Does Central Bank Intervention Stabilize Foreign Exchange Rates?

By Catherine Bonser-Neal

Since the adoption of a flexible exchange rate system in 1973, central banks of most industrialized countries have continued to intervene in foreign exchange markets. One reason is that exchange rate volatility has increased. To reduce volatility, many European countries have agreed to keep exchange rates within a band around a target exchange rate, implementing this policy by intervening in foreign exchange markets when necessary. Even without an explicit exchange rate commitment, countries such as the United States and Japan have intervened in foreign exchange markets to help stabilize exchange rates.

Opinions differ on whether central banks can stabilize exchange rates. Some analysts believe central bank intervention can reduce exchange rate volatility by stopping speculative attacks against a currency. Other analysts, though, believe central bank intervention may increase volatility if the intervention contributes to market uncertainty or encourages speculative attacks against the currency.

Catherine Bonser-Neal is an economist at the Federal Reserve Bank of Kansas City. Stacy Bear, a research associate at the bank, helped prepare the article.

This article presents empirical evidence on this controversy. The first section discusses why exchange rates are volatile and why policymakers may want to reduce volatility. The second section examines how central bank intervention may affect volatility. The third section presents empirical evidence suggesting that central bank intervention does not generally reduce exchange rate volatility. Rather, central bank intervention typically appears to have had little effect on volatility.

EXCHANGE RATE VOLATILITY

This section discusses the causes and consequences of exchange rate volatility. Also discussed are various ways to measure exchange rate volatility.

Causes of volatility

Exchange rate volatility is often attributed to three factors: volatility in market fundamentals, changes in expectations due to new information, and speculative "bandwagons" (Engel and Hakkio). Volatility in market fundamentals, such as the money supply, income, and interest rates, affects exchange rate volatility because the level of the exchange rate is a function of these fundamentals.

For example, large changes in the money supply can lead to changes in the level of the exchange rate. Changes in the level of the exchange rate in turn imply exchange rate volatility.

Changes in expectations about future market fundamentals or economic policies also affect exchange rate volatility. When market participants receive new information, they alter their forecasts of future economic conditions and policies. Exchange rates based on these forecasts will also change, thereby leading to exchange rate volatility. For example, news about a change in monetary policy may cause market participants to revise their expectations of future money supply growth and interest rates, which could alter the level and hence the volatility of the exchange rate.

In addition to being affected by expectations of future fundamentals and policies, volatility is also affected by the degree of confidence with which these expectations are held. For instance, if traders are uncertain about their forecasts of future economic conditions, they are more likely to revise their currency positions once new information becomes available. These revisions to currency positions in turn imply an increase in the frequency, and hence in the volatility, of exchange rate changes. In brief, exchange rate volatility tends to rise with increases in market uncertainty about future economic conditions and tends to fall when new information helps resolve market uncertainty.

Finally, exchange rate volatility can be caused by speculative bandwagons, or speculative exchange rate movements unrelated to current or expected market fundamentals. For example, if enough speculators buy dollars because they believe the dollar will appreciate, the dollar could appreciate regardless of fundamentals. If it then becomes apparent that market fundamentals will not sustain such an appreciation, active selling by the same speculators could cause the dollar to depreciate. Swings in the value of the dollar arising from such speculative forces can contribute to exchange rate volatility.

Consequences of volatility

Regardless of its origin, there are several reasons why authorities may want to reduce exchange rate volatility (Becketti and Sellon). One reason is that volatility may impede international investment flows. By adding risk to the rate of return on a foreign asset, exchange rate volatility may reduce investment in foreign financial assets. In addition, companies may be reluctant to build a new plant or purchase a foreign company if exchange rate uncertainty reduces the expected profits from such projects. As a result, exchange rate volatility could disrupt the efficient allocation of resources in the world economy by creating a disincentive for investment capital to move abroad.

Another reason why authorities may want to reduce volatility is that it may adversely affect international trade. Volatile exchange rates create uncertainty about the revenues to be earned on international transactions. Such volatility could force companies to add a risk premium to the costs of goods they sell abroad. If these costs are passed on to consumers in the form of higher prices, the demand for traded goods could decrease. In addition, firms themselves may be more reluctant to engage in international trade if exchange rate volatility adds an extra risk to their profits.

A final reason to reduce exchange rate volatility is that it could spill over into U.S. financial markets. If exchange rate volatility increases the riskiness of U.S. assets, the prices of these assets could also become more volatile. The increased volatility of financial markets could threaten the stability of the financial system and make monetary policy goals more difficult to attain.

Given these concerns, can exchange rate volatility be reduced? Exchange rate volatility depends in part on market expectations and market speculation. Some analysts believe central bank intervention in foreign exchange markets can reduce exchange rate volatility in two ways—by reducing the expected volatility of future market fundamentals and policies and by reducing the likelihood of speculative exchange rate movements. But before investigating whether central bank intervention can reduce volatility, it is first necessary to appropriately measure volatility.

Measuring volatility

While there are many ways to measure volatility, a useful measure to study the effects of central bank intervention should reflect the effects of intervention on both current and expected future exchange rate volatility. This property is important because intervention can have opposite effects on current and expected future volatility. For example, if intervention causes a large change in today's exchange rate but reduces foreign exchange market uncertainty, investors will observe an increase in current exchange rate volatility but a decrease in expected future volatility. A volatility measure that is forward-looking will capture both the immediate and longer term effects of intervention.

Commonly used measures of volatility, such as standard deviation and "generalized autoregressive conditional heteroskedasticity," or GARCH, estimates, are not forward-looking. The standard deviation measure is computed using only past values of the exchange rates. GARCH estimates of volatility are also calculated using a time series of past exchange rate changes. As a result, neither measure captures what volatility is expected to be in the future.

This study uses a measure known as *implied volatility*, which is derived from the price of a foreign currency option.[1] Implied volatility is forward-looking because it measures the market's forecast of future exchange rate volatility. As a result, it can capture both the immediate and longer term effects of central bank intervention.

A foreign currency option is a contract that gives the buyer the right, but not the obligation, to buy or sell foreign currency at a fixed price at some date in the future.[2] In the United States, currency option contracts conferring the right to buy or sell standardized amounts of foreign currency are traded on the Philadelphia Stock Exchange. The price of the currency option contract is determined in a competitive market and is quoted in terms of dollars per unit of foreign currency.

The price of a currency option is influenced by several factors. These factors include the underlying spot exchange rate, the fixed price (the "strike" or "exercise" price) at which the buyer of the option can buy or sell the foreign currency in the future, U.S. and foreign interest rates, and the expected standard deviation of the change in the spot exchange rate over the life of the option. The expected standard deviation, or volatility, of future exchange rate changes affects the price of the option because in many ways the option contract is like an insurance contract. In essence, the buyer of an option contract holds an insurance contract that places a bound on losses due to adverse exchange rate movements, but no bound on the gains due to favorable exchange rate movements. Because the losses are limited while the gains are unlimited, greater volatility of the exchange rate increases the value of the option and hence its price. The currency option's price therefore increases if exchange rate volatility is expected to increase, and the price falls if exchange rate volatility is expected to decrease.

Because option prices are partly a function of the expected standard deviation of future exchange

rate changes, one can extract this measure of expected volatility given knowledge of the option price and an option pricing model. The volatility estimate extracted in this manner is called implied volatility.

This measure of volatility is useful for several reasons. First, implied volatility is forward-looking because it reflects the market's expectation of the future standard deviation of the spot exchange rate. Second, implied volatility is a market-based measure of volatility. Currency option prices are determined in a competitive market using all available information. Hence, volatility estimated from the option price will also reflect these competitive forces and the market's information. Finally, because implied volatilities are available daily, measures of daily central bank intervention can be related to daily changes in exchange rate volatility to determine the direct impact of intervention.

Options data between 1985 and 1991 obtained from the Philadelphia Stock Exchange's transactions data base are used to estimate implied volatilities. The 1985-91 period was chosen for the following reasons. First, currency options have been traded on the Philadelphia Exchange only since 1982. As a result, implied volatilities cannot be estimated prior to 1982. Second, as discussed below, the bulk of intervention in the post-1980 period took place between 1985 and 1991. Intervention was rare between 1992 and 1994. While a significant amount of intervention occurred in 1995, the amounts for the year as a whole will not be disclosed until sometime in 1996. Estimates of volatility over the 1985-91 period, therefore, provide the most useful information on the effects of intervention on exchange rate volatility.[3]

Figure 1 shows the implied deutschemark and yen volatilities from 1985 to 1991. These implied volatilities are daily estimates of the market's forecast of the standard deviation of exchange rate changes over the average life of options in the sample. In this case, the average life equals slightly more than one month.[4] The figure shows that deutschemark and yen volatilities varied between 5 and 25 percent on an annual basis over this period, and that average volatility was 12.4 percent for the deutschemark and 11.1 percent for the yen. The relation between central bank intervention and exchange rate volatility is examined below.

HOW CENTRAL BANK INTERVENTION MAY AFFECT VOLATILITY

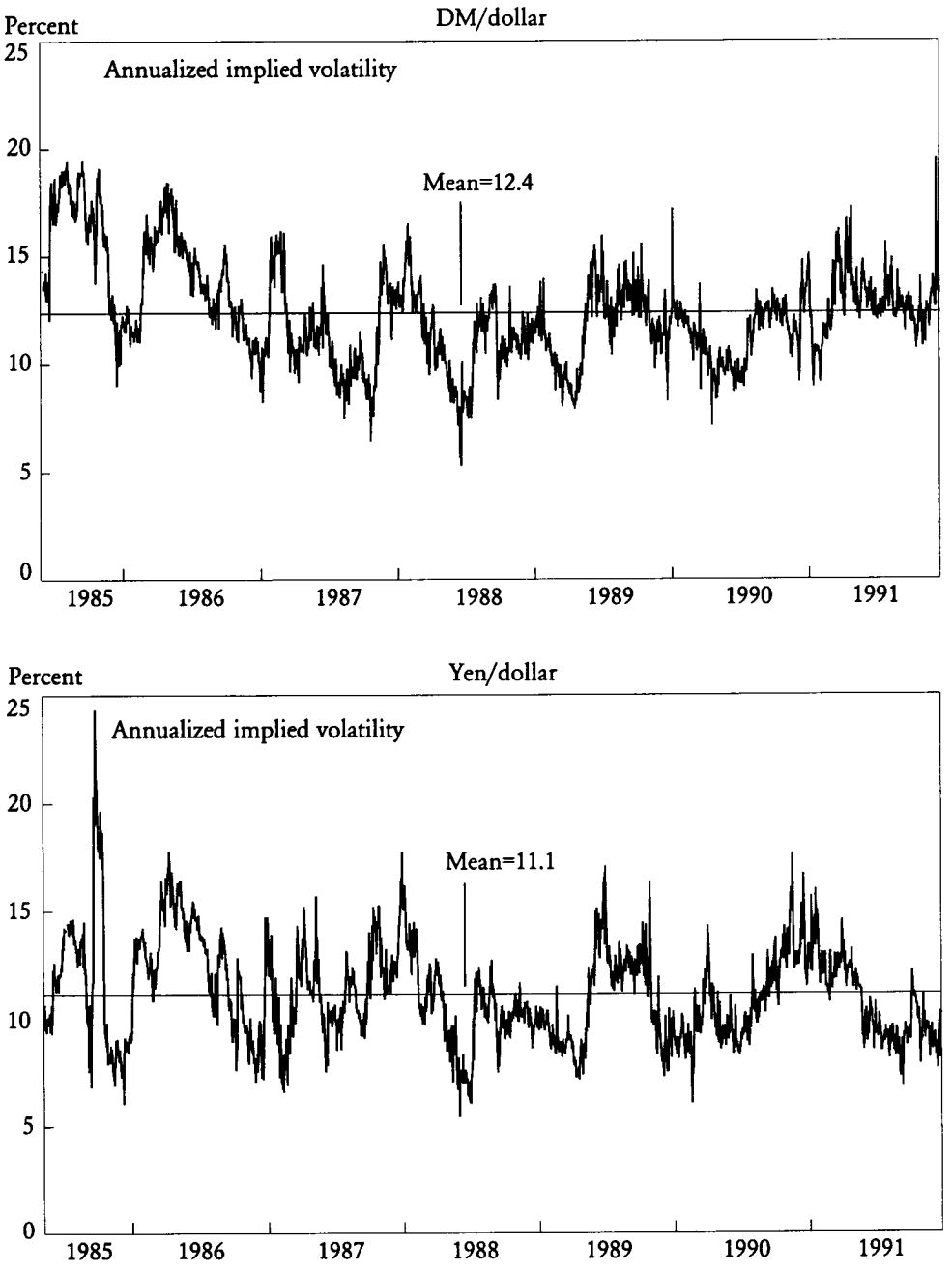
In a flexible exchange rate system there are no well-defined rules governing when central banks should intervene in foreign exchange markets. Instead, U.S. policy toward foreign exchange market intervention is guided by the concepts described in the International Monetary Fund's *Principles for the Guidance of Members' Exchange Rate Policies*–in particular, that "a member should intervene in the exchange market if necessary to counter disorderly conditions which may be characterized inter alia by disruptive short-term movements in the exchange value of its currency" (p. 11). How policymakers interpret the term "disorderly conditions" and consequently the amount and direction of intervention can vary over time.[5] Given the ambiguity surrounding the motivation for intervention, many have also questioned whether central bank intervention is effective in reducing volatility. This section describes U.S. intervention policy to "counter disorderly conditions" during the 1985-91 period of active intervention and discusses the potential effect of intervention on exchange rate volatility.

U.S. intervention policy

When the Federal Reserve intervenes in foreign exchange markets, it buys or sells foreign assets

Chart 1

DAILY EXCHANGE RATE VOLATILITY, 1985-91



Note: Volatility is measured by the implied exchange rate volatility imbedded in currency option prices.

in return for U.S. dollars. For example, if the Federal Reserve intervenes to reduce the dollar's value against the deutschemark, it buys deutschemark assets with dollars. This operation leads to an increase in dollar reserves and could lead to an increase in the U.S. money supply if no further action were taken. Federal Reserve operating procedures, however, routinely sterilize the effect of intervention on bank reserves. In the example, the Federal Reserve would sterilize the purchase of deutschemark assets by selling an equal amount of U.S. Treasury securities. Sterilized intervention therefore alters only the composition of U.S. and foreign securities in the hands of the public, leaving bank reserves and the money supply unchanged.

While intervention by U.S. monetary authorities to counter "disorderly" markets has been evident over the last ten years, the bulk of this intervention occurred from 1985 to 1991. The 1985-91 period can be divided roughly into three intervention regimes, reflecting different U.S. policies toward foreign exchange market intervention. These regimes fall into three time periods.

Plaza period	Jan. 1, 1985, to Feb. 21, 1987
Louvre period	Feb. 22, 1987, to Dec. 31, 1989
Post-Louvre period	Jan. 1, 1990, to Dec. 31, 1991

During the first regime, the Plaza period, the goal of intervention was an "orderly" depreciation of the dollar. This goal was formalized in the Plaza Agreement of September 22, 1985, by the finance ministers of the G-5 countries. In their policy statement, the ministers and governors of the G-5 countries stated that "exchange rates should better reflect fundamental economic conditions than has been the case. . . . In view of the present and prospective changes in fundamentals, some further orderly appreciation of the main nondollar currencies against the dollar is desirable. They stand ready to cooperate more closely to encourage this when to do so would be helpful." In brief, the G-5 ministers agreed to sell dollars to bring about an orderly decline in the value of the dollar.

The second intervention regime, the Louvre period, lasted from February 22, 1987, to December 31, 1989. In contrast to the earlier regime, which sought to change the level of the exchange rate, intervention during this period was used to stabilize exchange rates around existing levels. In their February 22, 1987 statement, the ministers and governors of the G-6 countries said that currencies were "within ranges broadly consistent with underlying economic fundamentals," and they agreed to "cooperate closely to foster stability of exchange rates around current levels." For this article, the end of the Louvre period is taken to be December 31, 1989.[6]

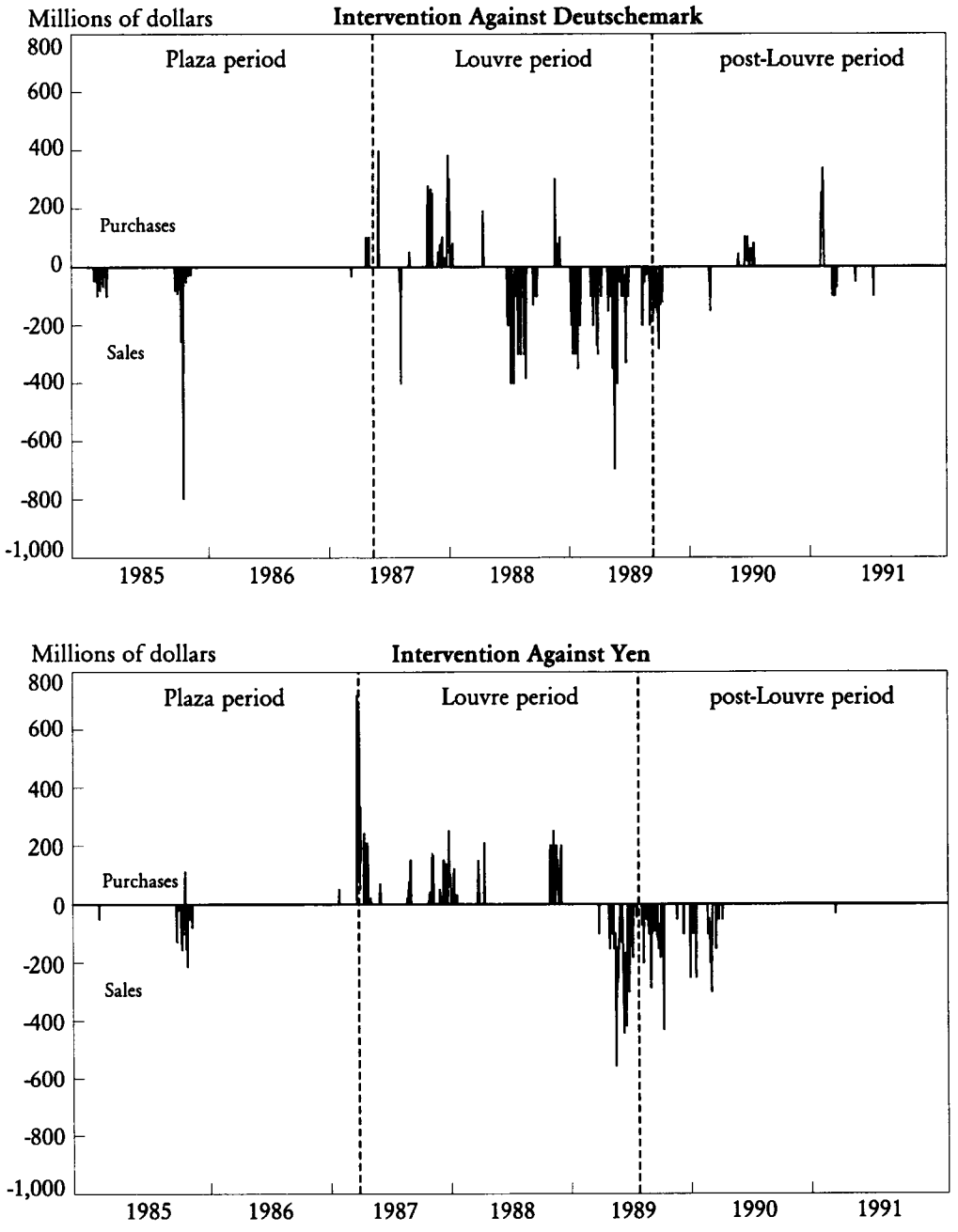
The third intervention regime, the post-Louvre period, lasted from January 1, 1990, to December 31, 1991. During this time, Federal Reserve intervention became less frequent and less likely to be coordinated with other central banks.[7]

Figure 2 shows the pattern of actual daily dollar purchases and sales by the Federal Reserve against the deutschemark and Japanese yen across these three regimes. The figure shows substantial variation in the frequency and magnitudes of intervention through time. In the first period, U.S. intervention was large in late 1985, coinciding with the September 1985 Plaza Agreement's call for an orderly depreciation of the dollar. During the 1987-89 period, intervention activity reflected the attempts of the Federal Reserve to stabilize DM/dollar and yen/ dollar exchange rates under the Louvre Accord. Finally, the frequency and average magnitude of Federal Reserve intervention decreased from 1990 to 1991.

Despite the differences in the implementation of intervention policy across the three regimes, exchange rate volatility remained a concern that guided policy. This concern dominated policy

Chart 2

FEDERAL RESERVE INTERVENTION



Source: Board of Governors of the Federal Reserve System.

decisions during the Louvre period, but it was also relevant during the Plaza period when authorities called for an *orderly* depreciation of the dollar. Volatility was even of concern during the post-Louvre period when intervention was less frequent, as evidenced by the perceptions of some that the United States had reestablished target zone ranges for the dollar (Bergsten). Whether central bank intervention was successful in reducing exchange rate volatility during the 1985-91 period is examined below.

The effects of central bank intervention

Just how central bank intervention affects exchange rate volatility depends on how it affects the causes of volatility—namely, the volatility of actual market fundamentals, changes in the expectations of future fundamentals or policies, and speculative bandwagons. Intervention typically has no direct impact on the first source of volatility, the volatility of actual market fundamentals, because intervention is sterilized. Theoretically, sterilized intervention should not affect the money supply, interest rates, or income.[8] Whether central bank intervention increases or decreases exchange rate volatility, therefore, depends on how intervention affects market expectations and speculative behavior. Because these effects are ambiguous, it is not clear how central bank intervention affects exchange rate volatility. That is, intervention could leave volatility lower, higher, or unchanged.

Intervention may decrease volatility. Central bank intervention may reduce exchange rate volatility if it resolves uncertainty by market participants about future monetary policy. For example, if the market is uncertain about the stance of monetary policy, then intervention to halt a drop in the dollar may signal that the Federal Reserve is committed to a tight monetary policy. The resolution of uncertainty about future monetary policy may then lead to less exchange rate volatility.[9]

Central bank intervention may also reduce exchange rate volatility by reducing the likelihood of a speculative bandwagon. The following example shows how intervention might reduce volatility if market participants think the central bank will intervene when speculative forces become dominant. Suppose the dollar exchange rate falls from DM 1.50/$ to DM 1.45/$. As speculators see the dollar falling, they may jump on the bandwagon thinking the dollar may fall further to DM 1.40/$. Under this scenario, speculators who sell $1 million at DM 1.45/$ could make a profit if the dollar falls to DM 1.40/$ and they reacquired dollars at the lower value.[10] However, if the central bank intervenes at DM 1.45/$ and pushes the dollar back to DM 1.50/$, then speculators could suffer a loss.[11] Speculators may therefore become reluctant to push the dollar down too rapidly if they believe the central bank will intervene to prevent the dollar from falling. By reducing selling pressure when the dollar starts to fall, central bank intervention could reduce speculative bandwagons and thereby reduce volatility.

Intervention may increase volatility. Central bank intervention could actually increase exchange rate volatility if intervention increases private sector uncertainty about central bank policies. In particular, market uncertainty about the existence, magnitude, and meaning of central bank intervention implies exchange rates could become less predictable and therefore more volatile. Suppose, for example, the central bank surprises traders by intervening to increase the value of the dollar but announces neither the intervention's magnitude nor its motivation. In making their trades, foreign exchange traders must now guess the meaning of the intervention and attempt to infer the implications of the action for future policy. Because their trades are based on incomplete information, traders will need to revise their currency positions once more information about intervention policy becomes

available. These changes in currency positions imply changes in the exchange rate and hence greater exchange rate volatility. Given that central banks rarely reveal their currency positions at the time they occur, uncertainty about central bank intervention is potentially an important source of exchange rate volatility.

Market uncertainty about the likelihood of future central bank intervention could also lead to greater exchange rate volatility. Because central banks do not announce their plans for intervention, foreign exchange traders must base their currency positions on their best guesses of whether and when central banks will intervene. These currency positions and hence exchange rates will change over time as traders reassess the likelihood of central bank intervention. Uncertainty over central bank intervention policy can therefore contribute to exchange rate volatility.

Central bank intervention can also increase exchange rate volatility by increasing the likelihood of speculative bandwagons. For instance, intervention might increase volatility if market participants think the central bank is unable or unwilling to prevent speculative forces from pushing the exchange rate in a particular direction. A slight change to the previous example makes the point. Again, suppose the dollar exchange rate falls from DM 1.50/$ to DM 1.45/$ and that speculators expect the dollar to fall further to DM 1.40/$. As before, a speculator selling the dollar at DM 1.45/$ might expect to realize a profit if the dollar falls to DM 1.40/$. The expected profit opportunity encourages other speculators to jump on the bandwagon, thereby actually pushing down the dollar. Unlike the previous example in which speculators thought the Federal Reserve would intervene to prevent the dollar from falling, they may now be uncertain about Federal Reserve intervention policy. For example, they may think the Federal Reserve will not intervene or they may think the amount of intervention will not be large enough to make a difference. For whatever reason, the uncertainty about intervention policy may encourage speculation and cause price changes and exchange rate volatility to be higher than in the absence of such intervention.

Intervention may have no effect on volatility. Finally, central bank intervention may have no impact on exchange rate volatility. The sheer size of the foreign exchange market makes this scenario a possibility. For example, in 1989 the average net daily volume of trading in the foreign exchange market was over $400 billion, while the average amount bought or sold by the Federal Reserve was about $150 million.[12] Thus, central bank intervention, which is such a small fraction of the overall market, typically less than 0.05 percent, is unlikely to have a large impact.

It is clear from the above discussion that theory is ambiguous on the effects of central bank intervention on exchange rate volatility. In addition, the effects of intervention can change over time as a result of variations in the credibility of intervention policy. Empirical evidence is needed, therefore, to assess the impacts of intervention on volatility and thereby shed light on the ability of central bank intervention to stabilize exchange rates.

EVIDENCE ON CENTRAL BANK INTERVENTION AND VOLATILITY

As discussed above, central bank intervention may increase, decrease, or have no effect on volatility. Empirical analysis is required to answer whether central bank intervention reduces exchange rate volatility. This section estimates a model that relates changes in deutschemark/dollar and yen/dollar volatility to central bank intervention and other economic variables.[13]

The model

To test whether central bank intervention reduces exchange rate volatility, an empirical model relating changes in volatility to intervention is required. Previous studies of the effect of central bank intervention estimate exchange rate volatility using GARCH methods. These GARCH estimates of volatility are then related to measures of U.S. and foreign central bank intervention. The results of such studies are mixed, with some studies finding intervention increases exchange rate volatility and others finding the opposite.[14]

The empirical model used in this study also relates exchange rate volatility to measures of central bank intervention, but it differs from the earlier models in two important respects. First, exchange rate volatility is measured by the implied volatility embedded in foreign currency option prices. The advantage of the implied volatility measure is that it is forward-looking and measures the market's forecast of the standard deviation of exchange rate changes over the next month. Second, the empirical model used in this study includes U.S. macroeconomic and other variables to ensure that volatility changes attributed to intervention do not in fact arise from some other macroeconomic cause of volatility. The U.S. macroeconomic variables include the change in the volatility of the S&P 500, the announced values of the money supply, trade deficit, consumer price index, producer price index, industrial production, and unemployment rate, as well as the unexpected components of these announcements. The other variables included in the regression are lagged exchange rate volatility to control for feedback effects from volatility to intervention, and a variable to capture any differences in volatilities as a result of the break in trading over weekends and holidays. Equations (1) and (2) summarize the empirical model used to test the effects of intervention on DM/dollar and yen/dollar exchange rate volatilities:[15]

$$\%\,\Delta\,(\textit{DM/dollar volatility}) = \beta 0 + \beta 1\ \textit{Fed intervention} + \beta 2\ \textit{Bundesbank intervention} + \beta 3\ \textit{Macro \& other variables} + \textit{error term}. \quad (1)$$

$$\%\,\Delta\,(\textit{yen/dollar volatility}) = \beta 0 + \beta 1\ \textit{Fed intervention} + \beta 2\ \textit{Bank of Japan intervention} + \beta 3\ \textit{Macro \& other variables} + \textit{error term}. \quad (2)$$

Equation (1) is estimated using actual intervention against the deutschemark by the Federal Reserve and German Bundesbank. Actual intervention data provide a daily record of the occurrence and amounts of intervention and were obtained from these central banks.

Equation (2) is estimated using actual Federal Reserve intervention against the Japanese yen. Because the Bank of Japan does not publicly report its daily intervention activities, actual Bank of Japan intervention cannot be used in the estimation of equation (2). This paper instead uses *Wall Street Journal* press reports to obtain a measure of Bank of Japan intervention. The *Wall Street Journal* contains a daily foreign exchange column which reports trader perceptions of the existence, but not the magnitude, of central bank intervention. As a result, the Bank of Japan intervention variable equals one if the *Wall Street Journal* reports intervention by the Bank of Japan, and zero otherwise.[16]

Empirical results

The empirical results from estimating equations (1) and (2) are summarized in Tables 1 and 2. Before looking at the results in detail, four results are summarized below:

(1) During the entire 1985-91 period, there is no evidence that central bank intervention reduced

Table 1

CENTRAL BANK INTERVENTION AND VOLATILITY: 1985-91

Dependent variable	Federal Reserve intervention	Bundesbank intervention	Bank of Japan intervention
Percent change in DM/dollar volatility	.0037* (1.66)	.0004 (.19)	
Percent change in yen/dollar volatility	.0011 (.31)		2.5964** (3.46)

* Indicates significance at the 10 percent level

** Indicates significance at the 5 percent level

Notes: The coefficients are multiplied by 100, and the t-statistics are in parentheses. The shaded areas indicate areas in which the coefficients on the intervention variables are significant at the 10 percent level.

exchange rate volatility and some evidence that volatility actually increased (Table 1).

(2) During the Plaza period, there is no evidence that central bank intervention affected exchange rate volatility (panel A of Table 2).

(3) During the Louvre period, there is evidence that central bank intervention increased volatility (panel B of Table 2).

(4) During the post-Louvre period, there is some evidence that central bank intervention decreased volatility, although most of the evidence points to no effect (panel C of Table 2).

Turning to the specific results, the rows of Tables 1 and 2 report the intervention variable coefficients from the estimation of equations (1) and (2). What matters in determining the effects of intervention on volatility are the sign and statistical significance of the coefficient. An intervention coefficient that is negative and significant suggests central bank intervention reduced exchange rate volatility and therefore was stabilizing. An intervention coefficient that is positive and significant suggests that intervention increased exchange rate volatility. Finally, an intervention coefficient that is insignificantly different from zero suggests that central bank intervention had no effect on exchange rate volatility. To simplify reading the table, a coefficient appears in a shaded box if the effect of intervention was statistically significant. Therefore, if no boxes are shaded, then intervention had no significant effect on volatility. In contrast, if many boxes are shaded, then intervention had a significant effect on volatility. In these cases, the sign of the coefficient indicates whether intervention increased or decreased volatility.

During the 1985-91 period, there is no evidence that central bank intervention decreased exchange rate volatility and some evidence that volatility increased. This evidence can be seen in Table 1, where two boxes are shaded and have positive coefficients. In particular, the first row of the table shows that Federal Reserve intervention had

Table 2

CENTRAL BANK INTERVENTION AND VOLATILITY: PLAZA, LOUVRE, POST-LOUVRE PERIODS

Dependent variable	Federal Reserve intervention	Bundesbank intervention	Bank of Japan intervention
	Panel A		
	Plaza period		
	January 1, 1985, to February 21, 1987		
Percent change in DM/dollar volatility	-.0002	-.0006	
	(-.10)	(-.55)	
Percent change in yen/dollar volatility	-.0195		2.6476
	(-.61)		(.98)
	Panel B		
	Louvre period		
	February 22, 1987, to December 31, 1989		
Percent change in DM/dollar volatility	.0102**	.0013	
	(3.09)	(.46)	
Percent change in yen/dollar volatility	.0029		3.0827**
	(.69)		(3.69)
	Panel C		
	Post-Louvre period		
	January 1, 1990, to December 31, 1991		
Percent change in DM/dollar volatility	-.0246**	.0041	
	(2.84)	(.66)	
Percent change in yen/dollar volatility	.0249		2.2009
	(1.18)		(.99)

See notes to Table 1.

a positive and significant effect on DM/dollar volatility, and the second row shows that reported Bank of Japan intervention had a positive and significant effect on yen/dollar volatility. Bundesbank intervention, however, did not significantly affect exchange rate volatility.

Since the credibility and effectiveness of intervention may change over time, Table 2 reports the effect of intervention on volatility during the Plaza, Louvre, and post-Louvre periods. The table shows that the effects of intervention on exchange rate volatility did indeed vary across time. Panel A shows that during the Plaza period, intervention had no significant effect on exchange rate volatility because none of the boxes are shaded. In contrast, panel B presents evidence that intervention increased volatility during the Louvre period. This can be seen because two boxes have positive coefficients and are shaded. Federal Reserve intervention led to greater DM/dollar volatility, while reported Bank of Japan intervention led to greater yen/dollar volatility. This increase in volatility occurred despite G-7 attempts to "foster stability of exchange rates around current levels." Finally, panel C presents some evidence that central bank intervention decreased exchange rate volatility, although most of the evidence points to no effect. This can be seen because only one box is shaded and it has a negative coefficient. That is, over this period, Federal Reserve intervention against the deutschemark led to a decline in DM/dollar volatility. Federal Reserve intervention against the yen, Bundesbank intervention, and reported Bank of Japan intervention had no significant effect on volatility.

To summarize, the evidence presented provides little support for the view that central bank intervention decreases exchange rate volatility. Indeed, from early 1985 until late 1991, central bank intervention generally had little effect on volatility and in some cases even increased exchange rate volatility. The empirical results also show that the effects of central bank intervention varied through time. For example, central bank intervention was associated with increases in DM/dollar and yen/dollar volatility during the Louvre period, but with a decrease in DM/dollar volatility during the post-Louvre period. Such differences in the volatility responses to intervention may have been due to differences in the credibility or effectiveness of intervention across different policy regimes.

CONCLUSION

Concerns over the adverse effects of exchange rate volatility have led central banks to intervene in foreign exchange markets in an attempt to reduce volatility. Whether central bank intervention can be used to stabilize exchange rates depends how intervention actually affects exchange rate volatility. Theory contains no clear predictions. Central bank intervention could reduce exchange rate volatility if it helps resolve market uncertainty about future fundamentals and policies or if it reduces the likelihood of speculative attacks on a currency. Conversely, if central bank intervention contributes to market uncertainty or if it encourages speculative attacks against a currency, then intervention could actually increase exchange rate volatility. Because theory is ambiguous, empirical analysis is needed to determine the effect of central bank intervention on exchange rate volatility.

This article has used estimates of daily DM/dollar and yen/dollar volatilities, as well as data on Federal Reserve, Bundesbank, and Bank of Japan intervention, from 1985 to 1991 to measure the effects of intervention on volatility. The evidence suggests that central bank intervention does not generally reduce exchange rate volatility. Rather, central bank intervention typically has little effect on exchange rate volatility and in some cases even increases volatility.

ENDNOTES

[1] Others who have used implied volatility to measure exchange rate volatility include Bailey, Bonser-Neal and Tanner, and Madura and Tucker. Bailey studies the effect of money supply announcements on implied exchange rate volatility, while Madura and Tucker study the effect of trade deficit announcements on implied exchange rate volatility. Bonser-Neal and Tanner are the first to examine the effects of central bank intervention on implied exchange rate volatility.

[2] See, for example, Hopper for a description of foreign currency options. Grabbe also provides a thorough discussion of currency options and of the factors which affect their value.

[3] Many types of currency option contracts are offered on the Philadelphia exchange, but the volatility estimate used here is based on at-the-money call options with from 7 to 100 days to maturity which are traded between 10:00 and 11:00 a.m. At-the-money call options convey the right, but not the obligation, to buy foreign exchange at a price that equals the exchange rate on the day the option is purchased. At-the-money call options with these maturities produce more reliable estimates of volatility because the difference between the estimated and the true option price is smaller for this class of options, and because they are the most actively traded (Bodurtha and Courtadon). The choice of options traded between 10:00 and 11:00 a.m. is based on the fact that trading volume for foreign currency options tends to be highest around this time of day. Choosing the time of day with the highest trading volume minimizes the number of days for which there are no observations.

[4] The algorithm proposed by Barone-Adesi and Whaley is used to calculate the implied volatilities of the foreign currency call options. The average maturity of options used in the volatility estimation was roughly 38 days; hence, the implied volatility represents the market's average forecast of exchange rate volatility over the next 38 days.

[5] In the United States, the monetary authority responsible for setting U.S. foreign exchange intervention policy is the U.S. Department of Treasury. The Federal Reserve acts as the agent for the U.S. Treasury. See Humpage for a more complete description of foreign exchange intervention policy.

[6] There are various views on when the Louvre period actually ended. Baillie and Humpage suggest the Louvre Accord broke down in late 1988. Wendy Dobson, who was Canada's G-7 deputy from 1987 to 1989, suggests the coordination underlying the Louvre Accord was breaking down in late 1989. Finally, Kaminsky and Lewis suggest the Louvre Accord had ended by February 1990. The Louvre period ending date used in this study is therefore in line with those estimated by others.

[7] As discussed earlier, intervention was even less frequent between 1992 and 1994. While there was more intervention in 1995, official intervention data for 1995 as a whole were not available at the time of this study.

[8] Sterilized intervention can in theory affect the exchange rate through what is known as the portfolio balance channel. Under this scenario, central bank intervention alters the relative quantities of domestic and foreign bonds in the hands of the public. If domestic and foreign assets are imperfect substitutes, then market participants will try to rebalance their portfolios following the intervention, thereby leading to changes in exchange rates and interest rates. While theoretically plausible, this portfolio balance channel has received little empirical support (Edison).

[9] This is an example of the expectations, or "signaling," channel through which sterilized intervention could affect the level of the exchange rate. For more discussion, see Edison.

[10] The gain is calculated as follows. At an exchange rate of DM 1.45/$, the speculator sold $1 million for DM 1.45 million. At an exchange rate of DM 1.40/$, the speculator can then sell the DM 1.45 million for $1,035,714, for a profit of $35,714.

[11] The loss is calculated as follows. At an exchange rate of DM 1.45/$, the speculator sold $1 million for DM 1.45 million. When the exchange rate rises back to DM 1.50/$, the speculator who sells DM 1.45 million for $966,667 would incur a loss of $33,333.

[12] See Bank of International Settlements for data on foreign exchange market activity. The average daily volume of trading in the foreign exchange market is now estimated to exceed $1 trillion.

[13] The model presented below is a simplified version of the empirical model found in Bonser-Neal and Tanner. That paper extends the model described in this article by examining the effects of intervention by all three central banks—that is, the Federal Reserve, the Bundesbank, and the Bank of Japan—on the volatility of DM/dollar and yen/dollar exchange rates, and by comparing the effects of actual versus reported central bank intervention. That paper also provides a more technical description of the variables and the calculation of implied volatilities.

[14] In particular, Baillie and Humpage find that intervention between February 1987 and February 1990 was associated with an increase in DM/dollar and yen/dollar exchange rate volatility, while Connolly and Taylor find that Bank of Japan intervention was associated with an increase in yen/dollar volatility between 1977 and 1979. Dominguez, on the other hand, finds actual U.S. intervention was associated with a decrease in DM/dollar and yen/dollar volatility between 1985 and 1991.

[15] Because options prices are quoted in terms of dollars per unit of foreign currency, the implied volatility used in the paper is actually the implied volatility of dollar/DM and dollar/yen exchange rates.

[16] In each regression, Federal Reserve intervention is recorded at time *t-1*, while Bundesbank and Bank of Japan intervention are recorded at time *t*. The reason is Federal Reserve intervention on day *t* may not be completed and hence not known by the time the volatility forecast is made at 11:00 a.m. in the options market. Federal Reserve intervention on day *t-1*, however, is known by 11:00 a.m. on day *t*. In contrast, Bundesbank and Bank of Japan intervention is known by 11:00 EST on day *t*. This is because the German market is six hours ahead of Philadelphia, while Japan is 14 hours ahead. Bundesbank and Bank of Japan intervention, which occurs on day *t*, can therefore be included in the regressions.

REFERENCES

Bailey, Warren. 1988. "Money Supply Announcements and the Ex Ante Volatility of Asset Prices," *Journal of Money, Credit, and Banking*, November, pp. 611-20.

Baillie, Richard T., and Owen F. Humpage. 1992. "Post-Louvre Intervention: Did Target Zones Stabilize the Dollar?" Federal Reserve Bank of Cleveland, working paper no. 9203.

Bank for International Settlements. 1990. *Survey of Foreign Exchange Market Activity.* Basle: Bank for International Settlements.

Barone-Adesi, Giovanni, and Robert E. Whaley. 1987. "Efficient Analytic Approximation of American Option Values," *Journal of Finance*, June, pp. 301-20.

Becketti, Sean, and Gordon H. Sellon, Jr. 1989. "Has Financial Market Volatility Increased?" Federal Reserve Bank of Kansas City, *Economic Review*, June, pp. 17-30.

Bodurtha, James N., and Georges R. Courtadon. 1987. "The Pricing of Foreign Currency Options," Salomon Brothers Center for the Study of Financial Institutions Monograph Series in Finance and Economics.

Bonser-Neal, Catherine, and Glenn Tanner. 1996. "Central Bank Intervention and the Volatility of Foreign Exchange Rates: Evidence from the Options Market," *Journal of International Money and Finance*, forthcoming.

Bergsten, C. Fred. 1993. "The Collapse of Bretton Woods: Implications for International Monetary Reform," in Michael D. Bordo and Barry Eichengreen, eds., *A Retrospective on the Bretton Woods System.* Chicago: University of Chicago Press, pp. 587-93

Connolly, Robert A., and William M. Taylor. 1994. "Volume and Intervention Effects on Yen/$ Exchange Rate Volatility, 1977-1979," in *Advances in Financial Planning and Forecasting*, vol.5, part A. Greenwich: JAI Press, pp. 181-200

Dobson, Wendy. 1991. *Economic Policy Coordination: Requiem or Prologue?* Washington: Institute for International Economics.

Dominguez, Kathryn. 1993. "Does Central Bank Intervention Increase the Volatility of Foreign Exchange Rates?" National Bureau of Economic Research Working Paper No. 4532.

Edison, Hali. 1993. *The Effectiveness of Central Bank Intervention: A Survey of the Post-1992 Literature,* Special Papers in International Economics No. 18, Princeton University.

Engel, Charles, and Craig S. Hakkio. 1993. "Exchange Rate Regimes and Volatility," Federal Reserve Bank of Kansas City, *Economic Review*, Third Quarter, pp. 43-58.

Grabbe, J. Orlin. 1991. *International Financial Markets.* New York: Elsevier Science Publishing Co., Inc.

Hopper, Gregory. 1995. "A Primer on Currency Derivatives," Federal Reserve Bank of Philadelphia, *Business Review*, May/June, pp. 3-14.

Humpage, Owen. 1994. "Institutional Aspects of U.S. Intervention," Federal Reserve Bank of Cleveland, *Economic Review*, First Quarter, pp. 2-19.

International Monetary Fund. 1989. *Selected Decisions and Selected Documents*, 14th Issue, April.

Kaminsky, Graciela L., and Karen K. Lewis. 1993. "Does Foreign Exchange Intervention Signal Future Monetary Policy?" National Bureau of Economic Research Working Paper No. 4298.

Madura, Jeff, and Alan Tucker. 1992. "Trade Deficit Surprises and the Ex Ante Volatility of Foreign Exchange Rates," *Journal of International Money and Finance*, October, pp. 492-501.