailing trend has been broken and that a trend reversal is being formed, noise traders may unwind their positions and take on new positions betting on the intervention-inspired reversal. Such shifts in noise traders' positions will perpetuate the effect of the initial intervention.

Given that the authorities' foreign reserve is limited relative to private funds,[16] a (sterilized) intervention operation that goes against the grain of most market participants has little hope of being successful, unless it can convince the market that it signals a credible monetary policy change. The authorities may prefer not to rely on the signalling channel, however, if they do not intend to change the future money supply. If so, they will have no choice but to rely on a well-designed intervention strategy for sterilized intervention to have an effect on the exchange rate beyond what may be predicted by the portfolio balance channel.[17]

For the noise trading channel to work successfully, however, the central bank must not only have up-to-date market intelligence and familiarity with noise traders' reaction functions, but also must be capable of conducting intervention covertly and deftly. For example, suppose the U.S. authorities regard the dollar as overvalued and resolve to lower it. If intervention is conducted covertly in a thin market, then chartists, unable to discern the sources of dollar supply, may incorporate the latest downward pressure on the dollar into their trendline analysis. Because of their practice of assigning much heavier weight to the most recent exchange rate movement in their forecast, the chartists may interpret the effect of intervention as an early warning of a change in market direction. They may then jump in to sell dollar assets, thereby helping to lower the dollar.

The noise trading channel hypothesis is supported by Goodhart and Hesse's (1993) finding that the authorities prefer to intervene in relatively thin markets. The authors think such a phenomena exists "..no doubt because it increases the likelihood of influencing the exchange rate." (p.383) In the same paper, the authors also write "The main argument in favor of hidden intervention seems to be that secret buying can often dissemble the true lack of demand for a currency in distress(if only to avoid a chartist 'resistance' line being transgressed)." (p.371)

I.C. Intervention strategies and exchange rate volatility

Since different policy goals and market conditions call for different strategies, the impact of intervention on exchange rate volatility conceivably can change signs under different circumstances. To illustrate, let's contrast the implications of two alternative intervention strategies on the intervention-exchange rate volatility relation.

Intervention Rule:

(A) If the dollar drifts downward in its intra-day movement, the Fed sells it to drive it down further; if the dollar rises, the Fed does nothing.

(B) If the dollar drifts downward in its intra-day movement, the Fed does nothing; if the dollar rises, the Fed sells it to drive it down.

Both Rules A and B are strategies of selling the dollar, but differ in the "timing" of intervention. Rule A, which leans *with* the wind in selling the dollar, will tend to have a positive impact on dollar exchange rate volatility. In contrast, Rule B, which leans *against* the wind in selling the dollar, will have a negative impact on volatility.

To illustrate that different market conditions and policy goals call for different strategies, let us consider the following two scenarios:

Scenario I (The Plaza Accord Scenario):

Market Conditions: The dollar has been falling gradually, but is still considered overvalued.

Policy Objective: To lower the dollar in an orderly fashion to be in line with its fundamental equilibrium value.

If noise trading is perceived to prevail in the foreign exchange market, Rube B would appear to be a more logical strategy to use to lower the dollar. Rule A--an intervention strategy of selling dollars when the dollar is already falling of its own accord-- may very well trigger a dollar selling frenzy. Rule B--an intervention strategy more thoughtful of its (potential) noise-trading effect on the dollar --is more likely to lower the dollar smoothly. If Rule B is adopted, intervention will *decrease* exchange rate volatility.

Scenario II (The Louvre Accord Scenario):

Market Conditions: The dollar has been on a rising trend, approaching or breaking the implicit upper band.

Policy Objective: To bring down the dollar and keep it within the band.

In such a scenario, a strategy of stirring a sense of uncertainty in the market may be more successful than a strategy of going against the market momentum. Hence, a strategy of secret intervention may be much more promising than overt intervention in a noise trading market.

With its limited resources, the Fed is more likely to succeed in reversing the dollar's direction if the market interprets the contrarian intervention transactions as coming from private sources and second guesses the ongoing market direction. That is, Rule A used in secrecy--sell dollars secretly when the dollar is showing short-run downward fluctuations in the prevailing upward trend, and do nothing if the dollar is rising-- would be a more promising strategy than Rule B.

Rule B--a strategy of selling dollars when the dollar is still rising strongly--is unlikely to work well, since it only gives position-takers an incentive to maintain and increase their long-dollar positions. If intervention fails to stop the dollar's rise, the position-takers would gain. If intervention succeeds in stabilizing the dollar, the position-takers would neither gain nor lose, but would hardly be discouraged from trying again the next day.

In contrast, Rule A--a strategy of selling dollars when the dollar is showing downward fluctuations (in a upward trend)--would be more effective in inducing traders to second guess the strength of the upward momentum, thereby discouraging one-way speculation and breaking the undesirable upward trend. By seizing the **moment** of the dollar's temporary deviation from its ongoing momentum to reinforce that deviation, the Fed is more likely to induce the market to second guess the dollar's direction.

Of course, whether the relationship between intervention and exchange rate volatility is positive or negative will depend on which intervention rule is actually adopted. If Rule A is adopted, intervention would tend to *increase* exchange rate volatility. If Rule B is adopted, intervention would tend to *decrease* volatility.

II. Empirical Estimations

This section estimates the effect of intervention on yen/dollar and DM/dollar exchange rate volatilities in the period between the Plaza Accord of 1985 and the Louvre Accord of 1987 (defined as the post-Plaza period in this paper) and in the post-Louvre period. These two periods are chosen because they are characterized by distinct policy objectives and market conditions.[18]

To increase the number of observations on other variables, the sample period for the post-Plaza regression starts in April 1985 and ends in December 1986, even though intervention during this sample period was not conducted until September 1985 and was discontinued completely during 1986 (see Figures 1 and 2). The sample period for the post-Louvre period regression starts in March 1987 and ends in December 1989.

II.A. Methodology

Because exchange rate volatility and intervention may be correlated with several common variables, a simple regression of the former on the latter may produce spurious estimation results. Consequently, we include six explanatory variables, in addition to intervention, to estimate the independent effect of intervention on exchange rate volatility. More specifically, we estimate the following equation:

(1) $V^i_t = \beta E(V^i_t/I_{t-1}) + \gamma INTV^i_t + \lambda_1 IDNS^i_t + \lambda_2 PPINS_t + \lambda_3 PAYNS_t + \lambda_4 TBNS_t + \lambda_5 CPINS_t + \lambda_6 MSNS_t + U_t$, i = yen/dollar, DM/dollar,

where,

V^i_t is the ex post volatility realized at the end of period t, calculated as the annualized standard deviation of daily changes of the log of the exchange rate over 10 business days during the two-week period. That is,

$$V^i_t = \left(\sum_{(j=t-9)}^{t} (C_j - \bar{C})^2/9 \right)^{1/2}$$

where $C_j = \ln(S_j) - \ln(S_{j-1})$, and $\bar{C} = \sum_{j=t-9}^{t} C_j/10$.

$E(V^i_t/I_{t-1})$ is the annualized exchange rate volatility expected to prevail over period t on the basis of information available at the end of period t-1 (implied by currency option prices at the end of period t-1);

$INTV^i_t$ is the cumulative absolute value of gross intervention (buying or selling dollars against currency i) by the United States over period t;

$IDNS^i_t$ is the absolute value of the change in interest rate differentials (between the euro-dollar rate and euro-yen or euro-DM rate) over period t;

$PPINS_t$ is the absolute value of the unexpected change in the growth rate of the producer price index over period t;

$PAYNS_t$ is the absolute value of the unexpected change in the non-farm payroll over period t;

$TBNS_t$ is the absolute value of the unexpected change in the merchandise trade balance over period t;

$CPINS_t$ is the absolute value of the unexpected change in the growth rate of the consumer price index over period t;

$MSNS_t$ is the absolute value of the unexpected change in the M2 money supply change.

The market's expected exchange rate volatility, $E(V^i_t/I_{t-1})$, is included in equation (1) to control for the volatility already expected based on available information. We assume that individual dealers will use all available information to form their expectations of future exchange rate volatility, even though they may not use the same model to process that information. That is, we assume $E(V_t/I_{t-1})$ -- exchange rate volatility expected to prevail at the end of period t based on the information available at the end of period t-1 -- has discounted all relevant information available before period t begins.

To control for changes in volatility attributable to new (non-intervention) information occurring during period t, we include six "news" variables in equation (1): changes in interest rate differentials (IDNS), unexpected changes in the producer price index (PPINS), unexpected changes in nonfarm payrolls (PAYNS), unexpected changes in the merchandise trade balance (TBNS), unexpected changes in the consumer price index (CPINS), and unexpected changes in the M2 money supply. To be sure, all sorts of "news" not included here can potentially affect both exchange rate volatility and intervention in a market with active noise trading. Indeed, any minor financial or political development can become important if it reaffirms the market's existing sentiment. Data limitations, however, constrain the number of "news" variables to be included in the regression. We choose the above six variables mainly because they meet the following two conditions: (i) both (unrevised) actual and (surveyed) expected data for the variable are available on a consistent basis, (ii) the variable appears to have been closely watched by market participants during the sample period.[19]

To recap, the inclusion of $E(V^i_t/I_{t-1})$ and the four news variables in equation (1) should control for most factors that may affect exchange rate volatility and intervention simultaneously. Factors occurring *before* period t that might affect both V^i_t and $INTV^i_t$ are controlled for by $E(V^i_t/I_{t-1})$, while factors occurring *during* period t are mostly controlled for by the four NEWS variables. Inclusion of these five variables in equation (1) thus enables us to estimate the impact of intervention on changes in exchange rate volatility not attributable to new (non-intervention) information or already expected by the market.

Before we estimate equation (1), we first estimate the time-series property of the dependent and independent variables. Table 2 shows that all variables appear to be stationary variables at the 5 percent significance level. We then estimate equation (1) with the ordinary least squares (OLS) method. The results are presented in Table 3.

The OLS estimator on intervention, however, is inefficient and unreliable for making inferences, because of the heteroskedasticity caused by overlapping data -- the data frequency is weekly but the period of observation is biweekly. Furthermore, if intervention is conducted in response to unexpected change in exchange rate volatility, then it may be correlated with the residuals, thereby causing the OLS estimator to be inconsistent. Consequently, we use the generalized method of moments (GMM) to estimate equation (1), using contemporaneous news variables, lagged exchange rate volatility and lagged intervention (whose lags are chosen properly to avoid being correlated with the residuals) as instruments. The results of GMM estimations are shown in Table 4A. To get an rough gauge of the significance of the potential bias resulting from omitted "News" variables, we also estimate equation (1) without including any News variables. The results are reported in Table 4B.

II.B. Data

Daily intervention data are obtained from the Board of Governors of the Federal Reserve System. Daily closing yen/dollar and DM/dollar exchange rates, and daily one-month Euro-currency interest rates are obtained from the Federal Reserve Bank of New York. Both the expected and actual (unrevised) data on non-farm payrolls, the producer price index, the merchandise trade balance, the consumer price index, and M2 money supply changes are obtained from MMS International.

We use the transactions data base provided by the Philadelphia Stock Exchange to construct expected volatility from currency option prices. To assess the time value of an American option properly, we follow Lyons (1988) and use the Binomial Option Pricing Method to construct the implied volatility from option prices.[20]

Both actual and implied volatilities are constructed based on observations over a two-week period (see Figure 3). For each Friday,[21] we choose the call option that is closest to being at-the-money,[22] with a time-to-maturity from two weeks to three months. Ideally, one should only choose options that have a time-to-maturity of exactly two weeks to avoid the bias that may result from the mismatch of the horizons of implied and actual volatilities.[23] However, it was impossible to have a continuous time series of implied volatility using only call options traded on each Friday (or Thursday) that were not only very close to being at-the-money, but also of a time-to-maturity of exactly two weeks.

II.C. Results

Table 3 shows the results of estimating equation (1) with the OLS method. The estimation results using the GMM are shown in Table 4A. (Money supply news is dropped from the final regression equations since the P-value of its coefficient is bigger than 0.60 for all four variants of the equation.) The top panel of the two tables reports the effect of U.S. sterilized intervention on yen/dollar exchange rate volatility in the two sub-periods, and the lower panel reports effect on DM/dollar volatility.

The results in Table 4A show that, by and large, surprises in macroeconomic data affected exchange rate volatility more in the post-Plaza period than in the post-Louvre period. The impact of intervention on exchange rate volatility was far more important than any news variables in three out of four cases. Only in one case -- the DM/dollar exchange rate volatility in the 1987-89 period -- was the impact of intervention on volatility about the same as that of one news variable (IDNS).

More important, Table 4A show that U.S. intervention significantly **reduced** both yen/dollar and DM/dollar volatilities in the **1985-86** post-Plaza period, but significantly **increased** both currencies' volatilities in the **1987-89** post-Louvre period. In the 1985-86 period, every $1 billion (gross) intervention lowered yen/dollar volatility by 0.255 and

DM/dollar volatility by 0.069.[24] In the 1987-89 period, every $1 billion intervention increased yen/dollar volatility by 0.055, and DM/dollar volatility by 0.058.[25]

These results, while interesting, would be rather puzzling unless analyzed from the noise trading perspective offered in the previous conceptual discussion. The two most notable hypotheses regarding sterilized intervention's impact on the exchange rate do not comment on the relationship between intervention and exchange rate volatility, let alone explains the flipping of signs in the estimated relationship between the two variables. In a noise trading framework, however, the opposite impact of intervention on exchange rate volatility in the two sample periods can be easily explained with the shift in policy objectives and market conditions from 1985-86 to 1987-89.

Under the Plaza Accord, U.S. intervention during 1985-86 sought to bring down the dollar, in an orderly fashion, to a level consistent with economic fundamentals. Because the dollar was already gradually declining prior to the Plaza Accord, the task of intervention amounted to ensuring the on-going downward adjustment of the dollar. That is, sterilized intervention was conducted to **reinforce** rather than **break** the existing trend-line. Since the objective stipulated that the goal of bringing down the dollar should be achieved in an orderly fashion, the U.S. authorities had to ensure that intervention did not become "too" successful, pushing the dollar into a free fall in the process.[26] The finding that intervention reduced both yen/dollar and DM/dollar exchange rate volatility suggests that the authorities adopted a volatility-reducing intervention strategy under the circumstances.

By the beginning of the 1987-89 period, the dollar had been on a downward trend for nearly two years. Consequently, the Louvre Accord of February 1987 shifted the policy objective to maintain exchange rate within an implicit target band. That is, intervention was supposed to change market attitudes and break the strong momentum in the "undesired" direction whenever the dollar showed signs of penetrating either bound of the (implicit) band. The timing and skillfulness of intervention during the Louvre period thus became particularly important.

Indeed, under such circumstances an intervention strategy which enhances uncertainty in speculators' minds may be critical to accomplishing the task. That is, the circumstances may very well have dictated a strategy of secretly selling dollars when the dollar was showing short-run downward fluctuations in an upward trend, and secretly buying dollars when the dollar was showing upward fluctuations in a downward trend. Our regressions show that U.S. intervention had a positive effect on both DM/dollar and yen/dollar volatilities and suggest that a volatility-enhancing strategy was undertaken in this period.

Admittedly, our estimation could be biased because foreign variables are not included in the regressions. However, the omission of foreign news variables should not be too problematic, since the most important ones - news about the foreign interest rate - are included. Since most foreign intervention conducted during the sample periods was intended to support U.S. intervention, the omission of foreign intervention is also unlikely to change the sign of the coefficient estimate on the intervention variable.[27]

III. Conclusion

This paper offers a hypothetical channel through which sterilized intervention may affect the exchange rate. The hypothesis predicts that central banks may, under certain circumstances, secretly use volatility-changing strategies to manage exchange rate levels. This hypothesis is strongly supported by the fact that the Fed frequently intervenes covertly in the foreign exchange market.

To see whether our hypothesis explains the actual relation between intervention and exchange rate volatility, we estimate the impact of U.S. intervention on dollar exchange rate volatility. We find that U.S. intervention reduced both yen/dollar and DM/dollar exchange rate volatilities during the 1985-86 post Plaza Accord period, but increased both volatilities during the 1987-89 post Louvre Accord period.

These seemingly puzzling results are easily explained in such a framework. In the post-Plaza period, a volatility-reducing strategy was logical because the policy objective was to bring down the dollar in an orderly fashion when the dollar was already on a downward trend. In contrast, a volatility-enhancing strategy was a rational choice in the post-Louvre period because the dollar was roughly at a desired level and the policy objective shifted to maintaining an implicit target band.

In sum, the noise trading channel hypothesis explains simultaneously, and plausibly, two otherwise puzzling phenomena: (1) the impact of intervention on exchange rate volatility changes signs across time, (2) central banks often intervene covertly in the foreign exchange market. This lends strong support to the noise trading channel hypothesis, even if it does not necessarily "prove" the hypothesis is true.

Notes

1. The U.S. Federal Reserve System is reported to routinely sterilize its foreign exchange intervention. Several studies also find that the Bank of Japan and Bundesbank have often, if not always, sterilized their foreign exchange intervention [see Obstfeld (1983), Neumann and von Hagen (1992), Takagi (1990)]. Because sterilized intervention does not alter the monetary base, it constitutes an independent policy tool for the purpose of managing the exchange rate, freeing other monetary policy instruments to pursue domestic objectives. Many economists question the effectiveness of sterilized intervention, however, precisely because it does not change the money supply.

2. The portfolio balance model maintains that, if foreign and domestic securities are considered imperfect substitutes in investors' portfolios, sterilized intervention can influence exchange rate levels by changing the relative supply of securities denominated in different currencies. The signalling channel hypothesis claims that, if the central bank is credible and the market is rational and forward-looking, sterilized intervention can influence the exchange rate by signalling future monetary policy. See Edison (1990, 1993) for a survey of the theoretical and empirical literature.

3. For example, the stated objectives of U.S. intervention before the Plaza Accord (from February 1981 to September 1985) was to limit intervention strictly to countering "disorderly market conditions," where these conditions were narrowly defined to include exaggerated exchange rate movements, wide spreads in quotations, etc.

4. This view is exemplified by a quote from the Wall Street Journal "The past has shown us that whenever the finance ministers from the Big Five get together there's a lot of rhetoric and little action. Any time there's talk of intervention and outside forces in the market, it creates volatility and uncertainty. But in the long term it doesn't have any lasting impact." (September 23, 1985)

5. Hung (1991b) argues that, if noise trading prevails in the foreign exchange market at least some of the time, central banks can use well-designed intervention strategies to induce noise traders to buy or sell a currency in such a way that the otherwise temporary effect of sterilized intervention is perpetuated. That is, sterilized intervention can affect the exchange rate through "the noise trading channel."

6. Klein (1993) reports that intervention during the same sample period was reported on 191 days, but correctly reported only on 145 days. According to Klein's numbers, about 62 percent of actual intervention was correctly reported in the period.

7. If the Fed intervenes by entering the interbank market, the market is usually aware of the intervention because interbank dealers handling intervention transactions tend to distribute the information. However, the Fed can prevent the market from knowing about an intervention -- that is, intervene covertly -- by entering the brokers market.

8. Dominguez and Frankel (1993) argue that central banks may use covert intervention because full disclosure of intervention operations is not an optimal policy. If intervention policy is sometimes ineffective due both to inconsistent central bank policy and other factors, market participants are more likely to give the central bank the benefit of the doubt when they cannot identify the source of the problem.

9. Some noise traders are non-chartists in that their prediction of future exchange rates relies more on reacting to news or rumors than technical trading rules.

10. The notion of noise trading can be dated back at least to Keynes (1930, 1936), who observed that the mentality behind much stock market trading activity was similar to that behind a beauty contest. This view has been revived and formalized by many economists to help explain inconsistencies in rational expectations models. See Shiller (1984), Kyle (1985), Summers (1986), Campell and Kyle (1987), De Long et al. (1987), De Long et al. (1990), Cutler et al. (1990).

11. This problem is even more serious in the foreign exchange market than in the equity market. Investors in the equity market can at least avail themselves of an agreed-upon fundamental model of stock price determination. In the foreign exchange market, however, the large number of empirically unsuccessful models of exchange rate determination makes it more difficult for fundamentalists to have perfect confidence in their own estimates.

12. Suppose that fundamentalists know that the dollar is overpriced against the yen and decide to sell the dollar short. Because of noise trading, these fundamentalists must bear the risk that the dollar will be even more overpriced when they have to cover their short position.

13. Most market maker banks have some kind of risk management policy that not only limits the maximum position that their currency dealers can take, but also requires that stop-loss orders be placed around technical levels.

14. Trading activities of noise traders tend to be correlated, because non-chartist noise traders tend to follow advisors who happen to be fashionable at the time, while chartists are inclined to share similar techniques of analysis.

15. Grawe and Vansanten (1990) also alluded to the possibility that sterilized intervention may have a significant and even lasting impact on the exchange rate when noise traders are present. Assuming that the market forecasts of exchange rates are formed both by a mix of chartists and fundamentalists, Grawe and Vansanten (1990) used model simulations to show that sterilized intervention as well as non-sterilized intervention may have a permanent effect on the exchange rate if executed in a timely manner.

16. The U.S. imposes a legal ceiling of $40 billion on the total official foreign currency holdings (held by FOMC and the Exchange Stabilization Funds together) for intervention purposes. U.S. intervention transactions per (intervention) day never exceed $2 billion, and exceeded $1 billion only on 6 days in May 1989. By comparison, the average gross daily

turnover of foreign exchange dollar trading in April 1989 was $167 billion in the United States alone, and $838 billion in all surveyed countries. (See "Survey of Foreign Exchange Market Activity" published by Bank for International Settlement, 1990.)

17. A large volume of empirical evidence suggests that the effect of sterilized intervention (on the exchange rate) through the portfolio balance channel is not quantitatively significant, even if it is statistically significant. See Edison (1990, 1993).

18. The objective of the Plaza Accord, announced on September 22, 1985, was mainly to bring down the dollar to be in line with economic fundamentals in an orderly fashion. The objective of the Louvre Accord, announced on February 22, 1987, was to foster greater stability of exchange rates around the levels prevailing at the time.

19. The only exception is money supply news, which is included in the regression even though money supply was not a closely watched variable during the sample period.

20. The Black-Scholes model can be derived from the Binomial Option Pricing model as a limiting case. A European option can be exercised only on the expiration date, while an American option can be exercised at any time up to and including the expiration date. Therefore, the close-form equilibrium valuation formula provided by Garman and Kohlhagen, a variant of the Black-Scholes model developed for valuing a European foreign exchange call, may not provide a precise valuation of an American option. Unfortunately, the currency options that were available in this country until late 1985 were American options.

21. If that Friday is not a business day, we use the closest Thursday.

22. Stan Beckers (1981) demonstrates that using only the implicit variance of the option nearest the money produces as good a prediction of future variance as other more elaborate selection/weighing schemes.

23. The option pricing model assumes that exchange rate volatility remains the same for the remainder of an option's life. Suppose that on a particular Friday, the only at-the-money option traded has a time-to-maturity of 30 days. Then the volatility implied by this option is the annualized volatility over the next 30 days. As such, it would only be technically proper if we compare the implied volatility calculated based on this option price with the annualized ex post volatility over the next 30 days.

24. Average actual (ex post) yen/dollar volatility was 0.104, and average actual DM/dollar volatility was 0.130 percentage points, during the 1985-86 sample period.

25. Average actual (ex post) yen/dollar volatility was 0.103, and average actual DM/dollar volatility was 0.103, during the 1987-89 sample period.

26. Given the environment where the dollar already was gradually moving down, and tactics other than intervention - public comments, trade policy, and so forth - were also used by the Reagan Administration to communicate its desire for a lower dollar, it would be no surprise if

authorities were concerned about the dollar moving down too fast and too much if intervention was conducted too aggressively.

27. See Dominguez and Frankel (1993) for a comparison of the direction and magnitude of intervention by the Federal Reserve System and that by Bundesbank during the 1985-88 period.

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Table 1. Actual versus Reported U.S. Intervention

Period	Days of Actual Intervention	Days of Reported Intervention	Days of Correctly Reported Intervention
Jan 85-Aug 85	8	13	3
Sep 85-Dec 85	22	20	15
Jan 86-Dec 86	0	3	0
Jan 87-Dec 87	53	35	22
Jan 88-Dec 88	50	45	37
Jan 89-Dec 89	99	69	53
Jan 85-Dec 89	**232**	**185**	**130**

Note: Data on reported U.S. intervention is based on the list of newspaper reports related to foreign exchange intervention provided in Dominguez and Frankel (1993).

Table 2. Testing for Unit Roots

Dickey-Fuller Regression of Variable X

$$\Delta X_t = \alpha + \beta X_{t-1} + \gamma_1 \Delta X_{t-1} + \gamma_2 \Delta X_{t-2} + \ldots + \gamma_p \Delta X_{t-p} + \mu_t$$

(Sample: April 1985 to December 1989, weekly data)

Variable	ADF-statistics	Variable	ADF-statistics
$E(V^{JY}{}_t)$	-4.83	$E(V^{DM}{}_t)$	-3.61
$V^{JY}{}_t$	-5.14	$V^{DM}{}_t$	-4.08
$INTV^{JY}{}_t$	-4.91	$INTV^{DM}{}_t$	-2.71
$IDNS^{JY}{}_t$	-3.85	$IDNS^{DM}{}_t$	-3.69
$PAYNS_t$	-3.97	$PPINS_t$	-2.77
$TBNS_t$	-4.77	$M2NS_t$	-3.28
$CPINS_t$	-4.72		

Note: The Dickey-Fuller regression was run with up to p=4 lags of ΔX_{t-p}, where the lag length p was chosen, as recommended by Campbell and Perron (1991).

Variables:

$E(V^{JY})$ = Expected Yen/$ exchange rate volatility,
$E(V^{DM})$ = Expected DM/$ exchange rate volatility,
V^{JY} = Actual Yen/$ exchange rate volatility,
V^{DM} = Actual DM/$ exchange rate volatility,
$IDNS^{JY}$ = News on interest rate differentials,
$IDNS^{DM}$ = News on interest rate differentials,
$INTV^{JY}$ = Absolute value of U.S. gross intervention against the yen (billions of dollars),
$INTV^{DM}$ = Absolute value of U.S. gross intervention against the DM (billions of dollars),
PAYNS = News on non-farm payrolls (millions of dollars),
PPINS = News on the U.S. PPI growth rate,
TBNS = News on the U.S. trade balance (billions of dollars),
CPINS = News on the U.S. CPI growth rate.

Table 3. Regression Analysis of Exchange Rate Volatilities
(Estimation Method: OLS)

Dependent Variable: Actual Yen/$ exchange rate volatility

Sample Period:	Apr 85-Dec 86	Mar 87-Dec 89
Regressor	Coefficient	Coefficient
$E(V^{JY}_t)$	0.729 (8.42)	0.913 (12.69)
$INTV^{JY}_t$	**-0.049 (-1.10)**	**0.023 (3.78)**
$IDNS^{JY}_t$	0.022 (1.21)	0.015 (1.05)
$PAYNS_t$	0.098 (1.17)	*
$PPINS_t$	0.042 (1.63)	*
$TBNS_t$	0.006 (1.34)	-0.002 (-1.01)
$CPINS_t$	*	*
Adjusted-R^2	-0.10	0.22

Dependent Variable: Actual DM/$ exchange rate volatility

Sample Period:	Apr 85-Dec 86	Mar 87-Dec 89
Regressor	Coefficient	Coefficient
$E(V^{DM}_t)$	0.879 (12.54)	0.744 (14.17)
$INTV^{DM}_t$	**-0.044 (-2.12)**	**0.019 (3.19)**
$IDNS^{DM}_t$	*	0.046 (3.54)
$PAYNS_t$	-0.069 (-1.08)	*
$PPINS_t$	0.032 (1.61)	*
$TBNS_t$	0.005 (1.66)	*
$CPINS_t$	0.087 (1.44)	*
Adjusted-R^2	0.29	0.30

(Numbers in parenthesis are t-statistics; asterisks indicate t-statistics are below 1.0.)

Explanatory Variables:

$E(V^{JY})$ = Expected Yen/$ exchange rate volatility,
$E(V^{DM})$ = Expected DM/$ exchange rate volatility,
$IDNS^{JY}$ = News on interest rate differentials,
$IDNS^{DM}$ = News on interest rate differentials,
$INTV^{JY}$ = Absolute value of U.S. gross intervention against the yen (billions of dollars),
$INTV^{DM}$ = Absolute value of U.S. gross intervention against the DM (billions of dollars),
PAYNS = News on non-farm payrolls (millions of dollars),
PPINS = News on the U.S. PPI growth rate,
TBNS = News on the U.S. trade balance (billions of dollars),
CPINS = News on the U.S. CPI growth rate.

Table 4A. Regression Analysis of Exchange Rate Volatilities
(Estimation Method: GMM)

Dependent Variable: Actual Yen/$ exchange rate volatility

Regressor	Coefficient (Apr 85-Dec 86)	Coefficient (Mar 87-Dec 89)
$E(V^{JY}_t)$	0.698 (8.94)	0.882 (11.23)
$INTV^{JY}_t$	**-0.255 (-3.16)**	**0.055 (2.80)**
$IDNS^{JY}_t$	0.032 (1.79)	0.021 (1.40)
$PAYNS_t$	0.120 (2.13)	*
$PPINS_t$	0.045 (1.54)	*
$TBNS_t$	0.005 (1.26)	*
$CPINS_t$	*	

Dependent Variable: Actual DM/$ exchange rate volatility

Regressor	Coefficient (Apr 85-Dec 86)	Coefficient (Mar 87-Dec 89)
$E(V^{DM}_t)$	0.862 (12.11)	0.702 (12.12)
$INTV^{DM}_t$	**-0.069 (-2.54)**	**0.058 (2.71)**
$IDNS^{DM}_t$	0.024 (1.00)	0.056 (3.62)
$PAYNS_t$	-0.067 (-1.48)	*
$PPINS_t$	0.026 (1.65)	*
$TBNS_t$	0.005 (2.40)	-0.002(-1.09)
$CPINS_t$	0.094 (1.58)	-0.037 (-1.25)

(Numbers in parenthesis are t-statistics; asterisks indicate t-statistics are below 1.0.)

Explanatory Variables:

$E(V^{JY})$ = Expected Yen/$ exchange rate volatility,
$E(V^{DM})$ = Expected DM/$ exchange rate volatility,
$IDNS^{JY}$ = News on interest rate differentials,
$IDNS^{DM}$ = News on interest rate differentials,
$INTV^{JY}$ = Absolute value of U.S. gross intervention against the yen (billions of dollars),
$INTV^{DM}$ = Absolute value of U.S. gross intervention against the DM (billions of dollars),
PAYNS = News on U.S. non-farm payrolls (millions of dollars),
PPINS = News on the U.S. PPI growth rate,
TBNS = News on the U.S. trade balance (billions of dollars),
CPINS = News on the U.S. CPI growth rate.

Table 4B. Regression Analysis of Exchange Rate Volatilities
(Estimation Method: GMM)

Dependent Variable: Actual Yen/$ exchange rate volatility

Sample Period:	Apr 85-Dec 86	Mar 87-Dec 89
Regressor	Coefficient	Coefficient
$E(V^{JY}_t)$	0.950 (16.01)	0.948 (18.59)
$INTV^{JY}_t$	**-0.149 (-1.92)**	**0.052 (2.78)**

Dependent Variable: Actual DM/$ exchange rate volatility

Sample Period:	Apr 85-Dec 86	Mar 87-Dec 89
Regressor	Coefficient	Coefficient
$E(V^{DM}_t)$	0.963 (22.97)	0.844 (18.97)
$INTV^{DM}_t$	**-0.055 (-2.57)**	**0.051 (2.80)**

(Numbers in parenthesis are t-statistics; asterisks indicate t-statistics are below 1.0.)

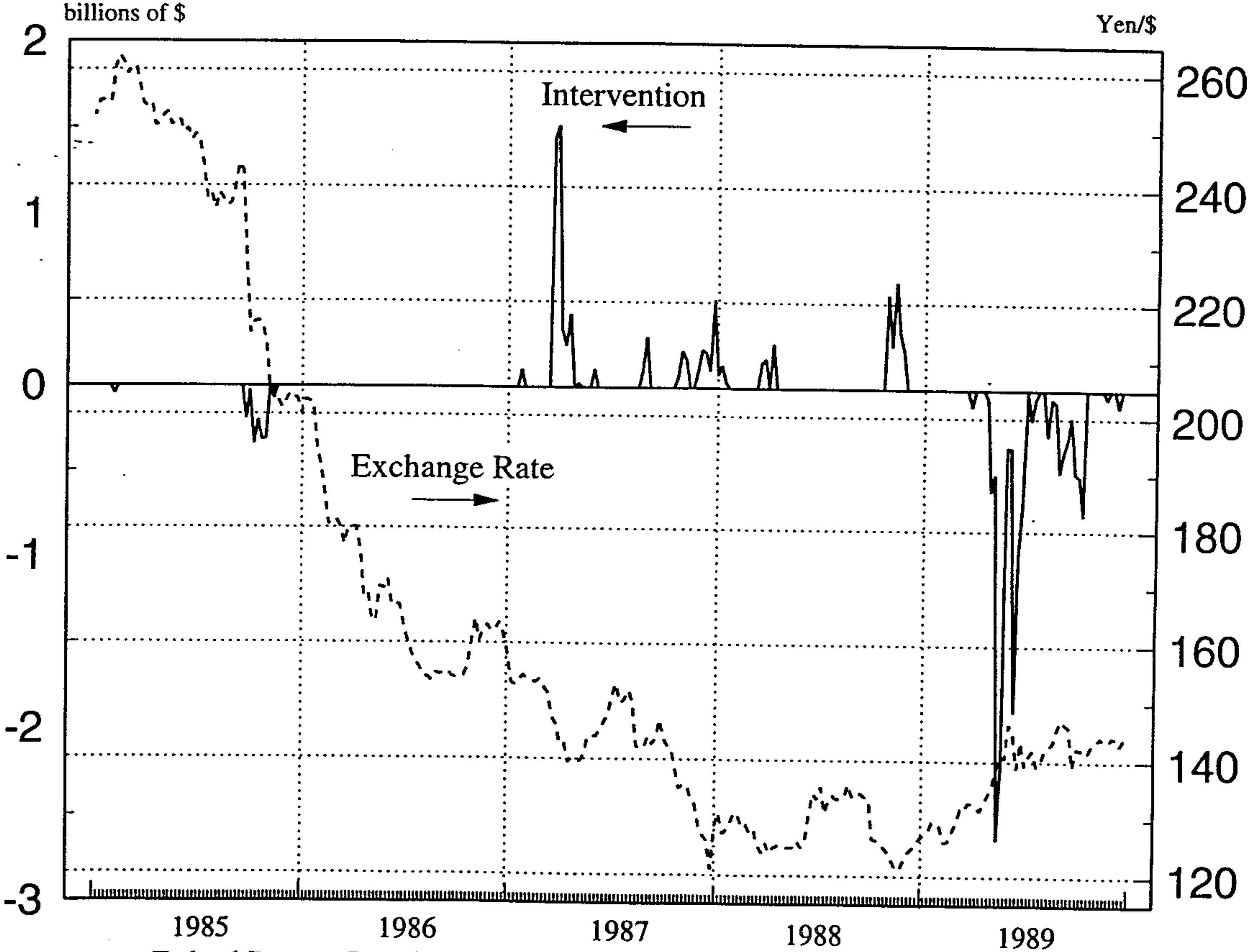
Explanatory Variables:

$E(V^{JY})$ = Expected Yen/$ exchange rate volatility,
$E(V^{DM})$ = Expected DM/$ exchange rate volatility,
$INTV^{JY}$ = Absolute value of U.S. gross intervention against the yen (billions of dollars),
$INTV^{DM}$ = Absolute value of U.S. gross intervention against the DM (billions of dollars).

Fig. 1

WEEKLY U.S. INTERVENTION and EXCHANGE RATE MOVEMENTS

(Net purchase or sale (-) of dollars)

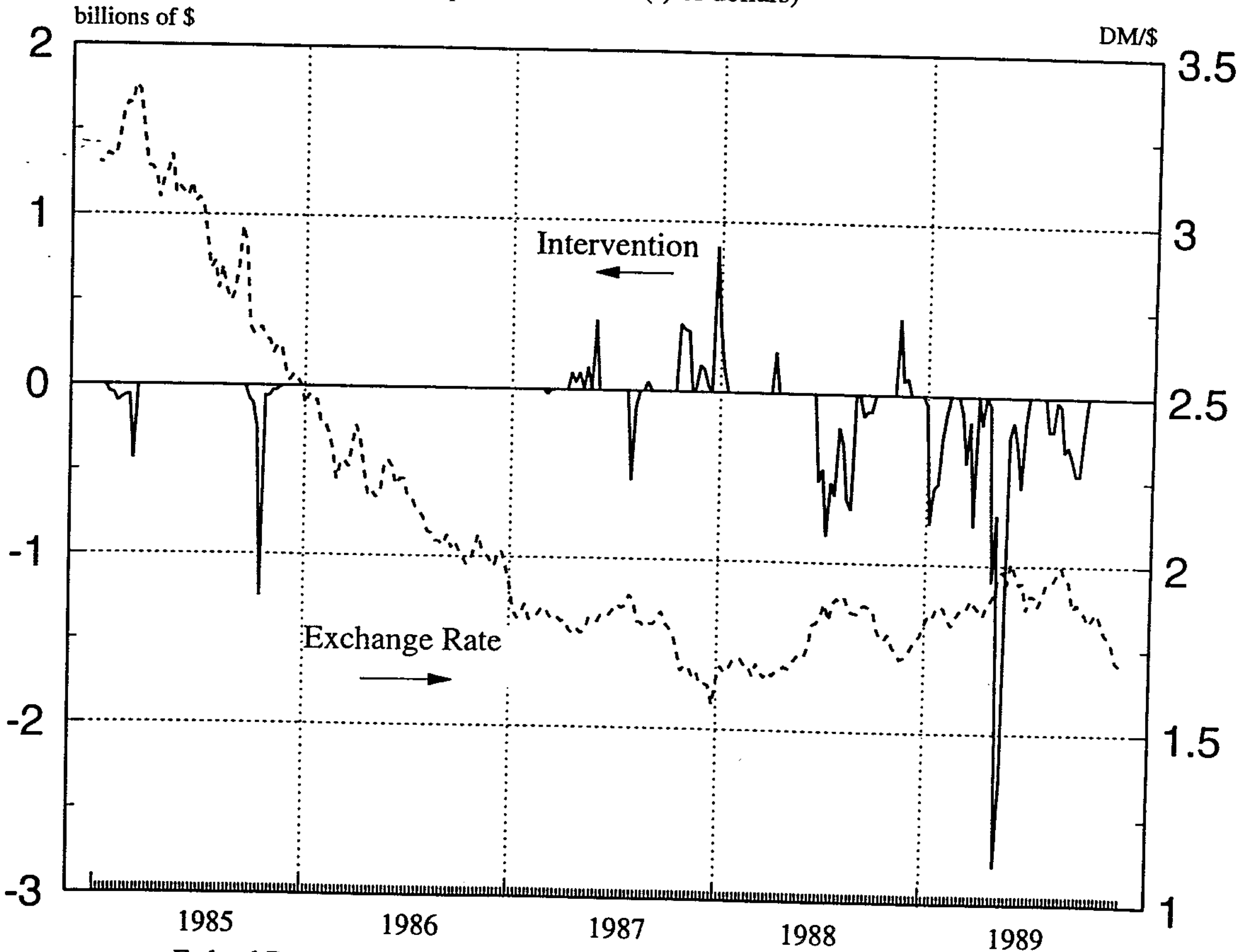


source: Federal Reserve Board

Fig. 2

WEEKLY U.S. INTERVENTION and EXCHANGE RATE MOVEMENTS

(Net purchase or sale (-) of dollars)



source: Federal Reserve Board

Fig. 3

ACTUAL VS. IMPLIED EXCHANGE RATE VOLATILITY

(Annualized standard deviation of daily change in log exchange rate)