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DOLLAR INTERVENTION AND THE DEUTSCHEMARK-DOLLAR EXCHANGE RATE: A DAILY TIME-SERIES MODEL

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Abstract

This paper develops a simultaneous time-series model to investigate the daily interactions between official exchange-market intervention and movements in the deutschemark-dollar exchange rate, from November 2, 1978, to October 31, 1979. The model is constructed using both morning-opening and afternoon-closing exchange-rate quotes. Using these two quotes, and making assumptions about the timing of intervention relative to the exchange-rate quotes, enables us to measure the causal relationships among contemporaneous variables. The results suggest that, over the period investigated, the Federal Reserve responded to exchange-rate movements in a manner consistent with a leaning-against-the-wind strategy, but that this intervention tended to accentuate slightly movements in the rate. This result seems to support claims that traders recognized intervention and traded against it.

I. Introduction

The major industrialized nations abandoned the Bretton Woods fixed-exchange-rate system in March 1973, after years of unsuccessful attempts to rectify its persistent problems. Observers have characterized the subsequent exchange-rate regime as a "dirty float." While the major industrialized countries generally have allowed fundamental market forces to determine their exchange rates, they periodically have bought and sold foreign exchange to influence the market outcome. The volume and frequency of exchange-market intervention have varied greatly among the developed countries.

In recent years, economists have begun to question the efficacy of foreign-exchange-market intervention, especially if intervention is sterilized, and especially if exchange markets are highly efficient (see Genberg 1981; Rogoff 1983; and Solomon 1983).[1] Such concerns resulted in the U.S. decision of March 1981 to reserve intervention only for countering unusually large fluctuations in the exchange markets (see Sprinkel 1980). Since that time, the United States has intervened on relatively few occasions. At the Versailles summit meeting in June 1982, many European governments criticized the U.S. decision to cease routine intervention, arguing that it contributed to increased, unnecessary volatility in foreign-exchange markets. A joint study of intervention proposed at the Versailles summit meeting, however, largely left the questions unresolved (see Jurgensen 1983).

This research investigates the short-term effectiveness of U.S. intervention in the foreign-exchange market. Existing research generally does not support the view that sterilized intervention has a long-term impact on the exchange rate, but researchers have not rejected the possibility of a near-term impact. Such an investigation involves answering two sets of questions. The first set of questions inquires about the Federal Reserve System's response to exchange-rate movements. Does the System buy (sell) dollars as the dollar depreciates (appreciates)? Does the Federal Reserve respond promptly to exchange-rate movements, or does it respond with a lag? A lagged response could imply greater exchange-rate volatility than a prompt response. Does the Federal Reserve respond to anticipated exchange-rate movements, or does it respond only to unanticipated exchange-rate movements? Does it respond in a manner that the market can anticipate? In a highly efficient exchange market, participants could predict and offset routine intervention.

The second set of questions inquires into the response of the exchange rate to the Federal Reserve System's intervention. Does an intervention purchase (sale) of dollars cause the dollar to appreciate (depreciate), and how big is any effect? The size of U.S. intervention could be too small relative to the scope of the exchange market to have an appreciable effect on the exchange rate. If intervention does affect the exchange market, how long does the impact persist? Even a shock will die out quickly in a highly efficient exchange market.

This paper develops a simultaneous time-series model to investigate the daily interactions between U.S. exchange-market intervention and the deutschemark-dollar exchange rate from November 2, 1978, to October 31, 1979. By incorporating both a morning-opening and an afternoon-closing exchange-rate quote and assuming that U.S. intervention occurs only in the interim, this study attempts to interpret the direction of causality between contemporary exchange-rate movements and intervention. The model also includes a variable for foreign intervention and breaks U.S. intervention into purchases and sales of deutschemarks and purchases and sales of all other foreign currencies.

II. Framework and Market Efficiency

Most economists regard foreign-exchange markets, like other asset markets, as highly efficient. An efficient market "fully reflects" all relevant available information about today's events and about predictable future events, including policy decisions. Following Fama (1970, pp. 384-5), the exchange market at any time, t, is assumed to possess a set, ϕ_t, of all available information relevant to exchange-rate determination. The conditional expectation of tomorrow's exchange rate can be expressed as:

(1) $E(S_{t+1}|\phi_t) = S_t + E(\Delta S_{t+1}|\phi_t)$,

where E is the expected-value operator, S is the exchange rate, and Δ designates the change in a variable. Assuming the exchange market is efficient:

(2) $E[S_{t+1} - E(S_{t+1}|\phi_t)] = 0$.

That is, the actual value of tomorrow's exchange rate is not expected to deviate from the value predicted today, given all available information. Therefore:

(3) $S_{t+1} = E(S_{t+1}|\phi_t) + a_{1t}$,

where $E(a_{1t}) = 0$, from the assumption expressed in equation 2. Finally, by substituting equation 1 into equation 3:

(4) $S_{t+1} = S_t + E(\Delta S_{t+1}|\phi_t) + a_{1t}$,

which implies that the change in the exchange rate from time t to time t+1 consists of an expected component, based on all information available at time t, and an unexpected component. The market, however, could incorporate all relevant information available at time t into S_t. In this case, $E(\Delta S_{t+1}) = 0$, and the exchange-rate series would resemble a random walk:

(5) $S_{t+1} = S_t + a_{1t}$.

The information set, ϕ_t, will include information about U.S. exchange-market intervention, Ω_t, which specifies a reaction function for intervention. (The sets, ϕ_t and Ω_t, could be equal.) Following the same arguments as were presented above, U.S. intervention (D) can be expressed as:

(6) $D_{t+1} = D_t + E(\Delta D_{t+1}|\Omega_t) + a_{2t}$,

which implies that the change in U.S. intervention between time t and time t+1 consists of an expected component based on the information set, Ω_t, and an unexpected component, a_{2t}, that represents policy shocks. A similar expression can be derived for foreign intervention, R:

(7) $R_{t+1} = R_t + E(\Delta R_{t+1}|\Omega^*_t) + a_{3t}$,

where Ω^*_t is the relevant information set contained in ϕ_t.

The reaction functions for the U.S. and the foreign central banks could contain the same arguments; therefore, D_t could be correlated with R_t. The sign of this correlation indicates cooperation or competition between the two intervention authorities, while the magnitude suggests the intensity of the relationship.

In a highly efficient exchange market, the participants learn to anticipate systematic intervention and incorporate this into their expectations of exchange-rate movements. Intervention could alter the anticipated exchange-rate path only by deviating from its normal behavior, or "shocking" the market. Such policies necessarily can be used only infrequently if they are to remain unpredictable. Moreover, a highly efficient market could quickly interpret such policy shocks and rapidly offset them when they terminate.

While exchange markets are highly efficient, they probably are not perfectly efficient. Information often is costly to obtain and slow to disseminate to all concerned parties. A consensual interpretation of events often forms rather slowly, The Federal Reserve and the Treasury might have better information than the market at certain times, such as when policymakers are considering a major change in monetary or fiscal policy, or when international diplomatic relations are strained. In the processing of normal information flows about real economic developments, prices, interest rates, and routine policy, there is little reason to suspect that policymakers are any better informed than the market participants.

In summary, the following general equations characterize a highly efficient exchange market:

(4) $S_{t+1} = S_t + E(\Delta S_{t+1} | \phi_t) + a_{1t}.$

(6) $D_{t+1} = D_t + E(\Delta D_{t+1} | \Omega_t) + a_{2t}.$

(7) $R_{t+1} = R_t + E(R_{t+1} | \Omega^*_t) + a_{3t}.$

III. Estimation

Using this general characterization of an efficient exchange market, we estimated a daily time-series model. The model incorporates both the New York morning-opening quote (9:30 am) and the New York afternoon-closing quote (4:30 pm). Obtained from the Federal Reserve Bank of New York, the exchange-rate data are daily averages of the opening or closing bid and ask quotes for the deutschemark-dollar exchange rate. The deutschemark-dollar rate was chosen because of its importance in exchange markets. There are 13 dates for which data were unavailable. These include Christmas and New Year's Day, on which no U.S. or foreign intervention took place, and eight U.S. holidays on which no U.S. intervention occurred, but on which foreign intervention is recorded. On the remaining three days, data for some of the exchange rates were missing. The blanks were filled with the previous day's observation, because univariate Box-Jenkins analysis indicated that the exchange-rate series followed a random-walk and, consequently, that today's rate is the best guide of tomorrow's rate.

The Board of Governors maintains the daily intervention data used in this analysis. The figures represent dollar purchases (+) or sales (-) in units of $1 million made by the United States and ten other large developed countries.[2] There is no standard criterion for defining intervention; consequently, some disagreement exists over the classification of certain transactions. Some official dollar purchases might be omitted from the data because the transactions were not expressly undertaken to alter the rate, even though they could have had that effect.[3] Nevertheless, exchange-rate-stabilization motives dominate movement in the series.

Central banks do not conduct their dollar intervention exclusively against deutschemark. The Federal Reserve, for example, often buys Swiss francs or Japanese yen, and non-German foreign central banks usually trade their currencies for dollars. Moreover, the deutschemark-dollar exchange rate is not the exclusive intervention target. Trades of dollars for deutschemark are expected to affect the deutschemark-dollar exchange rate directly, but dollar purchases or sales against other foreign currencies also can influence the deutschemark-dollar exchange rate through the cross-exchange rates. For any N convertible currencies, there exists a total of N(N-1) 1/2 exchange rates, but only N-1 of these will be independent (see McKinnon 1979, chap. 2). Arbitrage will maintain the exchange-rate configuration. We attempt to isolate the direct and indirect effects of U.S. intervention on the deutschemark-dollar exchange rate by breaking U.S. intervention into dollar intervention against deutschemark and dollar intervention against other currencies (see table 1 for a variable listing). A similar breakdown of foreign intervention was not possible.

The model is estimated for the year following the November 1, 1978, announcement of strengthening of U.S. intervention activity. (All data series contain 258 observations.) Between January 1, 1978, and October 31, 1978, the dollar depreciated nearly 17 percent against the deutschemark because of a poor U.S. current-account position and accelerating inflation. On November 1, 1978, President Carter, in conjunction with the Federal Reserve, announced a 1 percent increase in the discount rate, a $30-billion increase in U.S. foreign-currency reserves, and closer cooperation with the German Bundesbank, the Bank of Japan, and the Swiss National Bank. The intent of the November 1, 1978, policy change was to "correct what had become an excessive decline in the United States dollar in the exchange market" (Holmes and Pardee 1979, p. 67). The Federal Reserve sought to slow the decline in the dollar, or to lean against the wind.[4] During the next 12 months, the dollar appreciated 4.5 percent, on balance, against the deutschemark.

ARIMA technique. Jenkins (1979) describes the technique for simultaneously estimating relationships between two or more time series. Briefly, a review of the autocorrelations and of the cross-correlations between pairs of these time series provided an initial estimate of the structure of the model. Next, preliminary values were assigned to the parameters, and final values were jointly determined using approximate maximum-likelihood techniques. The structure of the model was modified, and the parameters re-estimated if not all of the final values from the first pass were statistically significant, and/or significant autocorrelation remained in the residuals.

Several considerations underlie the choice of the estimation technique employed in this study. First, it provides a direct test of the response of intervention to exchange-rate movements and of the effect of intervention on the exchange rate. Unlike much of the recent literature that seeks support for the portfolio-balance effect of intervention by testing for risk premia, this work does not involve estimation of a joint hypothesis (see Loopesko 1983). With respect to this issue, the results can be unambiguously interpreted. Unfortunately, the estimation procedure does not explain _how_ intervention affects the exchange rate, only _if_ intervention affects the rate.

The policy horizon adopted by the Federal Reserve for intervening to "calm disorderly markets" most often seems to be short-term.[5] Since this research investigates the short-term relationships between intervention and exchange-rate movements, it employs daily data. Although tests on data of less frequency (weekly, monthly) can provide an approximation to the short-run effect of intervention, such data lose information about the short-run relationships between exchange-rate movements and intervention. In August 1979, for example, monthly data reveal that the Federal Reserve bought a moderate number of dollars. The System, however, actually sold dollars on every day that it intervened except on two nonconsecutive days; on these days, it made large dollar purchases. Such daily variations contain much information about the causes and effects of intervention, but are "smoothed away" in less frequent data.

A major reason for adopting the estimation technique employed here is that it deals more explicitly than most of the existing literature with the difficult causality problem intrinsic to investigations of intervention and exchange-rate movements. Exchange-rate movements trigger intervention, but intervention influences exchange-rate movements. Causality is bidirectional. The ARIMA technique employed here provides a test of causality broadly consistent with the time-specific definition associated with Granger (1969). According to this definition, a stationary time series, X, is said to cause another stationary time series, Y, if one is better able to predict Y_t using all available information than using all available information except X. A problem in implementing this approach is interpreting the direction of causality implied by contemporaneous correlations when bidirectional causality is suspected. One generally cannot tell which contemporaneous variable influences which, unless information extraneous to the model is introduced. Empirical tests using monthly or quarterly data, therefore, lose one month or one quarter of data because of the problem in interpreting contemporaneous correlations. Daily data minimize this problem, but since the issue of interpreting the contemporaneous correlation persists, this study employs both a morning-opening exchange-rate quote and an afternoon-closing exchange-rate quote. On the assumption that U.S. intervention occurs after the morning-opening quote, but before the afternoon-closing quote, one can give a causal interpretation to the estimated coefficients.

The ARIMA technique also converts the time-series data on intervention and exchange rates to a stationary process. Many studies do not take this precaution; for example, using daily data, Wonnacott (1982) found lags in the Federal Reserve's reaction to exchange-rate movements of 30 days and 90 days. This result does not seem reasonable in view of the short policy horizon of most intervention and could result from autocorrelation in either the exchange rate or the intervention time series.

Finally, the ARIMA process allows the data to determine the structure of the model. Besides deciding which variables to include, the time period to consider, and the maximum lag length to test, the analysis places no prior restrictions on the model. The ARIMA process also is compatible with the notion of exchange markets as highly efficient; it describes the model in terms of a known and a random component.

One shortcoming of the model is that underlying the estimation technique is the assumption that the exchange rate and intervention time series contain all relevant information. Having additional information, for example, on interest rates would not improve one's ability to predict the exchange rate or intervention. The influence of any other contemporaneous, lagged, or future variable is assumed to be fully reflected in lagged values of the exchange rates or intervention terms or to be unanticipated. An obvious omission is a variable to control for monetary policy. The exchange market could view intervention as a signal of monetary policy. Without controlling for monetary policy, therefore, we might falsely attribute the influence of monetary policy on the exchange rate to intervention. The problem is that no relevant monetary aggregate exists on a daily basis, and interest rates are an ambiguous indicator of policy (see Rogoff 1983).

The model.

The resulting model is:

8. $SAM_t - \underset{(0.000)}{(1.000124B)} SPM_t = a_{1t}$,

9. $\underset{(0.000)}{(1-0.999883B)} SPM_t = a_{2t}$,

10. $\underset{(0.044)}{(1-0.463895B)} DDM_t = a_{3t}$,

11. $(1-\underset{(0.056)}{0.212335}B)\ DOT_t = a_{4t}$,

12. $(1-\underset{(0.097)}{0.409878}B)\ RUS_t - \underset{(0.053)}{(0.2660758)}\ DDM_t = a_{5t}$,

where B is a back-shift operator such that $B^n Z_t = Z_{t-n}$. The standard error of each estimated parameter appears below the relevant term except for equations 8 and 9, where the standard errors were so small that the computer program would not print them. All of the coefficients are statistically significant at the 95 percent confidence level. Rearranging the terms produces the following equations:

8'. $SAM_t = 1.000124\ SPM_{t-1} + a_{1t}$,

9'. $SPM_t = 0.999883\ SPM_{t-1} + a_{2t}$,

10'. $DDM_t = 0.463895\ DDM_{t-1} + a_{3t}$,

11'. $DOT_t = 0.212335\ DOT_{t-1} + a_{4t}$,

12'. $RUS_t = 0.409878\ RUS_{t-1} + 0.266075\ DDM_{t-1} + a_{5t}$.

In this model, lagged intervention terms do not appear directly in either of the exchange-rate equations, and lagged exchange rates do not appear directly in any of the intervention equations. This does not preclude interaction between the exchange rate and intervention. Such interaction is contemporaneous and is contained in the correlations between pairs of the $a_{it}(i = 1,2,3,4,5)$ shock terms. The a_{it} terms have zero means, constant variances, and they contain no autocorrelation. Pairs of the a_{it} terms, however, are correlated as shown in table 2. All of these correlations are significant at the 95 percent confidence level. The correlations between the contemporaneous shock terms also are part of this model and convey important information about intervention and the exchange rate.

The problem, however, is to determine the direction of causality underlying the contemporaneous correlations. Consider the contemporaneous correlation between the unanticipated movements in the morning-opening exchange-rate quote, a_{1t}, and unanticipated U.S. intervention in the deutschemark-dollar market, a_{3t}; it is negative and moderately strong. Is the negative correlation between these terms evidence of a leaning-against-the-wind intervention strategy (causality from a_{1t} to a_{3t}), or is it evidence of a perverse exchange-rate response to intervention (causality from a_{3t} to a_{1t})? Because a_{1t} represents unanticipated movements in the morning-opening quote (SAM), and because U.S. intervention occurs after the market's opening, we assume that causality runs from a_{1t} to a_{3t}. Figure 1 illustrates the assumed direction of causality among the contemporaneous shock terms. We assume that U.S. intervention, both DDM and DOT, ends at the closing of the market, so that causality runs from a_{3t} and a_{4t} to a_{2t}, with no feedback from a_{2t}. We also assume that unanticipated foreign intervention in the dollar market, a_{5t}, affects the afternoon-closing exchange rate, a_{2t}, but we are uncertain of the predominant direction of causality between a_{5t} and a_{1t}. Although the foreign market opens before the New York market, the New York market is open before the European market closes, and exchange-rate movements in the U.S. market can influence foreign intervention. Feedback, therefore, is highly likely between a_{1t} and a_{5t}. We also cannot specify causal relationships among the intervention terms, a_{3t}, a_{4t}, and a_{5t}. Finally, it seems reasonable that unanticipated movements in the morning-opening quote, a_{1t}, could influence movements in the afternoon-closing quote, a_{2t}.

Using these assumptions and following a procedure suggested by Sims, one can incorporate the information contained in the contemporaneous shock terms directly into the model. We hypothesize:

13. $a_{1t} = \alpha_{1t}$,

14. $a_{2t} = c_{21} a_{1t} + c_{23} a_{3t} + c_{24} a_{4t} + c_{25} a_{5t} + \alpha_{2t}$,

15. $a_{3t} = c_{31} a_{1t} + \alpha_{3t}$,

16. $a_{4t} = c_{41} a_{1t} + \alpha_{4t}$,

17. $a_{5t} = \alpha_{5t}$,

where a_{1t} and a_{5t} are exogenous variables, where the α_{it} $(i = 1,2,3,4,5)$ terms are "white noise," and where the remaining right-hand variables "cause" the appropriate left-hand variable. Equations 13 through 17 were rewritten in matrix form:

$$C \cdot A = \alpha,$$

where C is a matrix of the relevant parameters, A is a matrix of the initial a_{it} shock terms, and α is a matrix of shock terms after removing the relevant cross-correlations. We estimated the parameters in the C matrix, using ordinary least squares, and inverted the resulting C matrix to yield:

$$A = \hat{C}^{-1} \cdot \hat{\alpha}.$$

The estimates for equations 14 through 16 are:

18. $a_{2t} = 0.69391 \alpha_{1t} - 0.11166\ (10^{-4}) \alpha_{3t} - .03799\ (10^{-4}) \alpha_{5t} + \alpha_{2t}$,

19. $a_{3t} = - 7779.5846 \alpha_{1t} + \alpha_{3t}$,

20. $a_{4t} = - 614.06925 \alpha_{1t} + \alpha_{4t}$,

where all estimated parameters are significant at the 95 percent confidence level. In previous regressions the coefficient, c_{24} (suggested in equation 14), was not significantly different from zero, so it was omitted from equation 18. Table 3 shows the remaining cross-correlations between pairs of α_{it} terms.

Equations 13, 17, 18, 19, and 20 can be substituted back into equations 8' through 12' to incorporate the effects of contemporaneous intervention and exchange-rate movements directly in the model:

21. $SAM_t = 1.000124 \; SPM_{t-1} + \alpha_{1t}$,

22. $SPM_t = 0.999883 \; SPM_{t-1} + 0.69391 \; \alpha_{1t} - 0.000011 \; \alpha_{3t} - 0.000004 \; \alpha_{5t} + \alpha_{2t}$,

23. $DDM_t = 0.463895 \; DDM_{t-1} - 7779.5846 \; \alpha_{1t} + \alpha_{3t}$,

24. $DOT_t = 0.212335 \; DOT_{t-1} - 614.0693 \; \alpha_{1t} + \alpha_{4t}$,

25. $RUS_t = 0.409878 \; RUS_{t-1} + 0.266075 \; DDM_{t-1} + \alpha_{5t}$.

Equation 21 describes the morning-opening exchange rate (SAM) as approximately equal to the previous day's closing quote (SPM) plus an unanticipated component, α_{1t}. The α_{1t} component remains correlated with the unanticipated component for foreign intervention (α_{5t}), suggesting some interaction between the morning-opening exchange rate and foreign intervention (see table 3). Because the causal relationship is bidirectional, it could not be incorporated directly into the model.

Equation 22 relates the afternoon-exchange-rate quote (SPM_t) to its previous day's value and to shock terms associated with the morning-opening quote (α_{1t}), U.S. intervention against deutschemark (α_{3t}), and foreign dollar intervention (α_{5t}). Ignoring momentarily the intervention terms, one could interpret this equation in the following manner: in an efficient market, one expects the afternoon quote to equal the morning quote plus an unanticipated component. Similarly, that morning's quote should equal the previous day's closing quote plus a random component. The program, however, treats SPM_t and SAM_t as contemporaneous terms, even though SAM_t occurs before SPM_t. Time-series analysis does not admit contemporaneous variables in equations, because its primary objective is to forecast and, in a statistical sense, all contemporaneous terms and their interactions are unknown at time period, t. Any interaction among the contemporaneous terms not reflected by lagged terms is reflected in the correlations among the shock terms, and we have exploited this information as discussed above. Equation 22, therefore, relates SPM_t to SPM_{t-1}, hut SPM_{t-1} equals SAM_t plus a random term and, therefore, the information contained in SAM_t germane to setting SPM_t is reflected in SPM_{t-1} and the unanticipated term, α_{1t}, associated with the morning quote.

The coefficients in equation 22 associated with the intervention shock terms, α_{3t} (U.S. intervention against deutschemark) and α_{5t} (foreign dollar intervention), are negative. This suggests that intervention purchases of dollars cause the deutschemark-dollar exchange rate to fall; that is, intervention purchases of dollars cause the dollar to depreciate. From a central bank's perspective this is a perverse response. The magnitude of the coefficients, however, is fairly small. A U.S. $100 million purchase against deutschemark would cause the deutschemark-dollar rate to fall only 0.06 percent, or substantially less than one standard deviation in the actual fluctuations of the afternoon rate experienced over the period studied (see table 1). A foreign $100 million purchase would cause the deutschemark-dollar rate to fall less than 0.01 percent, again substantially less than one standard deviation in the actual fluctuations of the afternoon rate experienced over the period studied.

Equation 23 is a reaction function for U.S. intervention against deutschemark. It shows current dollar intervention against deutschemark

(DDM_t) being related to the previous day intervention (DDM_{t-1}), responding to unanticipated movements in the morning-opening deutschemark-dollar exchange rate (α_{1t}), and having an unanticipated component (α_{3t}). The sign on the coefficient associated with unanticipated movements in the exchange rate is negative, suggesting a leaning-against-the-wind response to unanticipated exchange-rate movements. When the deutschemark-dollar exchange rate rises (falls), the Federal Reserve System sells (buys) dollars to stem the dollar's appreciation (depreciation). A one-standard-deviation increase in α_{1t} will lead to a $59.0 million purchase of deutschemark.

Equation 24 describes U.S. intervention against currencies other than the deutschemark. The form of the equation is similar to that of equation 23. A one-standard-deviation increase in a_{1t} is associated with a $4.7 million purchase of foreign currencies other than deutschemark.

Equation 25 relates foreign dollar intervention (RUS_t) to its lagged value and lagged U.S. intervention against deutschemark (DDM_{t-1}). The positive coefficient associated with DDM_{t-1} suggests that, on average, from the November 2, 1978, to October 31, 1979, U.S. and foreign monetary officials cooperated in their intervention efforts, with foreign officials maintaining the U.S. intervention stance on the following day.

IV. Conclusion

This paper has presented a time-series analysis of the relationships among daily deutschemark-dollar exchange rates and daily U.S. and foreign intervention from November 2, 1978, through October 31, 1979. The results suggest that U.S. intervention reacted without a lag to unanticipated changes in the morning-opening exchange rate in a manner consistent with a leaning-against-the-wind strategy. Such a strategy would tend to dampen exchange-rate fluctuations if it actually influenced the exchange rate in the appropriate direction.

The results, however, do not indicate that intervention, as conducted over this period, was effective in changing the exchange rate in the desired direction. The signs on the intervention terms in the closing-quote exchange-rate equation suggest that U.S. and foreign intervention accentuated movements in the exchange rate. The size of this impact, however, was very small.

The response of the exchange rate to intervention seems perverse from the perspective of the central bank, but could be rational from the perspective of private exchange-market participants. Foreign-exchange traders could view central-bank intervention as a signal that the currency being purchased is fundamentally weak, and they could react to intervention by selling that currency. According to one anonymous foreign-exchange trader:

> There's an adage in the marketplace that says one should always go against an intervention, since any intervention reflects an inherent weakness in the currency being supported.
>
> (Wall Street Journal, August 3, 1983, p.3)

The model might have failed to measure a positive and significant coefficient on the intervention terms because intervention was too small relative to the flows of currencies in the market.[6] Over the period studied, for example, U.S. intervention against deutschemark averaged $26 million with a standard deviation of $161 million. Daily transactions in the exchange market, however, averaged in the billions. Arguing along similar lines, Hutchison (1984) contends that if sterilized intervention operates through a portfolio-balance effect, that is, by altering the relative stock of government bonds held by the public, then the scope of intervention must be large relative to the outstanding amounts of government debt held by the public. U.S. Treasury debt held by the public averaged approximately $630 billion over the period studied.

Although this study used daily data, the impact of intervention could die out too quickly to be picked up in the closing exchange-rate quote. A one-shot purchase of dollars could cause the dollar to appreciate for only a few hours, especially if the market is highly efficient and especially if exchange traders sense the Federal Reserve's presence in the market.

Although the results of this study suggest that intervention did not alter the exchange rate in a direction consistent with central bank objectives, they do not entirely preclude the use of sterilized intervention as an effective policy tool. Over the period studied, intervention was conducted frequently, and the objectives of intervention were announced on November 1, 1978. The market probably was well aware of the Federal Reserve's presence in the market. It is still possible that sterilized intervention, used periodically in a method that surprises the market, can be an effective short-term policy tool for influencing the exchange rate. The results of this study seem, therefore, to support the Treasury's March 1981 decision to use intervention very sparingly.

Footnotes

1. Exchange-market intervention refers to official purchases and sales of foreign currencies that nations undertake to influence the exchange value of their currencies. Intervention can be nonsterilized or sterilized. Nonsterilized intervention results in a change in relative money supplies. Sterilized intervention involves an additional open-market transaction in government securities that neutralizes any effect the foreign-currency purchases or sales have on the country's domestic money-stock growth.

2. The ten foreign countries are Belgium, Canada, France, West Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, and the United Kingdom.

3. Central banks often buy foreign currency for customer transactions. Usually the customer is the home-country government, and the funds might be used to repay official foreign-currency debts or to purchase military equipment. Central banks also buy foreign currency to build up or replenish foreign-currency reserves; sometimes they enter the exchange markets to convert interest payments on foreign reserves, which are paid in foreign currency, to domestic currency. The objective of such policies is other than altering the exchange rate.

Some countries, notably Japan, have been suspected of encouraging their domestic banks to make loans to foreigners or to buy and sell foreign exchange and of subsidizing such transactions through changes in official deposits at commercial banks. Such transactions are designed to alter the exchange rate, but are not recorded in the intervention data.

Finally, some countries, especially the United Kingdom, frequently intervene in small amounts to monitor the exchange market. Such intervention is more to gather information than to influence the exchange rate.

4. A leaning-against-the-wind intervention strategy is one in which a central bank buys (sells) its currency as it depreciates (appreciates) in foreign-exchange markets, but not in such quantities as to offset market trends completely. That is, the central bank attempts to smooth fluctuations in the exchange rate without reversing them.

5. The Federal Reserve intervenes to counter disorderly market conditions, a concept that has never been defined precisely (and probably could not be), but generally seems to depend on the trading desk's perception of the degree of confidence underlying the market's near-term exchange-rate forecast. The Federal Reserve usually identifies disorderly markets by abrupt changes in exchange rates, one-way markets, wide bid-ask spreads, and persistent bidding at which no offers are made. All of these are indicators of market uncertainty. Nevertheless, disorderly markets are ultimately in the eye of the beholder.

6. Some readers have suggested that the seemingly "perverse" response might be explained as follows: Each time the dollar depreciates (appreciates), the Federal Reserve buys (sells) dollars. The amount is too small to alter the dollar's direction, but it is sufficient to dampen the dollar's movement.

Consequently, closing-quote dollar depreciations continue to be correlated with dollar purchases. The problem with this argument is that the "perverse" coefficient describes a partial correlation. Even if the intervention were not sufficient to reverse the dollar's movement, intervention would be associated with smaller dollar movement. Hence, the partial correlation should have the expected sign, not the "perverse" sign, when intervention dampens exchange-rate movements.

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Table 1 Time-Series Variables

Variable	Definition	Mean[a]	Standard deviation[a]
SAM	morning-opening (9:30 am) deutschemark-dollar exchange rate.	1.8559	0.0437
SPM	afternoon-closing (4:30 pm) deutschemark-dollar exchange rate.	1.8555	0.0439
DDM	U.S. purchases (+) or sales (-) of dollars against deutschemark; $1 million.	26.3	161.2
DOT	U.S. purchases (+) or sales (-) of dollars against other foreign currencies; $1 million.	-2.6	26.6
RUS	aggregate dollar intervention by Belgium, Canada, France, West Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, and the United Kingdom.	-15.5	293.5

a. Measured from November 2, 1978, to October 31, 1979.

Table 2 Unanticipated-Movement Term and Associated Time-Series Variable as Calculated in the Model

Unanticipated term	Associated variable	Mean	Standard deviation
a_{1t}	SAM	-0.0	0.0076
a_{2t}	SPM	-0.0	0.0087
a_{3t}	DDM	12.5	139.6
a_{4t}	DOT	-2.4	25.5
a_{5t}	RUS	-19.9	246.9

Correlation matrix

	a_{1t}	a_{2t}	a_{3t}	a_{4t}	a_{5t}
a_{1t}	1.00	-	-	-	-
a_{2t}	0.79	1.00	-	-	-
a_{3t}	-0.42	-0.51	1.00	-	-
a_{4t}	-0.18	-0.23	0.38	1.00	-
a_{5t}	-0.36	-0.42	0.39	0.18	1.00

Table 3 Unanticipated-Movement Terms and Associated Time-Series Variable as Calculated in the Adjusted Model

Unanticipated term	Associated variable	Mean	Standard deviation
α_{1t}	SAM	-0.4391	0.00008
α_{2t}	SPM	0.2276	0.00005
α_{3t}	DDM	12.1	126.5
α_{4t}	DOT	-2.3	25.5
α_{5t}	RUS	-19.9	246.9

Correlation matrix

	α_{1t}	α_{2t}	α_{3t}	α_{4t}	α_{5t}
α_{1t}	1.00	--	--	--	--
α_{2t}	0.0	1.00	--	--	--
α_{3t}	0.0	0.0	1.00	--	--
α_{4t}	0.0	-0.03	0.34	1.00	--
α_{5t}	-0.36	0.0	0.26	0.12	1.00

Figure 1

Assumed Causal Relationship among Contemporaneous Terms