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MARKET RESPONSES TO COORDINATED CENTRAL BANK INTERVENTION

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ABSTRACT

The scale of unilateral and coordinated intervention in the foreign exchange market by the G-5 countries has become considerably larger over the last few years, following a period in which official U.S. policy was opposed to intervention. This paper examines market responses to official sterilized central bank intervention policy over the period 1985 through 1987. The efficacy of sterilized intervention is hypothesized to depend on the market's belief that central banks both have "inside" information about future monetary policy and the incentive to reveal that information truthfully through intervention signals. Central banks may agree to coordinate their intervention operations in order to influence the market's perception of the relative importance and credibility of own signals. Market responses to intervention over the period 1985 through 1987 are examined econometrically using heretofore unavailable daily data on G-3 unilateral and coordinated intervention operations. The empirical evidence indicates that: (1) even though daily intervention data are not published, market participants were generally able to comtemporaneously observe the source and magnitude of central bank intervention operations, (2) unilateral intervention significantly influenced market expectations in some periods, and (3) coordinated intervention had a significantly different and longer-term influence on market expectations than did unilateral intervention over the three year period examined.

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Introduction

Over the past several years central banks of the major industrial countries have intervened in foreign exchange markets in a manner and scale previously unobserved in the post Bretton Woods era. This period, further, stands in sharp contrast to the four years immediately preceding it during which the U.S. halted foreign exchange intervention operations altogether. This paper will examine central bank motivations behind and market responses to renascent intervention policy in the foreign exchange market over the period 1985 through 1987.

Not only did industrial country central banks unilaterally move toward larger scale foreign exchange market intervention, but central banks frequently coordinated their intervention operations over the three- year period under examination. In general, the welfare gains to international economic policy coordination rest on the existence of spillover effects of each country's policies on other countries. Presumably central banks coordinate their intervention operations because they believe that spillover effects exist and are economically important. Whether this belief is justified is examined in the paper by comparing the relative effectiveness of coordinated and unilateral foreign exchange intervention operations.

The academic literature to date has focused most intensively on the conditions under which coordinated monetary and fiscal policies can be welfare-improving (Hamada, 1976; Carlozzi and Taylor, 1985; Cooper, 1985; Rogoff, 1985; Fischer, 1988; Frankel and Rockett, 1988). Foreign exchange intervention policy coordination, while covered extensively in the popular press, has received less academic attention. (Notable exceptions include

Buiter and Eaton, 1985; Marston, 1988; Obstfeld, 1988.) The reason for this is twofold. First, the efficacy of official sterilized foreign exchange intervention is not well- established. Second, daily central bank intervention data are not publically available, precluding direct empirical examinations of intervention's influence on market expectations.[1]

This paper begins by examining the conditions under which unilateral foreign exchange intervention can serve as an effective policy instrument. The following section explores alternative hypotheses that can explain why central banks might find it in their interest to coordinate their intervention operations. The next two sections examine the empirical evidence on market reactions to unilateral and coordinated central bank intervention over the period 1985 through 1987. The empirical work was made possible by an agreement with the German Bundesbank allowing use of confidential daily intervention data. The final section presents conclusions.

I. The Efficacy of Unilateral Central Bank Intervention

In the aftermath of the breakdown of the Bretton Woods fixed exchange rate system, economists and policymakers voiced concern over the possibility that central banks would continue to use intervention policy to manipulate exchange rates away from their equilibrium levels. Freed from the discipline of a fixed rate system, the fear was that central banks might attempt, for example, to depreciate the domestic currency relative to other currencies in an attempt to increase export market shares.

Theoretical and empirical evidence, on the other hand, suggests that exchange rate manipulation through sterilized intervention alone should be of little concern. In the context of standard monetary models of exchange

rate determination, sterilized intervention can have no effect because it leaves the monetary base unchanged. In some portfolio balance models of exchange rate determination, in which foreign and domestic assets are imperfect substitutes, sterilized intervention may be effective if it alters the worldwide asset mix sufficiently to induce portfolio rebalancing (Kouri and Porter, 1974; Girton and Henderson, 1977; Branson, 1979). Empirical evidence, however, suggests that the change in relative asset stocks necessary to induce a change in relative asset prices is generally larger than typical intervention operations (Dooley and Isard, 1982; Frankel, 1979; Obstfeld, 1983; Rogoff, 1984; Lewis, 1988).

More recently, within the context of the asset approach to exchange rate determination, it has been shown that sterilized intervention policy can potentially serve an information or signalling role.[2] If exchange rates are forward-looking and expectationally efficient with respect to public information, then any policy action which conveys additional relevant information to the market can influence exchange rates. Intervention's potential role as a signal derives from the assumption that the central bank is understood to have superior or "inside" information about its own future monetary policy intentions. If sterilized intervention is used by central banks to convey this inside information to the market, then by observing intervention the market's information set will be expanded to include future monetary policy intentions. If credible, this information will influence the market's expectation of current and future exchange rates.[3]

Apart from verbal announcements,[4] sterilized foreign exchange intervention is unique among a monetary authority's policy tools in that it

can convey information without directly altering current period real money balances. Other policy instruments, for example, open market operations or changes in the discount rate, will certainly send signals about future monetary policy. However, they will also themselves affect real balances. In contrast, sterilized intervention explicitly leaves the monetary base unchanged, thereby allowing the central bank to send a signal without actually altering its current period monetary policy.

The same advantage that makes intervention a pure information transmission mechanism -- that it has negligible "real" effects -- opens up a second potential role for intervention policy. Intervention may also be used to manipulate exchange rate expectations. In periods when the central bank perceives strong benefits from short-term deviations from its announced long-term monetary policy, it may use intervention as a relatively costless way to "shore up" the credibility of its announced (as opposed to actual) policy. Compared to other potential signals the central bank does not directly bond itself to a particular monetary policy through intervention. Sending misleading intervention signals will be costly to the central bank, because it constitutes a bet against actual expected exchange rate movements. However, such a policy may be profitable when viewed in the context of the central bank's overall policy goals.

The potential conflict between what I will call the "targeting" objective of intervention policy and the "informative" objective is particularly appropriate in analyzing U.S. foreign exchange intervention policy. Intervention policy, unlike monetary policy, is not under the sole jurisdiction of the Federal Reserve Board. Foreign exchange intervention operations must be approved by and may come directly from the Treasury

Department. The Fed is, in principal, free of political pressures. However, this independence does not hold for the Treasury. There may be, therefore, periods in which the Treasury's exchange rate objectives are at odds with the Fed's monetary policy objectives.

The degree to which intervention can be manipulative depends upon how easily the market is able to spot misleading intervention signals. Consider the effects of "informative" intervention on the spot exchange rate, supposing initially that the central bank's true policy objective is unknown.[5] In period t, for example, the central bank attempts to buy credibility for its anti-inflationary monetary policy by intervening in support of the dollar.[6] In period t+1, information becomes available with which the market can determine the truthfulness of the previous period's intervention. Let Δs_{t+1} denote the deviation between the period t+1 spot exchange rate, s_{t+1}, and the current spot rate, s_t.

$$\Delta s_{t+1} = s_{t+1} - s_t \tag{1}$$

and let the current period exchange rate (in log form) be defined as:[7]

$$s_t = 1/(1+\beta) \sum_{j=0}^{\infty} [\beta/(1+\beta)]^j E_t(z_{t+j} | \Omega_t) \tag{2}$$

where

β is the interest semielasticity of money demand;

z_t is a vector of exogenous driving variables which include nominal and real differentials between the two countries;

Ω_t is the public information set at time t.

If the central bank has <u>complete</u> information about the period t+1 spot rate, then "informative" intervention, denoted I_t, incorporates all information in Ω_{t+1}. Substituting (2) into (1), and assuming that the

market believes that intervention is fully informative in the first period, the spot deviation can be expressed as:[8]

$$\Delta s_{t+1} = 1/(1+\beta) \sum_{j=1}^{\infty} [\beta/(1+\beta)]^j E(z_{t+j}|\Omega_{t+1}) - 1/(1+\beta) \sum_{j=0}^{\infty} [\beta/(1+\beta)]^j E(z_{t+j}|\Omega_t, I_t) = 0 \quad (3)$$

In period t+1 the market compares the observed spot rate with what was promised as revealed by period t intervention and reflected in the period t spot rate. A nonzero change in the spot rate informs the market that the previous period's intervention was not informative, and rational market participants will consequently bet against intervention in future periods.[9] If, alternatively, the central bank has incomplete information about the future spot rate (i.e., $\Omega_t + I_t \neq \Omega_{t+1}$), it is possible that $\Delta s_{t+1} \neq 0$ even when the central bank's objective is to intervene informatively. Further, if the central bank is known to have incomplete information on Ω_{t+1}, it is no longer strictly rational for investors to bet against future intervention as soon as $\Delta s_{t+1} \neq 0$.[10] If period t's unanticipated news ($\Omega_{t+1} - \Omega_t - I_t$) is a white noise process, then $\Sigma \Delta s_{t+1}$ should tend to zero over time. Investors may, therefore, determine over time whether intervention is informative on average.[11]

II. Motivations for Coordinated Central Bank Intervention

In this section, two alternative hypotheses are presented to explain why central banks may find it in their interest to coordinate their intervention operations with other central banks. Within the context of the signalling hypothesis, the efficacy of unilateral intervention operations rests critically on two assumptions: (1) the central bank is believed to have "inside" information about future monetary policy, and (2)

the central bank has the incentive to reveal that information truthfully. Central banks may agree to coordinate intervention operations with other central banks in order to convince the market that both of these conditions hold. Multiple signals will increase the total amount of "inside" information conveyed by intervention operations. Multiple coordinated signals, moreover, will not only increase the importance of any given signal but may also serve to increase the probability that the signal is true.[12] The additional costs of lost reputation among the coordinating central banks, over and above reputational considerations with the market, may serve to further restrain central banks from sending misleading signals. Alternatively, it may be more difficult for the market to learn if a given central bank signals falsely when intervention is coordinated.

In a world with more than one central bank and therefore multiple potential intervention signals, each individual central bank's ability to influence market expectations will depend on its reputation for truthful signals relative to other central banks. Moreover, the probability that signals will convey contradictory information in a world where each central bank engages in intervention operations, taking as given all other central bank interventions, is likely to be high. Central banks may be motivated to agree to coordinate intervention operations, therefore, in order to preclude the possibility that own signals will be offset or overpowered by signals from other more credible central banks.

Alternatively, central banks may agree to coordinate intervention operations in order to free-ride off other central banks' reputations for providing informative signals. For example, a central bank whose objective is to reduce inflation expectations can signal future contractionary

monetary policy by intervening in support of the domestic currency. If the signal is believed and inflation expectations do fall, however, the central bank may be tempted not to follow through with the promised contractionary monetary policy. The temptation to renege may be offset if the central bank knows that the market will eventually learn that the signal was false and thereafter bet against future intervention signals.[13] One way that the central bank can potentially lower the probability that the market will learn that the signal was false is to coordinate its intervention operations with other central banks.

The future monetary policy implications of coordinated intervention operations by several central banks are not unique. Within the signalling hypothesis, unilateral dollar asset purchases against foreign assets by the Fed, for example, would be uniquely consistent with future contractionary U.S. monetary policy. In the context of a coordinated operation, however, the same dollar supporting intervention is also consistent with no change in Fed policy and monetary expansion by other central banks. As long as the central banks do not disclose the details of the coordination agreement, and at least one bank follows through with its monetary policy commitment, it will be more difficult for the market to learn when an individual central bank shirks.[14] Central banks, therefore, may be able to signal their own intentions falsely while free- riding off another central bank's true signal. In this sense, coordinated intervention may allow central banks more latitude to influence exchange rates than would otherwise be the case.[15]

The ability of any given central bank to camouflage a misleading signal within a coordinated intervention operation rests on the willingness

of at least one other central bank to both coordinate and follow through with consistent monetary policy. Presumably central banks understand each other's incentives and will therefore only agree to coordinate when they perceive that it is in each of their best interests to follow through with the appropriate monetary policy changes. In practice, over the three year period examined in this paper, the G-3 central banks engaged in coordinated intervention operations on 81 out of 760 trading days. In the following section I briefly describe the context in which banks agreed to coordinate intervention operations and the empirical evidence on whether these operations were credible to market participants.

III. G-3 Intervention Operations from 1985-1987

The Intervention Data

Intervention operations data are published quarterly by the G-5 central banks. Given that central banks do not always intervene in one direction, even over short periods of time, however, quarterly intervention numbers are not particularly informative. Further, the advantage of sterilized intervention signals over other potential signals is that foreign exchange markets are always open. Intervention can be used to convey the arrival of new "inside" information to the market instantaneously. An empirical examination of intervention's influence, therefore, requires at a minimum intervention data on a daily basis. While it is puzzling that central banks do not publish historical daily intervention data, discussions with market participants suggest that those taking positions in the market quickly learn the source and magnitude of central bank intervention operations.[16]

The tests presented in this paper were made possible by special access

granted by the Deutsche Bundesbank to daily German intervention data (mainly in the dollar/deutschemark market) over the period January 1985 through December 1987.[17] The intervention data series measure daily net intervention operations by the Bundesbank in dollars, at current market values. The data include only discretionary Bundesbank intervention. Interventions which were mandated within the European Monetary System are excluded from the tests.

While the Fed did not grant official access to their daily intervention data over this period, I was able to construct a daily intervention series for the U.S. (including both Federal Reserve and Treasury initiated operations) from descriptions of foreign exchange desk operations published in the Federal Reserve Bank of New York Quarterly Review (FNYQR) and other Federal Reserve publications. Likewise, the Bank of Japan did not make available daily intervention data, but a dummy variable set to unity on the days that the Bank of Japan was in the market and zero otherwise was constructed for the three- year period under examination. This qualitative data on Bank of Japan intervention operations was constructed largely from references in Funabashi (1988) and Ito (1989). While it would be useful to have daily intervention data for all industrial country central banks over this period, due to availability constraints I focus on the operations of the three largest players, the Fed, Bundesbank, and Bank of Japan in the empirical work to follow.

Five Episodes of Coordinated G-3 Intervention

During President Reagan's first administration the dollar appreciated in nominal terms by over 40 percent against the deutchemark and over 20 percent against the yen before it reached its peak against those two

currencies in February 1985. Moreover, from March 1981 through December 1984 the U.S. did not engage in foreign exchange market intervention. Indeed, until early 1985 the administration stance, as articulated by Treasury Secretary Don Regan, was that a strong dollar was a sign of a strong U.S. economy. By January 1985, however, with the U.S. current account deficit nearing $100 billion, pressure both from U.S. exporting industries as well as Germany and Japan (fearing impending protectionist legislation) reportedly led to a reversal of the U.S. nonintervention policy (FNYQR, 1985, pp.58-60).

In mid-January 1985 the Ministers of Finance and the Central Bank Governors of the G-5 countries (France, Germany, Japan, the United Kingdom, and the United States) met in Washington, and for the first time since 1981 all countries including the U.S. agreed to "undertake coordinated intervention in the markets as necessary" (G-5 Announcement, January 17, 1985). In practice, the Bundesbank took the lead in this first episode of intervention coordination and sold a total of $3.5 billion from January through March 1985. The U.S. and Japan coordinated their intervention operations with the Bundesbank but entered the market on a much smaller scale; the U.S. sold $600 million over the same period (FNYQR, 1985). The U.S. backed-up its dollar sales intervention operations on May 20th by unilaterally reducing its discount rate by half a percentage point to 7.5%.

Newspaper accounts of intervention operations suggest that the market was at times misinformed about the level and degree of intervention coordination over this period. On a number of occasions the Wall Street Journal (WSJ) reported that the Fed had been active in the market when in fact only the Bundesbank sold dollars.[18] In other reports, traders stated

that they had bid up the dollar because they had expected some central bank resistance which never occurred.[19] In fact, the Bundesbank and the Fed had intervened against the dollar on some of those occasions. Likewise, among the central banks there seems to have been confusion over exactly what was accomplished during this first round of coordinated intervention. Spot mark-dollar and yen-dollar exchange rates clearly began their decline in this period as can be seen in Figure 1. Reportedly the Bundesbank's perception was that German intervention operations instigated the downward trend of the dollar. The U.S. and Japan, on the other hand, reportedly concluded - perhaps because neither had played an active role - that market forces had begun the dollar's descent (Funabashi, 1988, pp. 27).

The G-5's second round of coordinated intervention operations followed the announcement of the Plaza Agreement on September 22, 1985. In contrast to the perceived mixed signals earlier in the year, the post-Plaza intervention operations were observed by the market as more equally and forcefully shared across the central banks. Press accounts at the time suggest both that the concerted intervention operations "surprised" the market and that the perceived "signal" from the central banks was twofold. First, this round of intervention was understood to be specifically initiated by the U.S., thereby marking a definitive break from the previous U.S. strong dollar policy. The Fed dollar intervention sales were, further, "interpreted as eliminating the likelihood that the Fed would tighten reserve conditions in response to rapid U.S. monetary growth" (FNYQR, 1985-86, pp. 46). Second, newspaper accounts interpreted the unprecedented degree of G-5 cohesion in the post-Plaza period as a sign that the central banks viewed the U.S. current account deficit as a serious

SPOT DM/$ AND YEN/$ EXCHANGE RATES

SOURCE: DRI (LONDON CLOSE)

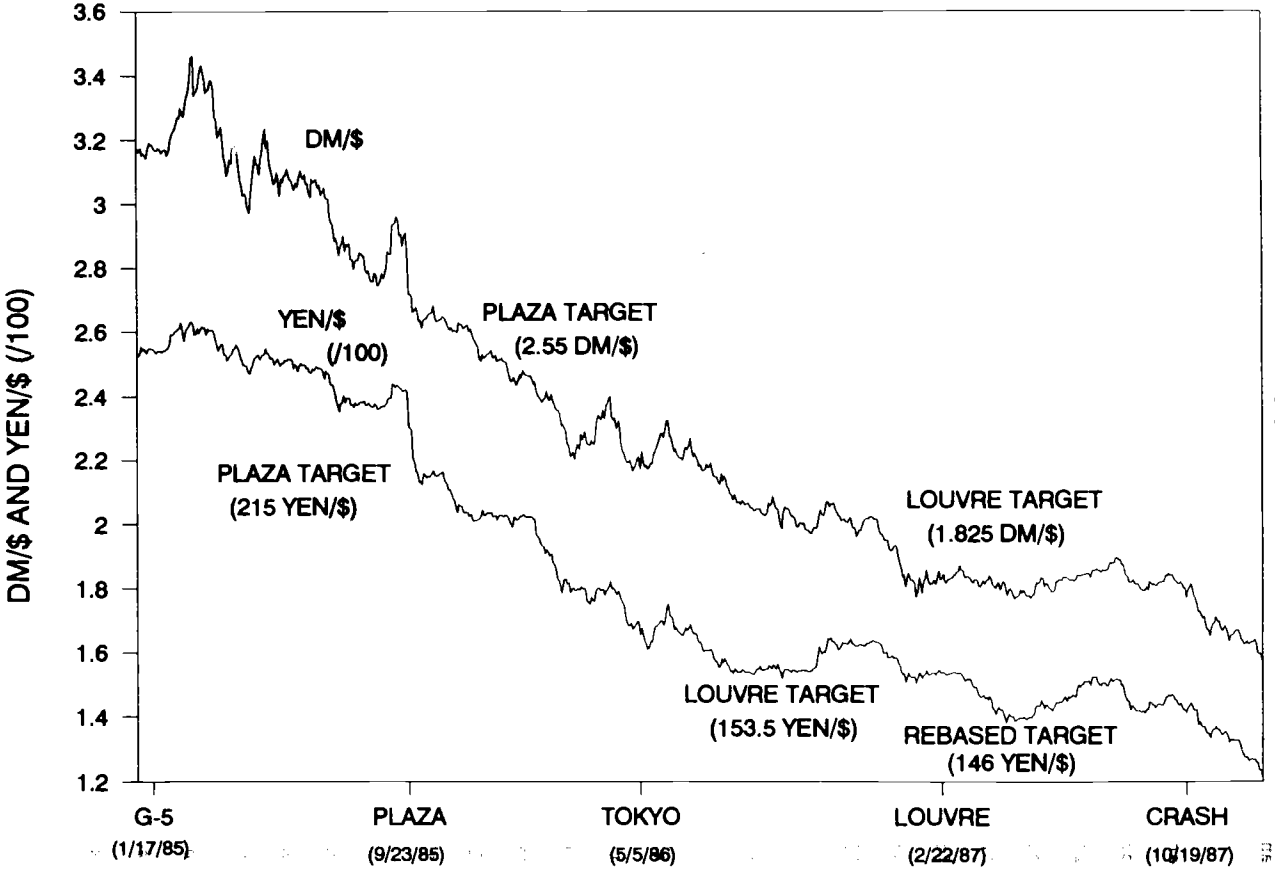

FIGURE 1

and common problem.

The Plaza Agreement communique, while more specific than the G-5 announcement after the January 1985 meeting, did not directly state the central banks' intention to coordinate intervention operations in the foreign exchange market. The communique stated that "in view of the present and prospective changes in fundamentals, some orderly appreciation of the main non-dollar currencies against the dollar is desirable. They [the Ministers and Governors] stand ready to cooperate more closely to encourage this when to do so would be helpful" (G-5 Announcement, September 22. 1985). Funabashi (1988) learned through private interviews with some of those present at the Plaza meeting that the central banks did, in fact, discuss and agree to specific intervention operations. According to Funabashi, the central banks agreed to conduct coordinated sales of up to $18 billion dollars over a six-week period with the bulk of the operations to be shared equally by the Fed, the Bank of Japan, and the Bundesbank. The aim was a 10 to 12 percent depreciation of the dollar relative to the yen and mark. (This meant a drop of the yen-dollar rate from 240 to 214-218 and a drop of the mark-dollar rate from 2.85 to 2.54-2.59 (Funabashi, 1988, pp.16-21).)

The market in the six weeks following the Plaza Announcement generally did correctly pickup the source and magnitude of central bank intervention operations in the foreign exchange market.[20] Moreover, on days when the banks did not intervene, newspapers reported that traders sold dollars out of fear that the banks might intervene. Overall, press coverage and analysis of central bank intervention operations after the Plaza announcement was more accurate and far exceeded the coverage that followed

the January G-5 meeting.

After the Plaza Agreement the G-5 central banks did not agree to coordinate intervention operations again until early 1987. Beginning in March 1986, however, traders reported that the Bank of Japan had unilaterally begun reverse intervention to slow the appreciation of the yen which had dropped below 180 yen per dollar (WSJ, March 18, 1986). The Bundesbank also engaged in unilateral dollar purchases to stabilize the mark at 2 marks per dollar in September 1986. While not directly intervening in this period, the U.S. was accused by the other members of the G-3 of "talking down" the dollar. This period therefore might be thought of as a time of mixed central bank signals.

Although the G-3 central banks did not coordinate intervention operations in 1986, they did coordinate reductions in their respective discount rates in March and April of that year. The stated purpose of the interest rate reductions was to stimulate demand in the three countries, and at the same time avoid further exchange rate changes. Figure 2 presents G-3 discount rates over the period 1985 through 1987. The Fed unilaterally reduced its discount rate by half a percent in July and August of 1986, reinforcing the view that the U.S. did not share the Bank of Japan's commitment to stabilize the yen-dollar rate.[21] It was not until November 1986 that the Bank of Japan backed its earlier unilateral intervention operations in support of the dollar with a reduction in the discount rate from 3.5 to 3 percent.[22]

In early May 1986 at the Tokyo Summit the G-7 countries (Canada and Italy in addition to the G-5 countries) set up what they termed a "multilateral surveillance" system. The idea, introduced by the U.S.

G-3 DISCOUNT RATES

(FED, BUNDESBANK, BANK OF JAPAN)

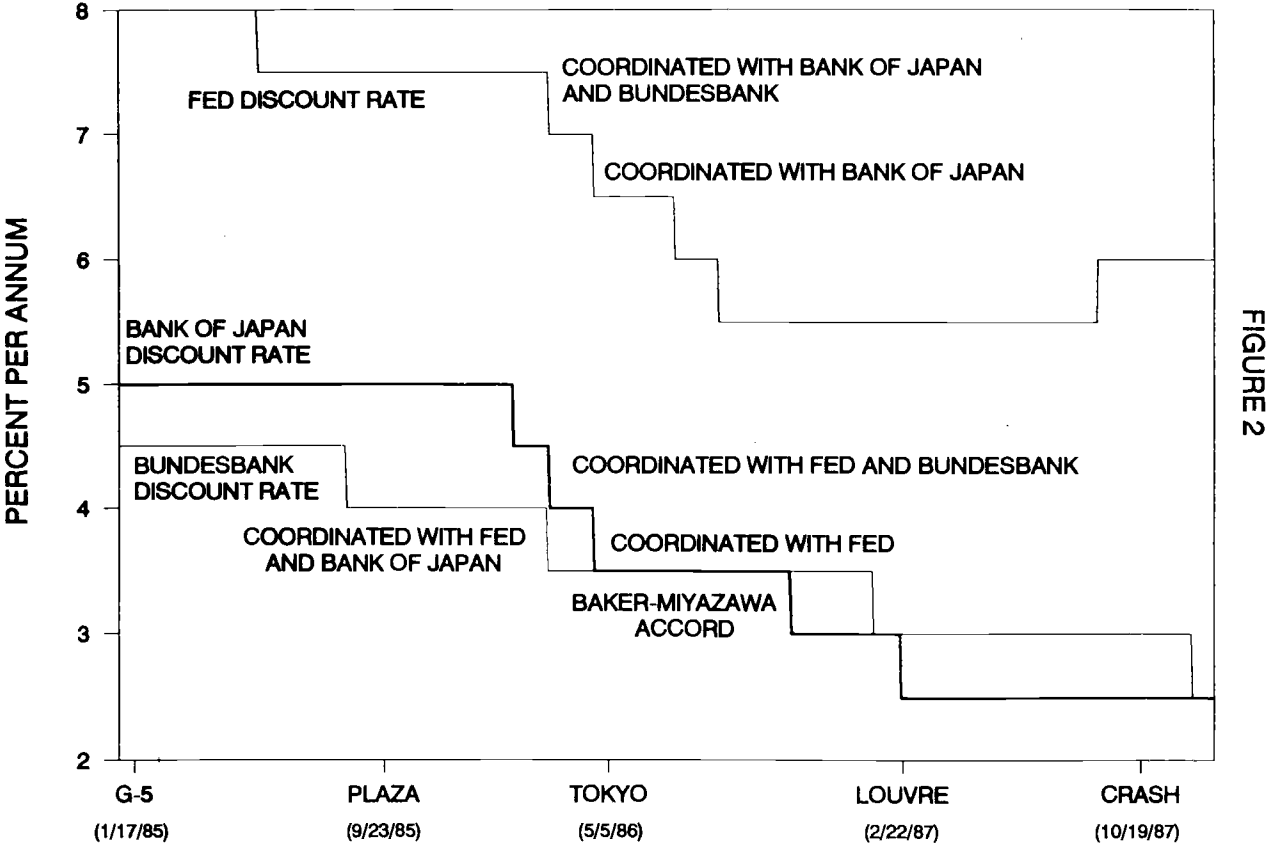

FIGURE 2

Secretary of the Treasury, James Baker, was for the member countries to periodically review a number of indicators of economic performance -- including GNP growth rates, inflation rates, interest rates, unemployment, fiscal deficit ratios, current account and trade balances, monetary growth rates, international reserves, and exchange rates -- in order to achieve more effective policy coordination. While no specific rules were established at the Summit as to what countries would do when the indicators diverged, the message picked up by newspaper reports was that the G-7 intended to engage in more than intervention policy coordination in the future.[23]

In mid-January 1987 the Bank of Japan was reported to have bought huge amounts of dollars as the yen-dollar rate hovered around the 150 level.[24] The Bundesbank joined the Bank of Japan in dollar supporting interventions on a number of occasions in January and announced a discount rate reduction on January 23rd. The Fed entered the market for the first time since the Plaza in support of the dollar on January 28th, purchasing $50 million against the sale of yen (FNYOR, 1987, pp. 69). While this intervention operation was coordinated with the Bank of Japan, newspaper reports noted the relatively small size of the U.S. transaction (WSJ, January 29, 1987). On February 20, 1987 the Bank of Japan backed its intervention operations by lowering its discount rate for the fifth time since January 1986 by one-half a percentage point.

The G-7 (excepting Italy) produced the Louvre Accord in late February 1987 which underscored that nominal exchange rates were "broadly consistent with underlying economic fundamentals" and should be stabilized at their current levels (G-6 Communique, February 22, 1987). The Accord's published

communique included specific fiscal policy commitments by each of the participating countries, including a German tax cut, Japanese fiscal stimulus and tax reform, and U.S. federal deficit reduction measures. The unpublished agreement, reported by Funabashi (1988), was for the U.S., Japan and Europe to spend up to $4 billion on intervention operations through early April in order to stabilize the mark and yen within a 5-percent band around 1.825 marks per dollar and 153.5 yen per dollar (Funabashi, 1988, pp. 177-187).

March 11th was the first day on which the Fed intervened to defend the Louvre ranges, purchasing $30 million against marks. Newspapers reported massive coordinated intervention by the central banks in late March.[25] The Bundesbank, however, did not join the coordination efforts in the dollar foreign exchange market until late April. The Fed coordinated daily intervention operations between March 23 and April 6th with the Bank of Japan and several European central banks, purchasing a total of $3 billion against yen (FNYOR, 1987, pp. 60). In the Tokyo market, the Bank of Japan reportedly bought $1.7 billion on March 24th and $2 billion against yen on March 27th (Ito, 1989, pp. 32).[26] In total, during the first quarter of 1987 the Bank of Japan purchased $16 billion against yen (Funabashi, 1988, pp. 188). Despite the large scale coordinated dollar support intervention operations by the Fed and the Bank of Japan, on April 7th the (unpublished) yen-dollar Louvre range was reportedly rebased to 146 yen per dollar to reflect current market conditions (Funabashi, 1988, pp. 189).

As is evident in Figure 1, the yen-dollar and mark-dollar exchange rates were relatively stable in the months following the Louvre Accord.

The G-3 central banks continued coordinated and unilateral intervention operations in support of the dollar throughout April and May. Further, movements in eurocurrency rates (shown in Figure 3) suggest that respective monetary policies were consistent with dollar supporting intervention operations over this period. The rising three-month eurodollar interest rate is indicative of relatively restrictive U.S. monetary policy. Likewise, declining euromark and euroyen interest rates over this period reflect relatively expansionary monetary policies in Germany and Japan.[27]

In early August 1987, for the first time since the Plaza, the Fed and the Bundesbank engaged in mark supporting intervention operations in order to maintain the Louvre mark-dollar target. In the following two weeks the G-3 reportedly coordinated small scale intervention operations, this time in support of the dollar.[28] On September 4th the Federal Reserve Board backed-up these intervention operations by unilaterally increasing the discount rate one-half percent to 6%.

The final episode of intervention coordination over this period occurred in the aftermath of the global stock market crash on October 19, 1987. From late October through December 1987 the G-3 central banks engaged in numerous large scale coordinated dollar supporting intervention operations. The U.S. purchased a total of $3,876 million and the Bundesbank purchased $2,704 million over the three-month period. The Bundesbank backed up its intervention operations with a discount rate cut on December 9th to 2.5 percent. Newspaper accounts in this period suggest that while traders were well-informed of the timing and magnitude of central bank intervention operations, dollar supporting intervention by the Fed was not credible. Market participants apparently perceived the U.S.

G-3 EUROCURRENCY RATES

SOURCE: DRI (LONDON CLOSE)

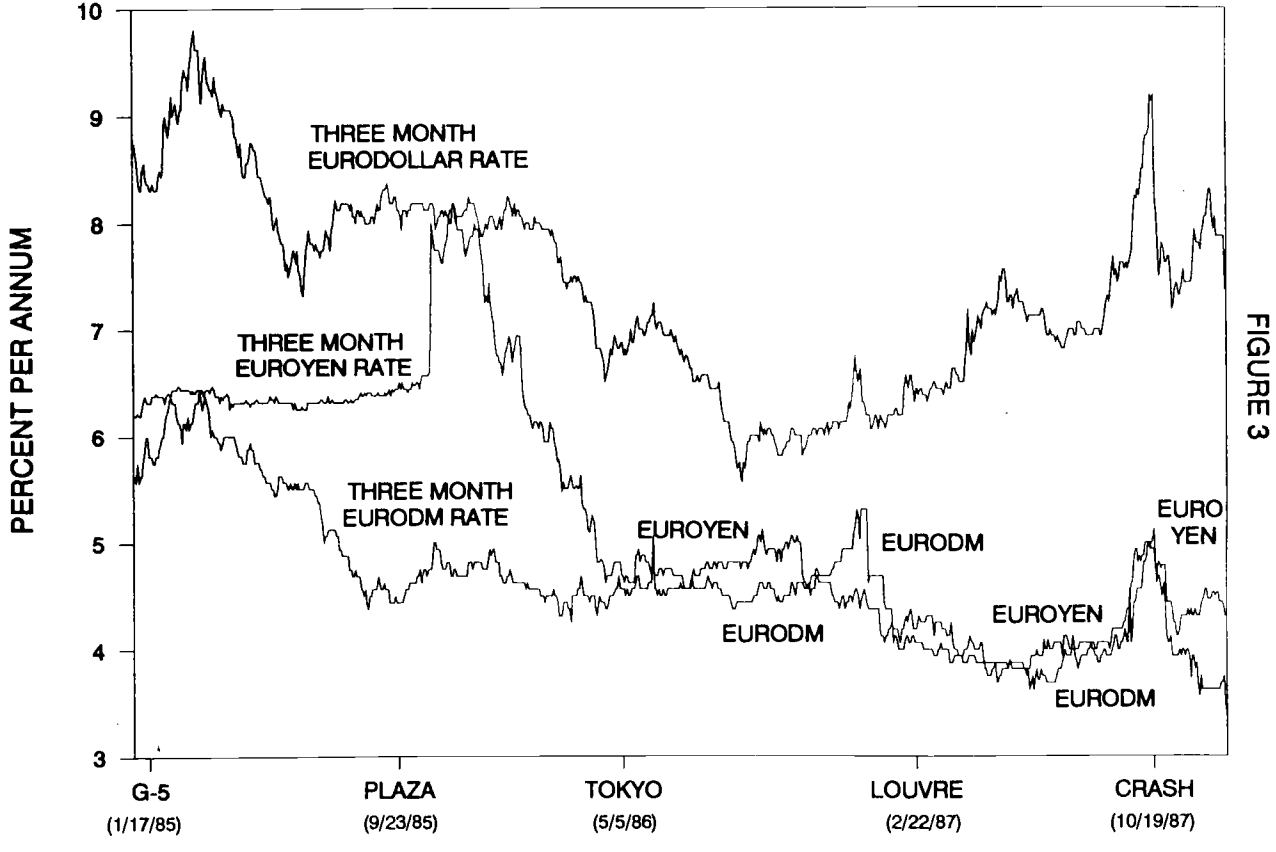

FIGURE 3

commitment to averting a post-crash liquidity crisis as stronger than its commitment to supporting the dollar.[29]

IV. Estimated Responses to Intervention Operations: 1985-87

Methodology

Newspaper accounts of unilateral and coordinated intervention operations by and large suggest that market participants contemporaneously observed central bank intervention signals over the three-year period under examination. This finding is reassuring. If market participants are not able to observe intervention operations, the signalling hypothesis has little practical relevance. However, newspaper accounts can only indicate whether or not the market observed intervention operations. At issue is whether and how the market responds to intervention information. In this section econometric tests are presented to examine whether unilateral and coordinated intervention operations significantly influence market expectations.

Direct econometric tests of the influence of foreign exchange intervention operations on exchange rates are not feasible for two reasons. First, there does not exist a consensus model of exchange rate determination in which intervention operations can be included on the right-hand-side to test for significant explanatory power. Second, intervention policy and exchange rate movements are potentially simultaneously determined. If exchange rates enter the central banks' objective function, then monetary policy and hence informative intervention signals will be influenced by exchange rate movements. Central banks may also intervene in a manner inconsistent with future monetary policy

intentions in order to explicitly manipulate exchange rate expectations. Under either scenario, contemporaneous movements in exchange rates may influence central bank decisions to intervene, and therefore intervention can not be assumed to be exogenous.[30]

One approach that avoids the potential simultaneity problem examines whether today's observed intervention helps explain the predictable component of ex post excess returns in the foreign exchange market. Ex post excess returns are defined as the realized profit a trader would make simultaneously borrowing in one currency and lending in another. In period t, for example, the investor borrows foreign currency for t+k periods at the foreign interest rate, $i^*_{t,t+k}$, and purchases domestic currency with the borrowed foreign currency at the spot exchange rate, s_{t-2}[31]. (Spot foreign exchange contracts for most currencies must be ordered two days before delivery, and market convention requires that currency transactions be made prior to investment transactions. Investors, therefore, must purchase the domestic currency two days in advance of taking out the foreign currency loan.) Simultaneously, the investor lends domestic currency for t+k periods at the domestic interest rate, $i_{t,t+k}$. Two days before the domestic loan matures, in period t+k-2, the investor purchases the foreign currency spot for delivery in period t+k. In period t+k the investor pays back the original foreign currency loan with the domestic currency earnings. The ex post return, $r_{t-2,t+k-2}$, on this set of transactions is the difference between the domestic and foreign interest rates minus the change in the spot exchange rate between period t-2 and period t+k-2.

$$r_{t-2,t+k-2} = (1 + i_{t,t+k}) - (1 + i^{*}_{t,t+k})(s_{t+k-2}/s_{t-2})$$

$$= [i_{t,t+k} - (i^{*}_{t,t+k})(s_{t+k-2}/s_{t-2})] -$$

$$[(s_{t+k-2} - s_{t-2})/s_{t-2}] \qquad (4)$$

If exchange rate expectations are unbiased and efficient, then ex post excess returns can further be decomposed into a spot rate forecast error which is uncorrelated with information available at time t-2, and a predictable expected risk premium on dollar assets. If we define $\epsilon_{t,t+k}$ as a white noise error term and E_t as the expectations operator, then exchange rate efficiency implies:

$$\epsilon_{t,t+k} = E_t s_{t+k} - s_{t+k} \qquad (5)$$

Define the expected risk premium on domestic assets, $\rho_{t-2,t+k-2}$, as the expected nominal return differential between domestic and foreign interest bearing assets:

$$\rho_{t-2,t+k-2} = (1+i_{t,t+k}) - (1+i^{*}_{t,t+k})E_{t-2}s_{t+k-2}/s_{t-2} \qquad (6)$$

Combining (5) and (6) and substituting in (4), ex post excess returns can be re-expressed as:

$$r_{t-2,t+k-2} = \rho_{t-2,t+k-2} + \epsilon_{t-2,t+k-2}(1 + i^{*}_{t,t+k})/s_{t-2} \qquad (7)$$

A regression of expost excess returns on variables observed at time t-2 or earlier provides a test of the joint hypothesis that the expected risk premium is zero and that the spot exchange market is informationally efficient. The potential signalling role of central bank foreign exchange intervention, described in Mussa (1981) and illustrated in Section I of this paper, does not rely on the existence of a risk premium.[32] The excess return regression specification is, therefore, restrictive because it tests whether intervention that provides information about the future relative supply of outside domestic assets influences market expectations by

changing the perceived relative riskiness of those assets. If investors are risk neutral, view foreign and domestic assets as perfect substitutes (uncovered interest parity holds), and intervention signals are informative and fully believed, then ex post excess returns will be uncorrelated with observed intervention. Alternatively, we can interpret a rejection of the null hypothesis as evidence that intervention signals systematically influence the expected risk premium.

Previous empirical tests of uncovered interest parity, recently summarized in Hodrick (1987), generally reject the hypothesis that the expected risk premium is zero. However, attempts to find a relationship between expost excess returns and variables that, in theory, should influence expected risk premia have had limited success.The advantage of the excess return regression specification is, therefore, that it fits into the large empirical literature on exchange rate expectations, and it allows intervention to influence expectations both through the portfolio and signalling channels.[33]

Loopesko (1984) tested whether cumulated foreign exchange intervention over the period 1978 to 1981 is a significant determinant of expost excess returns through its influence on investors' portfolio preferences. Intervention enters cumulatively in the regressions to reflect changes in current relative outside supplies of foreign and domestic assets. The hypothesis is that the perceived riskiness of domestic assets increases with increases in the current period relative supply of domestic to foreign assets held in private portfolios. Loopesko finds evidence weakly supportive of the hypothesis that the cumulative stock of intervention significantly explains expost returns on overnight investments.

If intervention's influence on market expectations is due to the information it conveys about monetary policy, then the source of intervention information should matter. As was discussed earlier in the paper, the efficacy of any given intervention operation will be a function of the intervening central bank's reputation for past informative signals. Alternatively, if intervention influences market expectations through its direct affect on current relative asset supplies, only the size and not the source of the intervention operation should matter. Likewise, there should be no distinction between coordinated and unilateral intervention operations of the same size if it is the stock and not the signalling effect that influences portfolio decisions.

In summary, if the expected risk premia are zero and intervention is fully believed, then observed intervention should be uncorrelated with expost excess returns.[34] Alternatively, if there exist risk premia on dollar assets that are an increasing function of the current and future relative supply of dollar assets held by the public, then intervention (defined as net purchases of dollar assets) should be negatively correlated with ex post excess dollar returns. A sterilized sale of dollar assets that signals future expansionary Fed monetary policy, for example, should lead to an increase in the expected dollar risk premia. Investors will require a higher return on dollar assets in order to willingly hold the larger current and future outstanding stock of dollar assets.

V. Results

Ex post returns on dollar assets were on average negative, on the order of 20 percentage points annually, over the three-year period 1985 through 1987. This stands in marked contrast to the previous four-year

period when excess dollar returns were equally large but significantly positive. Tables 1 and 2 present summary statistics on average daily annualized ex post dollar-mark and dollar-yen return differentials over the five coordination subperiods discussed previously as well as over the full three-year period. The realized dollar returns are calculated for the dollar-mark and dollar-yen markets using daily overnight, one-month and three-month eurocurrency interest differentials and changes in the exchange rate over corresponding time horizons. Tables 3 and 4 present summary statistics for average daily annualized over-night, one-month and three-month eurocurrency interest differentials. A comparison of the orders of magnitude in the two sets of tables indicate that much of the action in observed excess dollar returns is due to the depreciation of the dollar against the mark and yen over this period. Assuming that exchange rate expectations are unbiased, these statistics suggest that the expected risk premium on dollar assets declined significantly over the three year period under examination.

Table 5 presents average daily unilateral and coordinated intervention operations over each of the five subperiods and the full three year period. The intervention observations are in millions of dollars. The central banks sold dollars during the first two coordination subperiods in 1985 and generally purchased dollars in 1986 and 1987. Daily Fed and Bundesbank intervention include only those days on which each bank intervened unilaterally. Coordinated intervention is defined as the sum of central bank intervention operations on days where at least two out of the G-3 central banks intervened in the same direction. On days when the Bank of Japan was one of the coordinating banks, however, coordinated intervention

will not fully reflect total intervention operations because only qualitative data on Japanese intervention operations is available.

Given the two-day delivery lag for spot exchange rate transactions, only intervention observed at the time t-2 can influence the expected risk premia in the regressions. The spot and interest rate data used to calculate ex post excess returns are observed in the morning, and intervention data reflect official net purchases and sales of dollar assets at the end of the day. Intervention observations dated t-3 or earlier, therefore, are legitimate regressors.[35] Further, because the daily ex post excess returns series is overlapping in the sense that realized returns in the previous period will not be known for two days, one month and three months, respectively, the regressions were estimated assuming appropriate moving average processes for the disturbances.[36] Tables 6 through 11 present regression estimates of ex post dollar returns on unilateral and coordinated intervention operations over the five coordination subperiods described in the previous section as well as over the full three-year period under examination.

Table 6 presents ex post dollar return regression results for the first coordination subperiod, January through March 1985. Fed intervention is not included separately on the right-hand-side because the Fed did not intervene unilaterally over this period. The coefficient on Bundesbank intervention, β_2, is negative and significant in five out of six of the dollar-mark and dollar-yen return regressions over all three investment horizons. A one-million-dollar intervention sale by the Bundesbank over this period increased the annualized overnight dollar-mark and dollar-yen return differential by 57 and 37 basis points, respectively. The impact of

Bundesbank intervention on market expectations declined as the excess dollar return maturity length increased. Coordinated intervention operations also had a statistically significant but consistently smaller impact relative to unilateral Bundesbank operations on excess dollar returns. These results suggest that unilateral Bundesbank intervention was more credible than coordinated intervention in this subperiod.

Table 7 presents regression results for the second subperiod, the three-month period following the Plaza Agreement. In contrast to the earlier period, the coefficient on unilateral Bundesbank intervention is insignificant for all but the three-month dollar return differentials. The central bank with credibility in this subperiod apparently was the Fed. The coefficient on unilateral Fed intervention is significant at the .05 level in all but the overnight dollar-yen return regression. Moveover, the impact of Fed intervention on excess dollar returns did not decline as the length of the investment horizon increased as was the case in the previous subperiod. Coordinated intervention operations had significant and a statistically larger impact than unilateral operations on the one- and three-month dollar return differentials. A coordinated sale of one million dollars increased the annualized three-month dollar-mark return differential by 28 basis points. Given that the average coordinated operation involved dollar sales of just under 200 million dollars, these results suggest that coordinated intervention had a significant economic as well as statistical impact on market expectations.

Unilateral and coordinated Bundesbank and Bank of Japan intervention in the third subperiod involved purchases of dollar assets. This is the first subperiod in which intervention operations "leaned against" the direction

of change in exchange rates. Further, the Fed did not intervene in the foreign exchange market in this period and this noncoordination was interpreted in the press as a signal that the Fed did not want to see the dollar strengthen. The regression results for this subperiod, presented in Table 8, suggest that the G-3 "mixed signals" had little impact on market expectations. The coefficient on unilateral Bundesbank intervention is statistically significant but of the wrong sign for the one-month and three-month dollar return differential regressions. A one-million-dollar purchase by the Bundesbank increased rather than decreased three-month dollar-mark and dollar-yen return differentials by 3 basis points. Likewise, the coefficients on coordinated intervention operations are relatively large and significantly positive in four out of six regressions.

Regressions results for the post Louvre Accord subperiod are presented in Table 9. Perhaps as a consequence of the mixed signals in 1986, there is little evidence of intervention's influence in the post Louvre estimates. The coefficients on unilateral Fed and Bundesbank intervention are significant in only two of the six regressions. Coordinated dollar supporting intervention operations are also inconsistently significant. The significantly positive coefficient on unilateral Bundesbank intervention in the monthly regressions, moreover, indicates that dollar purchases by the Bundesbank again increased rather than decreased the one-month return differential on dollars over this period.

Table 10 presents regression results for the post stock market crash period in late 1987. The coefficient on unilateral Fed intervention is consistently large, significant and positive over the three investment horizons. A one-million-dollar purchase by the Fed increased the dollar

return differential by between 10 and 50 basis points depending on the investment horizon, with the size of the impact decreasing as the investment horizon increases. The coefficient on unilateral Bundesbank intervention is correctly signed for the first time since 1985 but is significant in only two of the six regressions. Coordinated intervention has a smaller impact on returns than unilateral Fed intervention, but likewise indicates that dollar supporting intervention increased rather than decreased excess dollar returns in this period.

Results for the full three-year period, presented in Table 11, show that the coefficient on coordinated intervention was significant in all but the overnight return differential equations. On average a coordinated purchase of one million dollars decreased the dollar return differential by 1 to 4 basis points. The average coordinated intervention operation involved a 200 million dollar asset purchase (sale) which is estimated to decrease (increase) the dollar return differential by 2 to 8 percent. The coefficient on unilateral Bundesbank intervention operations is insignificant across all investment horizons over the three year period. Unilateral Fed intervention likewise is only significant in two out of six excess dollar return regressions.

Overall, the regression results indicate that coordinated intervention operations over this three-year period consistently influenced longer-term market expectations. Unilateral intervention operations by the Fed and the Bundesbank had a less consistent influence on ex post excess returns but were also significant in some subperiods. The coefficient on unilateral Bundesbank intervention was highly significant in early 1985, suggesting that the German perception that it influenced the initial dollar decline

may have some basis. The coefficient on unilateral Fed intervention was significant and of the expected sign after the Plaza agreement. However, unilateral Fed intervention was also highly significant but of the wrong sign after the stock market crash, indicating that dollar supporting intervention by the Fed increased rather than decreased the dollar return differential. This finding is consistent with newspaper accounts which suggest that the market did not view Fed dollar supporting operations in late 1987 as credible.

VI. Conclusions

This paper examines market responses to official sterilized foreign exchange intervention over the period 1985 through 1987. Previous empirical studies have cast doubt on whether sterilized intervention operations can effectively be used by central banks as an independent policy instrument. Here intervention is viewed not as an independent policy tool, but rather as a means of conveying "inside" information to the market about future monetary policy. In a sense, credible intervention signals will, in the end, be nonsterilized when the central bank follows through with its promised monetary policy. Viewed in this context, it is perhaps not surprising that intervention operations were often found to significantly influence market expectations in the econometric tests presented.

Access to heretofore unavailable daily intervention data allowed an examination of whether market participants observe and respond to intervention signals. The evidence indicates that: (1) even though daily intervention data are not published, market participants were generally able to contemporaneously observe the source and magnitude of central bank

intervention operations, (2) unilateral intervention significantly influenced market expectations in some periods, and (3) coordinated intervention had a significantly different and longer-term influence on market expectations than did unilateral intervention over the three year period examined.

TABLE 1

Average Ex Post Excess Dollar-Mark Returns
Percent Per Annum

	1-day	30-day	90-day
G-5 (January - March 1985)	-2.17 (-0.12)	-10.39 (-1.08)	-18.94 (-9.44)**
PLAZA (September - December 1985)	-30.36 (-2.07)*	-36.39 (-11.11)**	-38.81 (-30.11)**
(September 1986 - January 1987)	-16.47 (-1.57)	-27.41 (-5.57)**	-27.27 (-16.37)**
LOUVRE (February - June 1987)	0.37 (0.41)	-0.40 (-0.16)	6.88 (5.24)**
CRASH (October - December 1987)	-28.83 (-1.91)	-28.52 (-4.81)**	0.02 (0.01)
(January 1985 - December 1987)	-11.34 (-2.86)**	-21.58 (-13.01)**	-20.50 (-27.83)**

The numbers in parentheses are the estimated t-statistics, * denotes rejection at the .05 level, and ** at the .01 level for the hypothesis that the return differential is equal to zero.

Ex post dollar-mark returns are calculated as:

$$[i_{t,t+k} - i^{*}_{t,t+k}(s_{t+k-2}/s_{t-2})] - [(s_{t+k-2} - s_{t-2})/s_{t-2}]$$

where $i_{t,t+k}$ = eurodollar deposit rate

$i^{*}_{t,t+k}$ = euromark deposit rate

s_t = dollar-mark spot exchange rate

k = one-day, one-month, or three-month maturity

TABLE 2

Average Ex Post Excess Dollar-Yen Returns
Percent Per Annum

	1-day	30-day	90-day
G-5 (January - March 1985)	-0.66 (-0.07)	-3.61 (-0.94)	-8.42 (-10.78)**
PLAZA (September - December 1985)	-34.13 (-2.46)*	-42.33 (-7.91)**	-43.58 (-22.36)**
(September 1986 - January 1987)	-0.77 (-0.08)	-0.81 (-0.17)	-17.26 (-9.49)**
LOUVRE (February - June 1987)	-11.19 (-1.11)	-17.68 (-3.23)**	3.00 (1.02)
CRASH (October - December 1987)	-34.71 (-2.29)*	-45.29 (-8.44)**	-17.76 (-7.50)**
(January 1985 - December 1987)	-12.18 (-3.59)**	-23.79 (-13.91)**	-22.68 (-25.10)**

The numbers in parentheses are the estimated t-statistics, * denotes rejection at the .05 level, and ** at the .01 level for the hypothesis that the return differential is equal to zero.

Ex post dollar-yen returns are calculated as:

$$[i_{t,t+k} - i^{*}_{t,t+k}(s_{t+k-2}/s_{t-2})] - [(s_{t+k-2} - s_{t-2})/s_{t-2}]$$

where $i_{t,t+k}$ = eurodollar deposit rate

$i^{*}_{t,t+k}$ = euroyen deposit rate

s_t = dollar-yen spot exchange rate

k = one-day, one-month, or three-month maturity

TABLE 3

Average Dollar-Mark Interest Differentials
Percent Per Annum

	1-day	30-day	90-day
G-5 (January - March 1985)	2.73 (52.82)**	2.76 (87.21)**	2.93 (70.23)**
PLAZA (September - December 1985)	3.49 (91.64)**	3.46 (95.43)**	3.39 (94.38)**
(September 1986 - January 1987)	1.51 (33.34)**	1.49 (35.93)**	1.41 (66.17)**
LOUVRE (February - June 1987)	2.61 (57.71)**	2.77 (72.36)**	2.89 (55.52)**
CRASH (October - December 1987)	3.43 (57.16)**	3.86 (47.06)**	3.81 (60.34)**
(January 1985 - December 1987)	2.66 (96.49)**	2.74 (96.89)**	2.76 (96.18)**

The numbers in parentheses are the estimated t-statistics; ** denotes rejection at the .01 level for the hypothesis that the interest differential is equal to zero.

Dollar-mark interest differentials are calculated as:

$$i_{t,t+k} - i^{*}_{t,t+k}$$

where $i_{t,t+k}$ = eurodollar deposit rate

$i^{*}_{t,t+k}$ = euromark deposit rate

k = one-day, one-month, or three-month maturity

TABLE 4

Average Dollar-Yen Interest Differentials
Percent Per Annum

	1-day	30-day	90-day
G-5 (January - March 1985)	2.14 (49.47)**	2.23 (83.07)**	2.61 (49.45)**
PLAZA (September - December 1985)	0.84 (8.49)**	0.64 (7.03)**	0.83 (9.88)**
(September 1986 - January 1987)	1.70 (31.23)**	1.66 (28.49)**	1.51 (36.96)**
LOUVRE (February - June 1987)	2.31 (27.25)**	2.52 (42.38)**	2.79 (43.51)**
CRASH (October - December 1987)	2.92 (27.16)**	3.19 (59.27)**	3.34 (72.98)**
(January 1985 - December 1987)	1.99 (59.64)**	1.99 (62.76)**	2.11 (67.28)**

The numbers in parentheses are the estimated t-statistics; ** denotes rejection at the .01 level for the hypothesis that the interest differential is equal to zero.

Dollar-yen interest differentials are calculated as:

$$i_{t,t+k} - i^*_{t,t+k}$$

where $i_{t,t+k}$ = eurodollar deposit rate

$i^*_{t,t+k}$ = euroyen deposit rate

k = one-day, one-month, or three-month maturity

TABLE 5

Daily Unilateral and Coordinated Intervention Operations
Millions of Dollars

	Avg	Max	Min
G-5 (January - March 1985)			
Fed		NA	
Bundesbank	-45	-201	-6
Coordinated	-423	-1009	-60
PLAZA (September - December 1985)			
Fed	-90	-265	-27
Bundesbank	-40	-93	-2
Coordinated	-198	-1037	-31
(September 1986 - January 1987)			
Fed		NA	
Bundesbank	135	719	3
Coordinated	50	70	20
LOUVRE (February - June 1987)			
Fed	217	273	80
Bundesbank	231	324	150
Coordinated	506	2273	129
CRASH (October - December 1987)			
Fed	165	175	156
Bundesbank	21	38	12
Coordinated	228	555	45
(January 1985 - December 1987)			
Dollar Purchases			
Fed	205	273	80
Bundesbank	118	719	3
Coordinated	208	555	45
Dollar Sales			
Fed	-86	-265	-27
Bundesbank	-43	-201	-2
Coordinated	-256	-1037	-31

Fed and Bundesbank intervention include only those days on which each bank intervened unilaterally. Coordinated intervention observations are the sum of Fed and Bundesbank intervention observations on days that both banks intervened in the same direction as well as days that the Bank of Japan coordinated with either bank.

TABLE 6

$$r_{t-2,t+k} = \beta_0 + \beta_2 I^b_{t-3} + \beta_3 I^c_{t-3} + \upsilon_{t-2,t+k}$$

SAMPLE: January - March 1985

Spot	β_0	β_2	β_3	R^2	χ^2	MA
\$/DM	-23.85	-0.57	-0.19	.11	6.11*	1
	(-1.16)	(-3.57)**	(-2.84)**			
\$/YN	-12.81	-0.37	-0.09	.11	7.92**	1
	(-1.41)	(-3.83)**	(-1.99)*			
\$/DM	-13.31	-0.51	-0.06	.08	4.92*	21
	(-0.36)	(-2.98)**	(-2.09)*			
\$/YN	-3.87	-0.14	-0.03	.06	3.94*	21
	(-0.25)	(-1.94)	(-1.98)*			
\$/DM	-19.10	-0.06	-0.01	.04	4.17*	61
	(-5.15)**	(-3.77)**	(-2.93)**			
\$/YN	-8.45	-0.11	-0.01	.01	3.86*	61
	(-4.84)**	(-2.63)**	(-1.97)*			

The numbers in parentheses are the estimated t-statistics of the coefficients, * denotes rejection at the .05 level, and ** at the .01 level for the hypothesis that the coefficient is equal to zero. Overnight, monthly and quarterly ex post return regressions were estimated using overlapping daily annualized data; the regression disturbances are assumed to follow a one, twenty-one, or sixty-one day moving average process, respectively. The $\chi^2(1)$ statistic pertains to the hypothesis that the coefficients on the intervention variables are statistically identical.

All intervention observations are in millions of dollars. Bundesbank (I^b) intervention includes only those days on which the bank intervened unilaterally. The Fed did not intervene unilaterally over this period. Coordinated intervention (I^c) observations are the sum of Fed and Bundesbank intervention observations on days that both banks intervened in the same direction as well as days that the Bank of Japan coordinated with either bank.

TABLE 7

$$r_{t-2,t+k} = \beta_0 + \beta_1 I^f_{t-3} + \beta_2 I^b_{t-3} + \beta_3 I^c_{t-3} + \upsilon_{t-2,t+k}$$

SAMPLE: September - December 1985

Spot	β_0	β_1	β_2	β_3	R^2	χ^2	MA
\$/DM	-26.66	-0.02	0.01	-0.71	.01	2.01	1
	(-1.49)	(-2.24)*	(1.02)	(-0.26)			
\$/YN	-30.86	-0.08	-0.42	-0.78	.01	1.81	1
	(-2.06)*	(-1.58)	(-1.04)	(-1.22)			
\$/DM	-40.44	-0.12	-0.16	-0.51	.09	7.78**	21
	(-5.18)**	(-2.55)*	(-1.81)	(-2.16)*			
\$/YN	-39.60	-0.07	-0.22	-0.57	.04	4.42*	21
	(-2.01)*	(-1.99)*	(-1.86)	(-1.98)*			
\$/DM	-41.10	-0.05	-0.12	-0.28	.07	21.17**	61
	(-20.25)**	(-4.32)**	(-3.92)**	(-5.12)**			
\$/YN	-47.05	-0.11	-0.17	-0.41	.07	10.17**	61
	(-16.98)**	(-6.51)**	(-2.31)*	(-5.87)**			

The numbers in parentheses are the estimated t-statistics of the coefficients, * denotes rejection at the .05 level, and ** at the .01 level for the hypothesis that the coefficient is equal to zero. Overnight, monthly and quarterly ex post return regressions were estimated using overlapping daily annualized data; the regression disturbances are assumed to follow a one, twenty-one, or sixty-one day moving average process, respectively. The $\chi^2(1)$ statistic pertains to the hypothesis that the coefficients on the intervention variables are statistically identical.

All intervention observations are in millions of dollars. Fed (I^f) and Bundesbank (I^b) intervention include only those days on which each bank intervened unilaterally. Coordinated intervention (I^c) observations are the sum of Fed and Bundesbank intervention observations on days that both banks intervened in the same direction as well as days that the Bank of Japan coordinated with either bank.

TABLE 8

$$r_{t-2,t+k} = \beta_0 + \beta_2 I^b_{t-3} + \beta_3 I^c_{t-3} + \upsilon_{t-2,t+k}$$

SAMPLE: September 1986 - January 1987

Spot	β_0	β_2	β_3	R^2	χ^2	MA
\$/DM	-17.37	-0.07	0.15	.05	18.93**	1
	(-1.74)	(-1.26)	(5.82)**			
\$/YN	-0.83	-0.04	0.04	.01	14.58**	1
	(-0.09)	(-0.97)	(8.14)**			
\$/DM	-30.11	0.10	0.22	.05	4.50*	21
	(-1.71)	(2.54)*	(3.49)**			
\$/YN	-3.13	0.11	0.14	.04	3.48	21
	(-0.16)	(2.91)**	(1.92)			
\$/DM	-28.19	0.03	0.12	.05	6.63**	61
	(-6.91)**	(2.11)*	(7.67)**			
\$/YN	-17.65	0.03	-0.07	.03	4.06*	61
	(-2.36)*	(4.35)**	(-1.82)			

The numbers in parentheses are the estimated t-statistics of the coefficients, * denotes rejection at the .05 level, and ** at the .01 level for the hypothesis that the coefficient is equal to zero. Overnight, monthly and quarterly ex post return regressions were estimated using overlapping daily annualized data; the regression disturbances are assumed to follow a one, twenty-one, or sixty-one day moving average process, respectively. The $\chi^2(1)$ statistic pertains to the hypothesis that the coefficients on the intervention variables are statistically identical.

All intervention observations are in millions of dollars. Bundesbank (I^b) intervention includes only those days on which the bank intervened unilaterally. The Fed did not intervene over this period. Coordinated intervention (I^c) observations are Bundesbank intervention observations on days that it intervened in the same direction as the Bank of Japan.

TABLE 9

$$r_{t-2,t+k} = \beta_0 + \beta_1 I^f_{t-3} + \beta_2 I^b_{t-3} + \beta_3 I^c_{t-3} + \upsilon_{t-2,t+k}$$

SAMPLE: February - June 1987

Spot	β_0	β_1	β_2	β_3	R^2	χ^2	MA
\$/DM	1.08	-0.13	0.04	-0.16	.02	2.26	1
	(0.11)	(-1.97)*	(0.42)	(-1.11)			
\$/YN	-12.07	-0.14	0.23	-0.17	.03	2.45	1
	(-1.09)	(-1.80)	(1.32)	(1.16)			
\$/DM	0.95	-0.06	0.08	-0.14	.09	10.14**	21
	(0.11)	(-2.46)*	(2.57)**	(-2.66)**			
\$/YN	-16.58	-0.05	0.22	-0.23	.08	6.91**	21
	(-0.69)	(-1.64)	(2.15)*	(-2.01)*			
\$/DM	6.29	0.01	0.04	-0.11	.03	4.01*	61
	(1.25)	(0.63)	(1.73)	(-1.97)*			
\$/YN	-0.83	-0.07	0.09	-0.13	.05	4.56*	61
	(-0.06)	(-1.55)	(1.84)	(-1.07)			

The numbers in parentheses are the estimated t-statistics of the coefficients, * denotes rejection at the .05 level, and ** at the .01 level for the hypothesis that the coefficient is equal to zero. Overnight, monthly and quarterly ex post return regressions were estimated using overlapping daily annualized data; the regression disturbances are assumed to follow a one, twenty-one, or sixty-one day moving average process, respectively. The $\chi^2(1)$ statistic pertains to the hypothesis that the coefficients on the intervention variables are statistically identical.

All intervention observations are in millions of dollars. Fed (I^f) and Bundesbank (I^b) intervention include only those days on which each bank intervened unilaterally. Coordinated intervention (I^c) observations are the sum of Fed and Bundesbank intervention observations on days that both banks intervened in the same direction as well as days that the Bank of Japan coordinated with either bank.

TABLE 10

$$r_{t-2,t+k} = \beta_0 + \beta_1 I^f_{t-3} + \beta_2 I^b_{t-3} + \beta_3 I^c_{t-3} + \upsilon_{t-2,t+k}$$

SAMPLE: October - December 1987

Spot	β_0	β_1	β_2	β_3	R^2	χ^2	MA
\$/DM	-26.73	0.55	-1.60	-0.03	.03	3.45	1
	(-1.39)	(3.01)**	(-0.68)	(-0.36)			
\$/YN	-32.52	0.51	-2.42	-0.02	.04	3.51	1
	(-1.79)	(2.74)**	(-0.77)	(-1.21)			
\$/DM	-38.84	0.35	-0.06	0.10	.08	4.91*	21
	(-2.17)*	(3.64)**	(-2.00)*	(1.96)*			
\$/YN	-55.08	0.31	-0.16	0.10	.09	4.64*	21
	(-4.86)**	(3.14)**	(-2.51)*	(2.84)**			
\$/DM	-4.29	0.11	-0.04	0.04	.10	4.37*	61
	(-0.55)	(2.23)*	(-0.25)	(2.45)*			
\$/YN	-20.72	0.10	-0.21	0.02	.08	5.79*	61
	(-3.01)**	(3.04)**	(-1.51)	(2.20)*			

The numbers in parentheses are the estimated t-statistics of the coefficients, * denotes rejection at the .05 level, and ** at the .01 level for the hypothesis that the coefficient is equal to zero. Overnight, monthly and quarterly ex post return regressions were estimated using overlapping daily annualized data; the regression disturbances are assumed to follow a one, twenty-one, or sixty-one day moving average process, respectively. The $\chi^2(1)$ statistic pertains to the hypothesis that the coefficients on the intervention variables are statistically identical.

All intervention observations are in millions of dollars. Fed (I^f) and Bundesbank (I^b) intervention include only those days on which each bank intervened unilaterally. Coordinated intervention (I^c) observations are the sum of Fed and Bundesbank intervention observations on days that both banks intervened in the same direction as well as days that the Bank of Japan coordinated with either bank.

TABLE 11

$$r_{t-2,t+k} = \beta_0 + \beta_1 I^f_{t-3} + \beta_2 I^b_{t-3} + \beta_3 I^c_{t-3} + \upsilon_{t-2,t+k}$$

SAMPLE: January 1985 - December 1987

Spot	β_0	β_1	β_2	β_3	R^2	χ^2	MA
\$/DM	-11.04	-0.01	-0.10	-0.01	.001	0.30	1
	(-2.72)**	(-2.12)*	(-1.51)	(-0.33)			
\$/YN	-12.06	-0.05	-0.02	-0.01	.001	0.14	1
	(-3.54)**	(-1.87)	(-1.31)	(-0.11)			
\$/DM	-21.89	0.05	-0.05	-0.01	.01	3.57	21
	(-3.73)**	(1.26)	(-1.07)	(-2.25)*			
\$/YN	-24.17	-0.03	-0.13	-0.01	.01	5.13*	21
	(-3.66)**	(-1.50)	(-3.13)**	(-2.16)*			
\$/DM	-20.95	-0.02	-0.03	-0.04	.06	4.35*	61
	(-5.66)**	(-2.10)*	(-1.14)	(-3.18)**			
\$/YN	-23.12	-0.03	-0.05	-0.01	.03	4.24*	61
	(-4.16)**	(-1.93)	(-1.84)	(-2.31)*			

The numbers in parentheses are the estimated t-statistics of the coefficients, * denotes rejection at the .05 level, and ** at the .01 level for the hypothesis that the coefficient is equal to zero. Overnight, monthly and quarterly ex post return regressions were estimated using overlapping daily annualized data; the regression disturbances are assumed to follow a one, twenty-one, or sixty-one day moving average process, respectively. The $\chi^2(1)$ statistic pertains to the hypothesis that the coefficients on the intervention variables are statistically identical.

All intervention observations are in millions of dollars. Fed (I^f) and Bundesbank (I^b) intervention include only those days on which each bank intervened unilaterally. Coordinated intervention (I^c) observations are the sum of Fed and Bundesbank intervention observations on days that both banks intervened in the same direction as well as days that the Bank of Japan coordinated with either bank.

1. While daily intervention data have not been made publically available, a number of authors have been granted special confidential access to the data. For example, the Working Group on Exchange Market Intervention established at the Versailles Summit in June 1982 was granted access to daily intervention data from England, Germany, Japan, Canada, France and the U.S. for the period 1978-1982. Staff Studies 126-135 published by the Board of Governors of the Federal Reserve System present some of the Working Group's findings.

2. See Mussa (1981) for an early description of the potential signalling role of official sterilized intervention policy.

3. Dominguez (1988) presents empirical support for the hypothesis that sterilized intervention by the Fed in certain periods is a leading indicator of future (unanticipated) Fed monetary policy.

4. Stein (1989) presents a "cheap talk" model to explain why under certain conditions (imprecise) verbal announcements by the Fed about future monetary policy intentions will be credible. The existence of a "cheap talk" equilibrium, however, should not preclude the additional use of intervention policy to convey monetary policy information to the market.

5. More specifically, given that the market does not know whether the Fed or the Treasury Department instigated the period t intervention.

6. The following example draws heavily from sections in Dominguez (1988).

7. See Mussa (1976) for the derivation of equation (2).

8. Uncovered interest parity is assumed in the derivation of equation (2). Here, therefore, I am explicitly assuming away the existence of a risk premium between foreign and domestic assets.

9. There exist a number of games in the literature which model the market's and the central bank's strategy set in similar formulations to this. See, for example, Barro and Gordon, 1983; Backus and Driffill, 1985; and Barro, 1986.

10. See Canzoneri (1985) and Cukierman and Meltzer (1986) for examples of models of incomplete (monetary) policy control. Cukierman and Meltzer show that in some circumstances imperfect policy control can be advantageous for policymakers. If the public cannot distinguish between changes in policy objectives and control errors, the policymaker is more likely to be able to surprise the public. In contrast, Canzoneri's reputational resolution to the problem of imperfect policy control leads to a worse off position for policymakers. Canzoneri's solution concept depends on the assumption that the market can coordinate on a threshold value for observed deviations from zero (inflation) which will deter the Fed from cheating. In equilibrium, the Fed will never cheat but in periods of large control errors the market will nevertheless punish the Fed by reverting to high inflation expectations.

11. Canzoneri (1985, p.1061) also brings up this possible resolution.

12. Here coordinated intervention is assumed to be simultaneous (same day) sterilized intervention operations by more than one central bank in support of (or against) the same currency. For example, a coordinated dollar support intervention operation would involve the purchase of dollar denominated assets with foreign currency denominated assets by more than one central bank. Over the period examined, coordinated operations as defined above generally coincided with periods following well-publicized G-5 and G-7 meetings.

13. Formally, the assumption here is that the game between the central bank and the market is repeated and both players have memories. In any given period, therefore, the players take into account the future consequences of their current actions (see Kreps and Wilson, 1982).

14. If we assume a one-for-one relationship between a given monetary policy and intervention operations, then the market will learn that the total monetary policy change was not consistent with the total amount of intervention when one or more central banks do not follow through. The market will not necessarily, however, be able to learn which central bank(s) free-rode.

15. A number of authors have suggested in analogous cooperative agreements that the players may agree on a trigger mechanism to deter any given player from cheating (see, for example, Green and Porter, 1984; Rotemberg and Saloner, 1986). In this context, if coordinating central banks cannot directly observe which of their members has shirked, they may decline to coordinate intervention operations for a prespecified period of time whenever there is evidence that total monetary policy changes are not consistent with total intervention operations.

16. Supporting evidence on this assertion is presented in the next section.

17. The agreement with the Bundesbank requires presentation of results in such a way as to maintain the confidentiality of the data.

18. Wall Street Journal, various issues from January 17, 1985 to February 1, 1985. On occasion central banks intervene on each other's behalf. It is, therefore, possible that over this period the Fed did intervene in the market but on behalf of another central bank. Unfortunately one cannot deduce from available information whether this was what in fact occurred during this period.

19. Wall Street Journal, various issues from February 7, 1985 to March 5, 1985.

20. Wall Street Journal and the London Financial Times, various issues from September 23, 1985 through November 15, 1985.

21. Funabashi (1988) reports that the U.S. attempted to convince the Japanese to coordinate discount rate reductions in the summer of 1986. The Bank of Japan apparently resisted the U.S. pressure in order to maintain the appearance of political independence. The Japanese general election was held in early July, and a discount rate cut might have been perceived as

"helping the Liberal Democratic Party leaders in the election" (p. 51).

22. The Bank of Japan discount rate cut was reportedly, in part, a result of the October Baker-Miyazawa Accord, "which traded assurances by Japan to cut the discount rate and initiate tax reform for those by the U.S. to stop depreciating the dollar". (Funabashi, 1988, p. 53)

23. Wall Street Journal and London Financial Times, various issues, May 6 through May 9, 1986.

24. Wall Street Journal, January 13 and January 19, 1987.

25. Wall Street Journal, March 24 through April 3, 1987.

26. Reported source: Nihon Keizai Shinbun.

27. Obstfeld (1988) describes that the "[U.S.] growth rate of M2 was held below the bottom of its target interval," while "Germany's central bank money stock was allowed to overshoot its 1987 target growth rate of 3 to 6 percent by a considerable margin" and "Japan's money supply grew at its fastest rate of the decade" (p. 17).

28. Wall Street Journal, August 20 through September 4, 1987 and the Federal Reserve Bank of New York Quarterly Review, Winter 1987-88.

29. Wall Street Journal, various issues, October 1987 through December 1987.

30. See Loopesko (1984) and Rogoff (1983) for further discussion of these points.

31. s_t is defined as the price of domestic currency in terms of foreign currency; $/DM.

32. I am grateful to Dale Henderson for stressing this point to me.

33. In Dominguez and Frankel (1989) using a two equation system, we focus on disentangling the current period portfolio effect and the signalling effect of central bank intervention operations.

34. If intervention is either not fully observed or not fully believed, I_t may be correlated with the spot rate forecast error.

35. The overnight eurocurrency interest rates are observed at 3:30 a.m. EST while the one-month and three-month eurocurrency interest rates are observed at noon EST. Intervention observed prior to noon on day t-2, therefore, could be included in the longer-horizon regressions. Because I do not have intraday information on the timing of intervention operations, however, only day t-3 intervention is included in the regressions. (Latter lags of both unilateral and coordinated intervention were also included in the regressions. Generally the lags were statistically insignificant and are, therefore, not included in the results presented.)

36. The regressions were estimated using Hansen's (1982) heteroskedasticity and autocorrelation consistent asymptotic covariance matrix, assuming a moving average process of order 1, 21, or 61 for the overnight, one-month and three-month errors, respectively.

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