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Foreign Exchange Intervention by the United States: A Review and Assessment of 1985-89

THE FEDERAL RESERVE Bank of New York, acting as an agent of the U.S. Treasury, occasionally intervenes in foreign exchange markets. These actions, which involve the purchase or sale of assets denominated in foreign currencies in exchange for dollars, are intended to affect the exchange rate by altering the asset supplies denominated in one currency relative to that of another. Intervention can be directed to a variety of objectives including a change in the level of the dollar exchange rate, a reduction in the volatility of the dollar's value around some level, or an adjustment of the Federal Reserve's holdings of assets denominated in foreign currencies relative to its holdings of dollar-denominated assets.

This article explains the mechanics of foreign exchange intervention for people who are not specialists in this area of study and identifies avenues through which sterilized intervention conceivably could affect the exchange rate. It then describes and analyzes daily data recently released by the Federal Reserve Board on its intervention activities in the Deutsche mark (DM) and Japanese yen for the period 1985-89. Because these data had been confidential and similar data from the Bundesbank and Bank of Japan still are not publicly available, investigating the effects of intervention on the exchange rate has been difficult for at least two reasons. First, without hard data on the activities of all central banks involved, statistical tests and inferences require assumptions about the unknown actions of some participants. Second, even with complete data, stating an hypothesis about the effectiveness of intervention is subject to further assumptions about the unknown objectives of the central banks involved.

Recognizing these limitations, the last section of this paper nonetheless attempts to test several hypotheses about the effectiveness of intervention.[1] While offering no firm conclusions on its effectiveness during the period examined, the

[1]See Almekinders and Eijffinger (1991) or Weber (1986) for a survey of issues and evidence on the effectiveness of intervention.

newly-released Fed data and some qualitative data on the timing of foreign central bank interventions give a flavor of the frequency and scale of these activities. And, under certain assumptions, these data also identify some circumstances under which intervention had statistically significant effects on the DM/dollar and yen/dollar exchange rates.

THE EXCHANGE RATE AND INTERVENTION

An exchange rate is simply the relative price of two currencies. So, for example, if two Deutsche marks can be exchanged for $1, the dollar price of 1DM is $.50; conversely, the DM price of $1 is 2DM. Just like any relative price in the marketplace, the value of the exchange rate is determined by the interaction of the supply and demand for the two currencies.

One reason for intervention is to avoid exchange rates that are higher (or lower) than some perceived "correct" level, which can have deleterious short-run effects on a country's international trade.[2] To see how foreign exchange intervention might be used to affect the level of the exchange rate, refer to figure 1. Panel A shows the markets for the dollar and DM, using an exchange rate of 2DM per $1 (1DM = $.50) as an initial market equilibrium. This equilibrium is shown by points A and A′ at the intersections of the respective supply and demand curves in the two markets.

Without developing a theoretical model of the variables that may cause a change in either the supply or demand for either currency—and, hence, cause a change in the exchange rate—assume that the demand for dollars by German citizens rises, shifting $D_\$^0$ rightward to $D_\$^1$ and creating a new equilibrium in the market for dollars at point B.[3] Here, the new DM price of $1 has risen to 2.5, which implies that, for an equilibrium to exist in the market for DM, the dollar price of one DM must have fallen to $.40 (1/2.5). A change in the equilibrium price of dollars will cause a corresponding change in the equilibrium price for DM because changes in supply (demand) of one currency necessarily will cause corresponding changes in the demand (supply) of the other currency to reach the new equilibrium price in that market. In other words, if the increased German demand for dollars raises its price to 2.5 DM, then German citizens have increased the supply of DM they are willing to offer for sale in the market for any given value of the exchange rate. Indeed, the DM supply curve (S_{DM}^0) must shift outward until, at its new position (S_{DM}^1), the dollar price of DM has fallen to the new equilibrium value of $.40.

If this change in the exchange rate were deemed undesirable by policymakers, then the two central banks that control the supplies of dollars and DM could alter these supplies to restore the original exchange rate of 2DM per dollar. Though central banks often attempt to act jointly, each reinforcing the action of the other, assume for present purposes that the Federal Reserve embarks on intervention alone.[4] If the Fed's intention is to restore the initial equilibrium, the figure shows that it must increase the supply of dollars to a position at $S_\$^1$ so that the intersection with $D_\$^1$ occurs at the original equilibrium exchange rate of 2DM per dollar (point C). The Fed would try to accomplish this by purchasing DM in the open market in exchange for dollars which, by withdrawing DM from circulation, would move the DM supply

[2]Purchasing a foreign good requires the exchange of the home currency for an amount of foreign currency equal to the foreign price of the good, so that changes in the exchange rate can affect the amount of goods one country exports and another imports. Indeed, many observers who perceive the persistent U.S. deficits in merchandise trade as a problem have recommended policies to reduce the dollar's value. Although a reduction in the dollar's *nominal* value is potentially a short-run stimulant to exports, only changes in its *real* value (nominal value adjusted for price level differences across countries) will have a permanent effect on exports. See Batten and Belongia (1984) for further discussion of the distinction between real and nominal exchange rates and the consequences of this distinction in debates about exchange rates and trade flows.

[3]Throughout, we will focus on the effects of changes in relative money supplies alone as the main determinants of exchange rate changes. This is not in itself controversial in theoretical discussions of exchange rate determination, although economists have been unable to agree on other elements of a theoretical model to represent exchange rate behavior. Other factors typically incorporated in such models are differentials between domestic and foreign real growth and between domestic and foreign interest rates. This potential role for interest rate differentials is discussed briefly in the appendix. For discussions of models of exchange rate determination see Krueger (1983). For a survey of some empirical issues, see Mussa (1979).

[4]This assumption is made for ease of exposition. Balbach (1978) presents an extensive list of ways that intervention may be conducted by involving the U.S. Treasury's Exchange Stabilization Fund, the Federal Reserve and foreign central banks. For a specific example of how the Bundesbank might act to support the value of the DM, see Batten and Ott (1984).

Figure 1
Panel A
Changing the Level of the Dollar's Value

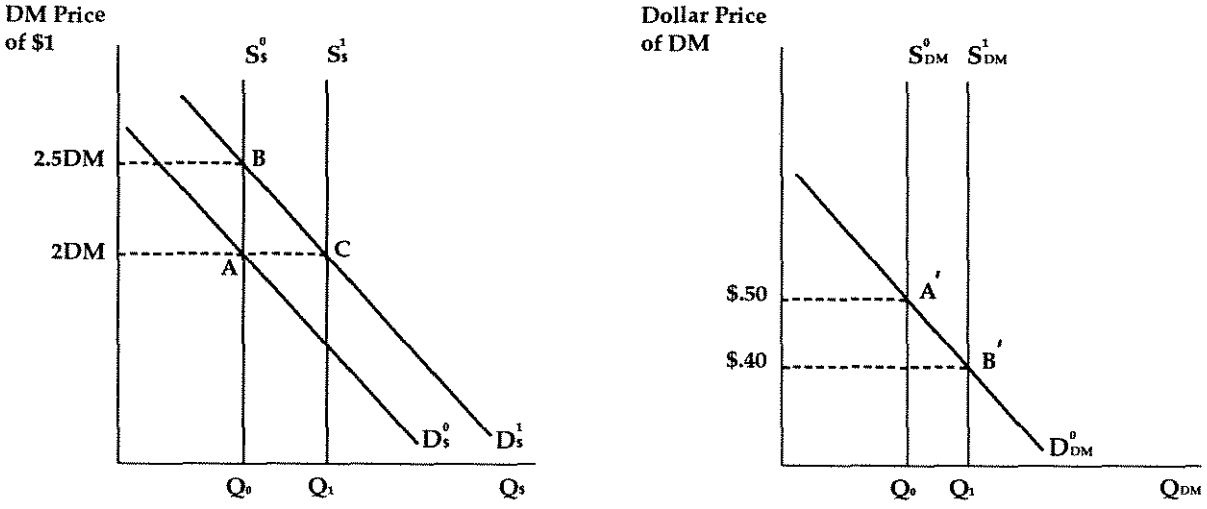
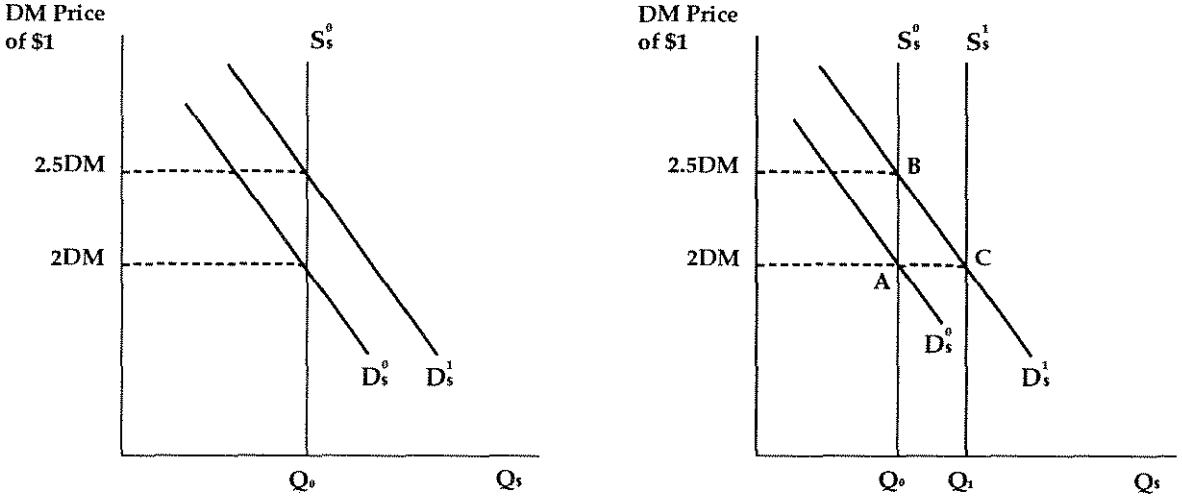


Figure 1
Panel B
Stabilizing the Dollar's Value Around a Target Level



curve back to its original position at S^0_{DM}. Increasing the quantity of dollars in circulation relative to DM will reduce the dollar's value in terms of DM. All other factors the same, this simple example shows how, by altering the relative quantities of any two currencies in circulation, central banks might be able to change the prevailing level of the exchange rate. Precisely how the Fed would conduct this operation is discussed in a later section.

Another point, which will be developed more fully, needs to be mentioned here. As the example shows, the exchange rate changes because the supply of dollars has changed relative to the supply of DM. Direct intervention is not necessary, however, to achieve this result. Instead, a central bank can affect the exchange rate (by design or as a side effect of actions directed to other goals) by changing its money supply during normal domestic open market operations and without any sales or purchases of foreign-denominated assets. Conversely, some central banks, such as the Bundesbank and Swiss National Bank, conduct their *domestic* monetary policy through transactions in the foreign exchange market rather than through transactions in a domestic credit market in the manner of the Fed's purchases and sales of U.S. Treasury securities.[5] Therefore, if intervention is to be viewed as an independent tool of monetary policy, it must be able to alter the exchange rate without affecting the operations of domestic monetary policy.

Intervention and Exchange Rate Volatility

In addition to altering the level of the exchange rate, another reason for intervention is to dampen the volatility of exchange rate movements. Though the level of the exchange rate might not change much over time, some people believe that erratic short-run fluctuations in the exchange rate can be destabilizing. For example, people in two countries may have contracts to buy or sell a good or service on an agreed date at an agreed price. A random fluctuation in the exchange rate just before the contract date will inflict unexpected losses on the buyer whose currency has depreciated (because he must give up more units of his domestic currency to get the same number of units of the foreign currency to pay the seller of the good). Conversely, the buyer whose currency has appreciated will realize windfall gains. To the extent these effects occur and are thought to be unpredictable, the exchange rate fluctuations behind them may impede international trade as exporters and importers perceive such transactions to be risky.[6] Indeed, the perception that exchange rate volatility impedes trade flows is the rationale for the current European Monetary System (EMS) and for the planned move to a single currency in the European Community (EC) by 1999.[7]

To see how intervention can reduce or eliminate volatility, consider panel B of figure 1. For simplicity, both panels refer only to the market for dollars. Referring to the left panel, assume there are random movements in the demand for dollars between positions at $D^0_\$$ and $D^1_\$$. For a given supply of dollars, the DM/$ exchange rate will fluctuate between 2.0 and 2.5. To offset these fluctuations, as shown in the right panel, the Federal Reserve could intervene to increase the supply of dollars to $S^1_\$$ when the demand for dollars rises to $D^1_\$$, and intervene to reduce the supply of dollars to $S^0_\$$ when the demand for dollars falls to $D^0_\$$. Abstracting from real-world problems such as adjustment lags, lack of information, changes in the supply or demand of DM, and other factors that may inhibit exchange rate smoothing, such a strategy conceivably could keep the DM/$ exchange rate at a value of 2.0 as it moved between the supply and demand equilibria represented by points A and C. The equilibrium at point B, where the exchange rate rises to 2.5, would be eliminated by successful intervention. Presumably, trade would increase if exporters and importers became convinced that intervention eliminated the risk of an exchange rate change.

[5]The foreign exchange market is used in these cases because the government securities market does not have the depth necessary for central bank open market operations.

[6]Buyers and sellers can protect themselves from these losses by hedging their transactions; see Williams (1986) for more detail on how hedging of foreign exchange risk can be accomplished. Rolnick and Weber (1989) report that the costs of hedging against this sort of exchange rate volatility range from 0.5 percent to 3 percent of total foreign sales. For the U.S. in 1989, this would have put the costs of hedging exchange rate risk between $6.5 billion and $39 billion.

[7]The EMS was founded in 1979 to keep bilateral exchange rates among EC currencies within relatively narrow bands—(+) or (−) 2 1/4 percent of an agreed level was typical for most currencies. For an overview of the mechanics of this system, see Ungerer, et al. (1986); for a critique, see Belongia (1988) or Meltzer (1990).

STERILIZED VS. UNSTERILIZED INTERVENTION

In the two examples of intervention just discussed, the value of the exchange rate was altered only if there was a change in one money supply relative to the other. Moreover, these examples assumed that only the Federal Reserve was intervening. Complications would arise if, on the one hand, one or more other central banks reinforced the Fed's activities by selling dollars and purchasing DM while the Fed was trying to reduce the dollar's value against DM. On the other hand, other central banks could have subverted the Fed's intervention goals had they made equal and offsetting purchases of dollars and sales of DM. Generally speaking, in the presence of large and highly developed world markets for the major currencies, the exchange rate between any two ultimately depends on the *world* supplies and demands for them rather than on the limited actions of just one central bank.

Although the case of two central banks working at cross-purposes may seem unlikely, individual central banks often take two, largely offsetting, actions when they intervene in exchange markets. This "sterilized" intervention occurs when a central bank undertakes an open market operation in its domestic market that exactly offsets the effects of its actions in the foreign currency market on the domestic money supply. Such intervention is called sterilized because the two actions, on net, produce no change in the domestic money supply. The problem, of course, is that, without affecting the money supply, there is presumably no avenue for sterilized intervention to affect the exchange rate.[8] Understanding these procedures will be important to the statistical tests that follow because Federal Reserve interventions are routinely sterilized.[9]

To understand sterilized intervention and the mechanics behind the shifts in the supply of dollars shown in figures 1A and 1B, consider the simplified Federal Reserve balance sheet shown in figure 2. Before any intervention occurs, the Fed's assets are U.S. Treasury securities and its liabilities are the reserves of the U.S. banking system; these two items are the sources and uses of the monetary base which, in turn, is the basis of the U.S. money supply. If the Fed wanted to increase the U.S. money supply, it would make an open market purchase of Treasury securities from U.S. banks and pay for them by crediting the reserve balances of these banks at the Fed. Thus, both the assets and liabilities sides of the Fed's balance sheet would increase. A simplified Federal Reserve balance sheet showing the effects of injecting reserves into the U.S. banking system is depicted in the top panel of figure 2.

Now consider what happens when the Fed decides to engage in foreign exchange intervention. Say that at 4:30 a.m. New York time (10:30 a.m. in Frankfurt, Germany), the Fed and the Bundesbank agree that they should try to reduce the value of the dollar by some amount. To do so, the U.S. money supply must be increased relative to the German money supply. As a matter of practice, the Fed could purchase DM-denominated deposits that large U.S. banks hold with German banks and pay for them in the same way the Fed would conduct a normal open-market operation: by crediting the reserve accounts of the U.S. banks that sold their DM deposits. These transactions are shown in the two left-hand accounts in the lower panel of figure 2.

The process does not end there, however. When the drafts made against the DM accounts of U.S. banks are presented by the Fed to the Bundesbank for clearing, this transaction adds the DM deposits of the Fed to the Bundesbank's liabilities but reduces the reserves of the German banking system; this is shown in the right-hand columns in the lower panel of figure 2. This draining decline in reserves reduces the German money supply. Conversely, the U.S. money supply rises because this transaction increases both the assets and liabilities sides of the

[8]A question arises, in the context of the simple supply and demand mechanics of exchange rate determination, why a central bank would engage in sterilized intervention. Two arguments have been advanced along these lines. A recent one, with some empirical support, is that such activities provide a valuable "signal" to participants in the foreign exchange market about the future course of monetary policy and its likely effects on future values of the exchange rate; see Dominguez (1988, 1990). Another argument, for which the empirical support has been mixed, is that foreign and domestic assets are imperfect substitutes and that, by altering their relative supplies through sterilized intervention, the exchange rate can be changed by affecting the differential between domestic and foreign interest rates. For a general review of theory and evidence, see Henderson (1984).

[9]See Balbach (1978).

Figure 2
Domestic Open Market Operations and Foreign Exchange Intervention

Panel A: An Expansionary U.S Open Market Operation

Federal Reserve Banks (FRB)		U.S. Commercial Banks (cb)	
Assets	**Liabilities**	**Assets**	**Liabilities**
+ U.S. Treasury securities	+ Reserves of cb	– U.S. Treasury securities	
		+ Reserves	

Panel B. U.S. Intervention to Reduce the Dollar

Federal Reserve Banks (FRB)		U.S. Commercial Banks (cb)		Bundesbank (B)		German Commercial Banks (Gcb)	
Assets	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**
+ DM deposits at B	+ Reserves of cb	+ Reserves			+ DM deposits of FRB	– Reserves	– DM deposits of cb
		– DM deposits at Gcb			– Reserves of Gcb		

Fed's balance sheet. If no further action is taken, these actions would reflect *unsterilized* intervention because they alter the relative supplies of dollars and DM.

Under current practices, however, the action made at 4:30 a.m. New York time will be reversed at 11:30 a.m. when the Open Market Desk of the New York Fed conducts its domestic open market operation for the day. To achieve its domestic reserve objectives, the Open Market Desk assembles projections each day of elements of the Fed's balance sheet. Thus, the staff will note that the foreign exchange activity of several hours ago had the effect of increasing the reserves of the U.S. banking system and will be reflected as an increase in the monetary base.

Consider, for example, that the Open Market Desk of the New York Fed would have determined—absent any intervention—that the System's domestic objectives for that day would be met without an open market operation. If the intervention activity caused a $1 billion increase in the monetary base, the domestic Desk, noting this effect, would undertake a $1 billion *sale* of U.S. Treasury securities to reduce reserves.

Thus, the desire to achieve its domestic monetary objective has led to actions that cancel the domestic effects on the money supply of the earlier intervention. Indeed, because offsetting domestic open market operations leave bank reserves, the monetary base, and, hence, the supply of dollars unchanged, the only effect of sterilized intervention is a change in the composition of the Fed's balance sheet. Its holdings of foreign-denominated assets increase and its holdings of U.S. Treasury securities fall, but the domestic money supply is unchanged. (See the appendix for a more detailed discussion of how other channels might operate and how sterilized intervention, in fact, may not be "sterilized" in the conventional use of the term.)

These mechanics highlight the fact that, if a central bank wishes to change the nominal value of its currency, it need not intervene in the foreign exchange market at all. Instead, because relative money supplies determine to a large extent the relative values of the two currencies in question, domestic open market operations alone can have the same effect on the exchange rate as unsterilized intervention.[10] Ac-

[10]Weber (1986) makes this point in much greater detail.

cording to the simple theory outlined in the preceding section, a central bank wishing to reduce its currency's nominal value need only engineer a rate of money growth faster than the growth rate of the money supply in the other country. In this context, the very rapid growth rate of M1 in the United States from May 1985 through December 1986 has been interpreted by some economists as an attempt by the Federal Reserve to reduce the dollar's value without engaging in any substantial intervention activity.[11] Conversely, an increase in the dollar's value can be achieved by engineering a relatively slower growth rate of the money supply.[12] This suggests that exchange market intervention may be motivated by a central bank's desire to give signals to market participants or to alter the relative shares of domestic and foreign assets on its balance sheet, rather than to alter the level of the exchange rate directly.

UNITED STATES INTERVENTION: 1985-89

Figures 3-6 provide a general reference to movements in the DM/$ and yen/$ exchange rates and the scale of U.S. intervention during the period 1985-89; neither the Fed nor the U.S. Treasury undertook any intervention in 1986. Negative values in the bottom portions of these figures indicate a sale of dollars—that is, a purchase of the foreign currency by the U.S. authorities. Although matching exchange rate and intervention data in this manner offers the temptation of making inferences about cause and effect, the discussion that follows will indicate that this strategy is not warranted.[13]

To put figures 3A and 3B, showing exchange rate and intervention data for 1985 in the proper context, note that the dollar's value peaked against both the yen and DM in February, then fell by more than 6.5 percent against both currencies by the end of August. During the weekend of September 22, 1985, the now-famous Plaza Accord was agreed upon in a meeting of Finance Ministers of the G-5 countries at the Plaza Hotel in New York. In effect, this agreement pledged support for coordinated intervention to reduce the dollar's value.[14]

In contrast to the press coverage of the time, the data show, first, that declines in the dollar's value between February and September occurred with little or no intervention by the Federal Reserve or the Treasury. Figures 3A and 3B also show that the United States limited its intervention activities to a period of 34 days immediately following the Plaza agreement. Finally, U.S. *cumulative* purchases of yen and DM during this 34-day period amounted to only $1.44 billion and $1.86 billion (equivalent), respectively. These figures can be contrasted with *daily* volume in the New York market alone that averaged $129 billion per day in April 1989.[15] Therefore, even if the comparable trading volumes of the London and Tokyo markets are ignored, (which would raise total daily volume to in excess of $400 billion) the actual scale of intervention typically was a trivial share of total volume in the foreign exchange market during this period.

The data for 1987 in figures 4A and 4B also highlight at least two interesting features of recent U.S. interventions. The first is that the dominant activity switched from purchasing foreign currencies and selling dollars—which would tend to reduce the dollar's value—to selling foreign exchange and buying dollars—actions consistent with supporting the dollar's value. The figures also show that this intervention occurred over a period of steady declines in the dollar's value. Indeed, between the time of the Plaza Accord in September 1985 and March 1987, when a new burst of intervention occurred, the dollar's value fell from 231.90 yen and 2.73 DM to 151.70 yen and 1.83 DM. Although no rationale was made public for each intervention, the data for early 1987 are consistent with the view that U.S. Treasury officials believed further declines in the value of the dollar below these levels should be resisted.

The Louvre Accord, reached on February 20, 1987, marks a second interesting period. This agreement brought together the G-7 Finance

[11]See, for example, Bernanke and Mishkin (1991).

[12]Bordo and Schwartz (1990, pp. 5-6) provide evidence on relative rates of M1 growth in the United States, Germany and Japan and corresponding movements in the DM/$ and yen/$ exchange rates since 1985.

[13]Briefly, if intervention is directed to *resisting* exchange rate changes, the coincidence of a large intervention and a change in the exchange rate would be evidence on the failure of intervention.

[14]For a critique of intervention since the Plaza Accord specifically, see Bordo and Schwartz (1990).

[15]See Federal Reserve Bank of New York (1989).

Figure 3a
DM/$ Exchange Rate Data for 1985

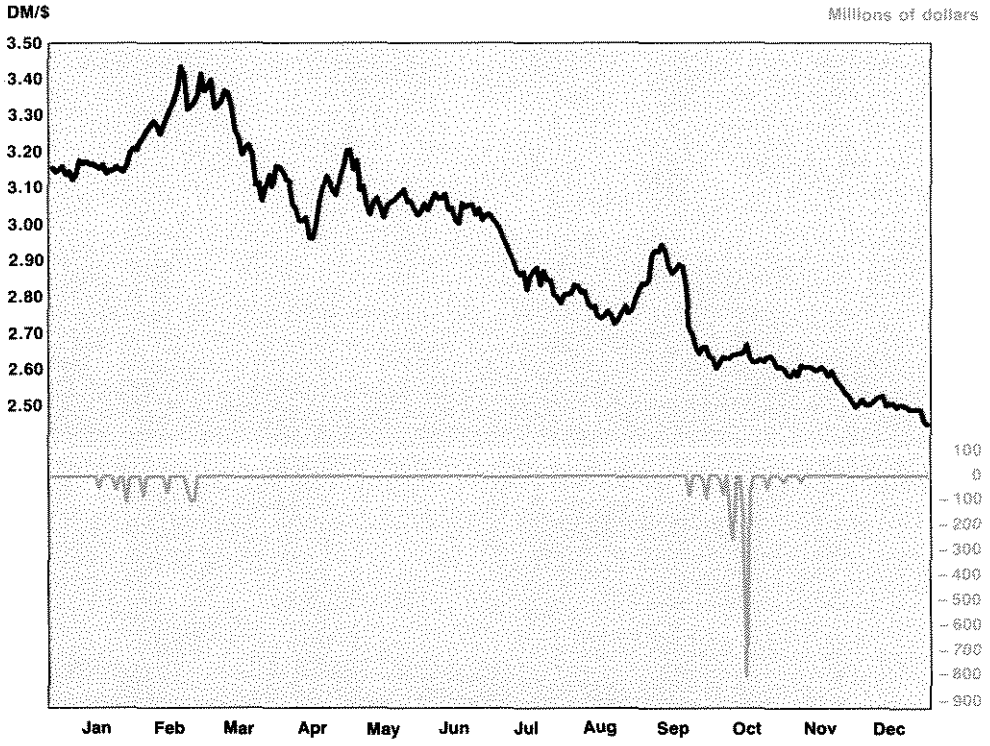


Figure 3b
Yen/$ Exchange Rate Data for 1985

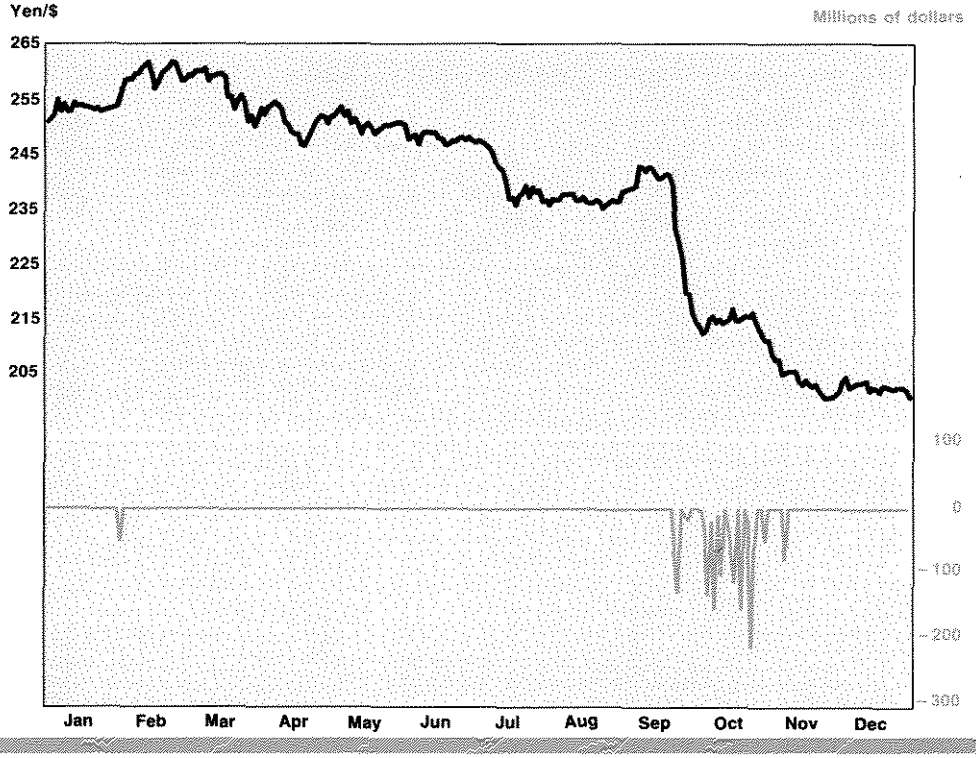


Figure 4a
DM/$ Exchange Rate Data for 1987

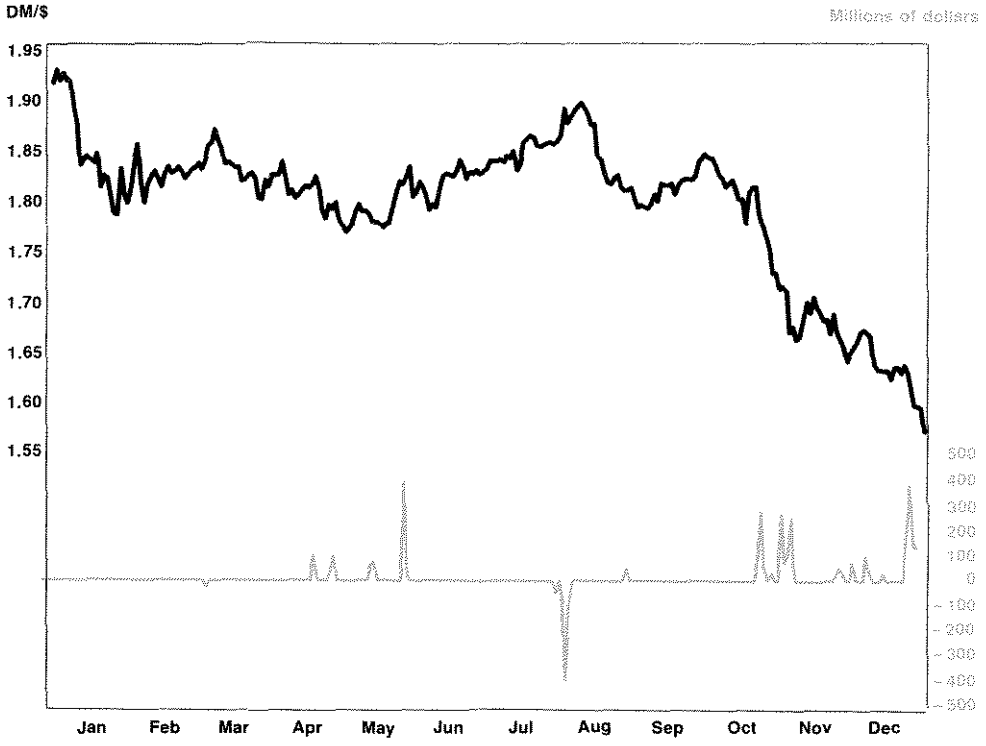


Figure 4b
Yen/$ Exchange Rate Data for 1987

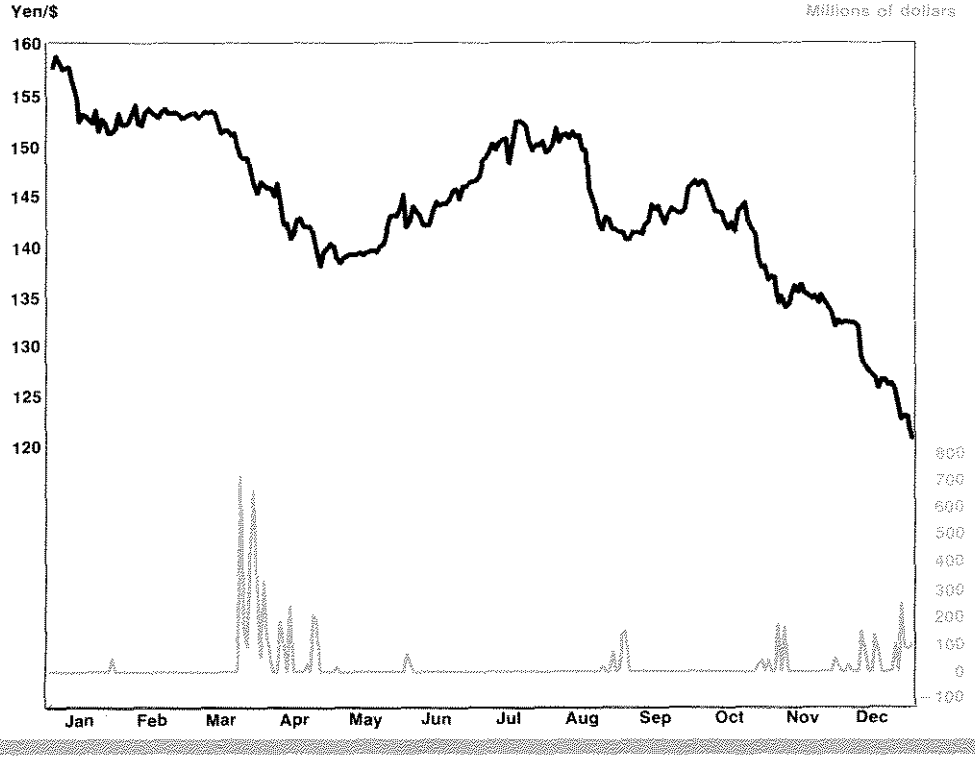


Figure 5a
DM/$ Exchange Rate Data for 1988

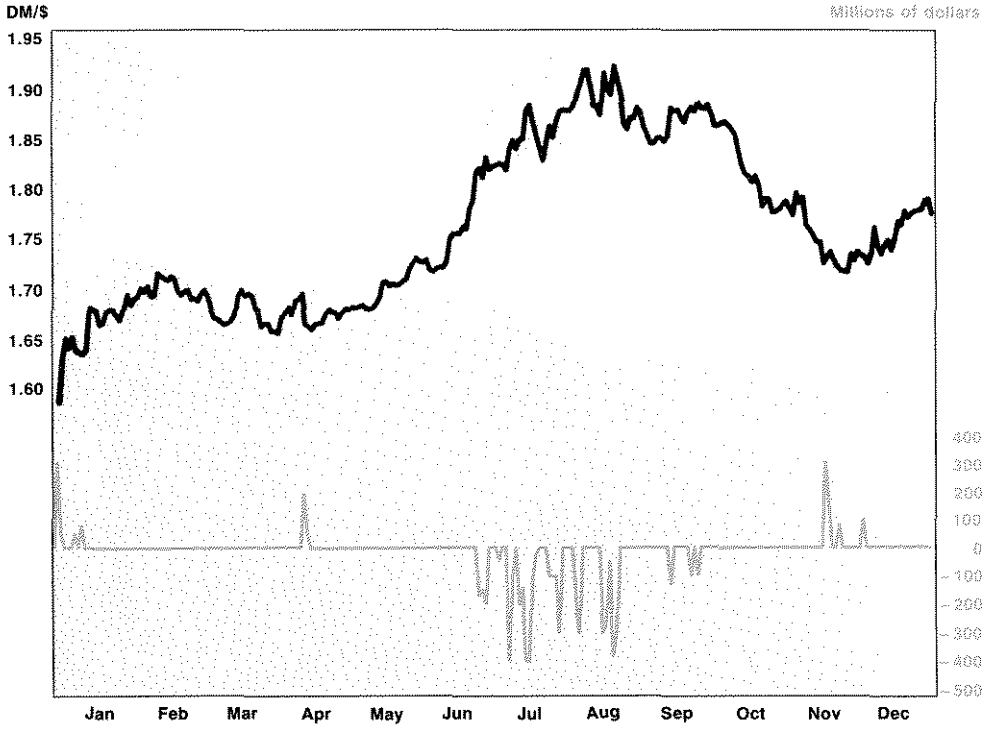


Figure 5b
Yen/$ Exchange Rate Data for 1988

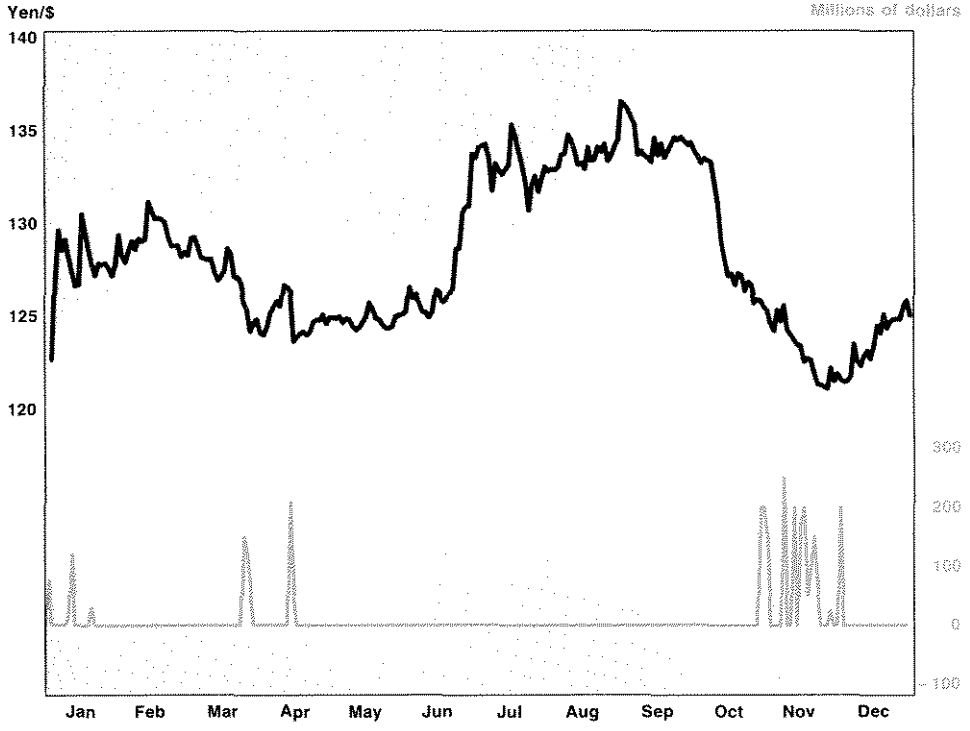


Figure 6a
DM/$ Exchange Rate Data for 1989

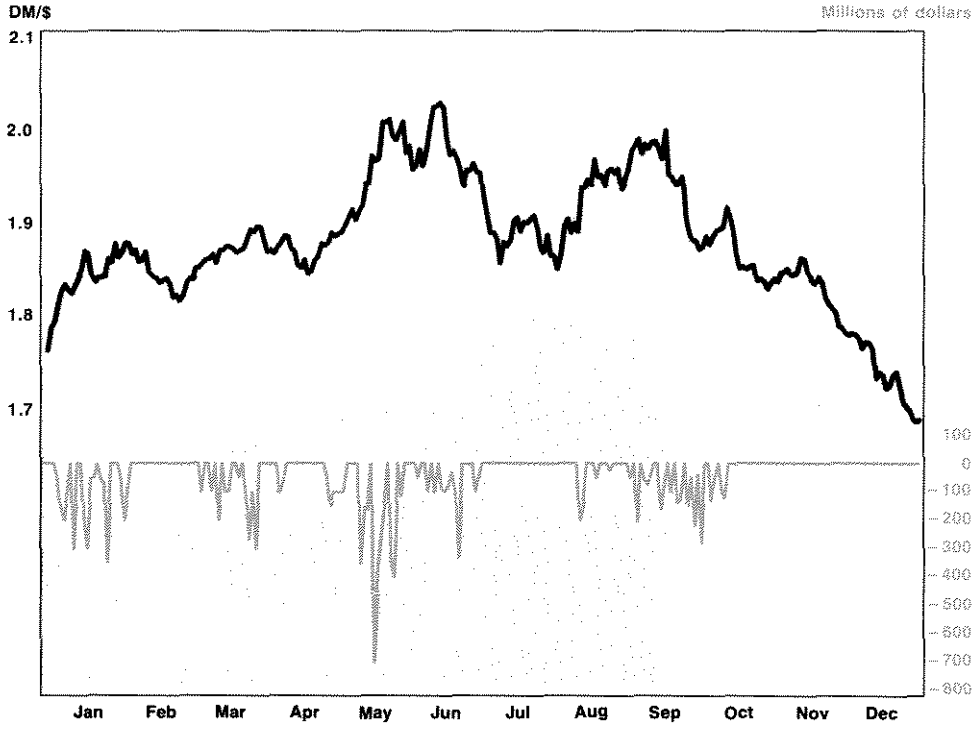
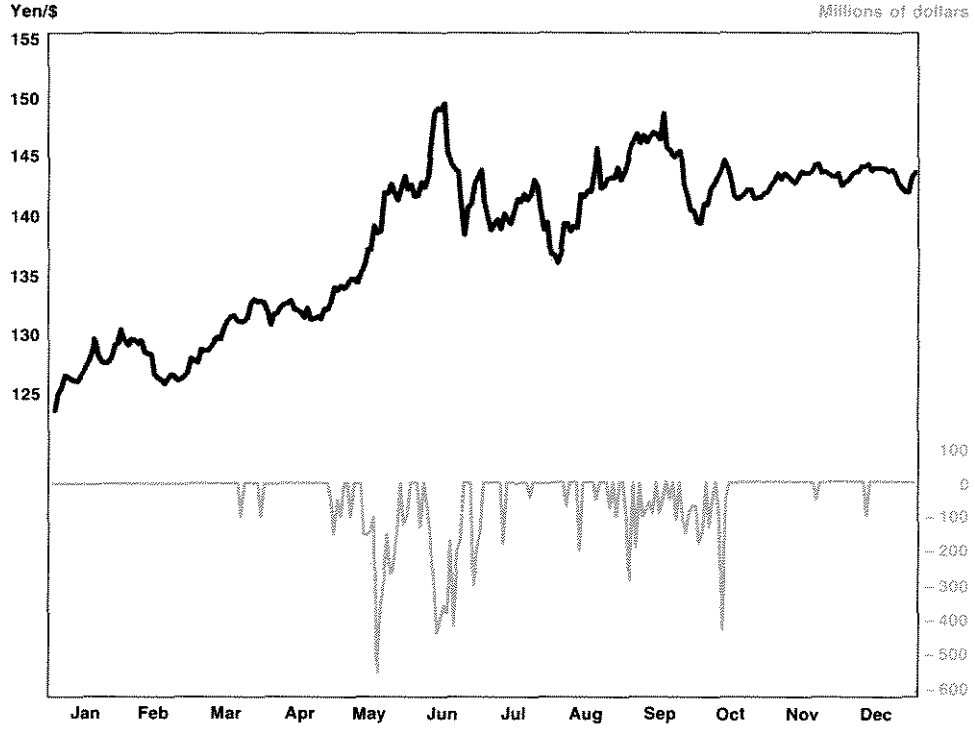


Figure 6b
Yen/$ Exchange Rate Data for 1989



Ministers to agree on intervention activities but, in contrast to Plaza, the Louvre Accord directed their attention to stabilizing exchange rates around then-current levels rather than changing the level itself.[16] As with Plaza, the United States followed this agreement with an initial burst of activity in March, the month following the agreement; during a period of 53 days, the U.S. authorities sold an equivalent of $4,088 million in yen and $782 million in DM. The United States did not intervene again in any concerted way until December when the dollar's value was approaching record lows for the postwar era. Even in this case, however, intervention by the United States had ceased by January 1988. One is left to speculate, then, whether the exchange rate levels at this point were consistent with the target zones established at the Louvre meeting in February or whether the United States had decided for some other reason to limit its intervention activities.[17] The remaining data for 1988, shown in figures 5A and 5B, reveal several episodes of intervention on both sides of the market: selling foreign exchange for dollars in the spring and fall and buying DM against dollars in the summer.

The data for 1989 (figures 6A and 6B), in contrast to the previous figures, show relatively persistent and consistent intervention against both the yen and DM. For the year as a whole, the United States bought, cumulatively, $10,925.60 million and $11,130.50 million (equivalent) of yen and DM, respectively; indeed, the United States purchased more DM and yen in 1989 than it did in the years 1985-88 combined. At the same time, the dollar's value moved in different directions against the two currencies, rising from 123.60 to 143.80 against the yen (+16 percent) and falling from 1.76 to 1.69 against DM (−4 percent). Although it is impossible to prove the counterfactual argument that the dollar's value would have changed even more without this intervention, its efficacy may be questioned if intervening in the same manner against two different currencies is associated with appreciations against one and depreciations against the other. Certainly this diverging pattern suggests the influence of some other factor on the exchange rate beyond intervention.

WHAT HAS INTERVENTION ACCOMPLISHED?

As noted in the introduction, the story of intervention is incomplete without looking at comparable data on the activities of the Bundesbank and Bank of Japan. Although data on the value of foreign central bank actions are not available, it is possible to identify days on which foreign central banks intervened. In making partitions of the data set, it is assumed that, at a minimum, these central banks were not working against Federal Reserve actions. In other words, we assume that on the days the Fed intervened, the Bundesbank and Bank of Japan either did nothing or they conducted a complementary intervention that would reinforce the effect of the Fed's actions.

It also should be noted that it is impossible, or at least very difficult, to refute the counterfactual argument—that the exchange rate would have changed without intervention. Indeed, without knowing the reasons for central bank actions, intervention may be motivated primarily by a desire to *resist*—rather than cause—changes in the exchange rate. Because this possibility is a hypothesis that cannot be tested, we will assume that, in the absence of intervention, the exchange rate would not have changed. We also will assume that the purpose of intervention was to make the exchange rate move in a certain direction even though a large change on the day of intervention might indicate the failure of an action that was intended to *prevent* a change in the exchange rate.

In view of the earlier discussion and these two assumptions, several hypotheses merit testing. The first is that the average absolute change in the exchange rate on days when the Fed intervenes alone should not be different from the changes in the exchange rate when no intervention occurs. This test is based on the earlier discussion of sterilized intervention, which predicted that its failure to change relative money supplies also should leave the exchange rate unaffected. A second test is motivated by the practice of the Bundesbank not to sterilize (at least not completely) *its* intervention; thus, on

[16]Funabashi, (1988).

[17]Target zones establish upper and lower bounds for the exchange rate. Typically, the exchange rate is free to vary within the established range but central banks pledge to engage in coordinated intervention if the exchange rate begins to move outside of the range.

Table 1

Mean Changes in the Absolute Value of the DM/$ Exchange Rate (*100)

Year	$\bar{X}_1$ (n)	$\bar{X}_2$ (n)	$\bar{X}_3$ (n)	$\bar{X}_4$ (n)
1985	1.00 (7)	1.36 (32)	3.05 (12)	2.05 (188)
1986	----	1.24 (15)	----	1.25 (226)
1987	1.21 (10)	1.01 (19)	1.27 (20)	0.77 (194)
1988	0.90 (4)	0.87 (42)	1.43 (30)	0.67 (165)
1989	0.76 (20)	0.84 (11)	0.99 (33)	0.91 (61)
All years	0.92 (41)	1.07 (119)	1.45 (95)	1.18 (834)

Test Statistics for Equality of Mean Changes (Absolute Values)

Year	$\bar{X}_1 = \bar{X}_4$	$\bar{X}_2 = \bar{X}_4$	$\bar{X}_3 = \bar{X}_4$	$\bar{X}_1 = \bar{X}_2$	$\bar{X}_1 = \bar{X}_3$	$\bar{X}_2 = \bar{X}_3$
1985	1.59	2.19*	1.75	0.86	1.41	2.39*
1986	----	0.04	----	----	----	----
1987	1.75	1.26	2.64*	0.67	0.16	0.87
1988	0.69	1.76	5.32*	0.07	0.91	2.62*
1989	0.75	0.28	0.49	0.28	0.97	0.52
All years	1.28	0.95	1.89	0.92	1.88	2.14*

Subscripts to $\bar{X}$s and null hypotheses indicate the following:

$\bar{X}_1$ = intervention only by Federal Reserve

$\bar{X}_2$ = intervention only by Bundesbank

$\bar{X}_3$ = intervention by both the Federal Reserve and Bundesbank

$\bar{X}_4$ = no intervention by either central bank

* = statistically significant at the 5 percent level

days when a foreign central bank intervenes alone, the average absolute change in the exchange rate should be significantly larger than on days when no intervention occurs.[18] The reason, of course, is that unsterilized intervention will affect relative money supplies and, therefore, should affect the exchange rate as well.

Making clear predictions about the effects of intervention on the volatility of daily exchange rate changes, however, is more difficult. Using the variance of daily absolute changes in the exchange rate as our measure of volatility, it is possible to argue that intervention, conceivably, could raise or lower the variance of exchange rate changes.[19] On one hand, if intervention is associated with larger average daily changes, the variance of these changes might rise as well. On the other hand, if the purpose of intervention is to reduce daily volatility in the exchange rate and it is successful, the variance could be smaller with intervention. With this uncertainty, the test results merely are reported, and one can simply make judgments about the effects (if any) of intervention on the variance of daily exchange rate changes.

The data for means and variances in tables 1-4 divide the data into four groups: days when the Fed intervened alone, days when a foreign cen-

[18]For evidence on the Bundesbank's practice of not completely sterilizing its intervention, see Neumann (1984).

[19]Because we are dealing with absolute changes, variance is measured as $\frac{1}{n}\sum_{i=1}^{n}\Delta e^2$, where n is the number of observations and e is the exchange rate.

Table 2

Mean Changes in the Absolute Value of the Yen/$ Exchange Rate (*100)

Year	$\bar{X}_1$ (n)	$\bar{X}_2$ (n)	$\bar{X}_3$ (n)	$\bar{X}_4$ (n)
1985	150.56 (9)	97.89 (18)	192.73 (11)	88.10 (201)
1986	- - - -	97.81 (47)	- - - -	86.14 (194)
1987	124.50 (6)	56.88 (33)	97.65 (37)	63.32 (167)
1988	73.50 (4)	72.12 (17)	62.31 (16)	54.03 (204)
1989	94.57 (7)	82.84 (6)	103.52 (27)	51.48 (85)
All years	117.62 (26)	82.31 (121)	104.67 (91)	70.97 (851)

Test Statistics for Equality of Mean Changes (Absolute Values)

Year	$\bar{X}_1 = \bar{X}_4$	$\bar{X}_2 = \bar{X}_4$	$\bar{X}_3 = \bar{X}_4$	$\bar{X}_1 = \bar{X}_2$	$\bar{X}_1 = \bar{X}_3$	$\bar{X}_2 = \bar{X}_3$
1985	2.02*	0.50	4.02*	0.77	0.45	1.87
1986	- - - -	0.82	- - - -	- - - -	- - - -	- - - -
1987	2.46*	0.58	3.04*	2.21*	0.74	2.40*
1988	0.71	1.19	0.58	0.02	0.33	0.31
1989	2.04*	1.38	3.51*	0.23	0.21	0.44
All years	3.09*	1.60	4.06*	1.63	0.49	1.75

Subscripts to $\bar{X}$s and null hypotheses indicate the following:

$\bar{X}_1$ = intervention only by Federal Reserve

$\bar{X}_2$ = intervention only by Bank of Japan

$\bar{X}_3$ = intervention by both the Federal Reserve and Bank of Japan

$\bar{X}_4$ = no intervention by either central bank

* = statistically significant at the 5 percent level

tral bank intervened alone, days when both intervened, and days when neither intervened. Tables 1 and 2 report means of the daily absolute changes in the DM/$ and yen/$ exchange rates, respectively, and tests for equality of means between various categories. Tables 3 and 4 repeat these categories for data on the variances of daily exchange rate movements. In all cases, the data are based on absolute values of daily changes because we do not know the specific intentions of intervention and our interest merely is in a central bank's ability to *change* the exchange rate.

In table 1, the data show that intervention was associated with a significant effect on the magnitude of the daily change in the DM/$ exchange rate in only three cases: in 1987 and 1988, when the Federal Reserve and Bundesbank both intervened on the same day and in 1985 when the Bundesbank acted alone. The two cases of significant effects when both central banks intervene is consistent with the notion that joint actions are associated with significantly larger exchange rate movements because they give signals about the future course of monetary policy and its likely effects on the exchange rate. These results also are consistent with the finding that coordinated interventions have larger effects on the exchange rate than unilateral interventions.[20]

In table 2, the effects of intervention on the yen/$ exchange rate are shown to be much

[20]See, for example, Dominguez (1990) or Loopesko (1984).

Table 3
Variances of Absolute Changes in DM/$ Exchange Rate

Year	$\hat{s}_1^2$	$\hat{s}_2^2$	$\hat{s}_3^2$	$\hat{s}_4^2$
1985	0.00018	0.00028	0.00220	0.00072
1986	------	0.00022	------	0.00030
1987	0.00021	0.00016	0.00028	0.00012
1988	0.00021	0.00013	0.00032	0.00009
1989	0.00011	0.00012	0.00018	0.00014
All years	0.00015	0.00019	0.00050	0.00030

F-statistics for Equality of Variances

Year	$\hat{s}_1^2 = \hat{s}_4^2$	$\hat{s}_2^2 = \hat{s}_4^2$	$\hat{s}_3^2 = \hat{s}_4^2$	$\hat{s}_1^2 = \hat{s}_2^2$	$\hat{s}_2^2 = \hat{s}_3^2$	$\hat{s}_1^2 = \hat{s}_3^2$
1985	4.11*	2.56*	3.04*	1.60	7.80*	12.50*
1986	---	1.37	---	---	---	---
1987	1.75	1.31	2.34*	1.33	1.78	1.34
1988	2.46	1.53*	3.70*	1.61	2.42*	1.50
1989	1.35	1.23	1.28	1.10	1.57	1.72
All years	1.97*	1.62*	1.66*	1.22	2.69*	3.27*

Subscripts to $\hat{s}^2$s and null hypotheses indicate the following:

$\hat{s}_1^2$ = intervention only by Federal Reserve

$\hat{s}_2^2$ = intervention only by Bundesbank

$\hat{s}_3^2$ = intervention by both the Federal Reserve and Bundesbank

$\hat{s}_4^2$ = no intervention by either central bank

* = statistically significant at the 5 percent level

stronger: in every year but 1988 (when intervention generally was limited), intervention either by the Fed alone or in concert with the Bank of Japan on the same day apparently was associated with significantly larger changes in the exchange rate.[21] It should be noted, however, that the significance of the Fed's unilateral interventions is based on only 26 observations during the entire 1985-89 sample period. Indeed, these tables show that the Fed intervened infrequently during the period.

Having found statistical significance for the effectiveness of intervention activities during certain periods, the potential *economic* significance of these effects is the next question to be investigated. Looking, for example, at the effects of joint intervention by the Fed and Bundesbank, the largest significant average absolute daily change in the exchange rate is found in 1988: 0.0143 pfennig. Based on an average value of 1.76 for the DM/$ exchange rate in 1988, an average absolute change of 0.0143 pfennig suggests that joint intervention is associated with average absolute changes in the exchange rate that are 0.81 percent greater than the changes that occur on days without intervention. Changes of similar magnitudes are found for the yen/$ rate. Overall, the economic significance of these results appears to be small despite the occasionally high level of statistical significance.

With respect to variances of daily changes in the exchange rate, reported in tables 3 and 4, a similar story carries through. For the DM/$ rate, most of the significant differences between

[21]For more on this story and related evidence, see Obstfeld (1991) and Dominguez (1990).

Table 4

Variances of Absolute Changes in Yen/$ Exchange Rate

Year	$\hat{s}_1^2$	$\hat{s}_2^2$	$\hat{s}_3^2$	$\hat{s}_4^2$
1985	7.96	2.01	6.32	1.37
1986	- - -	1.41	- - -	1.57
1987	2.46	0.69	1.55	0.74
1988	0.75	1.68	0.75	0.59
1989	1.58	1.47	2.13	0.51
All years	3.87	1.34	2.16	1.02

F-statistics for Equality of Variances

Year	$\hat{s}_1^2 = \hat{s}_4^2$	$\hat{s}_2^2 = \hat{s}_4^2$	$\hat{s}_3^2 = \hat{s}_4^2$	$\hat{s}_1^2 = \hat{s}_2^2$	$\hat{s}_2^2 = \hat{s}_3^2$	$\hat{s}_1^2 = \hat{s}_3^2$
1985	5.80*	1.46	4.60*	3.97*	3.15*	1.26
1986	- - -	1.11	- - -	- - -	- - -	- - -
1987	3.35*	1.07	2.11*	3.57*	2.25*	1.59
1988	1.28	2.87*	1.28	2.25	2.24	1.00
1989	3.09*	2.87*	4.16*	1.08	1.45	1.35
All years	3.80*	1.32*	2.12*	2.88*	1.61*	1.79*

Subscripts to $\hat{s}^2$s and null hypotheses indicate the following:

$\hat{s}_1^2$ = intervention only by Federal Reserve

$\hat{s}_2^2$ = intervention only by Japan

$\hat{s}_3^2$ = intervention by both the Federal Reserve and Japan

$\hat{s}_4^2$ = no intervention by either central bank

* = statistically significant at the 5 percent level

days of no intervention and some intervention occur when the Federal Reserve and the Bundesbank both act on the same day. For the yen/$ rate, however, significant differences are found for either the Fed or Bank of Japan acting unilaterally as well as for their joint actions. Intervention in all cases, however, seems to be associated with higher, not lower, variance of daily exchange rate changes. Again, caution should be exercised before attributing cause-and-effect to these findings: an equally plausible, but untestable, hypothesis implies that volatility might have been even greater on these days had it not been for the intervention.

CONCLUSIONS

The world's major central banks occasionally intervene in foreign exchange markets to affect the value of one currency relative to another. Since 1985, the official reasons for these activities changed from reducing the dollar's value to stabilizing it within some unspecified range of values. Because much of the related data are confidential and the stated objectives of intervention often are vague, researchers have been limited in their ability to answer a fundamental question: Does intervention work?

Using data recently released by the Federal Reserve, the answer seems to be that intervention is associated with significantly larger daily changes in the exchange rate when the Federal Reserve and a foreign central bank both intervene on the same day. This conclusion holds even though changes in the relative money supplies of two countries were described as the primary factor behind a change in the exchange rate and the Federal Reserve routinely sterilizes its intervention. Consistent with other work on coordinated intervention, it appears as if central bank actions are enhanced by the announcement of joint actions that send a stronger signal to the market about the future course of monetary policy and its possible effects on the exchange rate.

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Appendix
Is Sterilized Intervention Really Sterilized?[1]

The discussion in the text takes the conventional view that intervention is sterilized if the domestic central bank's activities have no net effect on the domestic money supply. As this appendix shows, however, actions by the Federal Reserve to leave the U.S. money supply unaffected by intervention still have the potential to affect a *foreign* money supply and both foreign and U.S. interest rates. In one case, the ratio of the foreign to U.S. money supplies will be altered, thereby opening a channel through which sterilized intervention, as conventionally defined, can affect the exchange rate. In the other case, domestic monetary policies that peg a short-run interest rate will require less-than-complete sterilization to keep interest rates unchanged.

Consider first figure A1, which extends the analysis of figure 2, panel B, in the text. New

[1] I am indebted to Manfred J.M. Neumann for making this observation and to Anatol B. Balbach and R. Alton Gilbert for developing these points in greater detail.

Figure A1

Sterilized Foreign Exchange Intervention by the Federal Reserve *with* Effects on German Money Supply: Fed Holds DM Deposits at the Bundesbank

Federal Reserve Banks (FRB)		U.S. Commercial Banks (cb)		Bundesbank (B)		German Commercial Banks (Gcb)	
Assets	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**
+ DM deposits at B	+ Reserves of cb	+ Reserves			+ DM deposits of FRB	– Reserves	– DM deposits of U.S. correspondent bank
		– DM deposits at Gcb			– Reserves of Gcb		
– U.S. Treasury securities	*– Reserves of cb*	*– Reserves*					
		+ U.S. Treasury securities					

entries to this original figure are shown in italics. Recall that the point of this figure originally was to show how unsterilized intervention would affect the exchange rate by expanding the U.S. money supply relative to the German money supply.

Picking up the story at this point, the Federal Reserve could sterilize its intervention by selling U.S. Treasury securities from its portfolio to U.S. commercial banks. This would lead to all four italicized entries in the balance sheets of the Federal Reserve and U.S. commercial banks: the Fed's balance sheet would shrink with declines both in its Treasury security assets and its reserves liabilities, while commercial banks would substitute Treasury securities for reserves in their portfolios. On net, the sale of U.S. Treasury securities to commercial banks and the consequent reduction in reserves will offset the increase in reserves associated with the initial intervention action and leave the U.S. money supply unchanged. Thus, in the conventional sense, the Fed has sterilized its intervention and, again in the conventional view, the exchange rate should be unaffected.

The figure shows, however, that if the Fed merely holds its acquired DM as a deposit at the Bundesbank, the Fed's activities will have *reduced* the German money supply. This is indicated by the declines in the reserve liabilities of the Bundesbank and reduction in the deposits of German commercial banks. By reducing the German money supply relative to the U.S. money supply, the Fed's actions should lead to an increased DM/$ exchange rate even though the intervention was "sterilized" in the United States.

Holding DM deposits at the Bundesbank, however, would be somewhat unusual for the Fed; typically, it invests its non-interest-earning DM deposits in interest-earning DM-denominated securities. In this more usual case, the Fed's "sterilized" intervention will not affect the German money supply if it buys German bonds in the open market. If it were to buy them directly from the Bundesbank, however, the German money supply still would be reduced as in the earlier example.

To see the mechanics of this effect, consider figure A2. This is a reproduction of figure A1, supplemented by additional transactions shown in italics. Picking up at the point where figure A1 ended—the Fed has sterilized its intervention and is holding a DM deposit at the Bundesbank—the Fed now buys German bonds in the open market from German commercial banks. When the Fed's transaction is complete, its DM deposits at the Bundesbank fall, the bond holdings of German commercial banks fall and the reserves of the German banking system rise; on net, these machinations offset the decline in the German money supply that would occur if the Fed merely held its DM deposits at the Bundesbank. In the United States, the Fed's actions substitute interest-earning German bonds in its portfolio in place of the non-interest-earning DM

Figure A2

Sterilized Foreign Exchange Intervention by the Federal Reserve *without* Effects on German Money Supply: Purchase of German Bonds in the Open Market

Federal Reserve Banks (FRB)		U.S. Commercial Banks (cb)		Bundesbank (B)		German Commercial Banks (Gcb)	
Assets	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**
+ DM deposits at B	+ Reserves of cb	+ Reserves			+ DM deposits of FRB	– Reserves	– DM deposits of U.S. correspondent bank
		– DM deposits at Gcb			– Reserves of Gcb	– *German bonds*	
– U.S. Treasury securities	– Reserves of cb	– Reserves			– *DM deposits of FRB*	+ *Reserves*	
		+ U.S. Treasury securities			+ *Reserves of Gcb*		
+ *German bonds*							
– *DM deposits at B*							

deposits and leave the U.S. money stock unaffected. Thus, in the case in which the Fed eventually holds German bonds purchased in the open market, its intervention is sterilized in the sense of causing no change in the ratio of German to U.S. money supplies.

Before considering the last case, in which the Fed buys German bonds directly from the Bundesbank, we need to ask whether this intervention really is sterilized in the sense that it should produce no effect on the exchange rate. Although relative money supplies are unaffected, the relative bond holdings of the central banks and the public have been altered and these portfolio substitutions can affect U.S. and German interest rates. In the U.S. market, for example, the Fed has induced U.S. banks to increase their holdings of U.S. Treasury securities; presumably, it did so by bidding Treasury prices down, thus raising U.S. interest rates. Conversely, it bought German bonds, presumably raising their prices and lowering German interest rates. Other things the same, these changes in interest rates should make capital flow into the United States and raise the dollar's value against the DM. Thus, an intervention that was designed to reduce the dollar's value tends to raise it because of these interest rate effects—even if the U.S. and German monetary bases are unchanged.[2] In addition to showing that it is possible for "sterilized" intervention to affect the exchange rate, this example also shows the effect to be in the *opposite direction* from the intent of the intervention. As a practical matter, these interest rate effects are likely to be small, but it is worth noting their existence as a possible channel for exchange rate effects from sterilized intervention.

Finally, consider the consequences of the Fed using its DM deposits at the Bundesbank to purchase German bonds directly from the Bundesbank. This case, shown in figure A3, has the

[2]The story actually is more complicated. First, to the extent that the Fed's initial (pre-sterilization) reserves injection is associated with a "liquidity effect," the subsequent rise in U.S. interest rates discussed at the end of this story may just offset the earlier interest rate decline and leave U.S. interest rates, on net, at their initial levels.

It also is not possible to isolate whether intervention of this sort will have effects on the spot or forward exchange rate. With covered interest parity, the dollar's forward premium will be reduced through a rise in the dollar's spot rate (as discussed in the example), a decline in the forward rate, or both. If there is no signaling effect, the bulk of the change will likely occur in the spot rate. Conversely, a strong signaling effect would likely affect the forward rate while having little effect on the spot rate. Whichever case prevails, the effects on the dollar's value are unlikely to coincide with the intent of the intervention.

Figure A3

Sterilized Foreign Exchange Intervention by the Federal Reserve *with* Effects on German Money Supply: Purchase of German Bonds from the Bundesbank

Federal Reserve Banks (FRB)		U.S. Commercial Banks (cb)		Bundesbank (B)		German Commercial Banks (Gcb)	
Assets	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**
+ DM deposits at B	+ Reserves of cb	+ Reserves		– *German bonds*	+ DM deposits *of FRB*	– Reserves	– DM deposits of U.S. correspondent bank
		– DM deposits at Gcb			– Reserves of Gcb		
– U.S. Treasury securities	– Reserves of cb	– Reserves			– *DM deposits of FRB*		
		+ U.S. Treasury securities					
+ *German bonds*							
– *DM deposits at B*							

Bundesbank exchanging German government bonds for its DM deposit liabilities to the Fed. This exchange, however, leaves in place the decline in deposits and reserves at German commercial banks originally shown in figure A1 and, hence, the German money stock also declines as it did in that first example. And, as before, the exchange rate would be expected to change because the ratio of U.S. to German money supplies will be affected. The upshot of these three cases is that what is typically called "sterilized" intervention has a variety of channels through which the exchange rate could be affected.