August 2, 2004

Fed Intervention, Dollar Appreciation, and Systematic Risk*

Richard J. Sweeney

The McDonough School of Business
Georgetown University
37th and "O" Sts., NW
Washington, DC 20057
(O) 1-202-687-3742
Fax 1-202-687-7639, - 4031
sweeneyr@georgetown.edu

Abstract: In a four-factor asset-pricing model estimated on daily data, Fed intervention significantly affects betas of surprises in the market return, expected inflation rate, yield curve, and corporate-bond risk premium. Fed foreign-currency sales cause economically and statistically significant increases in the systematic risk premium in appreciation and thus in the dollar's expected appreciation rate, the direction the Fed desires, and consistent with the signaling but not the portfolio balance channel. Intervention's effects on actual appreciation are less reliable; they depend on unpredictable risk-factor realizations. Even successful intervention to strengthen the dollar may be costly; by increasing the dollar's systematic risk, intervention reduces the attractiveness of U.S. relative to foreign investments. Further, uncertainty about future Fed interventions may induce resource misallocation: ceteris paribus, investors find it harder to estimate risk-adjusted discount rates and forecast the home-currency value of cash flows.

*Thanks are due in particular to Boo Sjöö and Clas G. Wihlborg, and to Dick Baillie, Jim Bodurtha, Wlodek Burstyn, Mats-Ola Forsman, Cam Harvey, Alex Humer, Mike Hutchison, Kenneth Kopeckny, Michael Leahy, Tony Lovesic, Christine P. Ries and Thomas D. Willett. Participants in the Claremont Seminar in Money and Finance, the Financial Economics workshop of the Gothenburg School of Economics, workshops at the Board of Governors of the Federal Reserve System, the Institute of Advanced Studies, Vienna, Lund University and the Copenhagen Institute of Management and The McDonough School of Business provided helpful comments on related papers. Ma Jun and Feng Yuanshi were research assistants. Part of this paper was done at the Gothenburg School of Economics. The McDonough School of Business provided summer research support and the Capital Markets Research Center provided research assistance.

Fed Intervention, Dollar Appreciation, and Systematic Risk

Abstract: In a four-factor asset-pricing model estimated on daily data, Fed intervention significantly affects betas of surprises in the market return, expected inflation rate, yield curve, and corporate-bond risk premium. Fed foreign-currency sales cause economically and statistically significant increases in the systematic risk premium in appreciation and thus in the dollar's expected appreciation rate, the direction the Fed desires, and consistent with the signaling but not the portfolio balance channel. Intervention’s effects on actual appreciation are less reliable; they depend on unpredictable risk-factor realizations. Even successful intervention to strengthen the dollar may be costly; by increasing the dollar’s systematic risk, intervention reduces the attractiveness of U.S. relative to foreign investments. Further, uncertainty about future Fed interventions may induce resource misallocation: ceteris paribus, investors find it harder to estimate risk-adjusted discount rates and forecast the home-currency value of cash flows.

Fed Intervention, Dollar Appreciation, and Systematic Risk

1. Introduction

Foreign-exchange markets have the largest volumes and lowest spreads and are the thickest and most liquid of financial markets. Not surprisingly, asset-pricing models, a key tool in understanding financial markets, are often applied to foreign exchange markets. Perhaps surprisingly, however, this is the first paper to use a multi-factor APM to analyze how government intervention affects expected appreciation. Instead, many previous papers that test for intervention effects on expected appreciation use portfolio balance or signaling models. It is difficult to interpret previous papers' results in terms of asset-pricing models: These papers omit the APM channels through which intervention affects expected appreciation—by changing appreciation's betas on risk factor realizations or by changing economy-wide risk premia. This paper focuses on intervention effects on appreciation's betas; in estimating equations, betas are conditioned on intervention variables. Because the data support APM specifications, previous estimating models are likely misspecified, causing bias and inefficiency, as shown below.

Previous papers' empirical results are mixed: many papers find no, small or statistically weak relationships, but others find stronger relationships. This paper reports strong and robust relationships: Estimates show that Fed sales of foreign currency, or purchases of dollars, on average increase the dollar's expected appreciation rate, the direction the Fed desires. The sign of intervention's effect is consistent with the signaling channel, but inconsistent with the portfolio balance channel. Foreign currency sales "work" by increasing the systematic risk premium in dollar appreciation. Thus, the estimated equations explain how intervention jointly affects expected appreciation and ***systematic*** exchange-rate risk, the foreign-exchange risk that matters to diversified decision-makers. These results on systematic risk complement previous investigations of intervention effects on total risk, on implied volatility in currency options, and on bid-ask spreads in currency quotes.

Equations are estimated for daily data on Fed intervention in Deutsche marks and Japanese yen. Four risk factors are used: surprises in the rate of return on the market, and in the inflation rate, yield curve and risk premium in corporate bonds, analogues of factors in APM equity- and bond-market studies. Intervention has statistically significant effects on market betas in all specification, and has statistically significant effects on betas of non-market factors in many specifications. Intervention effects on expected appreciation are economically significant. For example, at the sample-period maximum and minimum values of each factor's beta as functions of intervention, suppose each risk-factor realization rises, one at a time, by one standard deviation; across the four factors, appreciation is larger at the maximum than minimum beta by 2.08%/year to 2.75%/year for the DEM, and by 1.70%/year to 4.32%/year for the JPY.

Intervention effects on ***expected*** dollar appreciation are reliable. In APMs, intervention effects on ***actual*** appreciation depend on betas and also on risk-factor realizations; in the face of adverse factor realizations, intervention may be counterproductive by intensifying depreciation. Uncertainty about the actual effects of intervention may help explain the reluctance of many central banks to intervene since the early 1990s, as compared to the 1980s. Further, even successful intervention may be costly. Intervention that strengthens the dollar works by increasing the dollar's risk premium. Ceteris paribus, the required rate of return increases for investments with dollar risk, and foreigners invest less in the U.S. Similarly, U.S. investors face reduced exchange-rate risk abroad—the foreign-currency risk premium is the negative of the dollar's for this paper's log exchange rates—and thus invest more abroad, less in the U.S. Further, the unpredictability of Fed intervention tends to harm resource allocation: ceteris paribus, both U.S.

and foreign investors find it more difficult to estimate future currency betas for use in risk-adjusted discount rates, and to forecast the home-currency value of cash flows.

Section 2 shows how this paper is related to the literature, and Section 3 discusses how intervention affects expected appreciation in APMs. The data are discussed in Section 4. In Section 5, test results show that Fed foreign currency sales cause statistically and economically significant increases in dollar appreciation's systematic risk and thus in expected appreciation. In tests in Section 6, the data cannot reject the joint null that the exchange market is strong-form efficient relative to intervention, and that non-market-factor risk premia make zero net contribution to intervention's effect on expected appreciation. Section 7 offers some conclusions.

2. Relationship to the Literature

This paper finds strong and robust effects of Fed intervention on expected USD appreciation. In contrast, previous estimates of portfolio balance and signaling models often find no, small or statistically weak effects on appreciation (Dooley and Isard 1982, 1983; Frankel 1982a,b; Frankel and Engel 1984; Rogoff 1984; Engel and Rodrigues 1989; Giovannini and Jorion 1989; Ghosh 1992; Edison 1993 surveys earlier work, and Sarno and Taylor 2001 more recent work). These weak results may arise because the Fed's stated policy is to sterilize its intervention, and many observers doubt that sterilized intervention importantly affects appreciation. Data problems may play a role: these studies use quarterly, monthly or weekly rather than daily data, and outside assets or international reserves rather than intervention. More recent studies use daily intervention data.

A number of studies find that daily intervention and appreciation are significantly associated in single-equation regressions. In studies that regress appreciation on contemporaneous intervention (Loopesko 1984, Table 1; Catte, Galli and Rebecchini 1992; Dominguez and Frankel

1993a, Tables 7.1-7.7), estimates are subject to simultaneous equations bias, where significant estimates may arise even if intervention does not affect appreciation; indeed, some cite this bias as a partial explanation of why their estimated slopes often have "incorrect" signs (Dominguez and Frankel 1993a, 114-115). Other papers mitigate simultaneous equations bias by regressing appreciation on predetermined intervention (Dominguez 1990, Dominguez and Frankel 1993b, and Baillie and Osterberg 2000),[1] but this is not a panacea for bias. Predetermined intervention may be correlated with the estimating equation error, unless the exchange market is strong form efficient relative to intervention—and many observers are skeptical of this strong-form efficiency. This paper's specifications ensure that estimates are unbiased, even if currency markets are inefficient relative to predetermined intervention.

This paper reports test results for several intervention variables, but focuses on cumulative intervention, a stock. Portfolio balance theory calls for a stock measure of intervention, and signaling models are consistent with a stock measure; further, results are strongest for cumulative intervention. Data cannot reject that Fed cumulative intervention is integrated of order one, I(1). Previous papers that use cumulative intervention (Loopesko 1984, Tables 2-4; Dominguez and Frankel 1993a, Tables 7.6a-c, and 1993b, Tables 2-4) do not use econometrics appropriate for I(1) variables. In this paper's specifications, even if cumulative-intervention variables are I(1), slope estimates are unbiased and their t-values are asymptotically N(0, 1).[2]

This paper is aimed at comparability with the many studies that examine the effect of Fed intervention on appreciation, and thus omits Bundesbank and Bank of Japan intervention (BOJ

---

[1] For intra-day data, Dominguez (1999) finds leading and lagging interventions importantly affect appreciation; Dominguez (2003) finds that on intra-day data, intervention has short- but not long-term effects on volatility. Using intra-day price data from futures markets, Campbell and Huang (2002) investigate the effects on volatility of Fed open market operations for fixed income and foreign currency instruments.

[2] Stationarity issues may arise in papers that estimate portfolio balance models where the stock of reserves or outside assets, relative to a broad measure of wealth, is used. These papers do not investigate whether these ratios are I(1),

data are available only for the late 1990s on). A number of papers include Fed and foreign interventions, typically in examining the effects of coordinated intervention (Dominguez, 1990, 2003, Frankel and Dominguez 1993a, Fatum 2001, 2002, Fatum and Hutchison 2001, Galati and Melick 2002); the effects of coordinated intervention in APMs are reserved for future research.

This paper focuses on systematic risk, the risk that matters to diversified decision makers. This complements studies of intervention effects on total risk (Dominguez 1998, 1999, Baillie and Osterberg 1997, 2000), on implied volatilities in currency options (Bonser-Neal and Tanner 1996) and on currency bid-ask spreads (Naranjo and Nimalendren 2000).

3. Asset Pricing Models and Estimating Equations

This paper considers a linear APM for USD net appreciation, with exact factor pricing, time-varying betas that may depend on intervention, and time-constant risk premia. Intervention affects expected appreciation in this APM if it affects appreciation's betas on economy-wide risk factors. The null is that all of the beta-slopes on intervention are zero, and intervention thus does not affect expected appreciation. If estimation results show that intervention affects betas, then the estimated net effects on expected appreciation can be used to judge whether the data are consistent with the portfolio balance or the signaling channel: the net effect estimated below is positive, consistent with the signaling channel and inconsistent with the portfolio balance channel.

The APM is

$$R_{i,t} = E_{t-1} R_{i,t} + \sum^{K}_{k=1} \beta_{i,k,t}\, \delta_{k,t} + \varepsilon_{i,t}, \qquad E_{t-1} R_{i,t} = \sum^{K}_{k=1} \beta_{i,k,t}\, \lambda_k,\ i = 1,N.$$

$R_{i,t}$ is the excess rate of return on asset i in period t and E_{t-1} the expectations operator as of t-1. $\beta_{i,k,t}$ is asset i's beta on the k^{th} risk factor, $\delta_{k,t}$ and λ_k the k^{th} risk-factor realization and risk premium, $\varepsilon_{i,t}$ the mean-zero, idiosyncratic error term, serially uncorrelated and uncorrelated with all $\delta_{k,t}$ (E $\delta_{k,t}$

---

and do not use specifications that ensure test statistics have standard distributions.

$\varepsilon_{i,t} = 0$), and the zero-beta portfolio expected excess rate of return is zero. Combining,

$$R_{i,t} = \sum^{K}_{k=1} \beta_{i,k,t} \lambda_k + \sum^{K}_{k=1} \beta_{i,k,t} \delta_{k,t} + \varepsilon_{i,t}, \qquad i = 1,N.$$

Let the first risk factor be the surprise in "the" market return, where $\delta_{M,t} = (R_{Mt} - ER_M)$, $\lambda_M = ER_M$, and $R_{M,t}$ is the market's excess rate of return; empirical work since the 1980s questions the market's usefulness in explaining the cross-section, but not the time series, of asset returns. Then,

$$R_{i,t} = \beta_{i,M,t} R_{Mt} + \sum^{K}_{k=2} \beta_{i,k,t} \lambda_k + \sum^{K}_{k=2} \beta_{i,k,t} \delta_{k,t} + \varepsilon_{i,t};$$

the market premium necessarily drops out (Sweeney and Warga 1986), but not the non-market λ_k.

Much work stresses the importance of conditioning betas (Cochrane 2000): betas are conditioned on predetermined variables in Harvey (1991), Ferson and Harvey (1993, 1999), Solnik (1993), Lettau and Ludvigson (1999) and Santos and Veronesi (2003), among others. As Section 2 notes, several papers use predetermined intervention to explain appreciation. This paper assumes betas are linear in a predetermined[3] Fed intervention variable IV_t, or $\beta_{i,k,t+1} = \beta_{i,k,0} + \beta_{i,k,1} IV_t$. Thus,

$$(1)\quad R_{i,t+1} = (\beta_{i,M,0} + \beta_{i,M,1} IV_t) R_{M,t+1} + \sum^{K}_{k=2} (\beta_{i,k,0} + \beta_{i,k,1} IV_t) (\lambda_k + \delta_{k,t+1}) + \varepsilon_{i,t+1}$$

$$= \alpha_i + (\beta_{i,M,0} + \beta_{i,M,1} IV_t) R_{M,t+1} + \sum^{K}_{k=2} (\beta_{i,k,0} + \beta_{i,k,1} IV_t) \delta_{k,t+1} + \eta_i IV_t + \varepsilon_{i,t+1}, \quad i = 1,N,$$

where $\alpha_i = (\sum^{K}_{k=2} \beta_{i,k,0} \lambda_k)$ and $\eta_i = (\sum^{K}_{k=2} \beta_{i,k,1} \lambda_k)$.

This paper uses single-equation regressions, as do related papers (Baillie and Osterberg 1997, 2000, Dominguez 1990, 1999, Dominguez and Frankel 1993a,b,c). (1) suggests the estimating equation

$$(2)\ R_{t+1} = a + b_{M,0} R_{Mt+1} + b_{M,1} (IV_t R_{Mt+1}) + \sum^{K}_{k=2} [b_{k,0} + \sum^{K}_{k=2} b_{k,1} IV_t]\, \delta_{k,t+1} + c R_t + d IV_t + v_{t+1},$$

where asset subscripts are dropped for convenience. R_{t+1} is the USD net appreciation rate against the DEM or JPY, IV_t a Fed intervention variable for that currency, and v_{t+1} an error. $b_{M,0}$, $b_{M,1}$ and

---

[3] If betas depend on contemporaneous rather than predetermined intervention, Appendix A (available from the

$b_{k,0}$, $b_{k,1}$ are estimates of $\beta_{M,0}$, $\beta_{M,1}$ and $\beta_{k,0}$, $\beta_{k,1}$, and a, d are estimates of α, η. Lagged appreciation, included in some specifications, is consistent with efficiency if trading profits are not generated.

The expected appreciation rate from (1) is $ER_{t+1} = \alpha + (\beta_{M,0} + \beta_{M,1}\ IV_t)\ ER_{M,t+1} + \eta\ IV_t$, and intervention's effect on expected appreciation is $\partial ER_{t+1} / \partial IV_t = \beta_{M,1}\ E\ R_M + \eta$. If intervention has no effect on expected appreciation through the market factor, then $\beta_{M,1}$ must equal zero for $E\ R_M \neq 0$. If intervention has no effect on expected appreciation through non-market factors, then $\eta = (\sum^K_{k=2} \beta_{k,1}\ \lambda_k) = 0$; note that $\eta = 0$ is consistent with priced non-market factors (some $\lambda_k \neq 0$)[4] and with significant intervention effects on non-market betas (some $\beta_{k,1} \neq 0$), for example, $\beta_{k,1}\ \lambda_k = - \beta_{k',1}\ \lambda_{k'}$. The hypothesis that intervention has no effect on expected appreciation is that $b_{M,1} = 0$ and $d = 0$ in estimates of (2).

Bias and Efficiency in Previous Estimates. The significant estimates of intervention effects on betas reported below suggest that previous models are misspecified. Representative portfolio balance and signaling models are $R_{t+1} = \theta_0 + \theta_1\ (IV_t / A_t) + \nu_{t+1}$ and $R_{t+1} = \theta_0 + \theta_1\ IV_t + \nu_{t+1}$, depending on whether intervention is normalized by a broad asset stock, A_t (as discussed below). Using un-normalized intervention as an example, the APM in (1) can be re-written as

$$R_{t+1} = \alpha + [(\beta_{M,1}\ R_{M,t+1} + (\textstyle\sum^K_{k=2} \beta_{k,1}\ \delta_{k,t+1}) + \eta]\ IV_t + [(\beta_{M,0}\ R_{M,t+1}) + (\textstyle\sum^K_{k=2} \beta_{k,0}\ \delta_{k,t+1}) + \varepsilon_{t+1}],$$

giving the correspondences:

$\theta_0 = \alpha$; $\theta_{1,t} = [(\beta_{M,1}\ R_{M,t+1} + (\sum^K_{k=2} \beta_{k,1}\ \delta_{k,t+1}) + \eta]$; $\nu_{t+1} = [(\beta_{M,0}\ R_{M,t+1}) + (\sum^K_{k=2} \beta_{k,0}\ \delta_{k,t+1}) + \varepsilon_{t+1}]$.

Thus, θ_1 is a random coefficient $\theta_{1,t}$ that depends on risk-factor realizations; the error ν_{t+1} depends

---

author) shows how to re-specify (2) to give unbiased estimates, and shows that results do not change importantly.

[4] Equation (2) does not provide estimates of the individual non-market λ_k; these require system estimation. Reliable estimates of the λ_k require the time series and cross section to be large relative to the number of parameters, but the Fed intervenes in only the DEM and JPY. In principle, systems could be estimated for assets in additions to currencies, for example, stocks and bonds; this raises difficult issues, however, regarding timing of observations of variables relative to each other, for example, thin-trading problems.

on risk-factor realizations and the APM error.

Estimates of θ_1 are biased. The sample average of $\theta_{1,t}$ over T periods is $T^{-1} \sum^{T}_{t=1} \theta_{1,t} = [(\beta_{M,1} R_M + (\sum^{K}_{k=2} \beta_{k,1} \delta_k) + \eta]$, where R_M and δ_k are the sample averages of $R_{M,t+1}$ and $\delta_{k,t+1}$. Denote the OLS estimate of θ_1 as b; then, $E\ (b \mid R_M, \delta_k) = T^{-1} \sum^{T}_{t=1} \theta_{1,t}$ need not equal $(\beta_{M,1}\ E\ R_M + \eta)$ in finite samples—generally, $R_M \neq E\ R_M$ and $\delta_k \neq 0$. Because R_M, δ_k vary across samples, so does $E\ (b \mid R_M, \delta_k)$, and $E\ (b \mid R_M, \delta_k) < 0$ in some samples; this may help explain some of the variation in b across sample periods and it is sometimes negative in previous papers. The estimate of θ_1 is consistent, however; $\text{plim}\ E\ (b \mid R_M, \delta_k) = (\beta_{M,1}\ E\ R_M + \eta)$, because $R_M \rightarrow E\ R_M$ and $\delta_k \rightarrow 0$ as $T \rightarrow \infty$. Even asymptotically, however, θ_1 cannot be decomposed into market and non-market risk, $\beta_{M,1}\ E\ R_M$ and η. Because the variance of ν_{t+1} is $\sigma^2_\nu = [\beta^2_{M,0}\ \sigma^2_{RM} + (\sum^{K}_{k=2} \beta^2_{k,0}\ \sigma^2_{\delta k}) + \sigma^2_\varepsilon] > \sigma^2_\varepsilon$, decomposing ν_{t+1} by estimating $\beta_{M,0}$, $\beta_{k,0}$ reduces the error variance to σ^2_ε and increases efficiency.

Exchange-Market* In*efficiency and Simultaneous Equations Bias. If the exchange market is strong-form efficient relative to intervention, then using predetermined intervention avoids simultaneous equations bias—the predetermined IV_t contains no information on the APM error ε_{t+1}, and $E\ IV_t\ \varepsilon_{t+1} = 0$. Estimates of $\beta_{M,0}$, $\beta_{M,1}$, $\beta_{k,0}$, $\beta_{k,1}$ and η from (2) are thus unbiased, because $E\ \varepsilon_{t+1}\ IV_t\ R_{M,t+1} = 0 = E\ \varepsilon_{t+1}\ IV_t = E\ \varepsilon_{t+1}\ R_{M,t+1} = E\ \varepsilon_{t+1}\ IV_t\ \delta_{k,t+1} = E\ \varepsilon_{t+1}\ \delta_{k,t+1}$.

Some observers are skeptical of strong-form efficiency; for example, some argue that current intervention may affect "market psychology" in currency markets and thus future appreciation rates. Under ***in***efficiency, predetermined intervention IV_t may be correlated with ε_{t+1}, giving simultaneous equations bias. Suppose ε_{t+1} is linearly related to IV_t as $\varepsilon_{t+1} = \gamma\ IV_t + \omega_{t+1}$, and $E\ \omega_{t+1} = 0 = E\ \omega_t\ \omega_{t+j}$ for $j \neq 0$. Rewrite the APM equation (1) as

$$R_{t+1} = \alpha + \beta_{M,0}\ R_{M,t+1} + \beta_{M,1}\ (IV_t\ R_{M,t+1}) + \sum^{K}_{k=2} (\beta_{i,k,0} + \beta_{i,k,1}\ IV_t)\ \ \delta_{k,t+1} + (\eta + \gamma)\ IV_t + \omega_{t+1}.$$

Without loss of generality, let E ω_{t+1} IV$_t$ = 0 = E R_{Mt+1} ω_{t+1} = E $\delta_{k,t+1}$ ω_{t+1}. In (2), the $b_{M,0}$, $b_{M,1}$ and $b_{k,0}$, $b_{k,1}$ are free of simultaneous equations bias, because E ω_{t+1} $R_{M,t+1}$ IV$_t$ = 0 = E ω_{t+1} $R_{M,t+1}$ and E $\delta_{k,t+1}$ IV$_t$ ω_{t+1} = 0 = E $\delta_{k,t+1}$ ω_{t+1}. Further, d is free from simultaneous equations bias, because E ω_{t+1} IV$_t$ = 0. Identification of d now requires a maintained hypothesis, however, e.g., $\gamma = 0$ or $\eta = 0$.

Risk Factors. Daily-data risk factors used here are related to monthly-data factors that have been shown to be priced in past work (for example, Chen, Roll and Ross 1986, Sweeney and Warga 1986, Harvey 1991, Ferson and Harvey 1993, Lettau and Ludvigson 1999). Monthly-data risk factors include measures of (a) economic activity, for example, an industrial production or consumption index; (b) surprises in actual or expected inflation, for example, from CPI series; (c) yield curve surprises; and (d) corporate-bond risk premium surprises. In this paper,[5] (a) “the” market excess rate of return measures economic activity. (b) Surprises in a short-term interest rate can be interpreted as surprises in expected inflation, assuming inflation expectations dominate interest rate movements. (c) Surprises in the difference between long and short government yields measure yield-curve surprises. (d) Surprises in the difference between commercial and government bond yields measure surprises in the corporate-bond risk premium.

Measures of Fed Intervention. Investigators use cumulative intervention, CI$_t$ (Loopesko 1984, Dominguez and Frankel 1993a,b,c); flow intervention, I$_t$ (Baillie and Osterberg 1997, 2000, Dominguez 1990, 1999, Dominguez and Frankel 1993a,b); and a (1, 0, -1) indicator variable as I$_t$ > / < 0 (Dominguez and Frankel 1993a); for comparability, this paper does also. Portfolio balance theory calls for a stock variable—CI$_t$ rather than I$_t$—and signaling theory is consistent with a stock

---

[5] The risk factors used here are ad hoc, but because arbitrage pricing theory contains no information on which variables are economy-wide, priced risk factors, the researcher’s choice of risk factors is always ad hoc. As the text notes, the risk factor used here are daily-data analogues of priced factors from monthly-data studies.

Foreign-country risk factors might also be used. This would raise issues of timing—German markets are six hours ahead of New York, and Tokyo and New York are never open at the same time. Further, it is not clear which foreign factors are priced, and only priced factors should be included. Finally, using three foreign non-market factors, similar variable. For this paper's results to show whether the data are consistent with portfolio balance versus signaling channels requires experiments with CI_t. In portfolio balance models, stock variables are scaled by a measure of the total asset stock, A_t, suggesting CI_t / A_t.[6] Signaling models often enter CI_t un-scaled, though some argue information in intervention is relative to exchange-market volume, Vol_t, as in CI_t / Vol_t. Results are strongest for cumulative intervention measures, and the text reports on CI_t, CI_t / A_t, and CI_t / Vol_t; Appendix B (available from the author) reports on I_t and on dummy variables for $I_t > 0$ and $I_t < 0$. Note that in APMs that include CI_t, just as in portfolio balance models or in signaling models that use CI_t, the history of intervention affects expected appreciation, and a single intervention has long-lasting effects.

4. Data

Daily exchange rate, interest rate, and intervention data are from the Fed's Board of Governors. For comparability to past studies, the sample period is Jan. 2, 1985, to Dec. 31, 1991; this includes the Plaza Agreement of Sept. 1985 and Louvre Accord of Feb. 1987, intensively studied events (Baillie and Osterberg 2000, Lewis 1995a, Dominguez and Frankel 1993a). This period contains most Fed interventions in the floating-rate period, and was chosen in advance of examining data.

Intervention. Data are Fed interventions on its own account, purchases (+) and sales (-) of USD against Deutsche marks (DEM) and Japanese yen (JPY). Sample-period interventions are infrequent and tend to occur in bursts (Table 1). The average absolute value of intervention in DEM was approximately \$135m, in JPY \$138m, with maxima of \$797m and \$720m. These are small relative to exchange market daily volume (Table 1, Panel D), measured in billions of USD as: total volume; volume in U.S. markets; volume with USD as one side of trade; and volume of

---

to the three non-market U.S. factors, would require estimating six more slopes in each equation.

USD trades against the DEM or JPY.[7]

Exchange Rates and Interest Rates. As in previous work that uses predetermined intervention, day-t intervention is used to explain appreciation from day t to t+1. Exchange rates are noon bid prices; intervention might thus occur after the day-t rate is collected, allowing simultaneity problems. Fed officers state intervention generally occurs before noon, and several papers report it generally occurs before London closes at 1600 GMT (Goodhart and Hesse 1993, Humpage 1998, Neely 2002). In any case, results are insensitive to using intervention on day t-1 to explain appreciation from day t to t+1 (Appendix A, available from the author).[8]

For appreciation rates net of the interest-rate differential, daily USD and DEM overnight Euro deposit and JPY call money rates are used (JPY Euro rates are not available for the sample period). Because appreciation explains most variation in net appreciation, problems from non-synchronous collection of interest and exchange rates are minimal. Net appreciation shows small, significant first-order autocorrelation. Appreciation and risk-factor realizations are in continuously compounded terms.

Risk-factor realizations include surprises in: a short-term interest rate; yield-curve steepness, measured as the ten-year Treasury bond index less a short-term rate; and the corporate-bond risk premium, measured as the AAA corporate bond index less the ten-year T-bond index. The USD overnight Euro rate is used for the short-term rate. Surprises are found as ARIMA-model residuals; inferences do not change importantly in limited experiments using other methods to find surprises.

Rates of Return on the Stock Market. Results below use CRSP value-weighted rates,

---

[6] CI_t and A_t may be entered separately rather than as a ratio (Sarno and Taylor 2001).

[7] Some argue that 90-95 percent of volume is interbank transactions, or "fluff," and that netting out fluff better measures volume; net of fluff, Fed intervention is sizeable relative to volume.

[8] In experiments with closing rather than noon prices, results are not importantly affected.

including dividends. Results are robust across three other common measures. In particular, using the Morgan Stanley World Market Index has no important effect on results.

I(0) and I(1) Variables. Regressions below use intervention, I_t, and cumulative intervention, CI_t, found by cumulating daily values of Fed intervention. CI_t is also adjusted by dividing by the asset market's value (A_t), measured by the CRSP value-weighted index including dividends, or by exchange-market volume (Vol_t; Table 1's total-volume data are interpolated). Figures 1 and 2 show CI_t, CI_t / A_t and CI_t / Vol_t: each series is de-meaned and divided by its standard deviation. CI_t and CI_t / Vol_t are very similar, but CI_t / A_t diverges somewhat. For both currencies, the data cannot reject the null of a unit root in augmented Dickey-Fuller (ADF) tests on CI_t, CI_t / A_t and CI_t / Vol_t. Thus, estimates of d in (2), and its t-values, present familiar problems associated with I(1) regressors. Following Saikkonen (1991), including intervention leads and lags in estimating equations ensures the cumulative intervention measure's t-value is asymptotically N(0, 1).

In contrast, for each interaction term $\delta_{k,t}\, IV_{t-1}$, k=1,K, the data show little serial correlation and strongly reject the unit-root null in ADF tests, as expected;[9] thus, in regressions below these interaction terms' t-values are asymptotically N(0, 1) even if $IV_t \sim I(1)$ (Sims et al. 1990).

5. Intervention Effects on Betas: Empirical Results and Interpretation

For convenience in organizing discussion, this section focuses on intervention effects on betas when no cumulative intervention measure is entered separately. Section 6 discusses econometric issues that arise when CI_t, CI_t / A_t, or CI_t / Vol_t is entered separately; none is significant when entered separately, and they have little effect on estimates of betas' dependence on cumulative intervention.

---

[9] The APM assumption $E\, \delta_{k,t} = 0 = E(\delta_{k,t}\, IV_{t-1})$ implies $\delta_{k,t}\, CI_{t-1}$ is mean zero but shows conditional heteroscedasticity. The non-market risk factors are found as ARIMA-model residuals and thus have zero sample-period means, ensuring $E(\delta_{k,t}\, IV_{t-1}) = 0$. $E\, R_{M,t}$ is non-zero but small. In experiments with demeaned versions of $R_{M,t}$ or ARIMA-model residuals, results are virtually unchanged from using $R_{M,t}$.

5.A. Empirical Results. Table 2 shows OLS estimates of (2) for the DEM and JPY. Across estimating equations, lagged appreciation is generally significant, but including it has little effect on interaction-term slopes and t-values. Use of heteroscedasticity-consistent standard errors generally does not affect inferences.

The Market Rate of Return. Fed foreign-currency sales increase the market's beta ($b_{1,M} > 0$) and thus cause an increase in the dollar's risk premium and expected appreciation rate for $R_{M,t+1} > 0$. Estimates and t-values of $b_{M,1}$ are fairly stable across specifications; for example, DEM slopes range from 1.09×10^{-5} to 8.43×10^{-6} (with t-values of 3.368536 and 2.502430). Results are robust across different measures of the market excess rate of return and the market index used as A_t in CI_t / A_t; results are also significant across the three cumulative intervention measures (Appendix C, Table C.1, available from the author).

Non-Market Risk Factors. In Table 2, interaction terms for the three non-market risk factors enter significantly in many but not all specifications. When all three factors are included, generally at least one interaction term is insignificant (line 7); this may arise from the large correlation between surprises in expected inflation and the yield curve (-0.9223, in Table 1).

Degrees of Freedom for Cumulative Intervention Measures. The t-values are calculated for approximately 1750 degrees of freedom, but cumulative intervention changes only 199 times for the DEM, 170 for the JPY (Table 1). Interaction-term t-values may thus appear overstated. Each interaction term is a product, however; risk factors and thus interaction terms vary daily.

Specification Tests: Betas Conditioned on* Contemporaneous *Cumulative Intervention. If beta depends on contemporaneous rather than lagged cumulative intervention, then (2) is misspecified and may give biased estimates of $\beta_{1,M}$, $\beta_{1,k}$ and $(\eta + \gamma)$. Appendix A (available from the author) re-specifies (2) to provide unbiased estimates; in representative equations, slopes and t-values differ little from Table 2.

***Specification Tests: Betas Conditioned on Cumulative Intervention Lagged* Two *Days*.** Section 3 raised the possibility that intervention on day t might be determined simultaneously with appreciation from day t to day t+1. Appendix A considers estimating equations where beta is conditioned on cumulative intervention lagged two days, or CI_{t-1} is used to explain R_{t+1}. Slopes and t-values differ little from Table 2, as might be expected from strong persistence in CI_t.

Alternative Variables. Appendix C (available from the author) compares results for the cumulative intervention measures CI_t, CI_t / A_t and CI_t / Vol_t, in equations with the market and one non-market risk factor. Significance levels are close for CI_t and CI_t / Vol_t. For CI_t / A_t, results tend to be somewhat less significant for the DEM, somewhat more for the JPY.

5.B. Economic Significance of Intervention's Effects. Over the sample period 1985-1991, Figure 3 shows DEM and JPY market betas as functions of CI_t, or $\beta_{M,t+1} = \beta_{M,0} + \beta_{M,1}\, CI_t$ [figures are similar for CI_t / A_t and CI_t / Vol_t]. Beta variations are persistent, and economically and statistically significant. Note that betas change signs over time—if beta is linear in CI_t, it must equal zero for some CI_t. Recall that the issue of intervention's effect on expected appreciation is the sign of $b_{M,1}$—the effect of intervention on the market beta—not the sign of the market beta. Figure 4 shows DEM and JPY betas on the surprise in expected inflation as functions of CI_t [with similar figures for CI_t / A_t and CI_t / Vol_t]; figures are comparable for other non-market factors.

To illustrate the economic importance of intervention effects on appreciation, let each risk factor's realization increase, one at a time, by one standard deviation, σ_k; appreciation changes by $b_{k,t+1}\, \sigma_k = (b_{k,0} + b_{k,1}\, CI_t)\, \sigma_k$, with the change thus dependent on CI_t. Beta's values at the maximum and minimum values of CI_t are $(b_{k,0} + b_{k,1}\, CI_{max})$ and $(b_{k,0} + b_{k,1}\, CI_{min})$, and the difference between the maximum and minimum betas is $| b_{k,1} | (CI_{max} - CI_{min})$. Across the four factors, appreciation is larger at the maximum than minimum beta, by 2.08 to 2.75%/year for the DEM, and 1.70 to 4.32%/year for the JPY. (Appendix D, available from the author, gives details.) The ranges differ somewhat (though 4.29 is less than twice 2.75), but there is no reason they should be the same.

5.C. Effects on Expected versus Realized Appreciation. From Section 3, an increase in cumulative intervention changes expected appreciation by $\partial ER_{t+1} / \partial CI_t = \beta_{M,1}\ E\ R_M + (\eta + \gamma)$. Focus on the effects of CI_t on expected appreciation through the market beta, $\beta_{M,1}\ E\ R_M$; Section 6 discusses estimates of $(\eta + \gamma)$. The DEM's market beta is larger by 0.171855 when CI_t is at its maximum rather than minimum, and by 0.267772 for the JPY (Appendix D). Assume a market risk premium of 8%/year[10], approximately the sample-period mean. Evaluating this premium at the maximum rather than minimum beta increases expected appreciation by 1.38%/year (= 0.171855 x 8) for the DEM and 2.32%/year for the JPY [results are similar for CI_t / A_t and CI_t / Vol_t].

An increase in intervention reliably increases the market beta and thus reliably increases ***expected*** appreciation. Intervention's effects on ***realized*** appreciation are unreliable, because they depend not the expected but the ***realized*** market rate of return**.** A unit increase in CI_t affects realized appreciation by $\partial\ (b_{M,1}\ R_{M,t+1}\ CI_t) / \partial CI_t \approx b_{M,1}\ R_{M,t+1}$—correlations of $R_{M,t+1}$ with CI_t are small and insignificant, as market efficiency suggests. $R_{M,t+1}$ is volatile and largely unpredictable. Fed intervention on day t, aimed at strengthening the USD, works by increasing $\beta_{M,t+1}$, and thus intensifying appreciation's positive reaction to $R_{M,t+1} > 0$; if $R_{M,t+1} < 0$, however, then intervention strengthens USD ***de***preciation.

On any day, the odds are modestly but significantly better than even that $R_{M,t+1} > 0$, and

---

[10] Harvey (1989), Boudoukh, Richardson and Smith (1993) and Harvey and Siddique (2000) present evidence that in linear projections on predetermined information Ω_t, in some periods $E_t\ (R_{M,t+1} \mid \Omega_t) < 0$. The text's discussion can be taken as referring either to unconditional forecasts of $R_{M,t+1}$ or to days when $E_t\ (R_{M,t+1} \mid \Omega_t) > 0$. The literature contains

intervention thus works as intended; over the sample period, $R_{M,t+1} > 0$ on 54.27% of days, 3.6116 standard errors from 50%. The longer the central bank's time horizon, the greater the probability the market's *cumulative* excess return is positive, $CR_M > 0$, and intervention eventually works as intended. A high probability may require a long horizon, however; if daily excess returns are $IN(ER_M, \sigma^2_{RM})$ and sample-period estimates are used for population moments:[11]

Probability (in percent)		60	70	80	90
Required Horizon (in trading days)	56	234	645	1388	

90 percent probability requires 1388 trading days, or 5.55 trading years at 250 trading days/year.[12]

5.D. Portfolio Balance and Signaling Channels. Through the signaling channel, Fed purchases of USD—sales of foreign currency—are predicted to cause an ***increase*** in expected USD appreciation, consistent with the positive estimated relation in Table 2 between intervention and expected appreciation. Through the portfolio balance channel, however, Fed purchases of USD are predicted to cause a ***decrease*** in expected USD appreciation (for example, Rogoff 1984), inconsistent with results in Table 2.

Evidence in the literature on the signaling content of Fed intervention is mixed, but this might be expected: some intervention is secret and hence not intended as a signal, and the size of intervention is often highly uncertain.[13] Several studies examine intervention's information on

---

no suggestion that forecasts of market returns affect central-bank intervention decisions.

[11] Over a horizon of H trading days, the cumulative excess return, CR_M, is distributed $N(H\ ER_M, H\ \sigma^2_{RM})$. Normalizing, $[CR_M - (H\ ER_M)] / (H^{1/2}\ \sigma_{RM}) \sim N(0, 1)$. 60 percent probability of $CR_M >$ requires that 40 percent of the weight in N(0, 1) is in the left hand tail, which occurs at the distance -.26 from zero in N(0, 1) . Thus,

Probability (in percent)	60	70	80	90
Distance (below zero in N(0, 1))	.26	.525	.847	1.282

If the realization is at -.26, then $CR_M = 0$ and $-.26 = -(H\ ER_M) / (H^{1/2}\ \sigma_{RM})$ or $H = (.26)^2\ \sigma^2_{RM}/(ER_M)^2$. Over 1985-1991, the sample mean is .0003503/day, the standard deviation .0101103/day, and $[\sigma_{RM}/(ER_M)]^2 = (28.862)^2 = 833.005$. Thus, $H = (.26)^2\ \sigma^2_{RM}/(ER_M)^2 = 56.3$ days, etc. (The sample mean excess rate of return and standard deviation are 8.76 (=.0003503 x 25000) and 15.66 percent/year, roughly consistent with post-WWII estimates.)

[12] In calculations accounting for appreciation variability due to non-market risk factors, required horizons are larger.

[13] Dominguez and Frankel (1993a), Klein (1993) and Bonser-Neal and Tanner (1996) discuss the accuracy of news reports that the Fed has or has not intervened; reports on intervention size are generally qualitative and often erroneous. Bhattacharya and Weller (1997) develop an optimizing model in which a central bank always keeps secret

coming Fed policy, as measured by monetary aggregates or interest rates, with mixed results (Klein and Rosengren 1991, Lewis 1995b, Kaminsky and Lewis 1996, Bonser-Neal, Roley and Sellon 1998, Fatum and Hutchison 1999). The tenuous empirical support for monetary exchange rate models, however, suggests monetary-policy variables have little information about exchange rates;[14] if so, intervention that contains credible signals about the exchange rate may be uncorrelated with coming Fed policy.

6. Effects of Cumulative Intervention Measures Entered Separately

Section 3 proposes estimating equations in which cumulative intervention measures enter separately, as well as interacting with risk-factor realizations. As Section 3 discusses, tests of whether coefficients on cumulative intervention measures differ from zero test the joint null that (i) intervention does not affect expected appreciation through non-market risk premia, and (ii) the exchange market is efficient relative to predetermined intervention, or $\eta = (\sum^{K}_{k=2} \beta_{k,1} \lambda_k) = 0 = \gamma$.

The data cannot reject the null that CI_t contains a unit root, $CI_t \sim I(1)$, and similarly for CI_t / A_t, CI_t / Vol_t (Section 4). If $CI_t \sim I(1)$ and the maintained hypothesis is that net appreciation is stationary, $R_t \sim I(0)$, then CI_t and R_{t+1} cannot be related—the population correlation between I(1) and I(0) variables is zero. Failure of the data to reject the null of $CI_t \sim I(1)$ does not, however, make it certain that CI_t is I(1); CI_t may be I(0) but near integrated (NI), with a root near but less than unity. ***If*** CI_t is NI, then R_{t+1} and CI_t may be related. In the tests below, the maintained hypothesis is $R_t \sim I(0)$: the null is $CI_t \sim I(1)$ and thus CI_t does not enter the equation; the alternative is the joint hypothesis that $CI_t \sim I(0)$ and CI_t enters the equation (Sjöö and Sweeney 2000).

---

the amount, and sometimes the fact, of its intervention. Vitale (1999) develops conditions under which the central bank will always choose to keep secret its interventions.

[14] The seminal papers are Meese and Rogoff (1983 and 1988). More recently, Mark (1995) and Mark and Sul (2000) argue that monetary aggregates have long-run exchange-rate effects that are hard to tease out.

Because $CI_t \sim I(1)$ under the null, "unbalanced regression" problems affect the distribution of test statistics for CI_t entered separately (West 1988; Stock and West 1988; Sims, Stock and Watson 1990; Banerjee et al. 1993). The t-value for $CI_t \sim I(1)$ is asymptotically N(0, 1) only if intervention I_{t+h} and the abnormal return ε_t have zero correlation for ***all*** h. This is a stringent condition: exchange-market efficiency requires only that I_{t+h} and ε_t are uncorrelated for $h < 0$—intervention cannot forecast abnormal returns, but may react to current or past ε_t. With non-zero correlations between abnormal returns and intervention, the t-value's asymptotic distribution is non-normal and critical values depend on the magnitude of the correlations. For both the DEM and JPY, the data show small but significant correlations between abnormal returns and leading but not lagging intervention, or I_{t+h} and ε_t are correlated for some $h \geq 0$, but not for $h < 0$. From Saikkonen (1991), if a sufficient number of leading[15] values of I_t is included in the estimating equation, then CI_t's t-value is asymptotically N(0, 1) [and similarly for $\Delta(CI_t / A_t)$ and CI_t / A_t, etc.].[16] Estimating equations include six leads of I_t, found from the rule of thumb of using $T^{.25}$ (= 6.47) leads; using more leads make little difference. For $IV_t = CI_t, CI_t / A_t, CI_t / Vol_t$, the estimating equation is

$$R_{t+1} = a + (b_{M,0} + b_{M,1}\, IV_t)\, R_{Mt+1} + \Sigma^{4}_{k=2}\, (b_{k,0} + b_{k,1}\, IV_t)\, \delta_{k,t+1} + c\, R_t + d\, IV_t + \Sigma^{6}_{j=0}\, h_j\, \Delta IV_{t+j} + v_{t+1}.$$

All specifications include $R_{M,t+1}$, $R_{M,t+1}\, IV_t$, R_t, IV_t and ΔIV_{t+j}; each combination of one to three non-market factors (in pairs, $\delta_{i,t+1}$ and $\delta_{i,t+1}\, IV_t$) is tried. Asymptotically, the stationary interaction terms' estimated slopes are unbiased, with t-values N(0, 1) (Sims, Stock and Watson 1990).

Cumulative intervention measures entered separately are insignificant for both the DEM and JPY. For the t-test of $d = 0$, the maximum and minimum probability values across specifications and cumulative intervention measures are 0.83 to 0.62 for the DEM, 0.22 to 0.11 for the JPY.

---

[15] If intervention ***lags*** are also included, results change little.

Inferences about interaction terms ($R_{M,t+1}$ IV_t, $\delta_{i,t+1}$ IV_t) do not change importantly. For example, Table 2 shows three estimates for a specification that includes the market, the surprise in expected inflation, and the surprise in the corporate-bond risk premium. In line 6, CI_t does not enter separately; in line 6.a, CI_t enters separately; and in line 6.b, leads of ΔCI_{t+h} also enter. For the DEM, between lines 6 and 6.b, the slope (t-value) for the market-intervention term ($R_{M,t+1}$ CI_t) changes from 8.80×10^{-6} (2.615926) to 7.91×10^{-6} (2.364857). Relative changes in the other risk factors' slopes and t-values are smaller. Results are comparable for other cumulative intervention measures and for the JPY.

The data cannot reject the null that $(\eta + \gamma) = 0$. Ignoring the chance occurrence of the terms offsetting, $\eta \approx - \gamma$, then $(\eta + \gamma)$ is approximately zero because $\gamma \approx 0 \approx \eta$. $\gamma \approx 0$ implies the exchange market is approximately strong-form efficient. $\eta \approx 0$ implies intervention has negligible effects on expected appreciation through non-market risk factors; note, however, that $\eta = (\sum^{K}_{k=2} \beta_{1,k} \lambda_k) \approx 0$ is consistent with priced non-market risk factors ($\lambda_k \neq 0$) and non-zero betas ($\beta_{1,k} \neq 0$), for example, $\beta_{k,1} \lambda_k = - \beta_{k',1} \lambda_{k'}$.

7. Summary and Conclusions

Many papers examine intervention effects on expected appreciation in portfolio balance and signaling models; related papers examine intervention effects on various measures of appreciation risk. This paper gives an integrated discussion of Fed intervention effects on expected appreciation and on appreciation's ***systematic*** risk, by exploring intervention effects in multi-factor asset-pricing models. In APMs, expected appreciation rates depend on betas on the risk factors and on economy-wide risk premia. Intervention can affect expected appreciation only through affecting betas or risk premia; in this paper's estimating equations, appreciation betas are

---

[16] Another approach is to find critical values from simulation; for this paper's data, results are similar.

conditioned on intervention. A four-factor APM is used: appreciation depends on surprises in "the" asset market's return, and in expected inflation, the yield curve and the corporate-bond risk premium. For dollar appreciation relative to the DEM and JPY, intervention has economically and statistically significant effects on the market beta in all specifications; intervention also has significant effects on betas for non-market risk factors in many specifications. Fed intervention thus changes systematic risk in currencies by changing their betas; this result complements past work on intervention effects on measures such as total risk, implied volatilities in options prices, and currency bid-ask spreads.

One illustration of the economic significance of intervention effects on appreciation finds the sample-period maximum and minimum values of each factor's beta as functions of intervention. Each risk-factor realization is then increased, one at a time, by one standard deviation. Across the four factors, appreciation is larger at the maximum than minimum beta by 2.08% to 2.75%/year for the DEM, and 1.70% to 4.29%/year for the JPY.

Fed foreign-currency sales (dollar purchases) reliably increase the U.S. dollar risk premium and thus the dollar's ***expected*** appreciation rate, the result the Fed desires. This positive intervention effect is consistent with the signaling channel, but inconsistent with the portfolio balance channel. Intervention effects on actual appreciation are unreliable: Intervention works by intensifying appreciation's reaction to risk factor surprises; with adverse factor surprises, however, intervention effects may be opposite from desired. Uncertainty about the actual effects of intervention may help explain many central banks' reluctance to intervene since the early 1990s, as compared to the 1980s.

Even if intervention is successful, its costs may outweigh benefits. At the macro level, intervention that successfully strengthens the dollar does so by raising the dollar's risk premium.

Ceteris paribus, the required rate of return on investments with dollar risk rises relative to other investments, and foreigners invest less in the U.S. Similarly, U.S. investors face lower foreign-currency risk and thus invest more abroad, less in the U.S. (the foreign currency risk premium is the negative of the USD's for this paper's log exchange rates).

At the micro level, uncertainty about the timing and size of Fed interventions increases decision-makers' uncertainty, and may thus induce resource misallocation. First, a U.S. investor contemplating a foreign investment—or a foreign investor contemplating a U.S. investment—must choose a risk-adjusted discount rate that depends partly on the USD's systematic risk, and thus on Fed interventions. Because market participants often do not know of some of the Fed's past interventions, and seldom know their size, until data are released months later, the investor is uncertain about current beta risk. Of course the investor is uncertain about future interventions that will affect future beta risk. Second, in evaluating foreign projects the U.S. investor must find expected cash flows in USD, and the foreign investor contemplating a U.S. investment must find expected cash flows in foreign currency. Because future home-currency cash flows depend on the USD's time path and hence in part on Fed intervention, uncertainty regarding future Fed intervention ceteris paribus increases difficulties in estimating expected cash flows.

References

Baillie, Richard T., and William P. Osterberg, “Central Bank Intervention and Risk in the Forward Market,” Journal of International Economics 43 (1997), 483-97.

________, and ________. “Deviations from Daily Uncovered Interest Rate Parity and the Role of Intervention.” Journal of International Financial Markets, Institutions and Money 10 (2000), 363-379.

Banerjee, Anindya, Juan Dolado, John W. Galbraith, and David F. Hendry. *Cointegration, Error-Correction and the Econometric Analysis of Non-Stationary Data*. Oxford: Oxford University Press, 1993.

Bank for International Settlements. *Annual Report*. Basle, Switzerland: 1990, 1993, 1996, 1999.

Bhattacharya, Utpal, and Paul Weller, “The Advantage to Hiding One’s Hand: Speculation and Central Bank Intervention in the Exchange Market,” Journal of Monetary Economics 39 (1997), 251-277.

Bonser-Neal, Catherine, and Glenn Tanner, “Central Bank Intervention and the Volatility of Foreign Exchange Rates: Evidence from the Options Market,” Journal of International Money and Finance 15 (1996), 853-878.

________, V. Vance Roley and Gordon H. Sellon, Jr., “Monetary Policy Actions, Intervention, and Exchange Rates: A Reexamination of the Empirical Relationships Using Federal Funds Rate Target Data,” Journal of Business 71 (1998), 147-177.

Boudoukh, J., M. Richardson and T.M. Smith, “Is The Ex Ante Risk Premium Always Positive?” Journal of Financial Economics 34 (1993), 387-408.

Catte, P., G. Galli and S. Rebecchini, "Exchange Markets Can Be Managed!" International Economic Insights (Sept.-Oct., 1992), 17-21.

Chang, Yuanchen, and Stephen J. Taylor, “Intraday Effects of Foreign Exchange Intervention by the Bank of Japan,” Journal of International Money and Finance 17 (1998), 191-210.

Chen, Nai-fu, Richard Roll and Stephen A. Ross, “Economic Forces and The Stock Market: Testing The APT and Alternative Asset Pricing Theories,” Journal of Business 59 (1986), 383-403.

Cochrane, John H., “Asset Pricing,” NBER Reporter (Fall 2000), pp. 1-7.

Dominguez, Kathryn M., "Market Responses to Coordinated Central Bank Intervention," Carnegie-Rochester Series on Public Policy 32 (1990).

________, “Central Bank Intervention and Exchange Rate Volatility,” Journal of International Money and Finance 18 (1998), 161-190.

________. “The Market Microstructure of Central Bank Intervention.” Cambridge: National Bureau of Economic Research Working Paper, 1999.

________, “When Do Central Bank Interventions Influence Intra-Daily and Longer-Term Exchange Rate Movements?” Cambridge: National Bureau of Economic Research Working Paper, 2003.

________, and Jeffrey A. Frankel. *Does Foreign Exchange Intervention Work?* Washington, DC: Institute for International Economics, 1993a.

________, and ________, "Does Foreign-Exchange Intervention Matter? The Portfolio Effect," American Economic Review 83 (Dec. 1993b), 1356-69.

________, and ________, “Foreign Exchange Intervention: An Empirical Assessment,” in *On Exchange Rates*, Jeffrey A. Frankel, ed. Cambridge, MA: MIT Press, 1993c.

Dooley, Michael P., and Peter Isard, “A Portfolio-Balance Rational-Expectations Model of the Dollar-Mark Rate,” Journal of International Economics 12 (1982), 257-276.

________, and ________, "The Portfolio Balance Model of Exchange Rates and Some Structural Estimates of the Risk Premium," IMF Staff Papers (1983), 683-702.

Edison, Hali J. *The Effectiveness of Central-Bank Intervention: A Survey of the Literature After 1982*. Princeton, NJ.: Special Papers in International Economics, International Finance Section, Department of Economics, Princeton University, 1993.

Engel, Charles M., and Anthony P. Rodrigues, "Tests of the International CAPM with Time-Varying Covariances," Journal of Applied Econometrics (April-June 1989), 119-138.

Fatum, Rasmus**, “**On the Effectiveness of Sterilized Foreign Exchange Intervention.” Edmonton, Alberta: Working Paper, University of Alberta, 2001.

________, “Post-Plaza Intervention in the DEM/USD Exchange Rate,” Canadian Journal of Economics 35 (2002), 556-567.

________, and Michael Hutchison, “Is Intervention a Signal of Future Monetary Policy? Evidence from the Federal Funds Futures Market,” Journal of Money, Credit and Banking (1999), 54-69.

________, and Michael Hutchison. “Is Sterilized Foreign Exchange Intervention Effective After All? An Event Study Approach.” Edmonton, Alberta: Working Paper, University of Alberta, 2001.

Ferson, Wayne, and Campbell Harvey, “The Risk and Predictability of International Equity Returns,” The Review of Financial Studies 6 (1993), 527-566.

________, and ________, “Conditioning Variables and the Cross Section of Stock Returns, Journal of Finance 54, (1999), 1325-1360.

Frankel, Jeffrey A., "A Test of Perfect Substitutability in the Foreign Exchange Market," Southern Economic Journal 46 (April 1982), 406-416.

________, "In Search of the Exchange Rate Risk Premium: A Six-Currency Test Assuming Mean-Variance Optimization," Journal of International Money and Finance 1 (1982b), 255-274.

________, and Charles Engel, "Do Asset Demand Functions Optimize over the Mean and Variance of Real Returns? A Six-Currency Test," Journal of International Economics 17 (1984), 309-23.

Galati, Gabriele, and Will Melick. “Central Bank Intervention and Market Expectations.” BIS Papers No. 10. Basle: Bank for International Settlements, 2002.

Ghosh, Atish R., "Is It Signaling? Exchange Intervention and the Dollar-Deutschemark Rate," Journal of International Economics 32 (1992), 201-220.

Giovannini, Alberto, and Philippe Jorion, "The Time-Variation of Risk and Return in the Foreign Exchange and Stock Markets," Journal of Finance 44 (June 1989), 307-324.

Goodhart, Charles A.E., and Thomas Hesse, “Central Bank Forex Intervention Assessed in Continuous Time,” Journal of International Money and Finance 12 (1993), 368-389.

Harvey, Campbell R., "Time-Varying Conditional Covariances in Tests of Asset Pricing Models," Journal of Financial Economics 24 (1989), 289-317.

________, “The World Price of Covariance Risk,” Journal of Finance 46 (1991), 111-157.

________, and Roger Huang, “The Impact of the Federal Reserve Bank’s open market operations,” Journal of Financial Markets 5 (2002), 223-257.

________, and Akhtar Siddique, "Time-Varying Conditional Skewness and the Market Risk Premium,” Research in Banking and Finance I (2000), 25-58.

Humpage, Owen F., “U.S. Intervention: Assessing the Probability of Success,” Journal of Money, Credit and Banking 31 (1998), 731-747.

Kaminsky, Gabriella, and Karen K. Lewis, "Does Foreign Exchange Intervention Signal Future Monetary Policy?" Journal of Monetary Economics 37 (1996), 285-312.

Klein, Michael W., “The Accuracy of Reports of Foreign Exchange Intervention,” Journal of

International Money and Finance 12 (1993), 644-653.

________, and Eric S. Rosengren, “Foreign Exchange Intervention as a Signal of Monetary Policy,” New England Economic Review (1991), 39-50.

Lettau, Martin, and Sydney Ludvigson. “Resurrecting the (C)CAPM: A Cross-Sectional Test When Risk Premiums Are Time-Varying.” New York: Federal Reserve Bank of New York Working Paper, 1999.

Lewis, Karen K., "Occasional Interventions to Target Rates," American Economic Review 85 (1995a), 691-715.

________, “Are Foreign Exchange Intervention and Monetary Policy Related, and Does It Really Matter?” Journal of Business 68 (1995b), 185-214.

Loopesko, Bonnie, "Relationships Among Exchange Rates, Intervention, and Interest Rates: An Empirical Investigation," Journal of International Money and Finance 3 (1984), 257-277.

Mark, Nelson C., “Exchange Rates and Fundamentals: Evidence on Long-Horizon Prediction,” American Economic Review 85 (1995), 201-218.

________, and Donggyu Sul, “Nominal Exchange Rates and Monetary Fundamentals: Evidence from a Small Post-Bretton Woods Panel.” Columbus, Ohio: Working Paper, Department of Economics, The Ohio State University, 2000.

Meese, Richard A., and Kenneth Rogoff, “Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?” Journal of International Economics 14 (1983), 3-24.

________, and ________, “Was It Real? The Exchange Rate-Interest Differential Relation Over the Modern Floating Rate Period,” Journal of Finance 43 (1988), 933-948.

Naranjo, Andy, and M. Nimalendran, “Government Intervention and Adverse Selection Costs in Foreign Exchange Markets,” The Review of Financial Studies 13 (2000), 453-477.

Neely, Christopher J., “The Temporal Pattern of Trading Rule Returns and Exchange Rate Intervention: Intervention Does Not Generate Technical Trading Profits.” Journal of International Economics 58 (2002), 211-232.

Rogoff, Kenneth, "On the Effects of Sterilized Intervention: An Analysis of Weekly Data," Journal of Monetary Economics 14 (1984), 133-150.

Saikkonen, Pentti, “Asymptotic Efficient Estimation of Cointegrating Regression,” Economic Theory 7 (1991), 1-21.

Santos, Tano and Pietro Veronesi. “Labor Income and Predictable Stock Returns.” Chicago: University of Chicago Working Paper, 2003.

Sarno, Lucio, and Mark P. Taylor, “Official Intervention in the Foreign Exchange Market: Is It Effective and If So, How Does It Work?” Journal of Economic Literature 39 (2001), 839-868.

Sims, Christopher, James H. Stock, and Mark W. Watson, "Inference in Linear Time Series Models with Some Unit Roots," Econometrica 58 (1990), 113-144.

Sjöö, Boo, and Richard J. Sweeney, "Efficiency-Test Regressions: Is The Regressor Integrated?” Gothenburg, Sweden: Working paper, Gothenburg School of Economics, 2000.

Solnik, Bruno, “The Performance of International Asset Allocation Strategies Using Conditioning Information,” Journal of Empirical Finance 1 (1993), 33-55.

Stock, James H., and Kenneth D. West, “Integrated Regressors and Tests of the Permanent-Income Hypothesis,” Journal of Monetary Economics 21 (1988), 85-95.

Sweeney, Richard J., and Arthur D. Warga, “The Pricing of Interest-Rate Risk: Evidence from the Stock Market,” Journal of Finance 41 (1986), 393-410.

Vitale, Paolo, “Sterilized Central Bank Intervention in the Foreign Exchange Market,” Journal of International Economics 49 (1999), 245-267.

West, Kenneth, "Asymptotic Normality, When Regressors Have a Unit Root," Econometrica 56 (1988), 1397-1417.

Table 1: Properties of the Data

Panel A: Frequency and patterns of intervention (Wednesday, Jan. 2, 1985, to Tuesday, Dec. 31, 1991: 1757 trading-day observations)

Days with **nonzero** intervention (percent of total):
DEM 199 (11.326 percent of total days)
JPY 170 (9.6755 percent of total days)

Days with **purchases** of USD, sales of foreign currency:
DEM 61 (3.3718 percent of total days; 30.65 percent of DEM interventions)
JPY 65 (3.6944 percent of total days; 38.24 percent of JPY interventions)

Days with **sales** of USD, purchases of foreign currency:
DEM 138 (7.8542 percent of total days; 69.35 percent of DEM interventions)
JPY 105 (5.9760 percent of total days; 61.76 percent of JPY interventions)

Days with **any** intervention: 369 (21.001 percent of total days)
Days with **sales** of **both** DEM and JPY: 28 (1.5936 percent of total days; 7.59 percent of days with any intervention)
Days with **purchases** of **both** DEM and JPY: 63 (3.5856 percent of total days; 17.07 percent of days with any intervention)

		Interventions	
Period dates	Observations	DEM	JPY
Jan. 2, 1985, Dec. 31, 1985:	250	22	21
Jan. 2, 1986, Dec. 31, 1986:	251	0	0
Jan. 2, 1987, Dec. 31, 1987:	252	32	43
Jan. 4, 1988, Dec. 30, 1988:	251	36	22
Jan. 3, 1989, Dec. 29, 1989:	251	77	67
Jan. 2, 1990, Dec. 31, 1990:	251	19	16
Jan. 2, 1991, Dec. 31, 1991:	251	13	1
Whole sample: Jan. 2, 1985, Dec. 31, 1991:	1757	199	170

[a] Definitions of variables.
Appr.: The continuously compounded rate of appreciation of the USD from day t to t+1, plus the day-t difference in the continuously compounded rates of return on USD and foreign overnight deposits.
Market: The excess rate of return on the market, continuously compounded, CRSP value-weighted rate of return on the market, including dividends, from t to t+1, less the continuously compounded overnight Euro-dollar rate for day t.
CI_t; CI_t / Vol_t; $CI_t\ A_t$: Cumulative intervention by the end of day t, unadjusted; adjusted by interpolated exchange-market total volume; and adjusted by the size of the asset market as measured by the CRSP value-weighted index, including dividends.
[b] Data for 1989 cover only U.S., U.K., Japan and Canada trades, and thus are not comparable to later data.

Table 1 (cont.)

Panel B: Appreciation, the market and cumulative intervention—sample statistics and correlations [a]

		Appr.	Market	CI_t	CI_t / Vol_t	CI_t / A_t
DEM	Mean	-0.000357	0.000350	9291.885	16.14979	3.40E-06
	Median	-0.000109	-0.000723	13255.15	23.08997	3.91E-06
	Maximum	0.030911	0.180585	16479.65	28.29835	8.97E-06
	Minimum	-0.041267	-0.088333	713.1500	1.191374	1.58E-07
	Std. Dev.	0.007367	0.010110	5834.471	10.28186	2.58E-06
Corrs.	Appr.	1.000000	0.035010	0.010666	0.008631	-0.009459
	Market	0.035010	1.000000	0.011230	0.011501	0.021419
	CI_t	0.010666	0.011235	1.000000	0.999539	0.941608
	CI_t / Vol_t	0.008631	0.011501	0.999539	1.000000	0.950454
	CI_t / A_t	-0.009459	0.021419	0.941608	0.950454	1.000000
JPY	Mean	-0.000327	-0.000342	-765.8711	-1.238170	-1.23E-07
	Median	-8.89E-05	-0.000723	-1802.050	-3.096140	-6.17E-07
	Maximum	0.033771	0.180585	7089.550	12.07314	2.15E-06
	Minimum	-0.034687	-0.088333	-5946.950	-9.901941	-1.57E-06
	Std. Dev.	0.006605	0.010112	4211.783	7.095736	1.14E-06
Corrs.	Appr.	1.000000	0.051811	0.043895	0.044557	0.051121
	Market	0.051811	1.000000	0.003308	0.002952	3.89E-05
	CI_t	0.043895	0.003308	1.000000	0.999855	0.982190
	CI_t / Vol_t	0.044557	0.002952	0.999855	1.000000	0.985054
	CI_t / A_t	0.051121	3.89E-05	0.982190	0.985054	1.000000

Panel C: Risk factors—sample statistics and correlations

		R_M	YC_{sur}	$E\ IN_{sur}$	CB-RP
	Mean	-0.000342	-1.93E-08	2.10E-08	-8.96E-10
	Median	-0.000723	3.84E-07	-3.52E-07	-1.62E-08
	Maximum	0.180585	6.34E-05	0.000170	1.82E-05
	Minimum	-0.088333	-0.000171	-5.73E-05	-8.44E-06
	Std. Dev.	0.010112	9.94E-06	9.42E-06	2.14E-06
Corrs.	R_M	1.000000	-0.028984	-0.007788	0.077707
	YC_{sur}	-0.028984	1.000000	-0.922344	-0.231078
	$E\ IN_{sur}$	-0.007788	-0.922344	1.000000	-0.007627
	CB-RP	0.077707	-0.231078	-0.007627	1.000000

Panel D. Foreign-Exchange Market Volume (*billions*; Bank for International Settlements, *Annual Report*. 1990 - 1999)

	1989	1992	1995	1998
Total Volume	590	820	1137	1500
Volume in U.S.	115.2	166.9	244.4	350.9
Volume in USD	744	832.03	946.7	1441.53
USD/DEM Volume	96.6 [b]	295.89	253.9	290.5
USD/JPY Volume	64.1 [b]	221.22	242.0	266.6

Table 2.A. Asset Pricing Models: Cumulative Intervention, DEM [a]

$$R_{t+1} = a + b_{0,M} R_{M,t+1} + b_{1,M} (R_{M,t+1} CI_t) + [b_{0,sur1} YC_{sur,t+1} + b_{1,sur1} (YC_{sur,t+1} CI_t) + b_{0,sur2} IN_{sur,t+1} + b_{1,sur2} (IN_{sur,t+1} CI_t) + b_{0,sur3} CRP_{sur,t+1} + b_{1,sur3} (CRP_{sur,t+1} CI_t)] + c R_t + d CI_t + v_{t+1}$$

Line Num.	a	$b_{M,0}$	$b_{M,1}$	$b_{sur1,0}$	$b_{sur1,1}$	$b_{sur2,0}$	$b_{sur2,1}$	$b_{sur3,0}$	$b_{sur3,1}$	c	d
1.	-0.000349	-0.092300	1.09E-05							0.052861	
	-1.988571	**-2.367812**	***3.368536***							**2.221965**	
2.	-0.000374	-0.082789	1.01E-05	97.75575	-0.008433					0.051247	
	-2.133921	**-2.116646**	***3.109607***	**2.555878**	**-2.548336**					**2.155098**	
3.	-0.000389	-0.092881	1.10E-05			-82.96431	0.008837			0.051339	
	-2.179552	**-2.385116**	***3.399833***			**-2.108560**	**2.558143**			**2.159478**	
4.	-0.000344	-0.064837	8.73E-06					-466.0647	0.040289	0.052845	
	-1.960799	-1.592336	***2.591400***					**-2.348787**	**2.448498**	**2.217139**	
5.	-0.000365	-0.061429	8.43E-06	83.20549	-0.007031			-385.4337	0.033226	0.051432	
	-2.080004	-1.508683	**2.502430**	**2.137373**	**-2.07620**_4_			*-1.910242*	**1.976783**	**2.158675**	
6.	-0.000377	-0.065175	8.80E-06			-83.53177	0.008795	-469.1660	0.040301	0.051184	
	-2.145504	-1.602689	***2.615926***			**-2.123844**	**2.546362**	**-2.367196**	**2.452238**	**2.149465**	
6.a	-0.000491	-0.064964	8.77E-06			-84.59341	0.008851	-468.7876	0.040308	0.051100	1.22E-08 [b]
	-1.485349	-1.596994	***2.605928***			**-2.145601**	**2.559846**	**-2.364695**	**2.452073**	**2.145321**	0.406608
6.b	0.000618	0.058207	7.91E-06			86.04160	0.008745	476.7890	0.039085	0.046952	1.09E-08
	1.876658	1.439011	**2.364857**			**2.161302**	**2.520225**	**2.427419**	**2.402129**	**1.965600**	0.363975 [b]
7.	-0.000385	-0.064964	8.77E-06	114.0812	0.005001	28.04020	0.013641	-354.8925	0.045989	0.047680	
	-2.190751	-1.596994	**2.605928**	0.737072	-0.406793	0.179314	1.091264	-1.399505	**2.216883**	**2.003498**	

Notes to Table 2:

[a] The dependent variable is the continuously compounded rate of appreciation of the USD from day t to day t+1, plus the difference in the continuously compounded rates of return on USD and foreign overnight deposits, as of day t. The market is the continuously compounded excess rate of return on the CRSP value weighted market index, including dividends, from day t to day t+1, less the continuously compounded yield on an overnight Euro USD deposit. The predetermined cumulative intervention measures are CI_t / A_t, CI_t / Vol_t and CI_t. CI_t is Fed cumulative intervention by the end of day t; A_t is a proxy for the value of the asset market by the end of day t (the level of the CRSP value weighted market index, including dividends); Vol_t is a proxy for volume in the foreign-exchange market on day t. This table uses CI_t; tables in Appendix C allow comparisons across all three cumulative intervention measures.

[b] Line 6.a shows results when CI_t is entered separately, and line 6.b shows results when CI_t is entered separately and leading values of I_t are also entered.

Italics, **bold**, ***bold italics***: Significantly different from zero at the 10, 5 and 1 percent levels.

Table 2.B. Asset Pricing Models: Cumulative Intervention, JPY [a]

$$R_{t+1} = a + b_{0,M}\ R_{M,t+1} + b_{1,M}\ (R_{M,t+1}\ CI_t) + [b_{0,sur1}\ YC_{sur,t+1} + b_{1,sur1}\ (YC_{sur,t+1}\ CI_t) + b_{0,sur2}\ IN_{sur,t+1} + b_{1,sur2}\ (IN_{sur,t+1}\ CI_t) + b_{0,sur3}\ CRP_{sur,t+1} + b_{1,sur3}\ (CRP_{sur,t+1}\ CI_t)] + c\ R_t + d\ CI_t + v_{t+1}$$

Line Num.	a	$b_{M,0}$	$b_{M,1}$	$b_{sur1,0}$	$b_{sur1,1}$	$b_{sur2,0}$	$b_{sur2,1}$	$b_{sur3,0}$	$b_{sur3,1}$	c	d
1.	-0.000315	0.025666	2.07E-05							0.057171	
	-2.015430	*1.653766*	***5.156736***							**2.416911**	
2.	-0.000350	0.023316	1.92E-05	-43.19595	-0.014121					0.053577	
	-2.237135	1.499600	***4.755843***	**-2.534405**	***-3.108884***					**2.267970**	
3.	-0.000352	0.027043	2.08E-05			46.92099	0.008744			0.054693	
	-2.235363	*1.743863*	***5.188873***			***2.597421***	*1.844659*			**2.313299**	
4.	-0.000314	0.028763	1.58E-05					7.228262	0.073773	0.058701	
	-2.010648	*1.809328*	***3.734761***					0.096256	***3.702134***	**2.484951**	
5.	-0.000341	0.027723	1.53E-05	-38.08165	-0.010865			-32.92747	0.062797	0.055410	
	-2.181263	*1.744681*	***3.616240***	**-2.161255**	**-2.316342**			-0.426719	***3.071623***	**2.345326**	
6.	-0.000347	0.029993	1.60E-05			44.77185	0.008402	5.640364	0.072484	0.056363	
	-2.213955	*1.888475*	***3.782834***			**2.486507**	*1.778704*	0.075200	***3.641409***	**2.387246**	
6.a	-0.000310	0.029903	1.58E-05			41.99217	0.007912	6.685202	0.072759	0.055309	4.69E-08
	-1.940314	1.883123	**3.727718**			**2.315175**	*1.669710*	0.089139	***3.655638***	**2.341536**	1.258942
6.b	0.000358	-0.023486	1.52E-05			-45.44620	0.008662	22.80582	0.067916	0.050988	4.67E-08
	2.265264	-1.495573	***3.632497***			**-2.534447**	*1.829072*	0.307921	***3.452608***	**2.158936**	1.269644 [b]
7.	-0.000287	0.035322	1.32E-05	89.87524	-0.048305	137.0785	-0.038554	111.1306	0.023954	0.049907	
	-1.822198	**2.188676**	***3.071415***	*1.707082*	***-3.098832***	**2.538433**	**-2.456679**	1.191586	0.957796	**2.113032**	

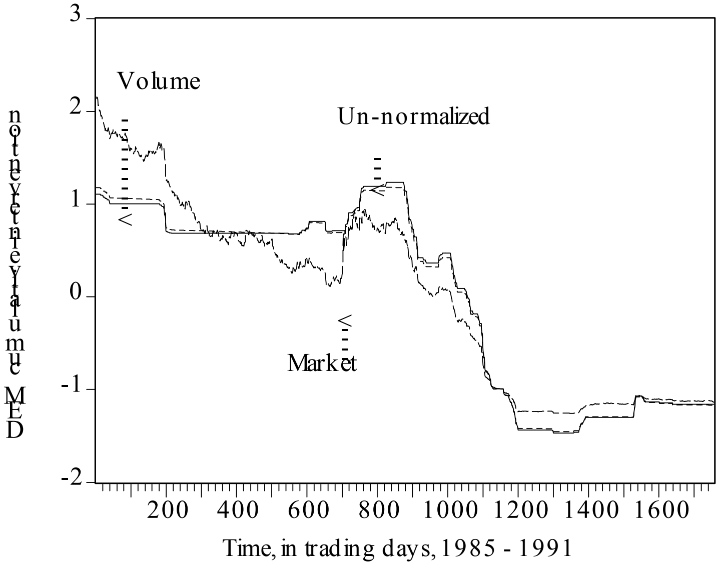
Notes to Table 2:

[a] The dependent variable is the continuously compounded rate of appreciation of the USD from day t to day t+1, plus the difference in the continuously compounded rates of return on USD and foreign overnight deposits, as of day t. The market is the continuously compounded excess rate of return on the CRSP value weighted market index, including dividends, from day t to day t+1, less the continuously compounded yield on an overnight Euro USD deposit. The predetermined cumulative intervention measures are CI_t / A_t, CI_t / Vol_t and CI_t. CI_t is Fed cumulative intervention by the end of day t; A_t is a proxy for the value of the asset market by the end of day t (the level of the CRSP value weighted market index, including dividends); Vol_t is a proxy for volume in the foreign-exchange market on day t. This table uses CI_t; tables in Appendix C allow comparisons across all three cumulative intervention measures.

[b] Line 6.a shows results when CI_t is entered separately, and line 6.b shows results when CI_t is entered separately and leading values of I_t are also entered.

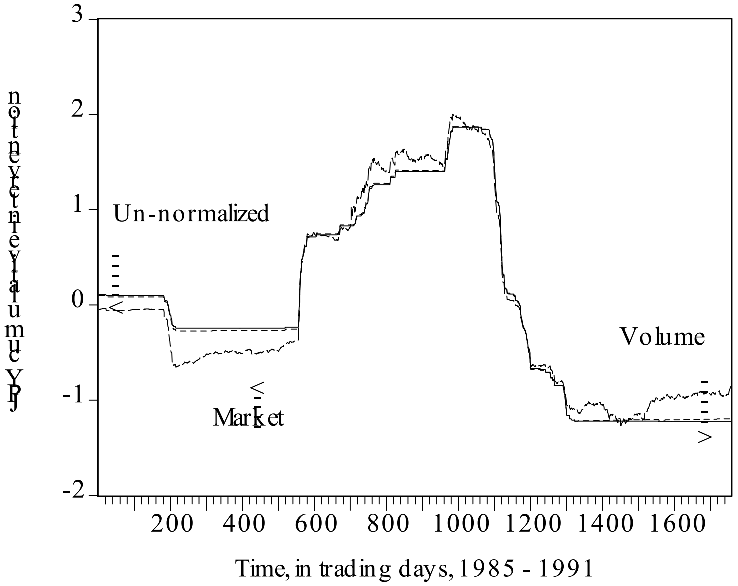
Italics, **bold**, ***bold italics***: Significantly different from zero at the 10, 5 and 1 percent levels.

Figure 1. Cumulative Intervention in DEM: Un-normalized, Normalized by the Market, Normalized by Volume



Source: Board of Governors
Cumulative intervention is the sum of Fed sales of foreign currency.
Each series is de-meaned and divided by its standard deviation.
Un-normalized: Cumulative Intervention
Voume: Cumulative Internvention / Exchange-Market Volume
Market: Cumulative Internvention / Stock Market

Figure 2. Cumulative Intervention in JPY: Un-normalized, Normalized by Market, Normalized by Volume



Source: Board of Governors
Cumulative intervention is the sum of Fed sales of foreign currency.
Each series is de-meaned and divided by its standard deviation.
Un-normalized: Cumulative Intervention
Volume: Cumulative Intervention / Exchange-Market Volume
Market: Cumulative Intervention / Stock Market

Figure 3. Market betas, as functions of cumulative intervention

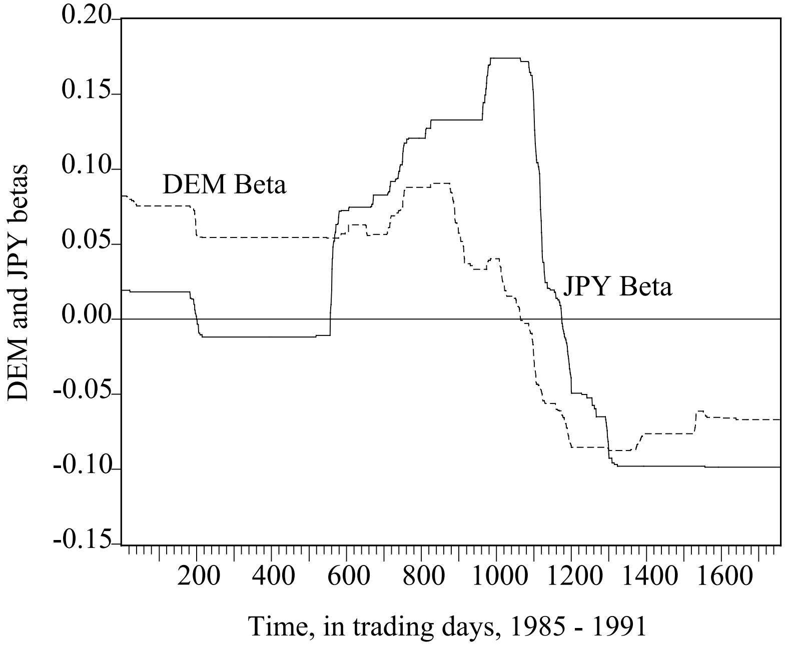
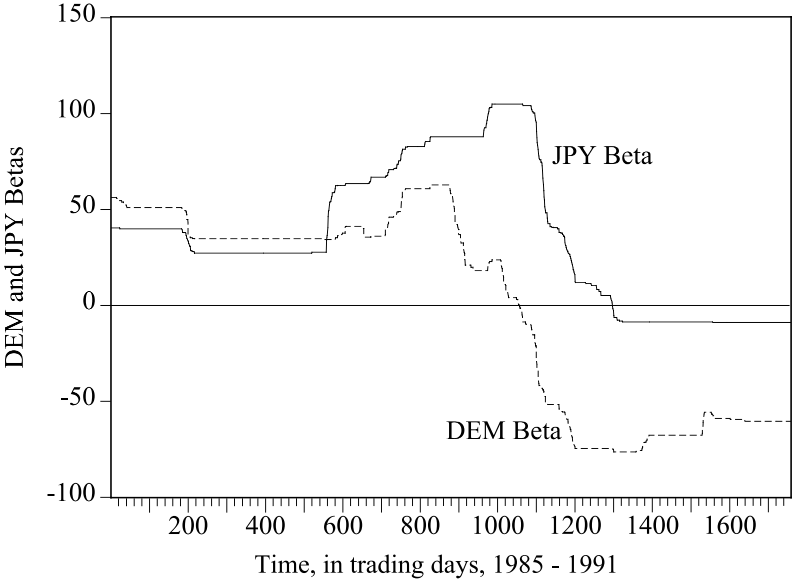


Figure 4. Betas on the surprise in expected inflation, as functions of cumulative intervention.



The surprise in the expected inflation rate is measured as the surprise in the overnight Euro deposit rate for the USD.