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POST-LOUVRE INTERVENTION: DID TARGET ZONES STABILIZE THE DOLLAR?

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ABSTRACT

At their Louvre meeting in February 1987, the Group of Seven (G7) countries agreed to stabilize dollar exchange rates. Over the next two years, central banks frequently bought and sold dollars in a manner broadly consistent with attempting to maintain target zones, and dollar exchange rates appeared more stable than they previously had been.

This paper investigates claims that the G3 (Germany, Japan, and the United States) successfully maintained target zones following the Louvre meeting. We use daily, official intervention data and simultaneous-equation techniques to estimate Probit reaction functions and GARCH exchange-rate equations. From the reaction functions, which include variables for target zones and market disorder, we construct Mill's ratios to serve as instruments for intervention. We introduce the Mill's ratios into both the conditional mean and conditional variance of the exchange-rate equations.

The results suggest that the G3 reacted to exchange-rate movements in a manner broadly consistent with maintaining target zones. With some notable exceptions, however, we do not find strong evidence that the intervention successfully influenced subsequent exchange-rate movements.

Introduction

This paper investigates claims that the United States, Germany, and Japan successfully maintained target zones following the February 20, 1987, Louvre meeting of the Group of Seven (G7) nations. At this meeting, the G7 countries agreed to stabilize the mark-dollar and yen-dollar exchange rates around their current levels through joint intervention. Although the official Louvre Communique made no mention of target zones, Funabashi (1988) shows that the participating finance ministers and central-bank governors, encouraged primarily by France and the United States, sought to implement them. Over the next two years, central banks frequently intervened, both buying and selling dollars in a manner broadly consistent with attempting to maintain target zones, and dollar exchange rates did appear more stable than they previously had been.

To investigate the target-zone hypothesis, we estimate two-equation systems for the mark-dollar and yen-dollar exchange rates, using official intervention data and simultaneous-equation techniques. Our first set of equations presents Probit reaction functions that calculate the probability of German, Japanese, and U.S. intervention as functions of a target-zone variable and of proxies for disorderly market conditions. From each reaction function, we compute a Mill's ratio to serve subsequently as an instrument for intervention in our exchange-rate equations. This second set of exchange-rate equations uses generalized autoregressive conditional heteroscedasticity (GARCH) techniques to model the influence of intervention on both the conditional mean and the conditional variance of the exchange-rate process.

Our results suggest that Germany, Japan, and the United States did attempt to maintain a target zone for both the mark-dollar and yen-dollar exchange rates, but that official dollar interventions generally failed to alter the direction of errant exchange rates. This could explain why the Group of Three (G3) seemed to abandon target zones by late 1988. Nevertheless, some of the results suggest that although intervention did not reverse exchange-rate movements, it may have smoothed them. We also find that intervention had mixed effects on exchange-rate volatility over the post-Louvre period.

Section I of this paper presents models for the Probit reaction functions and the GARCH exchange-rate equations. We estimate these models in section II. Here we discuss the construction of variables, notably our target estimates, and we describe the results in a fairly technical sense. In section III, we relate our findings to other research in this area.

I. The Model

Reaction function

Central banks buy and sell foreign exchange to influence trend movements in exchange rates, to calm disorderly markets, to alter their reserve holdings, and to fulfill a variety of customer transactions. We define intervention as official transactions to influence spot exchange rates and therefore consider only the first two of these motives. Intervention to affect the trend movements in exchange rates could include "leaning against (or with) the wind" or maintaining target zones. Intervention to calm disorderly markets lacks a precise definition, but officials generally identify disorderly markets in terms of short-term volatility. Our definition of intervention conforms to what Adams and Henderson (1983) classify as "active" intervention.

We model post-Louvre intervention as a function of a triggering mechanism that initiates intervention to alter trend movements in the exchange rate and as a function of a vector of variables that attempts to capture disorderly market conditions:

(1a) $Z^B_{i,t} = \gamma_0 + T^B_{i,t}\gamma^B_1 + D^B_{i,t}\gamma^B_2 + \epsilon^B_{i,t}$,

(1b) $Z^S_{i,t} = \gamma_0 + T^S_{i,t}\gamma^S_1 + D^S_{i,t}\gamma^S_2 + \epsilon^S_{i,t}$.

In our model, the superscripts B and S refer to intervention purchases and sales of U.S. dollars, respectively, and the subscript i (= 1,2) indexes the intervening country. In equation (1a), $Z^B_{i,t}$ is intervention purchases of dollars by the ith central bank at time period t; T^B_t is the corresponding target-zone triggering mechanism at time t, and D^B_t is a time-t vector of terms that defines disorderly markets.[1] Corresponding definitions apply to equation (1b). All central banks react to the same trigger mechanisms and to the same measures of disorderly markets. We also assume that

(2a) $\epsilon^B_i \sim N(o,\sigma^2)$,

(2b) $\epsilon^s_i \sim N(o,\sigma^2)$,

(3a) $E(\epsilon^B_i,\epsilon^B_j) = 0$ when $i \neq j$,

(3b) $E(\epsilon^S_i,\epsilon^S_j) = 0$ when $i \neq j$,

and

(4) $Cov(\epsilon^B_i,\epsilon^S_i) = O$.

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[1] As we will explain in section II, we include the lagged conditional variance from the exchange-rate equations as a measure of disorderly markets [see equations (7) and (14)].

Exchange-rate process

A substantial body of literature suggests that exchange rates follow a martingale process with a heteroscedastic error term. The GARCH model initially proposed by Bollerslev (1986) is particularly well suited to variables exhibiting such behavior.[2] The GARCH framework is also conducive to the study of intervention because it allows us to estimate simultaneously a conditional-mean equation and a conditional-variance equation, both of which can accommodate intervention terms on the right-hand side. We interpret intervention in the conditional-mean equation as measuring the impact of intervention on trend exchange-rate movements, and we regard intervention in the conditional-variance equation as measuring the ability of intervention to calm disorderly markets. Our exchange-rate model is

(5) $\Delta S_t = X_t\delta_1 + Z_t\delta_2 + \epsilon_t,$

(6) $\epsilon_t|\Omega_{t-1} \sim t(0,h_t,\nu),$

(7) $h_t = \omega_0 + \sum_{i=1}^{p}\alpha_i\epsilon_{t-i}^2 + \sum_{t=1}^{q}\beta_i h_{t-i} + X_t\tau_1 + Z_t\tau_2.$

In equation (5), ΔS_t is the log change in the spot exchange rate at time t from time t-1; X_t is a vector of exogenous variables, and Z_t is a vector of domestic and foreign intervention variables, such that

(8) $Z_t = [Z_{1,t}^B,\ Z_{2,t}^B,\ Z_{1,t}^S,\ Z_{2,t}^S].$

Equation (6) indicates that the distribution of the error term is conditional on information available at time t-1. By modeling the errors with a student-t distribution, we assume that the distribution is symmetric, but allow that it

[2] Bollerslev extended previous work by Engle (1982).

may be leptokurtotic. The distribution approaches normality as the parameter, ν, approaches 30. Equation (7) models the conditional variance, h_t, as an ARMA (p,q) process and as a function of exogenous variables and interventions at time t.

Instrument

Under the assumption that central banks maintain target zones, intervention and exchange rates are jointly determined. Direct estimation of this model will give biased and inconsistent results, because

(9) $Cov(Z,\epsilon) \neq 0.$

Probit estimation techniques allow us to construct an instrumental variable for the intervention terms without abandoning the GARCH framework.[3] To re-write equations (1a) and (1b), our criterion functions for intervention, in the standard form of a Probit model, we define vectors

(10a) $I^B_{i,t} = \begin{cases} 1 & if\ Z^B_{i,t} > 0, \\ 0 & otherwise; \end{cases}$

and

(10b) $I^s_{i,t} = \begin{cases} 1 & if\ Z^s_{i,t} > 0, \\ 0 & otherwise. \end{cases}$

Then, equations (1a) and (1b) become

(11a) $I^B_{i,t} = \gamma_0 + T^B_t\gamma^B_1 + D^B_t\gamma^B_2 + \mu^B_{i,t},$

(11b) $I^S_{i,t} = \gamma^S_0 + T^S_t\gamma^S_1 + D^S_t\gamma^S_2 + \mu^S_{i,t}.$

After obtaining maximum likelihood estimates of the parameters in equations

[3] See Maddala (1983) and Heckman (1979).

(11a) and (11b), we calculate inverse Mill's ratios, designated by λ^B or λ^S below, such that

(12a) $\lambda^B_{1,t} = (\phi[f_1(T^B,D^B)]/(\Phi[f_1(T^B,D^B)])$, if $I^B_{1,t} = 1$

(12b) $\lambda^B_{1,t} = (\phi[f_1(T^B,D^B)]/1 - \Phi[f_1(T^B,D^B)])$, if $I^B_{1,t} = 0$.

We construct similar inverse Mill's ratios for intervention sales of dollars.

In these expressions for the inverse Mill's ratios, ϕ and Φ are the standard normal density function and the cumulative standard normal density function, respectively. The Mill's ratios, λ^B and λ^S, are monotone decreasing functions of the probability that the corresponding central bank does not intervene, $(1 - \Phi[f_1(\cdot)])$.

As a second stage, we estimate the GARCH model in a form that allows the instrumental variables for intervention to enter both the conditional-mean and conditional-variance equations:

(13) $\Delta S_t = \delta_0 + X_t\delta_1 + \lambda_t\delta_2 + \epsilon_t$,

(14) $\epsilon_t|\Omega_{t-1} \sim t(0,\sigma^2,\nu)$,

(15) $h_t = \omega_0 + \sum_{i=1}^{p} \alpha_i\epsilon_{t-i} + \sum_{i=1}^{q} \beta_i\sigma^2_{t-i} + X_t\gamma_1 + \lambda_t\gamma_2$,

where

(16) $\lambda_t = [\lambda^S_{1,t}, \lambda^B_{1,t}, \lambda^S_{2,t}, \lambda^B_{2,t}]$

and where δ_1, δ_2, γ_1, and γ_2 are corresponding vectors of parameters.

II. Estimation

We estimate these models for U.S. and German intervention against the mark-dollar exchange rate and for U.S. and Japanese intervention against the yen-dollar exchange rate from February 23, 1987, through February 23, 1990. Our data set includes 757 daily observations. We also estimate the model over two subperiods: February 23, 1987, to September 30, 1988; and October 3, 1988, to February 23, 1990. Based on an inspection of the data, the former period seems more consistent with the target-zone hypothesis than the latter period. These subperiods contain 408 and 349 observations, respectively.

All exchange rates are from the New York market. All intervention data are from the Board of Governors of the Federal Reserve System and are maintained in dollars. Since the Louvre meeting of the G3, U.S. intervention policy has focused exclusively on the mark-dollar and yen-dollar exchange rates, and the United States has conducted all of its intervention in these currencies. Our estimates of the mark-dollar equations incorporate only U.S. and German intervention in dollars against marks. Similarly, our estimates of the yen-dollar equations utilize only U.S. and Japanese intervention in dollars against yen. We do not consider the effects of dollar, mark, or yen intervention by other central banks that could have influenced the mark-dollar or yen-dollar exchange rates through cross exchange rates.

Appendix A provides a detailed description of the raw data used in our experiment. The remainder of this section outlines our approach to estimating the model. We estimated the GARCH model from a package used in Baillie and Bollerslev (1989). We used Shazam version 6.2 for all other data calculations and to estimate the Probit functions.

<u>Reaction functions</u>

Funabashi provides a detailed discussion of the alleged post-Louvre target zones, including a somewhat vague empirical description of agreed intervention ranges.[4] A comparison of G3 intervention data with morning-opening New York exchange-rate quotations suggests that the G3 countries did attempt to pursue target zones for the mark-dollar and yen-dollar exchange rates, but the pattern did not seem to fit Funabashi's description. Table 1 identifies exchange rates that seemed to trigger intervention.[5] The behavior of intervention against the mark-dollar exchange rate seemed more consistent with the idea of a target zone than did intervention against the yen-dollar exchange rate, in that we could identify fewer changes in the mark-dollar intervention trigger. By late 1988, however, we had difficulty specifying targets for intervention against either exchange rate. This determined our choice of subperiods.

During the post-Louvre period, central banks seemed to intervene whenever the exchange rate breached the upper or lower target zone, and they generally continued to intervene as long as the exchange rate moved away from the trigger point. When an exchange rate began to move back toward the target, even if it remained outside the target zone, the central banks nearly always halted intervention. This approach would limit the drain on foreign currency reserves or would minimize the exchange-risk exposure associated with

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[4]At the Louvre meeting, finance ministers and central-bank presidents indicated their willingness to stabilize exchange rates "around current levels." Nevertheless, they did not seem to agree on a precise definition of target zones. Opinions varied about the central rates and about countries' obligations given various percentage deviations from those central rates. See Funabashi (1988).

[5]Klein and Lewis (1991) estimate target mark-dollar and yen-dollar exchange rates with upper and lower boundaries representing a 50 percent probability of intervention. Their estimation period runs from March 13, 1987 through October 9, 1987. They find that "... the market's perception of the target zone shifted significantly during the period." (p. 25)

acquiring foreign currency reserves, as the case may have been.[6] Sometimes an exchange rate would never fully recover to within the target zone before starting to deviate again, and central banks would seem to wait before again intervening. We interpret these later situations as representing a re-benchmarking of the target zones.

Accordingly, we construct the target-zone variable in the following manner:

(17) $T_L = b_L . d_L (SAM_L - SAM_t)$.

In equation (17), SAM_L is the hypothesized lower bound of the target zone based on the morning-opening New York quotation. (All exchange rates are in log form.) We let b_L equal one when the spot exchange rate fell below the lower bound, or $(SAM_L - SAM_t) > 0$. Otherwise b_L is zero. We let d_L equal one only when the spot exchange rate depreciated, $(SAM_t - SAM_{t-1}) < 0$. The terms b_L and d_L switch on the intervention signal whenever the exchange rate was below the lower target zone <u>and</u> was depreciating. We expect the estimated coefficient on T_L in the central-bank reaction functions to be positive. If central banks reacted to deviations in spot exchange rates from a target zone, we expect greater purchases of dollars (a positive value) to be associated with increases in T_L.

We construct a similar variable for the upper target range and expect its coefficient to be negative. When the spot rate rose above its target value, T_H becomes negative; the intervening central bank should have sold dollars (a positive value). We estimate separate equations for each country's decision to buy and to sell dollars, using the appropriate exchange-rate

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[6]For a discussion of central-bank exposure and the profitability of U.S. intervention, see Leahy (1989).

target.

We include two variables to gauge market disorder in the Probit reaction functions. One variable is dollar appreciations or depreciations, whether these occur inside or outside the target bands. We include the absolute value of dollar appreciations (depreciations) in the reaction functions for dollar sales (purchases). We expect a positive coefficient for each. For the United States, we measure the appreciation or depreciation as the change in the morning-opening exchange-rate quotes from the previous closing quotes: $(SAM_t - SPM_{t-1})$. For Germany and Japan, we measure the change in the previous day's closing quote from the previous day's opening quote: $(SPM_{t-1} - SAM_{t-1})$. This assures us that the exchange-rate changes are recent and that they occur before the intervention response.

As a second measure of disorderly markets, we include the square root of the lagged conditional variance from the exchange-rate equation; that is, we include $h_{t-1}^{1/2}$, where h_{t-1} is defined by equation (15). To do this, we first estimate a Probit reaction function, which contains only the trigger variable and the appreciation/depreciation variable, over the lagged data. We generate Mill's ratios $(\lambda^B_{1,t-1}, \lambda^B_{2,t-1}, \lambda^S_{1,t-1}, \lambda^S_{2,t-1})$ and, using these as instruments of intervention, we estimate the conditional mean and conditional variance of the exchange-rate process over the same lagged time period. We capture the lagged conditional variance from this equation and use its square root in the contemporaneous Probit reaction functions reported below.[7]

We also test for day-of-the-week effects in the intervention reaction

[7] We also consider the bid-ask spread as a measure of disorderly markets. Overall, they performed similarly. We did not include them in the equations.

functions. Dominguez (1988) suggests that U.S. intervention might be related to announcements about U.S. money growth. Because the Federal Reserve releases money data on Thursdays and because the Bundesbank often announces policy intentions on Thursdays, Dominguez's hypothesis suggests that we consider day-of-the-week effects in the intervention reaction functions. We include four day-of-the-week dummies in lagged Probit functions that we estimated over the full period. Using likelihood-ratio tests, we could not reject the null hypothesis of no day-of-the-week effects (see table 2). Moreover, no individual coefficient was statistically significant.

For each market, we estimate three sets of contemporaneous reaction functions: one set for the United States, one set for Germany or Japan, and one set for a combination of the United States and its foreign counterpart. Over this period, central banks closely coordinated their intervention. The estimated Probit reaction functions appear in tables 3.0._ for the full period, in tables 3.1._ for the first subperiod, and in tables 3.2._ for the final subperiod.[8]

The models seem to fit the data well, with two notable exceptions. During the first subperiod, Japan made no sales of dollars, and the U.S. made relatively few (see table 4). For this subperiod, we could not identify an upper target exchange rate (see table 1), nor could we relate U.S.

[8] We number tables 3, 5, and 6 as follows: The first digit refers to the overall table number. The second digit designates the time period, with 0 for the full period (February 23, 1987, to February 23, 1990), 1 for the first subperiod (February 23, 1987, to September 30, 1988) and 2 for the second subperiod (October 3, 1988, to February 23, 1990). The letters G and J indicate the foreign currency under consideration. Hence, table 3.0.G refers to the reaction function estimated over the entire sample for dollar intervention against German marks.

intervention to other reaction-function variables.[9] During the final subperiod (October 3, 1988, to February 23, 1990), the United States and/or Germany bought dollars on only 8 of the 349 business days in the sample. The Probit model would not converge over this subperiod.[10]

In all other cases, the upper and lower target mechanisms are significant at the 99 percent confidence level. This suggests that the central banks did attempt to maintain target zones in the manner that we hypothesized. Although the target-zone variables remain significant in the second subperiod, the target exchange rate changes more frequently and becomes increasingly difficult to identify.

In the mark-dollar market, the appreciation/depreciation variables for the full period are significant at the 95 percent confidence level for the United States and at the 90 percent confidence level for Germany and both countries combined. An inspection of the subperiods suggests that during the first subperiod, German monetary authorities were not inclined to intervene against a dollar appreciation, but did react to dollar depreciations. Both countries reacted to dollar appreciations in the second subperiod. In the yen-dollar market, the appreciation/depreciation variable is not significant, with the exception that the United States tends to buy dollars when the dollar

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[9] We generated a Mill's ratio for this period by estimating a Probit function, using only a constant. Although the Probit function does not converge properly, it produces a Mill's ratio that is perfectly correlated with the dichotomous intervention term and that is of the proper scale for inclusion in the exchange-rate equations.

[10] We altered some estimation procedures as we worked through this paper. The different treatments of the mark-dollar and yen-dollar Probit functions here are a case in point (see footnote 9). Throughout this paper, we note each of the procedural changes at the appropriate point. None affects the overall results. Our final paper will standardize all cases.

depreciates against the yen. This tendency seems to result only in the second subperiod.

The second measure of disorderly markets, the squared root of the conditional variance term, was significant in about half the cases. In all cases, except for the yen-dollar exchange rate in the last subperiod, volatility, measured by the conditional variance, tends to lead to dollar purchases more often than to dollar sales. The opposite holds in the yen-dollar market over the last subperiod.

Exchange-rate equation

Tables 5._._ and 6._._ present our estimates of the exchange-rate equations. We define the dependent variable in the exchange-rate equations as the log change in the New York closing exchange-rate quote (SPM_T-SPM_{T-1}). We assume that all intervention recorded at time t occurs between these two quotations.

The interpretation of coefficients on intervention terms is always difficult. Successful intervention undertaken after an exchange rate has breached a target boundary should return the exchange rate back to within the target range. Accordingly, one expects extramarginal intervention sales (purchases) of dollars to be associated with dollar depreciations (appreciations). When intervention occurs within the target range (intra-marginal interventions), its objective might be to smooth the exchange-rate path, but not to reverse it. Dollar sales (purchases) could be associated with dollar depreciations (appreciations), yet still smooth the exchange-rate path from what it otherwise might have been. Unfortunately, one never knows what the exchange rate otherwise would have done, so one can never unambiguously interpret such coefficients.

By far, most of the intervention undertaken following the Louvre meeting of the G7 occurs after the exchange rate breaches the target boundary as defined in this paper (see table 4). Nevertheless, we still face some ambiguities in the interpretations of coefficients on the exchange-rate equations, partly because some intervention in our study is intramarginal and partly because, despite the favorable result of the reaction functions, we do not have precise information about desired targets. Consequently, when we find intervention dollar sales (purchases) associated with dollar depreciations (appreciations), we cannot interpret the coefficient as showing a perverse response. Similar problems, however, confront the managers of foreign exchange desks at central banks, and they probably find little solace from such patterns.

Tables 5._._ show our estimates of the basic structure of the exchange-rate equation prior to testing for the effects of intervention. In each case, equation 1 provides an initial test for the presence of GARCH effects in the exchange-rate process. We regress the log change in the exchange rate on a constant and on a variance term. In all cases, the Q-statistics (with 15 degrees of freedom) suggest that the errors are not serially correlated. The Q-statistics for the squared error terms, however, are significant, indicating heteroscedasticity. The autocorrelations and partial autocorrelation of the error terms (not shown) exhibit mixed patterns, indicative of a GARCH (p,q) process.

In equation 2, we estimate a GARCH (1,1) model over each time period. In each case, the GARCH parameters are significant; the likelihood function increases significantly, and the adjusted Q-statistics no longer show the presence of GARCH effects. The only exception to this characterization is that the estimated values of the omegas, ω_0, in the final subperiod for both currencies are not significant.

The B1 and B2 statistics for equations 1 and 2 show that the error terms are biased (B1) and leptokurtotic (B2), despite the adoption of a GARCH (1,1) model. In equation 3, we alter the distribution parameter $1/v$ to allow a non-normal distribution for the error term. To do this, we get initial estimates from the B2 statistics and iterate until the values assumed in the model and the value implied by the subsequent B2 statistic are close.[11] The likelihood function improves as a result of altering the assumed distribution, but the error terms continue to be biased and leptokurtotic.[12]

In equation 4, we add explanatory terms. These include short-term interest-rate spreads, to capture short-term fluctuations in monetary policies, and dummy variables for U.S. and foreign holidays on which the markets were closed. Interest-rate spreads were significant, usually at the 95 percent confidence level, in both the conditional-mean equations and the

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[11] The distribution parameter and the B2 statistic are related according to $B2 = [3(v-2)]/(v-4)$. We also allowed the model to estimate the distribution parameter, but the results universally seemed too high relative to the B2 statistic. We do not report these results.

[12] When estimating the model for the mark-dollar exchange rate over the full time period, we adjusted the distribution parameter each time we introduced a new variable to the estimation sequence. When estimating the model for the subperiods, we wondered whether such a procedure might invalidate a strict interpretation of the likelihood ratio tests and adjusted the parameter separately. In no case, however, did a significant variable become insignificant, or vice versa, following a change in the distribution parameter.

conditional-variance equations. This is particularly true for estimates over the entire period and over the first subperiod. The only exception appears in the conditional variance for the yen-dollar exchange rate in the first subperiod. In the final subperiod, the interest-rate terms are not significant except in the variance of the yen-dollar exchange rate. The U.S. holiday dummies are usually significant in the conditional-variance equations, but not in the conditional-mean equations. This suggests that exchange-rate volatility increases when the market reopens after a holiday. Most holidays fall on Mondays or Fridays. Foreign holiday dummies were not significant, except for the German holiday dummy in the final subperiod. The overall unimportance of foreign holidays could result because we use New York exchange-rate quotations.[13]

We also tested for day-of-the-week effects in both the conditional-mean and conditional-variance equations over the entire period (February 23, 1987, through February 23, 1990). For the German mark, the day-of-the-week dummies were jointly significant neither in the mean (LR test = 5.6) nor in the variance (LR tests = 1.4). For the Japanese yen, the day-of-the-week dummies also were not jointly significant in the mean equation (LR test = 3.4) nor in the variance (LR test = 6.3). We consequently excluded these regressors.

Once we determined the basic model, we reestimated the distributional parameter (see footnotes 11 and 12). We refer to these equations as the basic models and maintain their general specification throughout the paper as a base

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[13] Initially, we intended to keep all nonintervention variables in the models for each subperiod. When the intervention terms were added, especially to the conditional-variance equations, many proved insignificant, and the model often would not converge. This was especially true over the subperiods. To facilitate convergence, we consequently dropped explanatory terms that proved to be insignificant.

for comparing the intervention terms. In some cases, however, as we added explanatory variables to the conditional-variance equations, the alpha component of the GARCH (1,1) model became weakly significant or insignificant at acceptable levels.

Intervention

The tables designated 6._._ show the results of adding the intervention terms to the basic exchange-rate equations. For each exchange rate, we enter intervention by the two principal central banks separately and as a summation of both. Over the post-Louvre period, central banks often closely coordinated their intervention efforts. Consequently, corresponding U.S. and foreign intervention terms are collinear, a problem that increases the estimated standard errors of the intervention terms and that biases their calculated t-statistics downward. Adding the relevant intervention transactions into a signal intervention term eliminates this problem.

Over the entire time period (table 6.0.G), German sales of dollars are statistically significant at the 90 percent confidence level in both the mean and the variance equations. In the mean equation, the coefficient's sign suggests that intervention sales of dollars promoted a dollar depreciation. This is consistent with the successful operation of target zones. In the conditional-variance equation, the coefficient on German dollar sales suggests, however, that intervention increased the volatility of the exchange-rate process. Over the entire period, Germany tended to sell dollars three times as often as it purchased them.

When we combine U.S. and German intervention, the estimated coefficients are statistically significant in the conditional-mean equation, but their signs do not conform to the target-zone hypothesis, implying at best that central banks managed to smooth exchange-rate movements during the period. The combined intervention terms are not statistically significant in the conditional-variance equations.

For intervention in the yen-dollar market over the full sample period (table 6.0.J), the estimated coefficients for Japanese purchases of dollars appear statistically significant at the 90 percent confidence level in the mean equation. The sign is not consistent with the target-zone hypothesis, but could indicate a successful smoothing operation. The coefficients for both U.S. and Japanese purchases of dollars are significant in the variance equations at the 95 percent level. The significant, positive coefficient on U.S. intervention sales suggests that intervention increased near-term volatility, while the significant, negative coefficient on Japanese dollar sales has the opposite implication. Over this period, Japan purchased dollars 1.2 times as often as it sold dollars. The United States, however, tended to sell dollars approximately 1.3 times as often as it bought them. When the individual transactions of the separate countries are combined, total intervention purchases are statistically significant at the 99 percent confidence level in the mean equation, with the sign on the coefficient indicative of a smoothing operation at best. Intervention purchases appear significant at the 95 percent level in the variance equation, indicating that intervention increased market volatility.

This mixed pattern of results highlights the importance of considering subperiods for intervention. As noted earlier, by late 1988, central-bank intervention no longer obviously conformed to a target zone. Consequently, we split the estimation period at the end of September 1988.

Over the first subperiod, the model for the mark-dollar exchange rate would not converge when the individual intervention terms were simultaneously included in the mean or variance equations. Table 6.1.G shows the results of entering individual intervention terms. None of the individual coefficients in the conditional-mean equations conforms with the target-zone hypothesis. The coefficient on German purchases of dollars, however, is statistically significant at the 95 percent confidence level. Its sign suggests that intervention, at best, could have smoothed dollar depreciations. None of the individual intervention terms is significant in the conditional variance equation. During this first subperiod, Germany tended to sell dollars nearly twice as frequently as it bought dollars.

When U.S. and German intervention is combined, however, the coefficient on intervention sales of dollars in the mean equation proves to be significant at the 99 percent confidence level, and its sign is consistent with the target-zone hypothesis. Overall, the combined transactions to sell dollars exceeded the combined transactions to buy dollars by approximately 1.5 times. The combined intervention terms are not statistically significant in the conditional-variance equations.

Over the first subperiod, Japan did not undertake intervention sales of dollars (see table 6.1.J). Japanese purchases of dollars are statistically significant at the 95 percent level in the mean equation, but with a sign that is, at best, consistent with smoothing. U.S. dollar sales are statistically significant at the 90 percent level in the variance equation. The coefficient on U.S. dollar sales in the conditional variance suggests that intervention sales of dollars increased exchange-rate volatility. When we combine the intervention terms, the coefficient for dollar purchases is significant at the

99 percent level, and its sign could indicate smoothing. Both combined dollar sales and dollar purchases are significant in the variance equation at the 90 percent level, but this intervention seemed to increase exchange-rate volatility.

Because the reaction functions for intervention purchases of dollars against German marks in the final subperiod would not converge, the corresponding mark-dollar exchange-rate equations consider only intervention sales of dollars (see table 6.2.G). Between October 3, 1988, and February 23, 1990, Germany bought dollars on only seven occasions and the United States bought dollars on only four occasions. During the final subperiod, none of the intervention terms in the conditional-mean equations is consistent with the target-zone hypothesis. The coefficient for combined dollar sales is statistically significant, but its coefficient is positive, suggesting that intervention could have smoothed trend exchange-rate movements, but did not reverse them. In no case during the second subperiod is intervention significant in the conditional variance of the mark-dollar equations.

We had difficulty getting the equation with individual interventions against Japanese yen to converge with intervention in the variance equation, so we present equations with only U.S. intervention in the variance (see table 6.2.J). Only U.S. purchases of dollars are significant in the mean equation, with a sign suggesting at best a smoothing operation. By allowing the distribution parameter ν to iterate, we were able to estimate a model with all of the intervention terms in both the mean and variance equation. Again, only U.S. intervention in the mean was significant. The estimate of the distribution parameter and its t-statistic, however, seems too large. When U.S. and Japanese intervention is combined, intervention is not statistically significant.

III. Conclusion

In this paper, we constructed a Probit reaction function and a GARCH exchange-rate model to investigate U.S. and German intervention in the post-Louvre period. We found that, after the Louvre meeting, Germany, Japan, and the United States reacted to exchange-rate movements in a manner consistent with an attempt to maintain a target-zone mechanism. They adjusted the target zone periodically, but with increasing frequency as time passed. By late 1988, however, we found it difficult to specify target exchange rates. Although most intervention was extramarginal by our definition of the target range, not all of it was.

During the post-Louvre period, the G3 countries also intervened in response to indications of market disorder. Countries sold (purchased) dollars in the face of dollar appreciations (depreciations), and market volatility, measured by the lagged conditional variance of the exchange-rate process, often influenced the probability of G3 intervention.

Results from estimating the reaction functions were fairly consistent over different time periods, across different currencies, and with respect to intervention purchases and sales. Results from estimating the exchange-rate equations, on the other hand, were not consistent. In the conditional mean equations, for example, we find some cases in which intervention reversed exchange-rate movements, and we find other cases in which intervention may have smoothed exchange-rate movements, even if it did fail to reverse them. Nevertheless, the sign and significance of the various coefficients change across time periods. Results that hold for sales of dollars often do not hold for purchases of dollars. We find similar patterns in the variance equations, with cases in which the coefficients showed that intervention significantly increased exchange-rate volatility and others in which intervention significantly lowered exchange-rate volatility. Yet, again, the pattern was never consistent across time periods, currencies, or types of intervention transaction.

These types of results for the conditional mean of exchange-rate processes now seem fairly standard among empirical investigations of intervention, as recent surveys by Edison (1990) and Humpage (1991) indicate. Together with a lack of strong support for a portfolio effect, they have led many researchers to conclude that intervention affects exchange rates by influencing market expectations [see Hung (1991a, 1991b)]. The impact of official transaction in foreign currency then depends on current market conditions and on the perceived information embodied in the intervention.[14] Even studies that find a fairly consistent portfolio-balance effect note that the expectational influence of intervention is vital in determining the overall effectiveness of intervention [see Dominguez and Frankel (1991)].

Recent theoretical work on target zones also might help to explain our failure to find compelling support for intervention, particularly the ability of intervention to reverse exchange-rate movements. Krugman (1991) indicates that if markets expect intervention at particular target exchange rates, these expectations alone will help stabilize the exchange rate within known target rates. Klein (1990), Klein and Lewis (1991), and Lewis (1990) extend this result to show that the expectation of intramarginal intervention further

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[14]This need not be information solely about future monetary policies. See Dominguez (1988) and Klein and Rosengren (1991).

stabilizes the exchange rate. Therefore, if market participants anticipated intervention to maintain target zones in the post-Louvre period, they would incorporate this into their quotations. Researchers then might find no correlation between intervention and exchange-rate movements, even though the threat of intervention altered the exchange-rate path.

These results assume that intervention targets were announced or that they evolved in a manner that allowed the market to learn governments' reaction functions. In the post-Louvre period, however, the G3 did not announce the target bands, nor even acknowledge that they existed. Moreover, the target bands were not fixed. It is not clear that following the Louvre meeting, the market was ever able to predict the G3 intervention points. Nevertheless, to the extent that they may have done so, intervention could have helped stabilize the exchange rate despite our inability to find a strong, consistent effect of intervention in the exchange-rate equations.

Like nearly all other empirical investigations of intervention, this paper has presented a statistical model of intervention, not a theoretical model. Moreover, we followed convention by assuming that intervention was sterilized. Nevertheless, we suspect that central banks did not completely divorce their post-Louvre intervention from their monetary policy. Pauls (1990) and Furlong (1989) both indicate that following the Louvre meeting, exchange-rate considerations became more important in FOMC deliberations. Neumann and von Hagen (1991) indicate that Germany does not always sterilize its intervention completely, as does Takagi (1989) for Japan. Although the interest-rate variable in our model sometimes seems sensitive to the intervention terms, preliminary tests suggest that collinearity is not a problem. This is an important area for further analysis. The working assumption of most research on intervention, that intervention is sterilized, might not be entirely appropriate.

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TABLE 1
Apparent Exchange-Rate Target Ranges
(foreign currency units per dollar)

I. German mark - U.S. dollar

Date of Change:	Low	High
February 20, 1987	1.800	1.870
December 22, 1987	1.625	1.820
July 1, 1988	1.720	1.820
March 3, 1989	*	1.860
July 3, 1989	*	1.900
December 1, 1989	1.620 [a]	*

II. Japanese yen - U.S. dollar

Date of Change:	Low	High
February 20, 1987	150.0Y	*
June 1, 1987	142.5Y	*
September 3, 1987	140.0Y	*
November 16, 1987	133.0Y	*
January 20, 1988	126.0Y	*
April 18, 1988	124.0Y	*
June 20, 1988	126.0Y	*
December 9, 1988	122.0Y	130.0Y
May 2, 1989		133.0Y
August 11, 1989		140.0Y
October 20, 1989		144.0Y

* Value is not apparent; we maintain previous value.

[a] Not obvious, but previous value no longer applies.

Note: High and low targets are based on a comparison of official intervention with morning-opening New York exchange-rate quotations.

Source: Authors' calculations.

TABLE 2

Likelihood Ratio Tests for Day-of-the-Week Effects
in the Reaction Functions

	Intervention against marks		Intervention against yen	
	Purchases	Sales	Purchases	Sales
United States	0.6	4.2	2.0	1.2
Germany	6.4	6.3	*	*
Japan	*	*	1.8	2.2

* Does not apply.

Source: Authors' calculations.

TABLE 3.0.G: PROBIT REACTION FUNCTIONS: INTERVENTION AGAINST GERMAN MARKS
Estimation Period: February 23, 1987 to February 23, 1990

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5	EQUATION 6
	US Dollar Sales	US Dollar Purchases	German Dollar Sales	German Dollar Purchases	Total Dollar Sales	Total Dollar Purchases
Constant	-1.3392	-3.0040	-1.0320	-2.9108	-1.0509	-2.2073
	(-4.3504)	(-6.5948)	(-3.7259)	(-7.0874)	(-3.7659)	(-5.5855)
Upper target	-33.837		-21.606		-29.573	
	(-8.6436)		(-5.8337)		(-7.4533)	
Lower target		28.174		21.685		27.984
		(7.4609)		(6.0797)		(7.3437)
Appreciation	0.70374		0.35055		0.33648	
	(3.4575)		(1.7763)		(1.7343)	
Depreciation		0.53044		0.39949		0.47914
		(2.3204)		(1.8122)		(2.2929)
$h_{(t-1)}$	-0.1025	1.4677	-0.12727	1.5977	0.0840	0.68433
	(-0.2225)	(2.3230)	(-0.30652)	(2.7760)	(0.2003)	(1.1731)
Log likelihood	-273.83	-111.39	-332.88	-138.82	-362.38	-157.12
Likelihood ratio test	86.9286	72.7387	44.1009	52.5353	74.1508	74.9647
	(df=3)	(df=3)	(df=3)	(df=3)	(df=3)	(df=3)
Correctly predicted	86.394%	95.376%	81.374%	94.320%	79.657%	93.527%
Total observations	757	757	757	757	757	757
Observations at 1	112	37	135	43	167	54
Observations at 0	645	720	622	714	590	703

Source: Authors' calculations.

TABLE 3.0.J: PROBIT REACTION FUNCTIONS: INTERVENTION AGAINST JAPANESE YEN
Estimation Period: February 23, 1987 to February 23, 1990

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5	EQUATION 6
	US Dollar Sales	US Dollar Purchases	Japanese Dollar Sales	Japanase Dollar Purchases	Total Dollar Sales	Total Dollar Purchases
Constant	-2.205	-2.2700	-1.8460	-2.057	-2.021	-2.015
	(-9.282)	(-8.609)	(-9.142)	(-8.932)	(-8.932)	(-8.837)
Upper target	-31.066		-31.173		-33.922	
	(-7.240)		(-7.325)		(-7.483)	
Lower target		28.707		33.842		35.793
		(7.076)		(8.633)		(8.863)
Appreciation	0.149		-0.031		0.035	
	(0.776)		(0.116)		(0.150)	
Depreciation		0.647		0.174		0.095
		(3.431)		(.912)		(.486)
$h_{(t-1)}$	1.062	0.753	0.644	1.060	1.1430	1.083
	(3.33)	(2.155)	(2.015)	(3.480)	(3.658)	(3.453)
Log likelihood	-216.04	-177.79	-228.72	-254.75	-269.40	-263.90
Likelihood ratio test	99.744	87.817	86.668	100.040	109.619	106.79
	(df=3)	(df=3)	(df=3)	(df=3)	(df=3)	(df=3)
Correctly predicted	90.000%	91.400%	89.400%	86.900%	86.900%	86.700%
Total observations	757	757	757	757	757	757
Observations at 1	85	65	88	105	116	112
Observations at 0	672	692	669	652	641	645

Source: Authors' calculations.

TABLE 3.1.G: PROBIT REACTION FUNCTIONS: INTERVENTION AGAINST GERMAN MARKS
Estimation Period: February 23, 1987 to September 30, 1988

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5	EQUATION 6
	US Dollar Sales	US Dollar Purchases	German Dollar Sales	German Dollar Purchases	Total Dollar Sales	Total Dollar Purchases
Constant	-2.0049	-3.0864	-1.0007	-3.4836	-2.2803	-3.1064
	(-4.0371)	(-5.6139)	(-2.6340)	(-6.4776)	(-5.8018)	(-6.6798)
Upper target	-55.563		-58.131		-55.264	
	(-6.5546)		(-6.6377)		(-6.3559)	
Lower target		22.653		13.46		21.188
		(5.5138)		(3.4491)		(5.3325)
Appreciation	0.70819		0.17276		0.25902	
	(2.0321)		(0.55716)		(0.8659)	
Depreciation		1.3544		1.0833		1.2434
		(3.6772)		(2.9184)		(3.4238)
$h_{(t-1)}$	0.33259	1.6965	-0.39313	2.5757	1.6268	2.2165
	(0.45165)	(2.2227)	(-0.68154)	(3.5046)	(2.7769)	(3.3266)
Log likelihood	-93.942	-81.255	-149.39	-95.678	-148.24	-105.24
Likelihood ratio test	50.9379	66.7198	55.7137	52.1683	67.9462	76.9232
	(df=3)	(df=3)	(df=3)	(df=3)	(df=3)	(df=3)
Correctly predicted	92.647%	92.402%	86.765%	91.176%	86.765%	91.176%
Total observations	408	408	408	408	408	408
Observations at 1	35	33	64	36	67	46
Observations at 0	373	375	344	372	341	362

Source: Authors' calculations.

TABLE 3.1.J: PROBIT REACTION FUNCTIONS: JAPANESE YEN
Estimation Period: February 23, 1987 to September 30, 1988

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5	EQUATION 6
	US Dollar Sales[a]	US Dollar Purchases	Japanese Dollar Sales[c]	Japanese Dollar Purchases	Total Dollar Sales[d]	Total Dollar Purchases
Constant	-2.3599	-2.5203		-2.3370		-2.2740
	(-5.3700)	(-7.7080)		(-8.3580)		(-8.3530)
Upper target[b]						
Lower target		20.4930		22.8890		24.2790
		(4.5710)		(5.4150)		(5.6300)
Appreciation	0.1590					
	(0.5200)					
Depreciation		0.8010		0.5110		0.3960
		(3.2910)		(1.7650)		(1.3750)
$h_{(t-1)}$	0.6810	-1.3650		1.8600		1.8480
	(1.1580)	(3.2180)		(4.9880)		(5.0510)
Log likelihood	-56.8300	-124.0100		-178.0800		-181.7000
Likelihood ratio test	1.5400	63.2860		71.8550		74.6150
	(df=2)	(df=3)		(df=3)		(df=3)
Correctly predicted	96.800%	87.300%		78.700%		78.700%
Total observations	408	408		408		408
Observations at 1	13	52		89		93
Observations at 0	395	350		319		315

a Probit function did not converge.
b Not discernible; see table 1.
c No Japanese dollar sales.
d Same as equation 1.

Source: Authors' calculations.

TABLE 3.2.G: PROBIT REACTION FUNCTIONS: INTERVENTION AGAINST GERMAN MARKS
Estimation Period: October 3, 1988 to February 23, 1990

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5	EQUATION 6
	US Dollar Sales	US Dollar Purchases[a]	German Dollar Sales	German Dollar Purchases[a]	Total Dollar Sales	Total Dollar Purchases[a]
Constant	-0.24396		-0.20091		0.44809	
	(-0.51546)		(-0.41971)		(1.1082)	
Upper target	-26.518		-12.233		-20.628	
	(-5.8200)		(-2.6663)		(-4.5298)	
Lower target						
Appreciation	0.68519		0.48785		0.39349	
	(2.6105)		(1.8250)		(1.5005)	
Depreciation						
$h_{(t-1)}$	-1.3379		-1.2492		-1.7716	
	(-1.8383)		(-1.7120)		(-3.0664)	
Log likelihood	-164.80		-168.86		-191.86	
Likelihood ratio test	38.7328		14.8535		34.4012	
	(df=3)		(df=3)		(df=3)	
Correctly predicted	79.083%		79.083%		73.926%	
Total observations	349	349	349	349	349	349
Observations at 1	77	4	71	7	100	8
Observations at 0	272	345	278	342	249	341

[a] Probit function would not converge.

Source: Authors' calculations.

TABLE 3.2.J: PROBIT REACTION FUNCTIONS: INTERVENTION AGAINST JAPANESE YEN
Estimation Period: October 3, 1988 to February 23, 1990

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5	EQUATION 6
	US Dollar Sales	US Dollar Purchases	Japanese Dollar Sales	Japanese Dollar Purchases	Total Dollar Sales	Total Dollar Purchases
Constant	-2.1810	-0.0059	-0.0020	-0.0903	-2.2017	-1.2097
	(-7.3060)	(-0.1593)	(-0.2528)	(-1.8590)	(-6.4171)	(-1.9192)
Upper target	-20.8850		-17.9230		-20.1880	
	(-4.4720)		(-4.2070)		(-4.3197)	
Lower target		67.2000		84.9500		95.1970
		(5.2920)		(6.0300)		(6.5040)
Appreciation	0.3910		0.1780		0.2860	
	(1.3530)		(0.5380)		(0.8550)	
Depreciation		0.4590		-0.0580		-0.3200
		(1.1180)		(-0.0880)		(-0.4470)
$h_{(t-1)}$	1.5110	-1.2510	0.9750	-1.4310	-2.0940	-1.1700
	(3.6830)	(-1.3730)	(2.5740)	(-1.6020)	(4.2640)	(-1.1660)
Log likelihood	-143.57	-37.62	-175.91	-39.15	-178.24	-44.62
Likelihood ratio test	68.16	35.82	42.33	51.59	66.98	58.31
	(df=3)	(df=3)	(df=3)	(df=3)	(df=3)	(df=3)
Correctly predicted	81.7%	96.3%	76.8%	96.6%	75.4%	96.0%
Total observations	349	349	349	349	349	349
Observations at 1	72	13	88	16	103	19
Observations at 0	277	336	261	333	246	330

Source: Authors' calculations.

TABLE 4
Intervention Relative to the Target Exchange Rate
(Numbers of interventions)[a]

I. Intervention against the Mark-Dollar Exchange Rate

A: Full Period: February 23, 1987 - February 23, 1990

U.S. Sales		U.S. Purchases
112	Total Intervention	37
100	Extramarginal	28
12	Intramarginal	9

German Sales		German Purchases
135	Total Intervention	43
101	Extramarginal	30
34	Intramarginal	13

Both Sales		Both Purchases
167	Total Intervention	54
129	Extramarginal	38
38	Intramarginal	16

B: First Subperiod: February 23, 1987 - September 30, 1988

U.S. Sales		U.S. Purchases
35	Total Intervention	33
32	Extramarginal	26
3	Intramarginal	7

German Sales		German Purchases
64	Total Intervention	36
49	Extramarginal	28
15	Intramarginal	8

Both Sales		Both Purchases
67	Total Intervention	46
51	Extramarginal	36
18	Intramarginal	10

C: Second Subperiod: October 3, 1988 - February 23, 1990

U.S. Sales		U.S. Purchases
77	Total Intervention	4
68	Extramarginal	2
9	Intramarginal	2

German Sales		German Purchases
71	Total Intervention	7
52	Extramarginal	2
19	Intramarginal	5

Both Sales		Both Purchases
100	Total Intervention	8
78	Extramarginal	2
22	Intramarginal	6

Table 4 (Continued)

II. Intervention against the Yen-Dollar Exchange Rate

A: Full Period: February 23, 1987 - February 23, 1990

U.S. Sales		U.S. Purchases
85	**Total Intervention**	65
70	**Extramarginal**	59
15	**Intramarginal**	6
Japanese Sales		Japanese Purchases
88	**Total Intervention**	105
83	**Extramarginal**	88
5	**Intramarginal**	17
Both Sales		Both Purchases
116	**Total Intervention**	112
97	**Extramarginal**	93
19	**Intramarginal**	19

B: First Subperiod: February 23, 1987 - September 30, 1988

U.S. Sales		U.S. Purchases
13	**Total Intervention**	52
0	**Extramarginal**	46
13	**Intramarginal**	6
Japanese Sales		Japanese Purchases
0	**Total Intervention**	89
0	**Extramarginal**	72
0	**Intramarginal**	17
Both Sales		Both Purchases
13	**Total Intervention**	93
0	**Extramarginal**	74
13	**Intramarginal**	19

C: Second Subperiod: October 3, 1988 - February 23, 1990

U.S. Sales		U.S. Purchases
72	**Total Intervention**	13
70	**Extramarginal**	13
2	**Intramarginal**	0
Japanese Sales		Japanese Purchases
88	**Total Intervention**	16
83	**Extramarginal**	16
5	**Intramarginal**	0
Both Sales		Both Purchases
103	**Total Intervention**	19
97	**Extramarginal**	19
6	**Intramarginal**	0

[a] Margins based on exchange rates in Table 1.
Source: Authors' calculations.

TABLE 5.0.G: BASIC EXCHANGE-RATE EQUATION: GERMAN MARK
Estimation Period: February 23, 1987 to February 23, 1990
Dependent Variable: Log Change in Closing Mark-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4
I. Conditional Mean				
Constant	-0.011	-0.006	0.002	-0.090
	(-0.411)	(-0.159)	(0.253)	(-1.859)
Interest-rate spreads				0.263
				(2.290)
US holiday dummy				0.075
				(0.513)
German holiday dummy				-0.069
				(-0.426)
II. Conditional Variance				
Omega	0.470	0.020	0.019	0.041
	(27.868)	(2.604)	(1.611)	(2.076)
Alpha		0.052	0.042	0.021
		(3.862)	(2.436)	(1.287)
Beta		0.907	0.914	0.896
		(36.705)	(23.607)	(21.775)
Interest-rate spreads				-0.048
				(-2.117)
US holiday dummy				0.308
				(2.768)
German holiday dummy				0.042
				(0.845)
1/v	0.010	0.010	0.129	0.126
	(normal)	(normal)	(fixed)	(fixed)
III. Diagnostics				
Log likelihood	-788.340	-775.570	-755.790	-742.890
Unconditional variance	0.470	0.470	0.470	0.466
B1 for E/SQRT(H)	-0.030	-0.115	-0.105	-0.060
B2 for E/SQRT(H)	5.100	4.570	4.592	4.528
Q(15) for E	14.574	14.574	14.574	13.730
Q(15) for E/SQRT(H)	14.574	13.353	13.446	16.114
Q(15) for E**2	53.100	53.197	53.335	54.941
Q(15) for E**2/H	53.100	21.462	22.295	17.021
Observations	757	757	757	757

Source: Authors' calculations.

TABLE 5.0.J: BASIC EXCHANGE-RATE EQUATION: JAPANESE YEN
Estimation Period: February 23, 1987 to February 23, 1990
Dependent Variable: Log Change in Closing Yen-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5
I. Conditional Mean					
Constant	-0.005	-0.001	0.006	-0.101	-0.110
	(-0.104)	(-0.032)	(0.329)	(-1.602)	(-1.774)
Interest-rate spreads				0.226	0.245
				(1.774)	(1.900)
II. Conditional Variance					
Omega	0.499	0.036	0.029	0.002	0.001
	(31.521)	(3.326)	(2.332)	(0.123)	(0.086)
Alpha(1)		0.091	0.101	0.107	0.108
		(4.708)	(3.541)	(3.503)	(3.528)
Beta(1)		0.838	0.835	0.794	0.794
		(23.367)	(18.038)	(16.657)	(16.844)
Interest-rate spreads				0.069	0.069
				(2.111)	(2.134)
U.S. holiday dummy				0.307	0.310
				(2.701)	(2.719)
1/v	0.010	0.010	0.155	0.155	0.154
	(normal)	(normal)			
III. Diagnostics					
Log likelihood	-815.64	-786.89	-754.13	-745.70	-745.20
Unconditional variance	0.505	0.505	0.505	0.504	0.504
B1 for E/SQRT(H)	0.066	-0.127	-0.154	-0.241	-0.239
B2 for E/SQRT(H)	6.130	5.320	5.444	5.392	5.402
Q(15) for E	13.190	13.190	13.190	12.808	12.733
Q(15) for E/SQRT(H)	13.190	12.673	12.447	13.845	13.717
Q(15) for E**2	96.675	96.570	96.353	95.259	95.288
Q(15) for E**2/(H)	96.675	11.145	9.672	7.122	7.097
Observations	757	757	757	757	757

Source: Authors' calculations.

TABLE 5.1.G: BASIC EXCHANGE-RATE EQUATION: GERMAN MARK
Estimation Period: February 23, 1987 to September 30, 1988
Dependent Variable: Log Change in Closing Mark-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5
I. Conditional Mean					
Constant	0.0032	0.0179	0.0113	-0.2268	-0.2146
	(0.0572)	(0.6082)	(0.3665)	(-2.3817)	(-2.2055)
Interest-rate spreads				0.5620	0.5446
				(2.9083)	(2.7668)
II. Conditional Variance					
Omega	0.4298	0.0249	0.0259	0.0732	0.0819
	(21.873)	(2.3683)	(1.3668)	(2.1034)	(2.0695)
Alpha		0.0669	0.0557	0.0000	0.0000
		(2.9892)	(1.8952)	(0.0000)	(0.0000)
Beta		0.8759	0.8770	0.9094	0.9070
		(22.7740)	(13.0780)	(19.5060)	(18.7140)
Interest-rate spreads				-0.1045	-0.1191
				(-2.1261)	(-2.1165)
U.S. holiday dummy				0.4355	0.4427
				(2.3345)	(2.2439)
1/nu	0.0100	0.0100	0.1334	0.1334	0.1575
	(normal)	(normal)	(fixed)	(fixed)	(fixed)
III. Diagnostics					
Log likelihood	-407.8300	-399.0100	-386.5600	-373.9400	-373.9000
Unconditional variance	0.4323	0.4324	0.4323	0.4248	0.4251
B1 for E/SQRT(H)	0.3422	0.1592	0.1747	0.0935	0.1095
B2 for E/SQRT(H)	5.6309	4.7201	4.7697	5.4351	5.5832
Q(15) for E	17.1822	17.1822	17.1822	17.7495	17.7337
Q(15) for E/SQRT(H)	17.1822	15.6510	15.8105	15.1891	15.1985
Q(15) for E**2	31.9534	32.0919	32.0326	28.5511	28.6806
Q(15) for E**2/(H)	31.9534	11.1285	11.8946	7.3672	7.5780
Observations	408	408	408	408	408

Source: Authors' calculations.

TABLE 5.1.J: BASIC EXCHANGE-RATE EQUATION: JAPANESE YEN
Estimation Period: February 23, 1987 to September 30, 1988
Dependent Variable: Log Change in Closing Yen-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5
I. Conditional Mean					
Constant	-0.034	-0.031	-0.024	-0.335	-0.335
	(-1.011)	(-0.875)	(-0.719)	(-2.207)	(-2.219)
Interest-rate spreads				0.724	0.723
				(2.109)	(2.113)
II. Conditional Variance					
Omega	0.525	0.042	0.041	0.089	0.087
	(24.223)	(2.707)	(1.732)	(1.523)	(1.540)
Alpha		0.097	0.099	0.094	0.093
		(3.762)	(2.495)	(2.250)	(2.262)
Beta		0.826	0.811	0.773	0.774
		(18.049)	(10.837)	(10.280)	(10.451)
Interest-rate spreads				-0.092	-0.092
				(-0.882)	(-0.896)
U.S. holiday dummy				0.479	0.480
				(2.024)	(2.049)
1/nu	0.010	0.010	0.156	0.156	0.151
	(normal)	(normal)			
III. Diagnostics					
Log likelihood	-448.150	-433.270	-412.740	-407.690	-407.940
Unconditional variance	0.527	0.527	0.527	0.527	0.526
B1 for E/SQRT(H)	0.420	0.077	0.073	0.070	0.070
B2 for E/SQRT(H)	6.915	5.461	5.485	5.300	5.300
Q(15) for E	15.610	15.610	15.610	15.880	15.880
Q(15) for E/SQRT(H)	15.610	16.110	16.260	14.280	14.260
Q(15) for E**2	51.660	51.590	51.420	49.710	49.720
Q(15) for E**2/(H)	51.660	7.860	7.580	4.480	4.470
Observations	408	408	408	408	408

Source: Authors' calculations.

TABLE 5.2.G: BASIC EXCHANGE-RATE EQUATION: GERMAN MARK
Estimation Period: October 3, 1988 to February 23, 1990
Dependent Variable: Log Change in Closing Mark-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5
I. Conditional Mean					
Constant	-0.0304	-0.0271	-0.0100	-0.0403	-0.0456
	(-0.7514)	(-0.5749)	(-0.2618)	(-0.7972)	(-0.8337)
Interest-rate spreads				0.2518	0.2390
				(1.3044)	(1.2134)
II. Conditional Variance					
Omega	0.5123	0.0153	0.0151	-0.0095	-0.0087
	(17.2768)	(1.5217)	(0.9680)	(-1.1775)	(-0.9359)
Alpha		0.0406	0.0295	0.0095	0.0090
		(2.7368)	(1.6258)	(0.5950)	(0.5309)
Beta		0.9308	0.9395	0.9975	0.9969
		(35.7720)	(22.1116)	(34.4939)	(30.9250)
Interest-rate spreads				-0.0073	-0.0072
				(-1.0529)	(-0.9601)
U.S. holiday dummy				0.0791	0.0750
				(1.3515)	(1.2059)
German holiday dummy				0.1805	0.1764
				(3.7413)	(3.4990)
1/v	0.010	0.010	0.1174	0.1174	0.1157
	(normal)	(normal)	(fixed)	(fixed)	(1.9387)
III. Diagnostics					
Log likelihood	-378.85	-375.20	-368.00	-360.78	-360.71
Unconditional variance	0.5133	0.5133	0.5138	0.5105	0.5111
B1 for E/SQRT(H)	-0.3534	-0.3599	-0.3495	-0.3934	-0.3919
B2 for E/SQRT(H)	4.5271	4.3285	4.3451	3.9239	3.9304
Q(15) for E	10.1787	10.1787	10.1787	9.2863	9.3064
Q(15) for E/SQRT(H)	10.1787	9.1047	9.3486	7.9788	7.9871
Q(15) for E**2	31.5527	31.5276	31.3726	31.9244	32.0141
Q(15) for E**2/(H)	31.5527	15.9551	17.4621	21.0641	20.9783
Observations	349	349	349	349	349

Source: Authors' calculations.

TABLE 5.2.J: BASIC EXCHANGE-RATE EQUATION: JAPANESE YEN
Estimation Period: October 3, 1988 to February 23, 1990
Dependent Variable: Log Change in Closing Yen-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5
I. Conditional Mean					
Constant	0.027	0.032	0.040	-0.043	-0.047
	(0.739)	(0.861)	(1.267)	(-0.616)	(-0.692)
Interest-rate spreads				0.155	0.163
				(1.211)	(1.249)
II. Conditional Variance					
Omega	0.480	0.024	0.017	-0.008	-0.008
	(18.610)	(1.860)	(1.378)	(-0.780)	(-0.802)
Alpha(1)		0.076	0.090	0.099	0.099
		(3.394)	(2.528)	(2.072)	(2.085)
Beta(1)		0.024	0.873	0.794	0.793
		(20.213)	(16.899)	(10.030)	(10.057)
Interest-rate spread				0.082	0.082
				(1.999)	(2.018)
Holiday dummy				0.269	0.269
				(1.921)	(1.932)
1/nu	0.010	0.010	0.156	0.156	0.151
	(normal)	(normal)			
III. Diagnostics					
Log likelihood	-366.330	-352.010	-339.850	-334.210	-334.300
Unconditional variance	0.478	0.478	0.478	0.478	0.478
B1 for E/SQRT(Q)	-0.398	-0.311	-0.334	-0.378	-0.379
B2 for E/SQRT(Q)	5.176	5.199	5.488	5.295	5.300
Q(15) for E	17.415	17.415	17.415	17.431	17.436
Q(15) for E/SQRT(H)	17.415	13.945	13.449	13.398	13.585
Q(15) for E**2	80.695	80.361	79.901	78.304	78.186
Q(15) for E**2/(H)	80.695	12.765	10.801	14.153	14.122
Observations	349	349	349	349	349

Source: Authors' calculations.

TABLE 6.0.G: EXCHANGE-RATE EQUATION WITH INTERVENTION AGAINST GERMAN MARKS
Estimation Period: February 23, 1987 to February 23, 1990
Dependent Variable: Log Change in the Closing Mark-Dollar Exchange Rate

	EQUATION 1	EQUATION 2
I. Conditional Mean		
Constant	-0.1395	-0.1265
	(-2.9247)	(-2.7593)
Interest-rate spreads	0.3865	0.3600
	(3.2791)	(3.1864)
US holiday dummy	0.1048	0.1156
	(0.6598)	(0.7997)
German holiday dummy	-0.0602	-0.0748
	(-0.3845)	(-0.4466)
US dollar purchases	-0.1111	
	(-1.5770)	
US dollar sales	0.0495	
	(1.1241)	
German dollar purchases	0.0023	
	(0.1050)	
German dollar sales	-0.1271	
	(-1.8550)	
Total dollar purchases		-0.1996
		(-4.2815)
Total dollar sales		0.0674
		(1.9604)
II. Conditional Variance		
Omega	0.0721	0.0458
	(2.8903)	(2.2328)
Alpha	0.0304	0.0257
	(1.5012)	(1.4736)
Beta	0.8457	0.8832
	(17.4451)	(20.7588)
Interest-rate spreads	-0.0899	-0.0527
	(-2.3288)	(-2.1299)
US holiday dummy	0.3189	0.2855
	(2.3288)	(2.5026)
German holiday dummy	0.0087	0.0173
	(0.1675)	(0.3567)
US dollar purchases	0.0384	
	(0.8963)	
US dollar sales	-0.0293	
	(-1.6226)	
German dollar purchases	0.0081	
	(0.2106)	
German dollar sales	0.0226	
	(1.6766)	
Total dollar purchases		0.0184
		(0.9950)
Total dollar sales		0.0044
		(0.6857)
1/v	0.1094	0.1123
	(fixed)	(fixed)

	EQUATION 1	EQUATION 2
III. Diagnostics		
Log Likelihood	-734.9500	-732.7300
Unconditional variance	0.4629	0.4583
B1 for E/SQRT(H)	-0.0256	-0.0155
B2 for E/SQRT(H)	4.1700	4.2211
Q(15) for E	12.0646	11.7337
Q(15) for E/SQRT(H)	13.5644	12.9838
Q(15) for E**2	60.1183	56.6346
Q(15) for E**2/H	19.2754	17.9283
Observations	757	757

Source: Authors' calculations.

TABLE 6.0.J: EXCHANGE-RATE EQUATION WITH INTERVENTION AGAINST JAPANESE YEN
Japanese Yen Estimation Period: February 23, 1987 to February 23, 1988
Dependent Variable: Log Change in Closing Yen-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4
I. Conditional Mean				
Constant	-0.080	-0.079	-0.099	-0.100
	(-1.437)	(-1.383)	(-1.637)	(-1.685)
Interest-rate spreads	0.1729	0.169	0.203	0.205
	(1.454)	(1.428)	(1.638)	(1.647)
Total dollar purchases			-0.170	-0.171
			(-4.734)	(-4.758)
Total dollar sales			-0.021	-0.023
			(0.557)	(-0.613)
U.S. dollar purchases	-0.083	-0.086		
	(-1.506)	(-1.578)		
U.S. dollar sales	0.072	0.071		
	(1.464)	(1.455)		
Japanese dollar purchases	-0.084	-0.082		
	(-1.698)	(-1.669)		
Japanese dollar sales	-0.042	-0.042		
	(-1.078)	(-1.068)		
II. Conditional Variance				
Omega	0.001	0.001	-0.0003	-0.0004
	(0.055)	(0.089)	(-0.026)	(-0.031)
Alpha	0.107	0.106	0.101	0.099
	(3.568)	(3.591)	(3.587)	(3.661)
Beta	0.801	0.801	0.810	0.811
	(18.333)	(18.531)	(19.291)	(19.904)
Interest-rate spreads	0.065	0.065	0.065	0.064
	(2.121)	(2.125)	(2.300)	(2.350)
Holiday	0.322	0.322	0.284	0.284
	(2.961)	(2.995)	(2.832)	(2.923)
Total dollar purchases			0.024	0.023
			(2.104)	(2.155)
Total dollar sales			0.011	0.012
			(0.865)	(0.961)
U.S. dollar purchases	0.010	0.010		
	(0.299)	(0.297)		
U.S. dollar sales	0.048	0.049		
	(2.104)	(2.182)		
Japanese dollar purchases	0.014	0.014		
	(0.593)	(0.599)		
Japanese dollar sales	-0.035	-0.036		
	(-2.079)	(-2.114)		
1/v	0.154	0.148	0.154	0.140
III. Diagnostics				
Log likelihood	-734.10	-734.46	-733.78	-734.73
Unconditional variance	0.501	0.510	0.495	0.495
B1 for E/SQRT(H)	0.147	-0.144	-0.113	-0.111
B2 for E/SQRT(H)	4.858	4.842	4.915	4.897
Q(15) for E	13.797	13.819	13.866	13.848
Q(15) for E/SQRT(H)	13.519	13.610	12.802	12.881
Q(15) for E**2	108.478	108.570	114.163	114.322
Q(15) for E**2/(H)	7.669	7.652	6.312	6.250
Observations	757	757	757	757

Source: Authors' calculations.

TABLE 6.1.G: EXCHANGE-RATE EQUATION WITH INTERVENTION AGAINST GERMAN MARKS
Estimation Period: February 23, 1987 to October 3, 1988
Dependent Variable: Log Change in the Closing Mark-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5	EQUATION 6	EQUATION 7
I. Conditional Mean							
Constant	-0.2662	-0.1961	-0.2727	-0.2863	-0.3406	-0.3343	-0.2721
	(-2.7363)	(-1.8975)	(-2.8720)	(-2.9620)	(-3.6650)	(-3.501)	(-2.7350)
Interest-rate spreads	0.5891	0.4968	0.5997	0.6287	0.7583	0.7234	-0.5934
	(2.9100)	(2.3266)	(3.0235)	(3.1915)	(3.9930)	(3.6860)	(2.8920)
U.S. dollar purchases	-0.0688		-0.0568	-0.0634	-0.0849		
	(-0.9409)		(-0.7990)	(-0.9080)	(-1.0780)		
U.S. dollar sales		0.0173					
		(0.2076)					
German dollar purchases	-0.1466		-0.1661	-0.1636	-0.1794		
	(-2.0456)		(-2.3860)	(-2.4380)	(-2.6280)		
German dollar sales		0.0475					
		(0.8859)					
Total dollar purchases						0.0538	0.0527
						(1.0170)	(0.9690)
Total dollar sales						-0.2726	-0.2732
						(-5.0680)	(-4.9760)
II. Conditional Variance							
Omega	0.0472	0.0886	0.0445	0.0568	0.0647	0.0561	0.0652
	(2.2975)	(2.0340)	(2.3585)	(2.3640)	(2.3650)	(2.0480)	(2.3470)
Alpha	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Beta	0.9404	0.9017	0.9375	0.9234	0.9148	0.9192	0.9096
	(32.5872)	(17.2359)	(31.5600)	(24.4200)	(23.3600)	(18.0580)	(18.3760)
Interest-rate spreads	-0.0716	-0.1270	-0.0657	-0.0812	-0.0965	-0.0781	-0.0927
	(-2.3990)	(-2.0611)	(-2.4100)	(-2.3150)	(-2.4160)	(-1.9880)	(-2.3270)
U.S. holiday dummy	0.4170	0.4771	0.3901	0.4012	0.4424	0.4582	0.4320
	(2.7570)	(2.1566)	(2.8683)	(2.4981)	(2.7290)	(2.1940)	(2.2630)
U.S. dollar purchases					0.0437		
					(1.2820)		
U.S. dollar sales				-0.0224			
				(-1.0220)			
German dollar purchases					-0.0300		
					(-1.0480)		
Total dollar purchases						0.0118	0.0143
						(1.1760)	(1.5070)
Total dollar sales						0.0098	0.0164
						(0.4480)	(0.8530)
1/v	0.1575	0.1575	0.1126	0.1126	0.1126	0.1575	0.1060
	(fixed)	(fixed)	(fixed)	(fixed)	(fixed)	(fixed)	(fixed)
III. Diagnostics							
Log likelihood	-369.9200	-374.2100	-369.7900	-368.2400	-368.4300	-362.6200	-363.0900
Unconditional variance	0.4169	0.4249	0.4164	0.4165	0.4167	0.4068	0.4073
B1 for E/SQRT(H)	0.2565	0.1113	0.2598	0.1670	0.2625	0.2213	0.2565
B2 for E/SQRT(H)	4.2326	5.4818	4.2080	4.2677	4.1988	4.0642	4.1200
Q(15) for E	15.5514	17.4832	15.6331	15.5263	14.9156	12.6838	12.6829
Q(15) for E/SQRT(H)	13.3831	15.4095	13.7030	14.9871	12.8721	12.5573	12.7956
Q(15) for E**2	34.9522	28.4005	35.2151	35.1672	35.7108	33.1517	33.9430
Q(15) for E**2/(H)	11.5320	7.4726	12.0093	11.2860	13.0163	13.1674	14.3391
Observations	408	408	408	408	408	408	408

Source: Authors' calculations.

TABLE 6.1.J: EXCHANGE-RATE EQUATION WITH INTERVENTION AGAINST JAPANESE YEN
Japanese Yen Estimation Period: February 23, 1987 to September 30, 1988

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4
I. Conditional Mean				
Constant	-0.226	-0.226	-0.209	-0.206
	(-1.505)	(-1.491)	(-1.414)	(-1.411)
Interest-rate spreads	0.447	0.447	0.400	0.393
	(1.301)	(1.290)	(1.175)	(1.166)
Total dollar purchases			-0.198	-0.200
			(-4.003)	(-4.027)
Total dollar sales			-0.063	-0.058
			(-0.772)	(-0.716)
U.S. dollar purchases	-0.055	-0.055		
	(-0.781)	(-0.785)		
U.S. dollar sales	-0.058	-0.058		
	(-0.712)	(-0.717)		
Japanese dollar purchases	-0.140	-0.140		
	(-2.360)	(-2.351)		
Japanese dollar sales				
II. Conditional Variance				
Omega	0.085	0.082	0.061	0.059
	(1.517)	(1.505)	(1.287)	(1.301)
Alpha	0.098	0.097	0.100	0.097
	(2.171)	(2.190)	(2.346)	(2.393)
Beta	0.752	0.756	0.772	0.776
	(10.219)	(10.501)	(11.729)	(12.292)
Interest-rate spreads	-0.070	-0.068	-0.034	-0.033
	(-0.650)	(-0.640)	(-0.362)	(-0.360)
Holiday	0.530	0.528	0.472	0.476
	(2.140)	(2.164)	(2.161)	(2.256)
Total dollar purchases			0.039	0.038
			(1.918)	(1.930)
Total dollar sales			0.089	0.087
			(1.656)	(1.708)
U.S. dollar purchases	0.038	0.037		
	(0.613)	(0.610)		
U.S. dollar sales	0.096	0.094		
	(1.667)	(1.673)		
Japanese dollar purchases	0.012	0.011		
	(0.313)	(0.313)		
Japanese dollar sales				
1/v	0.151	0.148	0.151	0.136
III. Diagnostics				
Log likelihood	-398.92	-399.05	-396.37	-397.03
Unconditional variance	0.516	0.516	0.510	0.510
B1 for E/SQRT(H)	0.168	0.163	0.190	0.181
B2 for E/SQRT(H)	4.946	4.924	4.776	4.749
Q(15) for E	18.870	18.870	18.800	18.770
Q(15) for E/SQRT(H)	19.890	19.800	19.920	19.850
Q(15) for E**2	61.330	61.350	65.090	65.310
Q(15) for E**2/(H)	5.500	5.410	5.430	5.420
Observations	408	408	408	408

Source: Author's calculations.

TABLE 6.2.G: EXCHANGE-RATE EQUATION WITH INTERVENTION AGAINST GERMAN MARKS
Estimation Period: October 3, 1988 to February 23, 1990
Dependent Variable: Log Change in Closing Mark-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4
I. Conditional Mean				
Constant	-0.0196	-0.0651	-0.0280	0.0071
	(-0.3630)	(-1.1678)	(-0.4700)	(0.1430)
Interest-rate spreads	0.1625	0.2796	0.1818	0.0880
	(0.8305)	(1.3979)	(0.8597)	(0.5550)
US dollar sales	0.0203	0.0527		
	(0.3262)	(0.8310)		
German dollar sales	0.0307	0.0065		
	(0.5261)	(0.1206)		
Total dollar sales			0.0901	0.0921
			(1.6989)	(1.9970)
II. Conditional Variance				
Omega	0.0086	-0.0097	-0.0093	-0.0091
	(-1.2956)	(-1.2298)	(-1.047)	(-1.974)
Alpha	0.0090	0.0100	0.0063	0.0069
	(0.4965)	(0.5561)	(0.3718)	(0.4310)
Beta(1)	0.9963	0.9980	1.0005	0.9976
	(35.0245)	(36.8894)	(35.7460)	(39.1910)
Interest-rate spreads	-0.0082	-0.0084	-0.0081	-0.0081
	(-1.0272)	(-0.8915)	(-0.9230)	(-1.1210)
US holiday dummy	0.0714	0.0712	0.0814	0.0868
	(0.8699)	(0.7455)	(1.1914)	(1.6080)
German holiday dummy	0.1924	0.2001	0.1907	0.1950
	(4.0386)	(3.8111)	(3.2538)	(4.2550)
US dollar sales	-0.0027	-0.0037		
	(-0.1808)	(-0.2117)		
German dollar sales	0.0023	0.0020		
	(0.1655)	(0.1273)		
Total dollar sales			-0.0007	-0.0003
			(-0.1020)	(-0.0490)
1/v	0.1035	0.1174	0.1174	0.1147
	(fixed)	(fixed)	(fixed)	(fixed)
III. Diagnostics				
Log likelihood	-360.6800	-360.1600	-359.4400	-360.1200
Unconditional variance	0.5134	0.5119	0.5128	0.5154
B1 for E/SQRT(H)	-0.4343	-0.3899	-0.4043	-0.4875
B2 for E/SQRT(H)	4.0520	3.8900	4.0730	4.3268
Q(15) for E	9.2008	8.9621	9.2400	9.4017
Q(15) for E/SQRT(H)	7.2639	7.1095	7.9496	7.5402
Q(15) for E**2	30.5055	32.7843	29.7344	29.3197
Q(15) for E**2/H	21.0006	20.6604	19.3900	20.0083
Observations	349	349	349	349

Source: Authors' calculations.

TABLE 6.2.J: EXCHANGE-RATE EQUATION WITH INTERVENTION AGAINST JAPANESE YEN
Estimation Period: October 3, 1988 to February 23, 1990
Dependent Variable: Log Change in the Closing Yen-Dollar Exchange Rate

	EQUATION 1	EQUATION 2	EQUATION 3	EQUATION 4	EQUATION 5
I. Conditional Mean					
Constant	-0.041	-0.041	-0.042	-0.052	-0.052
	(-0.587)	(-0.576)	(-0.653)	(-0.714)	(-0.707)
Interest-rate spreads	0.146	0.145	0.150	0.172	0.171
	(1.134)	(1.114)	(1.247)	(1.299)	(1.271)
Total dollar purchases				-0.105	-0.104
				(-1.312)	(-1.272)
Total dollar sales				0.0003	-0.001
				(0.024)	(-0.042)
U.S. dollar purchases	-0.224	-0.223	-0.225		
	(-1.951)	(-1.958)	(-1.941)		
U.S. dollar sales	0.105	0.103	0.112		
	(1.471)	(1.420)	(1.810)		
Japanese dollar purchases	0.100	0.101	0.107		
	(0.798)	(0.809)	(0.847)		
Japanese dollar sales	-0.062	-0.061	-0.065		
	(-1.017)	(-1.002)	(-1.313)		
II. Conditional Variance					
Omega	-0.010	-0.009	-0.011	-0.008	-0.008
	(-0.845)	(-0.830)	(-0.851)	(-0.819)	(-0.861)
Alpha	0.101	0.098	0.115	0.081	0.077
	(2.110)	(2.114)	(1.867)	(1.998)	(2.033)
Beta	0.795	0.801	0.797	0.837	0.843
	(10.284)	(10.658)	(8.909)	(12.630)	(13.465)
Interest-rate spreads	0.081	0.078	0.085	0.062	0.059
	(2.055)	(2.060)	(1.506)	(1.930)	(1.978)
Holiday	0.249	0.242	0.282	0.226	0.218
	(1.884)	(1.905)	(1.706)	(1.982)	(2.045)
Total dollar purchases				-0.007	-0.007
				(-0.251)	(-0.254)
Total dollar sales				0.010	0.011
				(0.680)	(0.848)
U.S. dollar purchases	-0.033	-0.032	-0.060		
	(-1.228)	(-1.225)	(-1.086)		
U.S. dollar sales	0.013	0.015	0.032		
	(0.678)	(0.822)	(0.820)		
Japanese dollar purchases			0.023		
			(0.345)		
Japanese dollar sales			-0.026		
			(-0.851)		
1/v	0.151	0.143	0.225	0.151	0.135
			(308.9)		
III. Diagnostics					
Log likelihood	-330.08	-330.25	-329.08	-333.23	-333.500
Unconditional variance	0.4788	0.4786	0.4792	0.4759	0.4758
B1 for E/SQRT(H)	-0.352	-0.336	-0.342	-0.317	-0.304
B2 for E/SQRT(H)	5.094	4.989	5.071	4.832	4.742
Q(15) for E	15.613	15.634	15.594	16.720	16.734
Q(15) for E/SQRT(H)	10.667	10.721	11.016	12.976	12.998
Q(15) for E**2	76.647	76.726	76.445	78.710	78.786
Q(15) for E**2/(H)	15.113	15.528	15.520	15.746	16.198
Observations	349	349	349	349	349.000

Source: Authors' calculations.

APPENDIX A: Data Description

We use the following data series either to estimate the model or to construct variables. The data sets contain 761 observations beginning on February 23, 1990. We estimate all of the models beginning at the fifth observation, February 20, 1987, the day before the G7 met. We utilize 757 observations.

Interest rates:

ibnk	West German 3-month interbank rate. DRIFACS PLUS.
genski	Japanese Gensaki 3-month rate. DRIFACS PLUS.
tbill	U.S. Treasury bill rate. DRIFACS PLUS.

Exchange Rates:

idmbid1	mark-dollar exchange rate; morning-opening bid. FRBNY
idmofr1	mark-dollar exchange rate; morning-opening offer. FRBNY
idmbid5	mark-dollar exchange rate; closing bid. FRBNY
idmofr5	mark-dollar exchange rate; closing offer. FRBNY
iynbid1	yen-dollar exchange rate; morning-opening bid. FRBNY
iynofr1	yen-dollar exchange rate; morning-opening offer. FRBNY
iynofr5	yen-dollar exchange rate; closing bid. FRBNY
iynofr5	yen-dollar exchange rate; closing offer. FRBNY

Target Zone Variables (see table 1):

lowtarg	mark-dollar rate at which the U.S. tended to purchase dollars.
hightarg	mark-dollar rate at which the U.S. tended to sell dollars.
lowyen	yen-dollar rate at which the U.S. tended to buy dollars.
highyen	yen-dollar rate at which the U.S. tended to sell dollars.

Dummy Variables

ushol	dummy variable equal to 1 on the day after a U.S. holiday. On U.S. holidays, exchange-rate data were either missing or incomplete. Any intervention on U.S. holidays was added to the previous observation.
gerhol	dummy variable for German holidays. If the NY market was open, we replaced any missing German interest-rate observation with the rate on the previous day. There were 20 German holidays.
japhol	dummy variable for Japanese holidays. If the NY market was open, we replaced any missing Japanese interest-rate observation with the rate on the previous day. There were 33 Japanese holidays.
mondum	dummy variable equal to one on Mondays.
weddum	dummy variable equal to one on Wednesdays.
thudum	dummy variable equal to one on Thursdays.
fridum	dummy variable equal to one on Fridays.