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Does Foreign Exchange Intervention Matter? Disentangling the Portfolio and Expectations Effects

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Does Foreign Exchange Intervention Matter ?

Disentangling the Portfolio and Expectations Effects

ABSTRACT

The time is ripe for a re-examination of the question whether foreign exchange intervention can affect the exchange rate. We attempt to isolate two distinct effects: the portfolio effect, whereby an increase in the supply of marks must reduce the dollar/mark rate (for given expected rates of return) and the additional expectations effect, whereby intervention that is publicly known may alter investors' expectations of the future exchange rate, which will feed back to the current equilibrium price. We estimate a system consisting of two equations, one describing investors' portfolio behavior and the other their formation of expectations, where the two endogenous variables are the current spot rate and investors' expectation of the future spot rate. We use new data sources: actual daily data on intervention by the Fed, the Bundesbank, and the Swiss National Bank, newspaper stories on exchange rate policy announcements and known intervention, and survey data on investors' expectations. We find evidence of both an expectations effect and a portfolio effect. The statistical significance of the portfolio effect suggests that even sterilized intervention may have had positive effects during the sample period. For the magnitude of the effects to be large requires that intervention be publicly known.

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I. Introduction

Until recently, there was an unusual degree of consensus among economists, and among policy-makers and participants in the financial markets as well, that intervention by central banks in the foreign exchange market did not offer an effective or lasting instrument for affecting the exchange rate, at least not independently of monetary policy. The 1982 G-7 economic summit at Versailles commissioned a study of intervention, known as the Jurgenson report, which found that the effects were small and transitory at most.[1]

We think that the time is ripe for new statistical testing of the question. Many policy-makers and foreign exchange traders believe that the intervention operations that have taken place since the Plaza Agreement of September 1985 have had an effect, especially when operations are coordinated. Moreover, the theoretical case against the effectiveness of intervention is not as clear as a reading of the economics literature might suggest.

The academic literature is predicated on the distinction between intervention operations that are sterilized and those that are allowed to affect the money supply. In this paper we do not concentrate on this distinction. We study the intervention operations that actually took place between 1982 and 1988, regardless of whether they were sterilized. But we do begin in section II with a review of the issues involved.[2]

In this paper we focus on the two possible channels through which intervention (whether sterilized or not) can influence the foreign exchange rate: the portfolio and the expectations channels. Intervention can, even if sterilized, influence exchange rates through the *portfolio channel* provided foreign and domestic bonds are considered imperfect substitutes in investor's portfolios. Intervention

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[1] Many of the econometric results, finding little or no effect, were reported in Rogoff (1984) and Henderson and Sampson (1983).

[2] For authoritative statements, see Henderson (1984) or Obstfeld (1990).

operations that, for example, increase the current relative supply of mark to dollar assets that private investors are obliged to accept into their portfolios, will force a decrease in the relative price of mark assets.[3] Intervention can also influence exchange rates, regardless of whether foreign and domestic bonds are imperfect substitutes, through the *expectations channel*. The public information that central banks are intervening in support of a currency (or are planning to intervene in the future) may, under certain conditions, cause speculators to expect an increase in the price of that currency in the future. Speculators react to this information by buying the currency today, bringing about the change in the exchange rate today.

While some previous empirical studies of foreign exchange intervention operations have found evidence from daily data that central banks have had a statistically significant effect on exchange rates (Loopesko (1984) and Dominguez (1987,1990)), the studies were not able to distinguish whether the effect was coming through the portfolio or the expectations channel. The goal of this study is to disentangle the influence of the two potential channels during the most recent experience with central bank intervention operations. The empirical work was made possible by agreements with the U.S. Board of Governors of the Federal Reserve System, the German Bundesbank and the Swiss National Bank allowing use of previously unavailable daily intervention data over the period 1982-1988.[4]

In addition to actual intervention data we introduce information on investors' exchange rate expectations and news of exchange rate policy changes. These data allow us to estimate a two-equation system: an expectations-formation equation and a portfolio-diversification equation. Our conclusion, based on our findings for the dollar/mark exchange rate, is that *both* the portfolio and expectations channels were effective during the sample period.

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[3] The exchange rate reaction to an increase in the relative supply of outside foreign assets may be reduced if there is an increase in their expected rate of return that induces a corresponding increase in demand.

[4] With the understanding that the Bundesbank data be used under certain restrictions.

II. The Standard Theory: Sterilized Versus Nonsterilized Intervention

There are three standard arguments as to why the effects of intervention should be very small: the small size of intervention relative to the total market, Ricardian equivalence, and high international asset substitutability. The latter two, if valid, imply that the effects of sterilized intervention should be small or zero. The first implies that the effects of intervention should be relatively small even if nonsterilized.

While the scale of intervention operations in recent years is unprecedented, it remains small relative to the stocks or flows in the foreign exchange market. The total net stocks of currencies that could in theory be brought into the foreign exchange market at any time are enormous. U.S. M2, for example, currently exceeds $3,000 billion. By comparison the average coordinated intervention operation in support of the dollar during the period January 1985 to December 1988 involved $278.5 million, while the average coordinated sale of dollars involved $373.2 million.

Standard models of exchange rate determination at least allow non-sterilized intervention to have an effect on the exchange rate in proportion to the change in the relative supplies of domestic and foreign money, just as any other form of monetary policy does. The idea that *sterilized* intervention operations have any effect at all, on the other hand, is less accepted. Those that conclude that sterilized intervention can have no effect, base their arguments on either "Ricardian equivalence" or the high substitutability between foreign and domestic bonds. We consider these two arguments in turn.

If government bonds imply the public liability of future taxation to service them, and if investors look far into the future, optimize intertemporally, and internalize the welfare of future generations, then government bonds are not true "outside" assets. If government bonds are not true outside assets, it follows that swaps in their currency composition have no effect on the foreign exchange market equilibrium.[5] There are many arguments against Ricardian equivalence, both theoretical and empirical; it is the sort of proposition that one would like to test rather than impose.

Even if it is granted that government bonds are "outside" assets, the second line of argument against the effectiveness of sterilized intervention is that domestic and foreign bonds are perfect substitutes, so that changes in their relative supply have no effect. A less extreme version of the argument is that substitutability is very high, even if not literally infinite, so that intervention (in the relevant magnitudes) can have very little effect quantitatively. One point that is often missed is that, even if it is true that the effect of sterilized intervention on the differential in rates of return is very close to zero, the effect on the *level* of the exchange rate may be relatively large. As long as changes in bond supplies matter, they should have a proportionate effect on the exchange rate (which is the relative price of foreign bonds, in the portfolio model, not just the relative price of money) in the absence of changes in the risk premium, no matter how high the degree of substitutability.[6]

Even for those who hold either to Ricardian equivalence or to the assumption that foreign and domestic bonds are perfect substitutes, there remains a channel whereby sterilized intervention can have an effect on exchange rates. Intervention operations can effect exchange rates through the *signalling channel* if they are used by central banks as a means of conveying (or signalling) to the market inside information about future monetary policy. If market participants believe central bank intervention signals, then even though today's money supply has not changed, expectations of future monetary policy will change. When the market revises its expectations of future money supplies, it also revises its expectations of the future spot exchange rate, which brings about a change in the current rate. The signalling channel is thus one example of the expectations channel mentioned in the

[5] For example, Frankel (1979).

[6] Frankel (1985, 213-215). Once effects on the expected future rate of change in the exchange rate are taken into account, the exchange-rate effect of a one percent change in the relative supply of foreign assets could be either more or less than one percent.

preceding section.[7]

It is known that daily intervention by the Federal Reserve Bank of New York is fully and automatically sterilized: the foreign exchange trading room immediately reports its dollar sales to the open market trading room, which then buys that many fewer bonds, so that the daily money supply is precisely what it would have been if no intervention had occurred. This leaves open the possibility that a Federal Reserve Board decision to try to influence the exchange rate will result in both intervention and a different money supply, say on a monthly basis. The Bundesbank and other smaller central banks are less prone to complete sterilization than are the U.S. authorities. To the extent that the market learns about central banks' future monetary policy intentions by observing intervention, that is a case of the signalling hypothesis.[8] To summarize, sterilized intervention could have an effect on the exchange rate *either* if domestic and foreign bonds are imperfectly substitutable outside assets, *or* if public knowledge of intervention today alters expectations of future policy. Both of these possibilities are empirical questions, and are tested in this paper.

III. The Standard Econometrics

The portfolio-balance theory says that investors diversify their holdings among domestic and foreign assets -- including bonds, if we do not rule them out *a priori* on the grounds of Ricardian equivalence -- as functions of expected rates of return. Measuring the expected rates of return requires both data on interest rates, which are readily available, and data on investors' expectations of exchange rate changes, which are not. Some early tests assumed away this problem by setting

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[7] An influential statement is Mussa (1981).

[8] Trying to test the signalling hypothesis by observing what happens to the money supply *ex post*, in finite samples, would be a dubious way of approaching the question. Intervention is at best but one of many factors relevant for determining the future money supply; in finite samples the relationship might not be detectable.

expected depreciation equal to zero, and simply looking for a relationship between the level of the exchange rate and the supplies of domestic and foreign assets.[9] But, even aside from the expectations problem, these studies were plagued by a second econometric difficulty: simultaneity.

A regression specification that avoids this simultaneity problem takes the dependent variable to be the differential in expected *rates of return* between domestic and foreign assets, rather than the *level* of the exchange rate, and uses *ex post* changes in the exchange rate to measure investors' expectations by invoking the methodology of rational expectations.[10] Begin by considering the asset-demand function that determines the portfolio share x that is allocated to mark assets, as a function of the risk premium, rp:

$$x_t = a + b rp_t \tag{1}$$

where $rp_t = i^{DM}_{t,k} - i^{\$}_{t,k} + \Delta s^e_{t,k}$, $i^{DM}_{t,k}$ is the k-period-ahead euroDM interest rate, $i^{\$}_{t,k}$ is the k-period-ahead eurodollar interest rate, and $\Delta s^e_{t,k}$ is the expected k-period-ahead change in the log of the dollar/mark spot exchange rate.[11] Now invert the equation to express the risk premium as a function of the aggregate supplies of assets that must be held in market equilibrium:

$$rp_t = -ab^{-1} + b^{-1}x_t \tag{2}$$

If domestic and foreign assets are perfect substitutes, then b is infinite, the coefficient b^{-1} in equation

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[9] For example, Branson, Haltunnen and Masson (1977). A more recent attempt, with better measures of asset supplies, is Golub (1989).

[10] See Dooley and Isard (1983) and Frankel (1982a).

[11] x_t is defined as:

$$x_t = \frac{S_t M_t}{W_t}$$

where S_t is the \$/DM spot exchange rate, M_t is the total quantity of mark assets in investors' portfolios (denominated in marks), and W_t is total wealth (denominated in dollars).

(2) is zero, and changes in assets supplies have no effect on the risk premium. According to the rational expectations methodology, the *ex post* change in the exchange rate, $\Delta s_{t,k}$, can be substituted for the expected change because the only difference is a forecast error, $\epsilon_{t,k}$, that is independent of x_t (and of all other variables that are contemporaneously observable). So we can run a regression on the resulting equation.

$$i_{t,k}^{DM} - i_{t,k}^{\$} + \Delta s_{t,k} = -ab^{-1} + b^{-1}x_t + \epsilon_{t,k} \tag{3}$$

The regression estimate of the coefficient b^{-1} in equation (3) is generally found to be insignificantly different from zero, a failure to reject the joint null hypothesis of perfect substitutability and rational expectations.[12] One possible explanation for this result is that there is insufficient power in the test. One way of bringing additional information to bear is to assume that investors choose their portfolio allocation, x_t, to optimize a function of the mean and variance of end-of-period wealth, from which it follows that equation (1) holds with a constraint imposed: the coefficient is inversely proportionate to v, the variance of the return differential.[13] In the case where goods prices are nonstochastic, v is simply the variance of exchange rate changes, and a, the minimum-variance portfolio, is closely related to the share of German goods in the consumption basket of the investor. The inverted form, equation (3), becomes:

$$i_{t,k}^{DM} - i_{t,k}^{\$} + \Delta s_{t,k} = -a(rv) + (rv)x_t + \epsilon_{t,k} \tag{4}$$

where we have defined r to be the constant of proportionality, which is the coefficient of relative risk-

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[12] At least that is what studies find when assets supplies (x_t) are computed to include not only foreign exchange intervention, but also government budget deficits, and other forms of asset creation that usually dwarf intervention in magnitude. E.g., Dooley and Isard (1983), Frankel (1982a), and Boothe, Clinton, Cote, and Longworth (1985). Studies that focus more narrowly on daily changes in asset supplies through foreign exchange intervention do sometimes find an effect on the differential in rates of return: Loopesko (1984) and Dominguez (1990).

[13] References include Kouri and de Macedo (1978), Dornbusch (1983), Frankel (1982b), Adler and Dumas (1983), and Branson and Henderson (1985).

aversion.[14]

The rational expectations methodology assumes that the regression error and forecast error are identical, so that the equation can be estimated subject to the constraint that the coefficient is proportionate to the variance of the error term. Despite the presumed increase in power, the empirical literature generally fails to reject the null hypothesis of perfect substitutability, which is now interpreted as risk-neutrality ($r=0$).[15] This finding is the same when the variance, v, is allowed to vary over time, as in the popular ARCH models.[16]

Notwithstanding the elegance of the rational expectations methodology, econometric problems remain in the estimation of an equation like (4), and they may be responsible for the results. The possibility of simultaneity bias arises if the regression error includes either measurement error in x, or an error term in the asset demand equation (1). Addressing this possible source of simultaneity bias in the estimation of portfolio-balance equations is one of the several goals of this study.

IV. Expectations, and Our Two-Equation System

The second set of econometric difficulties with estimating equation (4) concern the measurement of the expectations variable in the risk premium. Even if the rational expectations methodology is valid, i.e, the forecast error, $\epsilon_{t,k}$, is uncorrelated in-sample with all other contemporaneous variables, there is the undeniable problem that the magnitude of the error term is extremely large. This could lead to low power: a failure to reject risk-neutrality even though the

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[14] This is the simplified form of the equation in Dornbusch (1983), where a is interpreted as equal to the share of German goods in the consumption basket of the investor in question. Krugman (1981) pointed out that a correct treatment of the convexity term that arises from Jensen's Inequality makes the constant term $-(ra - a + 1/2)v$, instead of $-a(rv)$. In what follows, the variable in the regression is v in either case, and it is only the interpretation of its coefficient that is affected.

[15] Frankel (1982b).

[16] For example, Engel and Rodrigues (1989) and Giovannini and Jorion (1989).

coefficient of risk-aversion is in reality greater than zero. Furthermore, there is reason to think that *ex post* changes in the exchange rate are a particularly bad measure of what investors expected *ex ante*. Independent estimates of market forecasts of exchange rates, drawn from survey data, suggest that expected depreciation varies closely with the forward discount, while *ex post* changes in the exchange rate do not, and tend if anything to lie in precisely the opposite direction.[17] We choose to measure expectations by using the survey data rather than ex post changes, on the grounds that (a) the evidence of bias is damaging for the latter, and (b) the magnitude of the measurement error is almost certainly larger for ex post changes than for the survey data.

Thus the equation now becomes:

$$i_{t,k}^{DM} - i_{t,k}^{\$} + \Delta\hat{s}_{t,k}^{e} = \beta_0 + \beta_1 v_t + \beta_2 v_t x_t + u_{t,k} \tag{5}$$

where $\Delta\hat{s}_{t,k}^{e}$ is the expected change in the spot rate between period t and t+k measured by the survey data, $\beta_1=-ar$, $\beta_2=r$ and the error term, $u_{t,k}$, is now meant to reflect any measurement error in the data, rather than investors' forecasting errors.[18] In light of the many studies concluding that exchange rate changes have variances that are autocorrelated over time, we choose to estimate the variance, v_t, as the daily variance of exchange rate changes over the preceding week. To our knowledge, despite the spread of the use of the survey data, they have not been used together with data on asset supplies and variances to estimate a risk premium equation.

Equation (5), which captures the portfolio channel through which intervention may have an effect, is only one of two equations in the system we estimate. The other is an equation of expectations formation, where the dependent variable, the change in investors' forecasts of the

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[17] Froot and Frankel (1989).

[18] If the measurement error is in the survey data OLS estimates of (5) will be appropriate. However, if the asset data are measured with error or if asset demands are given by the mean-variance specification plus an error term, then the regression will be subject to simultaneity bias and (5) should be estimated using instrumental variables.

expected future spot rate, is measured using the survey data.

Although a number of different surveys at different horizons are available, we use here the 4-week ahead survey forecasts conducted by Money Market Services, International, for the period October 24, 1984 to December 30, 1988.[19] Unlike some other surveys, it is conducted on a weekly basis (since July 1985; before that it was conducted every two weeks). In addition, we report results for an earlier period November 17, 1982, to October 10, 1984, when the survey was conducted every two weeks and pertains to 3-month ahead forecasts. One might expect that intervention would have a greater effect in the later period, since the Reagan Administration's firm commitment to free-floating began to change when Donald Regan and Beryl Sprinkel were succeeded at the Treasury by James Baker and Richard Darman in January 1985 and when the Plaza Agreement followed in September.

The second equation in our system is:

$$(\hat{s}^e_{t,k} - \hat{s}^e_{t-j,k}) = \alpha_0 + \alpha_1(s_t - s_{t-j}) + \alpha_2(s_t - \hat{s}^e_{t-j,k}) + \alpha_3 ANNOC_t + \alpha_4 REPINT_t + \alpha_5 SECINT_t + \varepsilon_t \tag{6}$$

where $(\hat{s}^e_{t,k} - \hat{s}^e_{t-j,k})$ is the revision in the log of the MMS survey prediction of the k-period ahead dollar/mark spot rate from time t-j to time t, s_{t-j} is the log of the spot rate on the day of the last MMS survey, $ANNOC_t$ and $REPINT_t$ are (1,0,-1) dummy variables which capture reports of exchange rate policy news since the last survey date, $SECINT_t$ is a (1,0,-1) dummy variable for non-reported intervention operations since the last survey date and ε_t is the error term[20].

Our expectation equation specification is general in that it allows for both extrapolative and adaptive expectations. At the 4-week horizon, respondents have been observed to put negative weight

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[19] These data were introduced in another context by Dominguez (1986) and Frankel and Froot (1987).

[20] Equation (6) does not suffer from the overlapping observation problem familiar from studies of bias in forecasts of future spot rates, because the dependent variable is the change in expectations, not the prediction error.

on the lagged spot rate and more-than-unit weight on the contemporaneous spot rate, so that they are extrapolating the recent trend into the future to get their forecast.[21] α_1 is our extrapolative parameter. Bandwagon expectations are the special case $\alpha_1 > 0$ and $\alpha_2 = 1$. Previous work has also found evidence that respondents form their predictions adaptively, putting positive weight on the lagged survey prediction (Frankel and Froot (1987)). $(1-\alpha_2)$ is our speed of adaptation parameter. Adaptive expectations are the special case $\alpha_1 = 0$ and $\alpha_2 < 1$. Static expectations are the special case $\alpha_1 = 0$, $\alpha_2 = 1$. Expectations are stabilizing overall if $\alpha_1 + \alpha_2 < 1$, and destabilizing overall if $\alpha_1 + \alpha_2 > 1$.

We also include two news variables in our expectations equation in order to capture information appearing in the newspaper about changes in central bank's exchange rate policy since the last survey date. $ANNOC_t$ is set equal to +1 if there were central bank announcements in support of the dollar (including, for example, announcements of G-7 meetings to deal with dollar weakness), -1 if there were official announcements against the dollar, and 0 if there were no such announcements. $REPINT_t$ is set equal to +1 if there were reports of central bank intervention in support of the dollar, -1 if there were reports of intervention against the dollar, and 0 if there were no such reports. The fifth independent variable included in the regression is secret intervention, denoted $SECINT_t$. $SECINT_t$ is set equal to +1 if there were no reports of intervention when a central bank in fact intervened in support of the dollar, -1 if interventions against the dollar were not reported, and 0 otherwise. We expect the two news variables, $ANNOC_t$ and $REPINT_t$ to have a negative effect on expectations of the future dollar/mark rate. If non-reported intervention is truly secret, we expect the

[21] Frankel and Froot (1990). Models based on technical analysis (which often essentially extrapolate past trends) are more widely-used by professional forecasting services, especially at short horizons, than models based on macroeconomic fundamentals (which could be viewed as regressive expectations). Of 27 foreign exchange forecasting services reviewed by Euromoney magazine in 1988, 12 used only technical models, only 1 relied exclusively on fundamentals models, and 12 used a combination of the two techniques.

coefficient on $SECINT_t$, α_5, to be zero.

Equations (5) and (6) make up our two-equation system. The two endogenous variables are the current period spot rate and survey expectation of the future spot rate. We are able to deal with the potential simultaneity problems in both equations by using the exogenous variables from each equation as instruments for the other equation. The instruments for equation (5) include last period's spot exchange rate, s_{t-j}, last period's survey expectation of the future spot rate, $\hat{s}^e_{t-j,k}$, and the news variables, $ANNOC_t$ and $REPINT_t$, from equation (6). The instruments for equation (6) include the variance of spot changes since the last survey date, v_t, and the total quantity of marks sold in foreign exchange intervention (measured in marks), IDM_t, from equation (5). This instrumental variable procedure is equivalent to a two-stage-least-squares procedure.

V. The Estimation Results

Before examining our two-equation system estimates, it is useful to check whether movements in spot exchange rates are indeed correlated with our constructed news variables. The upper half of Table 1 presents estimates from a regression of the change in the spot rate over the period in which news occurs on the news variables and secret intervention. Although the low R^2s suggest that a relatively small proportion of the variance in exchange rate changes are explained by the news variables, in the latter subperiod both $ANNOC_t$ and $REPINT_t$ are statistically significant and correctly signed. Official announcements and reports of intervention in support of the dollar during a given week are positively associated with dollar appreciation over the week. If one wished to interpret these preliminary regressions causally, as a sort of reduced form, they would say that reports of intervention in support of the dollar are associated with an estimated appreciation of 0.4%. The dummy variable that captures secret intervention, $SECINT_t$ is statistically insignificant over the two subperiods, as expected.

The lower half of Table 1 presents estimates over the latter subperiod, for a regression against intervention magnitudes, distinguished according to whether intervention was reported.[22] Although the coefficient on $ANNOC_t$ continues to be significant and correctly signed, reported intervention, $REPINT_t$, is significant and correctly signed only when it is cumulated from the beginning of the sample period.[23] This suggests that even when intervention is known to be taking place, market participants are unaware of (or unconcerned with) the magnitude of the operation.

We turn now to estimates of our structural two-equation system. Table 2 presents the expectations equation regression results for the early sample period. News reports appear to have had no effect on expectations in the early period 1982 through 1984. However, the instrumental variable estimates for the same regression over the 1985-1988 subperiod, presented in Table 3, indicate a marked change in regime. The coefficients on the news variables appear with the correct sign and are statistically significant in all the regressions for the latter sample: newspaper reports of exchange rate policy announcements and central bank intervention in support of the dollar tend to lower expectations of the future dollar/mark exchange rate. The average effect of reported intervention on the 1-month ahead expectations of the dollar/mark exchange rate ranged between .4 and .6 percent. The effect of official announcements was twice as large, ranging between .9 and 1.1 percent.

In Table 3 the coefficient on the lagged spot rate, $-\alpha_1$, and the coefficient on the lagged expectation, $(1-\alpha_2)$, are each statistically different from both zero and one. In other words, there is

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[22] Weekly exchange rate change regression estimates using intervention magnitudes over the early sample period are available from the authors upon request.

[23] The daily intervention data provided by the central banks measure official net purchases or sales of dollars in the foreign exchange market. Central bank interest payments and receipts on reserve assets are not included in the data. Intervention is measured in three ways in these regressions. "One-day" intervention is Fed and Bundesbank purchases of dollars on the day before the survey. "Two-week" or "one-week" intervention is cumulated between survey dates, so that it measures total Fed and Bundesbank dollar purchases since the last survey. "Cumulative" intervention is cumulated from the beginning of the sample period and therefore measures the relative stock supplies of outside assets denominated in dollar and mark currencies.

evidence of extrapolative behavior *and* gradual adaptation. Expectations are overall neither stabilizing nor destabilizing.

We now turn to the risk-premium, the portfolio equation (5). The intervention variable (defined as x_t in the text) is measured as a percent of total wealth W_t in Tables 4 and 5.[24] Wealth, W_t, is measured as the total supply of U.S. and German federal government debt that has been issued and so must be held in investors' portfolios.[25] Further, we disaggregate the intervention variable by including Fed and Bundesbank intervention separately. The three separate sets of regressions, therefore, include intervention measured as the sum of Bundesbank and Fed intervention, intervention by the Bundesbank, and intervention by the Fed.

The coefficient on the variance of spot changes is statistically significant in all the regressions over the latter subperiod, presented in Table 5. This finding is itself of interest. But our primary focus here is on the effect of intervention. As discussed earlier, single-equation estimates of the portfolio regression are vulnerable to concerns of simultaneity bias if there are either measurement errors in the asset supply data or error terms in the asset demand equation. In the instrumental variable regressions over the latter subperiod, October 1984 to December 1988, the coefficient on intervention is generally statistically significant, regardless of how it is measured.

The finding that the instrumented coefficients on the Fed and Bundesbank intervention variables are statistically significant in equations (5) (for the latter sample period) implies that

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[24] Estimates of equation (5) with intervention measured in millions of dollars, rather than as a percent of total wealth, are available from the authors upon request. The estimated coefficients on both the variance and intervention variables are qualitatively similar (in terms of statistical significance) to those reported in Tables 4 and 5.

[25] The U.S. wealth proxy is from various issues of the Treasury Bulletin, Table FD-1. Summary of Federal Debt, "Total Securities Held by the Public". The German wealth proxy is from various issues of Deutsche Bundesbank Monthly Report, VII. Public Finance, Table 9, Indebtedness of the Federal Government, "Total", and was translated into dollars using end-of-month IFS exchange rates. Both data series were converted from monthly to weekly series using linear extrapolation.

intervention, even if sterilized, had an effect. If mark and dollar assets were perfect substitutes, then the coefficient should have been zero: changes in asset supplies would have no effect on the risk premium.

In order to check that the results reported in the tables are robust we re-estimated equation (5) (a) excluding outliers, (b) without the variance constraint, and (c) using intervention data from the Swiss National Bank. In order to examine the influence of outliers on the results we searched for regression residuals from equation (5) that were greater than 2.5 times the standard error of the regression estimate. Over the full sample period two observations met the criterion, September 25, 1985 (the second trading day after the Plaza Accord) and March 5, 1986. In regressions excluding the two outlying observations the coefficient estimates on the intervention variable in (5) are virtually identical to those reported in the tables.[26] In a second set of tests we examine the sensitivity of the reported results to the mean-variance specification by re-estimating (5) without constraining the variance and intervention to enter multiplicatively. The estimated coefficients on the intervention variables are qualitatively identical (in terms of statistical significance) to those reported in the tables over both sample periods.[27]

In Table 6 we present estimates of equation (5) using intervention data from the Swiss National Bank (SNB). The Fed and the Bundesbank are two of the more economically powerful central banks; this additional set of tests allows us to examine whether operations by a smaller central bank are equally as effective. Our choice of countries and sample period was dictated by the availability of daily intervention data. The sample period in Table 6 is January 1987 through

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[26] The coefficient estimates on the variance terms, however, both decreased in size and are no longer statistically significant except when intervention is cumulated from the beginning of the sample period.

[27] Regression results excluding outliers and the variance constraint are available from the authors upon request.

December 1989 because the SNB was not an active participant in the foreign exchange market until 1987. It is not possible in the Swiss case to distinguish between reported and actual intervention. The single-equation regression results presented in Table 6 indicate that only when Fed and SNB intervention are combined is the variable statistically significant.[28]

VI. A Summary of the Quantitative Effects

Our two-equation system estimates indicate that official announcements about exchange rate policy and reports of intervention influence exchange rate expectations; and intervention operations influence the risk premium. In this section, we make use of some of the parameter estimates from our regression analyses as an example to calculate the effect of intervention on the $/DM exchange rate. We assume in these calculations that interest rates in the United States and Germany are held constant. If interest rates were allowed to vary, then the effects in a general portfolio-balance model might be either smaller or larger than those reported here. Sterilized intervention in support of the dollar, for example, might drive down dollar interest rates, reducing the demand for dollar assets and thereby mitigating the effect on the exchange rate.

First, consider the effect of intervention on the exchange rate if it is not known publicly. We begin with the baseline case where expectations are assumed to be neither extrapolative nor adaptive. Under these assumptions, the intervention has no effect at all on the risk premium. If the risk premium does not change, then equation (5) indicates that x_t does not change.

Recall that x_t, the portfolio share that is allocated to mark assets, is defined as S_tM_t/W_t. Analogously, the portfolio share that is allocated to dollar assets, $1-x_t$, is defined as D_t/W_t, where D_t is the total quantity of dollar assets held in investors' portfolios and $S_tM_t + D_t = W_t$. S_t, the spot

[28] Recall that OLS estimates of the risk premium equation are unbiased if (random) measurement error in the survey data is assumed to be the sole source of regression error.

exchange rate, is thus equal to:

$$S_t = \frac{D_t}{M_t} \frac{x_t}{1 - x_t} \tag{7}$$

From this expression for S_t, it is evident that the effect of intervention on the exchange rate is in proportion to the supply of mark assets in investors' portfolios. What is the effect of 100 million dollars of intervention? If we are thinking of the special case where only non-sterilized intervention matters, then the definition of M_t is relatively clear: total reserve money supplied to the banking system by the Bundesbank, which, as of the end of 1988, was \$ 124.19 billion.[29] Thus the effect is only .081 per cent. If we are thinking of sterilized intervention, then the effect of 100 million dollars of intervention will be even smaller, because M_t is the total supply of mark-denominated bonds, rather than just money. It should be emphasized that these small magnitudes derive solely from the small size of intervention relative to the relevant denominators, and not from any parameters that we have estimated. But it is worth recalling again that this effect, even if small, is nonetheless not zero, according to our rejection of perfect substitutability between mark and dollar bonds.

To get large effects on the exchange rate, we need the public to hear the news of the intervention. Our second experiment considers the effect of such information in isolation, as reflected in the coefficient on the reported intervention dummy variable, even if such intervention is in fact not taking place. If intervention actually takes place *and* is publicly reported, then its total effect would be the sum of the (small) effect reported in the preceding paragraph, plus the (much larger) effect reported in the next paragraph. Under our baseline case (no change in interest rates and no extrapolative or adaptive expectations), the risk premium simply changes by the coefficient of $REPINT_t$ in the expectation equation. Such a change in the risk premium will have a large effect on

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[29] DM 221.1 billion / 1.7803 DM/\$. These numbers are from line 14 and line ae, respectively, for Germany in the International Financial Statistics.

the demand for mark versus dollar assets.

In order to calculate the effect of a report of intervention on the exchange rate we need to return to equation (7). The log form of equation (7) is:

$$\log S_t = \log\left(\frac{D_t}{M_t}\right) + \log(x_t) - \log(1 - x_t) \tag{8}$$

The derivative of the log of the spot exchange rate with respect to reported intervention can be calculated using (8) and the knowledge that x_t is a function of the risk premium, rp_t, which is in turn a function of expected depreciation, $\Delta\hat{s}^e_{t,k}$, which is in turn a function of the news variables, $REPINT_t$ and $ANNOC_t$.

$$\frac{d\log S_t}{dREPINT_t} = \left[\frac{1}{x_t} + \frac{1}{1 - x_t}\right]\frac{dx_t}{drp_t}\frac{drp_t}{dREPINT_t} \tag{9}$$

The derivative of x_t with respect to the risk premium is $(v_t\beta_2)^{-1}$ from equation (5). If we rearrange equations (5) and (6), hold interest rates constant and set $\alpha_1=1$ and $\alpha_2=0$, we see that the derivative of the risk premium with respect to reported intervention is equal to the derivative of the expected depreciation with respect to reported intervention, which is α_4 from equation (6). As an example, if we take $x=.5$ and take our parameter estimates from I_t defined as cumulative intervention, the effect of an intervention report on the exchange rate is 2.3%.[30] If we measure x_t at the end of the sample period (.112)[31] the effect is approximately twice as large. If we take β_2 estimates from one-day or one-week intervention equations the effect is much smaller.

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[30] $[1/x + 1/(1-x)]\alpha_4/(v_t\beta_2) = [1/.5 + 1/.5](.006)/(1.049) = .0228$. We use $\alpha_4=.006$ from Table 3, the average value of v_t over the latter subperiod, which was .00005803, and $\beta_2=18081$ from Table 5.

[31] Total debt issued by the German government divided by the total of German and U.S. debt was .112 at the end of 1988.

The signalling effect of news on the exchange rate seems high. One's intuition that the effect should, in reality, be smaller can easily be fit into any of several categories. First, it is possible, even if we are talking about intervention that is sterilized in the sense that there is no change in the money supply, that the interest rates will absorb some of the impact of the decreased demand for mark assets (the German interest rate rising and the U.S. interest rate falling), so that the depreciation of the mark will be smaller. One would need to specify a complete portfolio balance model to answer how big the changes in the interest rates would be. But the effect on the nominal interest differential need not be large to damp significantly the reported effect on the spot rate.

Second, if one wishes to depart from the baseline case to consider the possibility of extrapolative expectations, then the effects reported above obtain only in the long-run equilibrium in which s_t-s_{t-1} is zero. The short-run impact effect could be smaller.[32] For some readers an intuitively appealing implication of extrapolative expectations is that, after the first-week impact of the news, market forecasters react further to the observed change in the exchange rate by jumping on the bandwagon, so that the effect grows in subsequent weeks. Others may prefer to believe that expectations are regressive rather than extrapolative; or that newspaper reports or other random disturbances to the level of the spot rate, to the extent that they are not confirmed subsequently by actual observed changes in macroeconomic fundamentals, will gradually lose their effect on the spot rate as time passes, and that this "unwinding factor" is not adequately captured in our equations. This last possibility would constitute a third factor that could reduce the effect on the spot rate in long-run equilibrium below that reported above.[33]

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[32] On the other hand, if market participants are believed to have adaptive or regressive expectations, then the impact in short-run equilibrium will be <u>higher</u> than in long-run equilibrium, the familiar overshooting hypothesis.

[33] A related point concerns the famous "Lucas critique." If the Central Bank adopted a policy of routinely making public announcements of its intervention -- which is not its practice now -- each announcement would not continue to have the same impact as in our estimates (unless, perhaps, it was

Our own inclination is to believe that expectations only tend to be extrapolative in occasional periods: "speculative bubble" environments, when the foreign exchange market "loses its moorings" and forecasters forget about fundamentals. Of course, these are precisely the periods in which Central Bankers might be most interested in using the tool of intervention.[34]

The last circumstance in which the effect on the spot rate would be less than that estimated here is if the event occurs during a period when the variance is higher than it is on average. Again, these might be the precisely periods in which Central Bankers would be most interested in using intervention as a short-term tool, to smooth "disorderly markets."[35]

Our results cannot be viewed as definitive. Nevertheless, to sum up, the findings for the dollar/mark rate during our mid-1980s sample period are generally favorable for the effectiveness of intervention. There appear to be statistically significant effects *both* through the expectations channel *and* through the portfolio channel. The quantitative effects can vary, depending both on the particular estimates chosen for the key parameters and on the precise experiment that one wishes to consider. But we hope that the statistical significance of the effects that we find will contribute to a re-evaluation of the conventional wisdom as to the ineffectiveness of intervention.

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sufficiently backed up by a correspondingly greater degree of actual changes in asset supplies). Our estimates only purport to say what the effect was during the regime actually in effect during the sample period.

[34] References include Krugman (1985), Frankel (1985), Marris (1985), Frankel and Froot (1990), and Williamson and Miller (1987).

[35] On the other hand, the financial press often talks of central bankers' intervention operations as seeking to have an effect on market behavior precisely by *creating* extra volatility, and thereby "punishing" speculators. Our estimates imply that a change in volatility can indeed have a significant impact on investors' asset demands. But, aside from the difficulty of driving out destabilizing speculators without also driving out stabilizing speculators, and aside from the general undesirability of creating needless volatility, there is another problem with this theory. If the supply of dollar assets in the market exceeds the share in the minimum-variance portfolio, then an increase in the variance will work to *depreciate* the dollar (for a given risk premium), which may not be the direction desired by the authorities.

VARIABLE DEFINITIONS AND DATA SOURCES

s_t: log of the \$/DM (or \$/SWF) spot exchange rate at time t (Source: DRI)

$\hat{s}^e_{t,k}$: log of Money Market Services median k-period-ahead expectation for the \$/DM (or \$/SWF) rate at time t (Source: MMS)

v_t: daily variance of \$/DM (or \$/SWF) exchange rate changes over the preceding week

$i^{DM}_{t,k}$: euro-DM k-period-ahead interest rate at time t (Source: DRI)

$i^{\$}_{t,k}$: euro-\$ k-period-ahead interest rate at time t (Source: DRI)

$i^{SWF}_{t,k}$: euro-SWF k-period-ahead interest rate at time t (Source: DRI)

I_t: central bank intervention, in millions of \$, known at time t[36] (Sources: Fed, Bundesbank and Swiss National Bank)

IDM_t: central bank intervention, in millions of DM, known at time t

$ANNOC_t$: +1 for official central bank announcements in support of the dollar since the last MMS survey date (Source: newspapers[37])

-1 for official central bank announcements against the dollar since the last MMS survey date (Source: newspapers)

0 for no relevant central bank announcements

$REPINT_t$: +1 for reported central bank intervention in support of the dollar since the last MMS survey date (Source: newspapers)

-1 for reported central bank intervention against the dollar since the last MMS survey date (Source: newspapers)

0 for no reports of central bank intervention

$SECINT_t$: +1 if $I_t > 0$ and $REPINT_t = 0$

-1 if $I_t < 0$ and $REPINT_t = 0$

0 otherwise

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[36] Intervention variables are known at time t (purchases and sales through the end of day t-1) and are defined in terms of number of dollars purchased.

[37] Newspapers included the Wall Street Journal, London Financial Times and New York Times.

TABLE 1

$$(s_t - s_{t-j}) = \gamma_0 + \gamma_1 ANNOC_t + \gamma_2 REPINT_t + \gamma_3 SECINT_t + \eta_t$$

WEEKLY EXCHANGE RATE CHANGE EQUATION

	SMPL: 11/82 - 10/84 (OBS=54,j=14)		SMPL: 10/84 - 12/88 (OBS=185,j=7)	
γ_0	0.001	(0.005)	0.003	(0.001)**
γ_1	-0.011	(0.011)	-0.008	(0.003)**
γ_2	0.011	(0.007)	-0.004	(0.002)*
γ_3	0.006	(0.004)	0.003	(0.004)
ρ	0.181	(0.143)	-0.013	(0.076)
D.W.	1.94		2.01	
R^2	0.14		0.06	

$$(s_t - s_{t-j}) = \phi_0 + \phi_1 ANNOC_t + \phi_2 |REPINT|_t * I_t + \phi_3 |SECINT|_t * I_t + \nu_t$$

SAMPLE: October 1984 - December 1988, OBS=185, j=7

	ONE-DAY[a]		ONE-WEEK[b]		CUMULATIVE[c]	
ϕ_0	0.003	(0.001)**	0.003	(0.001)**	0.003	(0.001)**
ϕ_1	-0.008	(0.003)**	-0.008	(0.003)**	-0.008	(0.003)**
ϕ_2	0.183	(0.099)	0.016	(0.024)	-0.003	(0.001)**
ϕ_3	0.510	(0.312)	0.132	(0.076)	0.001	(0.002)
ρ	-0.046	(0.075)	-0.023	(0.075)	-0.018	(0.076)
D.W.	2.01		2.01		2.00	
R^2	0.07		0.06		0.08	

a) Intervention variable is measured at the end-of-day prior to the survey.
b) Intervention variable is an accumulated measure between survey forecasts.
c) Intervention variable is an accumulated measure from the beginning of the sample period.

Standard errors are in parentheses. * denotes significance at the 95% level; ** denotes significance at the 99% level. The coefficients on $|REPINT|_t * I_t$ and $|SECINT|_t * I_t$ (ϕ_2 and ϕ_3) and their corresponding standard errors are multiplied by 10^4 for readability. ρ is the estimated first lag correlation coefficient.

TABLE 2

SAMPLE: November 1982 - October 1984

$$(\hat{s}^e_{t,k} - \hat{s}^e_{t-j,k}) = \alpha_0 + \alpha_1(s_t - s_{t-j}) + \alpha_2(s_t - \hat{s}^e_{t-j,k}) +$$

$$\alpha_3 ANNOC_t + \alpha_4 REPINT_t + \alpha_5 SECINT_t + \varepsilon_t$$

BI-WEEKLY THREE-MONTH-AHEAD SURVEY EXPECTATION EQUATION

(OBS=54, k=90, j=14)

INSTRUMENTS: v_t, IDM_t

	ONE-DAY[a]		TWO-WEEK[b]		CUMULATIVE[c]	
α_0	0.005	(0.006)	0.006	(0.006)	0.008	(0.008)
α_1	0.414	(0.400)	0.328	(0.367)	-0.069	(0.609)
α_2	0.406	(0.210)†	0.420	(0.217)†	0.432	(0.279)
α_3	-0.002	(0.008)	-0.002	(0.008)	-0.005	(0.010)
α_4	0.002	(0.007)	0.003	(0.006)	0.008	(0.009)
α_5	-0.001	(0.004)	-0.001	(0.004)	0.003	(0.006)
$\chi^2(1)$	7.990**		7.177**		4.123*	
$\chi^2(2)$	7.822**		9.272**		1.984	
D.W.	2.09		2.05		1.90	
R^2	0.72		0.70		0.51	

a) Intervention instrumental variable (IDM) is measured at the end-of-day prior to the survey.
b) Intervention instrumental variable is an accumulated measure between survey forecasts.
c) Intervention instrumental variable is an accumulated measure from the beginning of the sample period.

Standard errors are in parentheses. † denotes significance at the 90% level; * denotes significance at the 95% level; ** denotes significance at the 99% level. The $\chi^2(1)$ statistic pertains to the hypothesis that $\alpha_2=1$ (expectations are not adaptive); and $\chi^2(2)$ pertains to the hypothesis that $\alpha_1=\alpha_2=0$ (expectations are not extrapolative, but are completely adaptive).

TABLE 3

SAMPLE: October 1984 - December 1988

$$(\hat{s}^{e}_{t,k} - \hat{s}^{e}_{t-j,k}) = \alpha_0 + \alpha_1(s_t - s_{t-j}) + \alpha_2(s_t - \hat{s}^{e}_{t-j,k}) +$$

$$\alpha_3 ANNOC_t + \alpha_4 REPINT_t + \alpha_5 SECINT_t + \varepsilon_t$$

WEEKLY ONE-MONTH-AHEAD SURVEY EXPECTATION EQUATION

(OBS=186, k=30, j=7)

INSTRUMENTS: v_t, IDM_t

	ONE-DAY[a]		ONE-WEEK[b]		CUMULATIVE[c]	
α_0	0.005	(0.001)**	0.006	(0.001)**	0.005	(0.001)**
α_1	0.394	(0.194)*	0.442	(0.219)*	0.146	(0.253)
α_2	0.559	(0.116)**	0.626	(0.116)**	0.478	(0.134)**
α_3	-0.009	(0.002)**	-0.009	(0.002)**	-0.011	(0.003)**
α_4	-0.005	(0.002)**	-0.004	(0.002)*	-0.006	(0.002)**
α_5	0.005	(0.003)	0.005	(0.003)	0.007	(0.003)*
$\chi^2(1)$	14.362**		10.379**		15.144**	
$\chi^2(2)$	17.821**		18.724**		6.599**	
D.W.	2.24		2.23		2.10	
R^2	0.67		0.67		0.61	

a) Intervention instrumental variable (IDM) is measured at the end-of-day prior to the survey.
b) Intervention instrumental variable is an accumulated measure between survey forecasts.
c) Intervention instrumental variable is an accumulated measure from the beginning of the sample period.

Standard errors are in parentheses. * denotes significance at the 95% level; ** denotes significance at the 99% level. The $\chi^2(1)$ statistic pertains to the hypothesis that $\alpha_2=1$ (expectations are not adaptive); and $\chi^2(2)$ pertains to the hypothesis that $\alpha_1=\alpha_2=0$ (expectations are not extrapolative, but are completely adaptive).

TABLE 4

SAMPLE: November 1982 - October 1984

$$i_{t,k}^{DM} - i_{t,k}^{\$} + \Delta\hat{s}_{t,k}^{e} = \beta_0 + \beta_1 v_t + \beta_2 v_t I_t + u_{t,k}$$

BI-WEEKLY THREE-MONTH-AHEAD RISK PREMIUM EQUATION

(OBS=55, k=90, j=14, Intervention expressed as percent of wealth)

INSTRUMENTS: s_{t-j}, $\hat{s}^e_{t-j,k}$, $ANNOC_t$, $REPINT_t$

	ONE-DAY[a]		TWO-WEEK[b]		CUMULATIVE[c]	
I. I_t *includes Fed and Bundesbank intervention*						
β_0	0.009	(0.004)*	0.009	(0.004)*	0.006	(0.003)†
β_1	-29.414	(57.324)	-40.692	(59.879)	379.336	(114.945)**
β_2	3542.750	(9985.341)	-107.899	(845.643)	626.214	(145.494)**
ρ	0.626	(0.196)**	0.624	(0.203)**	0.282	(0.365)
D.W.	2.16		2.15		1.95	
R^2	0.41		0.41		0.38	
II. I_t *includes only Bundesbank intervention*						
β_0	0.009	(0.004)*	0.009	(0.004)*	0.006	(0.003)†
β_1	-55.013	(61.489)	-38.274	(60.584)	379.794	(113.241)**
β_2	-10852.20	(21127.040)	23.917	(908.781)	655.648	(149.214)**
ρ	0.642	(0.190)**	0.633	(0.198)**	0.267	(0.402)
D.W.	2.15		2.16		1.95	
R^2	0.40		0.42		0.38	
III. I_t *includes only Fed intervention*						
β_0	0.009	(0.004)*	0.009	(0.004)*	0.007	(0.004)
β_1	-27.376	(55.542)	-44.542	(47.667)	376.248	(181.149)*
β_2	-14638.35	(25150.980)	-6663.846	(8435.426)	13539.500	(5610.806)*
ρ	0.615	(0.203)**	0.644	(0.191)**	0.565	(0.363)
D.W.	2.17		2.17		2.09	
R^2	0.41		0.40		0.29	

a) Intervention variable is measured at the end-of-day prior to the survey.
b) Intervention variable is an accumulated measure between survey forecasts.
c) Intervention variable is an accumulated measure from the beginning of the sample period.

Standard errors are in parentheses. † denotes significance at the 90% level; * denotes significance at the 95% level; ** denotes significance at the 99% level. The coefficient on $v_t I_t$ (β_2) and its corresponding standard error are divided by 100 for readability. ρ is the estimated first lag correlation coefficient.

TABLE 5
SAMPLE: October 1984 - December 1988

$$i_{t,k}^{DM} - i_{t,k}^{\$} + \Delta\hat{s}_{t,k}^{e} = \beta_0 + \beta_1 v_t + \beta_2 v_t I_t + u_{t,k}$$

WEEKLY ONE-MONTH-AHEAD RISK PREMIUM EQUATION

(OBS=185, k=30, j=7, Intervention expressed as percent of wealth)

INSTRUMENTS: s_{t-j}, $\hat{s}^{e}_{t-j,k}$, $ANNOC_t$, $REPINT_t$

	ONE-DAY[a]		ONE-WEEK[b]		CUMULATIVE[c]	
I. I_t *includes Fed and Bundesbank intervention*						
β_0	0.001	(0.002)	0.002	(0.001)	0.002	(0.002)
β_1	57.399	(18.529)**	42.164	(14.037)**	231.559	(74.438)**
β_2	6000.177	(2502.075)*	1464.781	(580.168)*	180.809	(65.347)**
ρ	0.297	(0.200)	0.327	(0.215)	0.389	(0.211)†
D.W.	2.12		2.12		2.17	
R^2	0.06		0.13		0.12	
II. I_t *includes only Bundesbank intervention*						
β_0	0.002	(0.002)	0.003	(0.001)†	0.001	(0.001)
β_1	40.039	(14.196)**	33.844	(13.042)**	461.932	(115.108)**
β_2	6313.085	(3086.048)*	1940.330	(944.745)*	427.283	(112.087)**
ρ	0.338	(0.178)†	0.331	(0.200)†	0.304	(0.447)
D.W.	2.15		2.13		2.11	
R^2	0.13		0.15		0.09	
III. I_t *includes only Fed intervention*						
β_0	0.001	(0.001)	0.002	(0.002)	0.002	(0.002)
β_1	53.239	(20.998)*	42.451	(14.688)**	73.241	(22.761)**
β_2	8125.240	(5098.826)	2168.151	(1115.875)†	400.618	(175.468)*
ρ	0.329	(0.177)†	0.353	(0.194)†	0.482	(0.182)**
D.W.	2.14		2.14		2.25	
R^2	0.08		0.13		0.05	

a) Intervention variable is measured at the end-of-day prior to the survey.
b) Intervention variable is an accumulated measure between survey forecasts.
c) Intervention variable is an accumulated measure from the beginning of the sample period.

Standard errors are in parentheses. † denotes significance at the 90% level; * denotes significance at the 95% level; ** denotes significance at the 99% level. The coefficient on $v_t I_t$ (β_2) and its corresponding standard error are divided by 100 for readability. ρ is the estimated first lag correlation coefficient.

TABLE 6
SAMPLE: January 1987 - December 1989

$$i_{t,k}^{SWF} - i_{t,k}^{\$} + \Delta s_{t,k}^{e} = \beta_0 + \beta_1 v_t + \beta_2 v_t I_t + u_{t,k}$$

WEEKLY ONE-MONTH-AHEAD SWISS FRANC RISK PREMIUM EQUATION

(OBS=156, k=30, Intervention expressed in millions of $s)

	ONE-DAY[a]		ONE-WEEK[b]		CUMULATIVE[c]	
I. I_t *includes Fed and Swiss National Bank intervention*						
β_0	0.002	(0.001)	0.002	(0.001)	0.002	(0.001)
β_1	47.784	(15.435)**	52.623	(15.892)**	51.972	(15.966)**
β_2	0.094	(0.059)	0.027	(0.016)†	0.002	(0.001)†
ρ	0.232	(0.079)**	0.238	(0.079)**	0.276	(0.078)**
D.W.	1.99		1.99		2.00	
R^2	0.12		0.12		0.11	
II. I_t *includes only Swiss National Bank intervention*						
β_0	0.002	(0.001)	0.002	(0.001)	0.002	(0.002)
β_1	48.467	(15.635)**	48.749	(15.704)**	43.207	(16.773)**
β_2	-0.291	(0.537)	0.034	(0.118)	0.013	(0.014)
ρ	0.282	(0.079)**	0.269	(0.080)**	0.278	(0.078)**
D.W.	2.01		2.01		2.00	
R^2	0.11		0.11		0.11	
III. I_t *includes only Fed intervention*						
β_0	0.002	(0.001)	0.002	(0.001)	0.002	(0.002)
β_1	47.721	(15.408)**	52.754	(15.829)**	51.803	(15.968)**
β_2	0.106	(0.062)†	0.027	(0.016)†	0.002	(0.002)
ρ	0.229	(0.079)**	0.237	(0.080)**	0.276	(0.078)**
D.W.	1.98		1.99		2.00	
R^2	0.12		0.12		0.11	

a) Intervention variable is measured at the end-of-day prior to the survey.
b) Intervention variable is an accumulated measure between survey forecasts.
c) Intervention variable is an accumulated measure from the beginning of the sample period.

Standard errors are in parentheses. † denotes significance at the 90% level; ** denotes significance at the 99% level. ρ is the estimated first lag correlation coefficient.

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