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FEDERAL RESERVE BANK OF CLEVELAND

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U.S. exchange-market interventions have no apparent effect on market fundamentals, but may influence expectations. If intervention can accurately forecast exchange-rate movements, knowledge that the Federal Reserve was trading will cause traders to alter their prior estimates of the distribution of exchange-rate changes. This paper finds that U.S. intervention has value only as a forecast that recent exchange-rate movements will moderate, but not that they will reverse. Less than half of the interventions, however, seem successful, and the favorable results are generally confined to two relatively short periods that are characterized by uncertainty about future Federal Reserve policies.

1. Introduction

Official U.S. foreign-currency transactions have no apparent effect on the basic economic determinants of exchange rates, but may sometimes color the market's perceptions and expectations of those fundamentals. To do so, U.S. monetary authorities must be able to improve the flow of information to the private sector through their official transactions. The market will view the Federal Reserve as an informed trader only if that intervention accurately predicts future exchange-rate movements. Using a test suggested by Merton (1981), developed in Henriksson and Merton (1981), and applied to U.S. intervention profits by Leahy (1995), this paper investigates the value of U.S. intervention in forecasting subsequent exchange-rate movements.

A principal difficulty in applying this test arises in determining exactly what information about equilibrium exchange-rate patterns U.S. monetary authorities intend to relay to the market. I offer four specific definitions against which I test the forecast value of intervention. Although these definitions are somewhat arbitrary and are not comprehensive, each is readily verifiable and each is consistent with the rather nebulous official criterion of "calming market disorder."

The results offer three insights into U.S. interventions: First, official U.S. foreign exchange transactions have value as a signal that current appreciations or depreciations will slow. Intervention does not indicate that the exchange rate will change direction, nor even that it will appreciate or depreciate. Second, although intervention has had positive forecast value, the actual number of successful transactions is relatively small. Third, U.S. intervention generally had forecast value only during the Plaza episode (September 23, 1985, through December 31, 1985) and immediately following the 1987 stock-market

crash (October 19, 1987, through December 31, 1987). At other times after the Louvre Agreement, when the United States attempted to stabilized dollar exchange rates, and during the recent period of reluctant U.S. involvement, intervention has had no obvious forecast value. These results suggest that intervention's ability to influence exchange rates is rather limited.

The next section briefly summarizes current thinking about the relationship between intervention and exchange rates. Section 3 defines the four success criteria for intervention. Section 4 describes the Henriksson and Merton test, and the results follow in section 5. The paper concludes with a summary and a comparison with some other results.

2. Intervention and the Channels of Influence

Economists' doubts about the effectiveness of U.S. intervention originate with the Federal Reserve's practice of routinely sterilizing the monetary effects of its official exchange-market transactions through offsetting open-market operations. The Fed does so to avoid conflicts with domestic monetary-policy objectives and to prevent the U.S. Treasury, which directs U.S. intervention and maintains its own foreign-exchange accounts, from impinging on the Federal Reserve's independence.[1]

Although this monetary offset eliminates the most obvious and direct influence that intervention could have on exchange rates—relative changes in the U.S. and foreign money stocks—the process alters the currency composition of publicly held government debt. According to the portfolio-balance approach to exchange-rate determination, changes in the currency composition of outstanding debt can affect exchange rates, independent of monetary policies. With the possible exception of Dominguez and

Frankel (1993), empirical studies find no evidence that intervention alters exchange rates through a portfolio-balance channel (see Edison [1993]).

Even if intervention does not operate by changing stocks of money and government bonds, it might still influence exchange rates by affecting either the market's perception of current fundamentals or its expectations about future changes in fundamentals. Traditional asset market approaches to exchange-rate determination treat information as a costless public good, with spot exchange rates serving a purely allocative function. Such models perform poorly, especially out of sample, and they can explain neither the large volume of trades nor the volatility of exchange rates.

In response, microstructure approaches to exchange markets relax the assumptions that information is publicly available and that agents in the market are homogeneous in their interpretations of information and in their degree of risk aversion. Ito (1988), for example, suggests that market participants are not homogeneous in their beliefs. Ito, Lyons and Melvin (1998) provide evidence of private information. The prevalence of profitable technical trading rules, as demonstrated by Neely, Weller, and Dittmar (1997), also attests to information asymmetries. Goldberg and Frydman (1996) show that imperfect knowledge about fundamentals can generate exchange-rate patterns more consistent with observed exchange-rate behavior than with rational expectations models. Under all such circumstances, prices play more than an allocative role; they can convey information signals that affect agents' preferences directly.

Monetary authorities might sometimes possess better information than other market players and might use intervention as a means of conveying that information to the market. A central bank, for example, could have superior knowledge about an

impending change in monetary policy or about the exchange-rate consequence of current macroeconomic developments in general.[2] Nevertheless, it remains open to debate whether a central bank routinely has better information than other experienced market participants—even about monetary policies. Should a central bank routinely have superior information, knowledge that the Federal Reserve was transacting on that knowledge would have value to other traders, even if intervention did not directly change market fundamentals. What follows is a test of the proposition that the Federal Reserve is an informed trader.[3]

3. Successful Intervention

The stated objective of U.S. intervention policy is to "counter disorderly market conditions," a goal that eludes a simple, precise, or even objective definition. In the following analysis, I define successful interventions in terms of four specific criteria. The idea is that a successful intervention provides some unspecified information that alters exchange rates in an identifiable manner. While these definitions might not encompass every possible interpretation of a successful intervention, they are all readily verifiable and cover a range of outcomes that most economists would regard as consistent with the goal of countering disorderly markets.

Alter Exchange Rates

The first success criterion presumes that U.S. monetary authorities use official sales or purchases of foreign exchange to signal that market fundamentals are consistent with a dollar appreciation or depreciation, respectively. Accordingly, under the first success criterion, $w1s_t$ equals one—indicating success—whenever an official U.S. sale of

foreign currency (German marks or Japanese yen) is associated with a dollar appreciation:[4]

$$1a)\quad w1s_t = \begin{cases} 1 \text{ if } I_t > 0 \text{ and } \Delta S_t > 0, \\ 0 \text{ otherwise.} \end{cases}$$

I define $w1b_t$ analogously for official U.S. purchases of foreign exchange:

$$1b)\quad w1b_t = \begin{cases} 1 \text{ if } I_t < 0 \text{ and } \Delta S_t < 0, \\ 0 \text{ otherwise.} \end{cases}$$

In these expressions, I_t is official U.S. intervention at time *t*, with positive (negative) values indicating sales (purchases) of foreign exchange. The United States conducts all of its intervention in either German marks or Japanese yen. The exchange-rate term $\Delta S_t = SPM_t - SAM_t$, where SAM_t and SPM_t are the morning opening (9:00 a.m.) and afternoon closing (4:00 p.m.) bid quotations.[5] These are taken from the New York market. As Goodhart and Hesse (1993) indicate, nearly all U.S. intervention occurs between these times, typically while the European markets are still open. The exchange rates are either German marks or Japanese yen per dollar.

Change the Direction of the Exchange Rate

A second, more stringent, success criterion assumes that U.S. monetary authorities intend official sales of foreign exchange as a signal that the dollar will stop depreciating and will appreciate instead. Similarly, official purchases of foreign exchange are a forecast that the dollar will stop appreciating and will depreciate. Again, I presume that officials have some superior information about that prospect. Accordingly:

$$2a)\quad w2s_t = \begin{cases} 1 \text{ if } I_t > 0 \text{ and } \Delta S_t > 0 \text{ and } \Delta SAM_t < 0, \text{ and} \\ 0 \text{ otherwise.} \end{cases}$$

and

2b) $w2b_t = \begin{cases} 1 \text{ if } I_t < 0 \text{ and } \Delta S_t < 0 \text{ and } \Delta SAM_t > 0, \text{ and} \\ 0 \text{ otherwise.} \end{cases}$

In expression 2, $\Delta SAM_t = SAM_t - SAM_{t-1}$ and all other variables are defined as before.

Smooth Exchange-Rate Movements

Empirical estimates of intervention reaction functions typically report evidence of smoothing exchange-rate movements or leaning against the wind as a policy objective (see Almekinders [1995] and Edison [1993]). Through its intervention, the United States may intend to indicate to the market that the current rate of appreciation or depreciation will slow, but will not reverse itself. Accordingly:

3a) $w3s_t = \begin{cases} 1 \text{ if } I_t > 0 \text{ and } \Delta S_t > \Delta SAM_t \text{ and } \Delta S_t < 0 \text{ and } \Delta SAM_t < 0, \text{ and} \\ 0 \text{ otherwise.} \end{cases}$

and

3b) $w3b_t = \begin{cases} 1 \text{ if } I_t < 0 \text{ and } \Delta S_t < \Delta SAM_t \text{ and } \Delta S_t > 0 \text{ and } \Delta SAM_t > 0, \text{ and} \\ 0 \text{ otherwise.} \end{cases}$

Foster Exchange-Rate Movements

U.S. monetary authorities may sometimes attempt to encourage a movement of the dollar that was already underway—to lean with the wind. In such a case, intervention sales or purchases of foreign exchange would attempt to signal that market fundamentals are consistent with a continued appreciation or depreciation of the dollar, but at a faster pace. Reflecting this criterion:

4a) $w4s_t = \begin{cases} 1 \text{ if } I_t > 0 \text{ and } \Delta S_t > \Delta SAM_t \text{ and } \Delta SAM_t > 0, \text{ and} \\ 0 \text{ otherwise.} \end{cases}$

and

4b) $w4b_t = \begin{cases} 1 \text{ if } I_t < 0 \text{ and } \Delta S_t < \Delta SAM_t \text{ and } \Delta SAM_t < 0, \text{ and} \\ 0 \text{ otherwise.} \end{cases}$

To convey the information outlined under any or all of these criterion successfully, intervention must forecast with a high frequency of success. Otherwise, the market will not regard the Federal Reserve as an informed trader. The next section defines a "high frequency" of success.

4. Forecast Value

Merton (1981) and Henriksson and Merton (1981) develop a nonparametric test to evaluate investment managers' ability to predict the relative performance of stocks and bonds. Leahy (1995) used this procedure to investigate profits from intervention. Treating intervention as an official forecast of near-term dollar movements, I apply the Henriksson and Merton procedure. Evidence of exceptional forecasting skills would suggest that U.S. monetary authorities acted with superior information and that they successfully conveyed that information to the market. An advantage of this procedure is that it does not require specific assumptions about the distribution of exchange-rate changes. A disadvantage is that it only investigates the number of times intervention is successful, not the magnitude of any effect.

As an illustration of the procedure, I will discuss U.S. purchases of German marks with the objective of promoting a dollar depreciation against the mark (criterion 1a) over the entire January 1985 through March 1997 sample period. Consistent with the success criterion, I define:[6]

6a) $p1 = \text{prob}[w1a = 1 | \Delta S > 0]$, and $1 - p1 = \text{prob}[w1a = 0 | \Delta S > 0]$

and

6b) $p2 = \text{prob}[w1a = 0 | \Delta S \leq 0]$, and $1 - p2 = \text{prob}[w1a = 1 | \Delta S \leq 0]$.

In expression 6a), $p1$ is the probability that the Federal Reserve successfully sells foreign exchange on a given day conditional on the dollar appreciating over that day, and $p2$ is the probability that the Federal Reserve does not sell foreign exchange conditional on the exchange rate not appreciating. According to Merton (1981), a necessary and sufficient condition for intervention to have no predictive value to the market is that $p1 = 1 - p2$, or that $p1 + p2 = 1$. In this case, traders would not modify their prior estimates of the distribution of exchange-rate changes as a result of intervention. If instead intervention conveyed perfect information to the market, $p1 = 1$ and $p2 = 1$ and $p1 + p2 = 2$. For a forecast to have positive value, $p1 + p2 > 1$. Similarly, for a forecast to have negative value, $p1 + p2 < 1$.[7]

I obtain estimates of the respective probabilities from the sample data (see table 1). For the case at hand: n_1 is the number of successful mark purchases (51); n_2 is the number of unsuccessful mark purchases (87 = 138 - 51); N_1 is the number of dollar depreciations in the entire sample (1,564), and N_2 is the remaining number of observations (1,508 = 3,072 - 1,564). It follows that: $E(n_1/N_1) = p1$ and $E(n_2/N_2) = 1 - p2$. Hence, $\hat{p}1 + \hat{p}2 = 0.975$.

Henriksson and Merton (1981) show that under the null hypothesis ($p1 + p2 = 1$), the number of correct interventions will have a hypergeometric distribution. This provides a direct test of the null hypothesis, which does not depend on estimates of the

conditional probabilities. Assuming that n_1 is a hypergeometric random variable, I reject the null that $p1 + p2 = 1$ in favor of $p1 + p2 > 1$, if the probability of observing a greater number of successes is very small—less than 5 percent.[8] I reject the null hypothesis in favor of $p1 + p2 < 1$ if the probability of observing a greater number of successes is very large—more than 95 percent.

5. Empirical Results

I applied the Henriksson-Merton test procedure to each of the success criteria (expressions 1 through 4) over the entire sample and over five subsamples. As indicated in the text below, the subperiods represent fairly distinct episodes of intervention in terms of either the volume, or the objectives, of intervention.[9] Tables 1 through 6 present the results. In each table, the total number of observations (business days) in a period appears at the top of the first column. Column one lists the various success criteria. The number of interventions appears in the second column, and the corresponding number of successful interventions shows in the third column. The fourth displays the percentage of successful interventions. As indicated in column 4 of table 1, for example, 37 percent of U.S. purchases of German marks and 46 percent of U.S. purchases of Japanese yen were associated with dollar depreciations against these currencies.

The fifth column, labeled "virtual successes," counts the number of times over the sample period that the exchange rate behaved in a manner consistent with the corresponding success criterion, whether or not intervention took place. The sixth column expresses this count as a percentage of the total number of observations. Table 1 indicates that over the entire sample period, the mark-dollar exchange rate appreciated on

1,564 days out of 3,072 (or 51 percent of the days), and the yen-dollar exchange rate appreciated on 1,466 (or 48 percent).

Columns 7 and 8 present the estimated conditional probabilities, and the test statistic appears in column 9. I reject the null in favor of positive forecast value if 1-CDF (in column 10) is less than 5 percent and in favor of negative forecast value if 1-CDF is greater than 95 percent. The last column summarizes the results; a blank indicates no forecast value.

I next consider each subperiod—tables 2 though 4—before returning to the entire period (table 1) as a summary.

Plaza Period: September 1985 through December 1985

In early 1985, the dollar began to depreciate against the German mark and Japanese yen from its unusually high levels in the early 1980s. In January and February, the United States occasionally bought modest amounts of foreign exchange to stem any hesitation or reversal in the dollar's movement. In late September, the G5 countries signed the Plaza Accord, which pledged them to joint intervention with the objective of fostering a further depreciation.[10] Intervention was relatively heavy in late September and in October. Between September 23, 1985 and December 31, 1985, the United States purchased German marks on only 14 days and purchased Japanese yen on 20 days. The United States undertook no sales of foreign exchange in 1985.

The test results in table 2 permit one to reject the null hypothesis of no forecast value in only two cases: Purchases of yen and marks have positive forecast value as a prediction that yesterday's dollar appreciation would moderate today. That is, U.S. monetary authorities could signal through their official purchases of marks and yen that

upticks in a generally downward-moving market would moderate, but not that they would reverse themselves. This result is roughly similar to that in Humpage (1988), which found very limited evidence of success using regression techniques. Most striking in table 2, however, is that contrary to the common perception of the period, the U.S. did not lean with the wind. If it attempted such a maneuver, it failed. Intervention had no value as a forecast that the dollar would appreciate or depreciate, or that it would change directions.

First Louvre Period: February 1987 through October 1987

On February 22, 1987, the G7 countries met at the Louvre and agreed to joint intervention with the objective of stabilizing dollar exchange rates at current levels.[11] The United States intervened frequently and heavily against German marks and Japanese yen, often in concert with Germany and Japan, through March 1990. I have divided the period into three sections. During the first, which extended up to the October 16, 1987 stock-market crash, the United States intervened on 13 days against German marks and on 25 days against Japanese yen (see table 3). Intervention against German marks was split fairly evenly between purchases and sales. Intervention against yen was more frequent, but consisted entirely of sales. During this interval, the United States moderately tightened ("snugged up") monetary policy.

As table 3 indicates, only U.S. intervention sales of yen during this period had positive forecast value and then only as a predictor that the previous day's dollar depreciation would moderate over the current day (leaning against the wind). Out of the 25 interventions, 36 percent were successful, substantially above the expected outcome (16 percent). A higher-than-expected proportion of German purchases was successful (20

percent), but not enough to reject the null hypothesis of no forecast value at the 95 percent confidence level. U.S. intervention did not have positive forecast value for any other success criteria during this period.

Second Louvre Period: October 1987 through December 1988

Although monetary policy briefly eased immediately following the October 19, 1987 stock market crash, the Federal Reserve tightened policy thereafter through the end of 1988. Between October 19, 1987 and December 30, 1987, the United States intervened against German marks on 55 occasions, with purchases and sales of marks fairly evenly split. Over the same period, the United States sold yen on 39 days. As table 4 indicates, U.S. intervention had positive value as a forecast that recent dollar movements—against both the mark and the yen—would moderate, but not reverse. The proportion of successful interventions was substantially greater that the proportion of virtual successes during this period. These results indicate that intervention successfully leaned against the wind in the aftermath of the stock-market crash.

Table 4 also shows that U.S. purchases of German marks had negative value as a forecast that the dollar would depreciate. The number of successes seems lower than one might randomly find. As noted earlier, this implies that the market could benefit from betting against the Fed. Notice, however, that this result is not inconsistent with the positive value of intervention as a forecast of leaning against the wind: Fed purchases of German marks implied that the dollar would not depreciate, but that it would continue to appreciate, albeit at a slower pace.

Third Louvre Period: January 3, 1989 through April 1990

The spirit of close cooperation, the hallmark of the Louvre accord, waned after the stock market crash and throughout this later period. U.S. monetary policy eased somewhat after August 1989. During this interval, the United States purchased German marks on 79 occasions and Japanese yen on 83 occasions. Intervention had no positive forecast value over this period, under any criterion. In one case, purchases of German marks, intervention had negative forecast value. These results may explain the FOMC dissents on intervention-related directives and Federal Reserve's growing reluctance to participate with the Treasury in intervention over this period (see Humpage [1994]).

Limited Intervention: August 1990 through March 1997

During this last period, the United States grew increasingly reluctant to enter the foreign-exchange market. The Federal Reserve intervened on 28 days against German marks and on 21 days against Japanese yen. Nearly all the official transactions were sales of foreign exchange, which suggests that intervention broadly aimed at limiting any softening in the dollar relative to the mark or yen. During this period, the United States frequently seemed to have undertaken interventions out of a desire to show cooperation with the Bundesbank or the Bank of Japan, rather than out of a firm belief that the dollar was inconsistent with market fundamentals. In hindsight, this seems an adequate interpretation, since U.S. intervention over this period only had forecast value in two disparate cases: purchases of marks under a leaning-against-the-wind success criterion and purchases of yen under a leaning-with-the-wind success criterion. Since the numbers of interventions and successes in both cases are very small, these results could be spurious.

Full Sample: September 1985 through March 1997

The results for the entire sample period largely reflect the pattern that predominates in most of the subperiods: U.S. official exchange-market transactions have positive value as a forecast that any current dollar appreciation or depreciation will slow in the immediate term. This seems to suggest that U.S. intervention can successfully lean against the wind. By no other criterion does U.S. intervention have positive forecast value. Notice, however, that the percentage of interventions that successfully leans against the wind (24 percent) remains small. Only a small number of interventions—less than half—actually prove successful by any criterion. From a policy perspective, intervention does not seem very effective.

Overall, U.S. intervention purchases of German marks had negative forecast value. As noted above, this result is not incompatible with the finding of positive forecast value for a leaning-against-the-wind criterion.

The fact that U.S. intervention has negative forecast value in terms of leaning with the wind may simple reflect U.S. monetary authorities'desire to avoid this type of intervention. For example, when the United States operates to stem a dollar depreciation, it has a finite stock of foreign reserves to sell. To conserve foreign exchange, the Fed may abstain from attempting to promote upticks in the market, and may instead wait to see if these movements sustain themselves. Similarly, when the dollar is appreciating, official purchases of foreign exchange increase the exchange-risk exposure of U.S. monetary authorities to foreign-currency losses. To avoid increasing this exposure unnecessarily, the United States may not buy foreign exchange when the dollar tips lower (lean with the wind). Instead, the Fed may abstain from intervening as long as the

depreciation continues, even though it feels that the dollar is overvalued at current exchange rates.

6. Conclusions

Many economists believe that U.S. exchange-market intervention can affect dollar exchange rates only through an expectations channel. This requires that U.S. monetary authorities have some advantage over private market participants with respect to the acquisition and interpretations of information pertinent to the pricing of foreign exchange. This paper tested that proposition.

Using a technology suggested by Merton (1981) and Henriksson and Merton (1981), I asked if private-market participants could improve their near-term predictions of the dollar from knowledge that the Federal Reserve was intervening. The first major result of this paper is that official U.S. foreign exchange transactions have positive forecast value only as predictions that recent dollar appreciations or depreciations will immediately dampen. This seems to suggest that intervention could reduce exchange-rate volatility. Recent studies using either GARCH or implied volatility from options prices have obtained mixed results respecting the impact of intervention on exchange-rate volatility. Chang and Taylor (1998), using Reuters screen data, find that volatility increases after reports of intervention. Dominguez (1998) finds that secret intervention increases volatility. Baillie and Osterberg (1997a b) find that intervention increases volatility. Bonser-Neal and Tanner (1996) find intervention either has no effect or increases implied volatility. Unlike the current study, which counts events, these studies compare quantitative magnitudes. A few large effects might dominate.

The finding that Federal Reserve intervention has positive value as a forecast that recent exchange-rate changes will moderate seems consistent with LeBaron (1996) and Neely and Weller (1997), who find that intervention improves the profitability of technical trading rules. Successfully leaning against the wind suggests that U.S. monetary authorities incurred a short-term loss, since they acquired a currency that subsequently depreciated. Both LeBaron and Neely and Weller refer to leaning against the wind as a possible explanation for their results. This study supports their conjecture.

One must temper the policy implications of this first finding with the second result: The proportion of successful interventions is relatively small—generally less than half. If intervention operates primarily by influencing expectations, then conditioning intervention on another event that also affects expectations could raise the probability of success. Humpage (1996) concluded that coordinating intervention with another central bank can improve the probability of success. That paper also found that engaging in very large interventions seemed to increase the probability of success, and that simultaneously undertaking compatible monetary-policy changes guaranteed it.

Most of the successes in this paper were concentrated in two subperiods, that following the Plaza Accord and that following the 1987 stock-market crash. Empirical results in intervention studies are often not robust across time periods, which suggests that intervention's marginal contribution to information flows varies with market circumstances. The Plaza period and the stock-market period were by uncertainty about future U.S. monetary policy. Under such circumstances, official information about the market may be particularly valuable.

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ENDNOTES

[1] Under the Gold Reserve Act of 1934, the Exchange Stabilization Fund (ESF) of the U.S. Treasury maintains primary responsibility for intervention in the United States. The Federal Reserve intervenes both as the ESF's agent and for its own account. Usually, the Fed and Treasury act in concert and split the transactions equally between their accounts.

[2] Dominguez and Frankel (1993) provide direct evidence that intervention affects expectations, but the connection between intervention and future monetary policy changes remains controversial. Dominguez (1992) offers an early instance of monetary policy signaling. Lewis (1995) finds that intervention Granger-causes some U.S. monetary policy variables between 1985 and 1990, but suggests that the short-run relationship may reflect the timing of sterilization. Klein and Rosengren (1991) conclude that intervention did not precede monetary-policy changes between late 1985 and late 1987. Kaminsky and Lewis (1996) offer evidence of signaling, but often in an inconsistent direction.

[3] In LeBaron (1996) and Neely and Weller (1997), profits from technical trading rules increase when those rules incorporate information about intervention, suggesting that intervention conveys information.

[4] To apply the tests, one must consider sales and purchases of foreign exchange separately. The United States never bought *and* sold foreign exchange in close time proximity.

[5] The information flows investigated in Chang and Taylor (1998) and Ederington and Lee (1995) justify restricting the duration to a short (one-day) period.

[6] Henceforth, I drop the time subscripts.

[7] Interventions that are consistently wrong also convey useful information to the market. The market can profit by betting against the intervention: Sell when the Fed buys. LeBaron (1996) and Neely and Weller (1997) found that profitable technical trading rules often traded against the Fed.

[8] That is, I reject if one minus the cumulative density function for the hypergeometric distribution (1-CDF) is less that 5 percent.

[9] The subperiods exclude January 3, 1985 through September 20, 1985, because the United States only intervened on eight days; January 2, 1986 through February 20, 1987, because the United States only intervened once, and May 1, 1990 through July 7, 1990, because the 17 operations against German marks did not attempt to affect exchange rates. The Fed undertook these to adjust ESF balances and to facilitate a reversal of outstanding

warehousing operations. A warehousing operation is a swap between the Fed and the ESF whereby the Fed acquires foreign exchange and the ESF receives dollars.

[10] The Group of Five (G5) countries are France, Germany, Japan, the United Kingdom, and the United States.

[11] The Group of Seven (G7) countries are the G5 countries plus Canada and Italy.

Table 1: Full Sample Period January 4, 1985 to March 3,1997

Observations = 3072

Success #1: App./Dep.		*Intervention*		*Virtual*						
against **GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w1s)	76	35	46%	1461	48%	0.024	0.975	0.999	0.559	
Purchases (w1*b*)	138	51	37%	1564	51%	0.033	0.942	0.975	0.999	**Negative**
against **JAPANESE YEN**										
Sales (w1*s*)	82	34	41%	1523	50%	0.022	0.969	0.991	0.916	
Purchases (w1*b*)	108	50	46%	1466	48%	0.034	0.964	0.998	0.580	

Success #2: Change Direction		*Intervention*		*Virtual*						
against **GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w2*s*)	76	24	32%	747	24%	0.032	0.978	1.010	0.055	
Purchases (w2*b*)	138	36	26%	779	25%	0.046	0.956	1.002	0.376	
against **JAPANESE YEN**										
Sales (w2*s*)	82	24	29%	754	25%	0.032	0.975	1.007	0.129	
Purchases (w2*b*)	108	30	28%	746	24%	0.040	0.966	1.007	0.164	

Success #3: Leaning-Against		*Intervention*		*Virtual*						
against **GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w3*s*)	76	15	20%	473	15%	0.032	0.977	1.008	0.113	
Purchases (w3*b*)	138	28	20%	437	14%	0.064	0.958	1.022	0.017	**Positive**
against **JAPANESE YEN**										
Sales (w3*b*)	82	29	35%	459	15%	0.063	0.980	1.043	0.000	**Positive**
Purchases (w3*s*)	108	23	21%	488	16%	0.047	0.967	1.014	0.049	**Positive**

Success #4: Leaning-With		*Intervention*		*Virtual*						
against **GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w4*s*)	76	3	4%	258	8%	0.012	0.974	0.986	0.893	
Purchases (w4*b*)	138	5	4%	284	9%	0.018	0.952	0.970	0.991	**Negative**
against **JAPANESE YEN**										
Sales (w4*s*)	82	1	1%	247	8%	0.004	0.971	0.975	0.992	**Negative**
Purchases (w4*b*)	108	4	4%	234	8%	0.017	0.963	0.980	0.925	

Table 2: Plaza Period September 23, 1985 to December 31, 1985

Observations = 68

Success #1: App./Dep.		*Intervention*		*Virtual*						
against **GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w1*s*)	0			30	44%					
Purchases (w1*b*)	14	6	43%	38	56%	0.158	0.733	0.891	0.788	
against **JAPANESE YEN**										
Sales (w1*s*)	0			25	37%					
Purchases (w1*b*)	20	9	45%	42	62%	0.214	0.577	0.791	0.940	

Success #2: Change Direction		*Intervention*		*Virtual*						
against **GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w2*s*)	0			21	31%					
Purchases (w2*b*)	14	4	29%	19	28%	0.211	0.796	1.006	0.338	
against **JAPANESE YEN**										
Sales (w2*s*)	0			17	25%					
Purchases (w2*b*)	20	5	25%	19	28%	0.263	0.694	0.957	0.513	

Success #3: Leanin-Against		*Intervention*		*Virtual*						
against **GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w3s)	0			9	13%					
Purchases (w3b)	14	2	14%	3	4%	0.667	0.815	1.482	0.007	**Positive**
against **JAPANESE YEN**										
Sales (w3*s*)	0			13	19%					
Purchases (w3*b*)	20	3	15%	5	7%	0.600	0.730	1.330	0.024	**Positive**

Success #4: Leaning-With		*Intervention*		*Virtual*						
against **GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w4*b*)	0			6	9%					
Purchases (w4*s*)	14	0	0%	10	15%	0.000	0.759	0.759	0.918	
against **JAPANESE YEN**										
Sales (w4*b*)	0			8	12%					
Purchases (w4*s*)	20	0	0%	2	3%	0.000	0.697	0.697	0.505	

Table 3: First Louvre Period February 23, 1987 to October 16, 1987

Observations = 167

Success #1: App. / Dep.		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w1*s*)	8	2	25%	81	49%	0.025	0.930	0.955	0.841	
Purchases (w1*b*)	5	2	40%	84	50%	0.024	0.964	0.988	0.506	
***against* JAPANESE YEN**										
Sales (w1*s*)	25	9	36%	80	48%	0.113	0.816	0.929	0.859	
Purchases (w1*b*)	0			83	50%					

Success #2: Change Direction		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w2*s*)	8	2	25%	47	28%	0.043	0.950	0.993	0.401	
Purchases (w2*b*)	5	2	40%	47	28%	0.043	0.975	1.018	0.136	
***against* JAPANESE YEN**										
Sales (w2*s*)	25	8	32%	42	25%	0.190	0.864	1.054	0.135	
Purchases (w2*b*)	0			43	26%					

Success #3: Lean-Against		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w3*s*)	8	1	13%	23	14%	0.043	0.951	0.995	0.303	
Purchases (w3*b*)	5	1	20%	25	15%	0.040	0.972	1.012	0.162	
***against* JAPANESE YEN**										
Sales (w3*s*)	25	9	36%	27	16%	0.333	0.886	1.219	0.002	**Positive**
Purchases (w3*b*)	0			27	16%					

Success #4: Lean-With		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w4*s*)	8	0	0%	9	5%	0.000	0.949	0.949	0.364	
Purchases (w4*b*)	5	0	0%	12	7%	0.000	0.968	0.968	0.314	
***against* JAPANESE YEN**										
Sales (w4*s*)	25	0	0%	11	7%	0.000	0.840	0.840	0.842	
Purchases (w4*b*)	0			12	7%					

Table 4: Second Louvre Period October 19, 1987 to December 30, 1987

Observations = 303

Success #1: App. / Dep.		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w1*s*)	29	14	48%	149	49%	0.094	0.903	0.997	0.463	
Purchases (w1*b*)	26	8	31%	149	49%	0.054	0.883	0.937	0.962	**Negative**
***against* JAPANESE YEN**										
Sales (w1*s*)	39	16	41%	154	51%	0.104	0.846	0.950	0.873	
Purchases (w1*b*)	0			142	47%					

Success #2: Change Direction		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w2*s*)	29	10	34%	78	26%	0.128	0.916	1.044	0.091	
Purchases (w2*b*)	26	7	27%	74	24%	0.095	0.917	1.012	0.284	
***against* JAPANESE YEN**										
Sales (w2*s*)	39	11	28%	85	28%	0.129	0.872	1.001	0.408	
Purchases (w2*b*)	0			72	24%					

Success #3: Lean-Against		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w3*s*)	29	10	34%	44	15%	0.227	0.927	1.154	0.001	**Positive**
Purchases (w3*b*)	26	7	27%	43	14%	0.163	0.927	1.090	0.019	**Positive**
***against* JAPANESE YEN**										
Sales (w3*s*)	39	16	41%	46	15%	0.348	0.911	1.258	0.000	**Positive**
Purchases (w3*b*)	0			46	15%					

Success #4: Lean-With		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w4*s*)	29	0	0%	25	8%	0.000	0.896	0.896	0.928	
Purchases (w4*b*)	26	0	0%	29	10%	0.000	0.905	0.905	0.935	
***against* JAPANESE YEN**										
Sales (w4*s*)	39	1	3%	22	7%	0.045	0.865	0.910	0.806	
Purchases (w4*b*)	0			23	8%					

Table 5: Third Louvre Period January 3, 1989 to April 30, 1990

Observations = 335

Success #1: App. / Dep.		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w1*s*)	0			168	50%					
Purchases (w1*b*)	79	31	39%	161	48%	0.193	0.724	0.917	0.952	**Negative**
***against* JAPANESE YEN**										
Sales (w1*s*)	0			180	54%					
Purchases (w1*b*)	83	39	47%	146	44%	0.267	0.767	1.034	0.198	

Success #2: Change Direction		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w2*s*)	0			87	26%					
Purchases (w2*b*)	79	21	27%	87	26%	0.241	0.766	1.008	0.382	
***against* JAPANESE YEN**										
Sales (w2*s*)	0			79	24%					
Purchases (w2*b*)	83	24	29%	83	25%	0.289	0.766	1.055	0.125	

Success #3: Lean-Against		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w3*s*)	0	0		46	14%					
Purchases (w3*b*)	79	15	19%	50	15%	0.300	0.775	1.075	0.093	
***against* JAPANESE YEN**										
Sales (w3*s*)	0	0		36	11%					
Purchases (w3*b*)	83	18	22%	62	19%	0.290	0.762	1.052	0.153	

Success #4: Lean-With		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w4*s*)	0			28	8%					
Purchases (w4*b*)	79	4	5%	25	7%	0.160	0.758	0.918	0.746	
***against* JAPANESE YEN**										
Sales (w4*s*)	0			36	11%					
Purchases (w4*b*)	83	3	4%	24	7%	0.125	0.743	0.868	0.889	

Table 6: Limited Intervention August 1, 1990 to March 3, 1997

Observations = 1669

Success #1: App. / Dep.		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w1*s*)	22	9	41%	800	48%	0.011	0.985	0.996	0.672	
Purchases (w1*b*)	6	2	33%	845	51%	0.002	0.995	0.998	0.668	
***against* JAPANESE YEN**										
Sales (w1*s*)	17	8	47%	842	50%	0.010	0.989	0.999	0.515	
Purchases (w1*b*)	4	2	50%	781	47%	0.003	0.998	1.000	0.266	

Success #2: Change Direction		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w2*s*)	22	6	27%	397	24%	0.015	0.987	1.003	0.254	
Purchases (w2*b*)	6	1	17%	432	26%	0.002	0.996	0.998	0.487	
***against* JAPANESE YEN**										
Sales (w2*s*)	17	4	24%	409	25%	0.010	0.990	0.999	0.407	
Purchases (w2*b*)	4	1	25%	404	24%	0.002	0.998	1.000	0.248	

Success #3: Lean-Against		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w3*s*)	22	3	14%	247	15%	0.012	0.987	0.999	0.415	
Purchases (w3*b*)	6	2	33%	253	15%	0.008	0.997	1.005	0.048	**Positive**
***against* JAPANESE YEN**										
Sales (w3*s*)	17	4	24%	242	14%	0.017	0.991	1.007	0.087	
Purchases (w3*b*)	4	1	25%	283	17%	0.004	0.998	1.001	0.136	

Success #4: Lean-With		*Intervention*		*Virtual*						
***against* GERMAN MARKS**	*Interventions*	*Successes*	*Percentage*	*Successes*	*Percentage*	*P1*	*P2*	*P1 + P2*	1 - CDF	Value
Sales (w4*s*)	22	0	0%	145	9%	0.000	0.986	0.986	0.866	
Purchases (w4*b*)	6	1	17%	150	9%	0.007	0.997	1.003	0.095	
***against* JAPANESE YEN**										
Sales (w4*s*)	17	0	0%	132	8%	0.000	0.989	0.989	0.755	
Purchases (w4*b*)	4	1	25%	124	7%	0.008	0.998	1.006	0.030	**Positive**