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The Relationship of the Exchange Risk Premium
to Net Foreign Assets and Central Bank Intervention

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Abstract

This paper takes another look at the portfolio theory of exchange rate behavior, using a survey-based definition of the risk premium and measuring the portfolio variable by the net stock of foreign assets. The model relates the risk premium to net foreign assets, together with related equations for expectations, the current account, and central bank intervention. Estimation from weekly data relating to the US dollar and the German mark over the period 1983-1988 shows significant effects of the current account and central bank intervention on the exchange rate. Alternative specifications do not fare as well.

1. Introduction¹

In the 1980's most tests of the portfolio theory of exchange rates (Frankel 1982, Engel and Frankel 1984, Dooley and Isard 1983) took the point of view of an international investor allocating a portfolio over the range of available outside assets supplied by the issuers of the principal international currencies, the dollar, mark, and yen, among others. These tests generally failed to show that changes in the available stocks of outside assets had any significant influence on the risk premium assumed by the theory to be required to induce the investor to diversify the portfolio in the proportions made available by the various governments. The risk premium was typically measured by the *ex post* observed excess return on the foreign asset, on the rational expectations hypothesis that the *ex ante* risk premium would differ from the *ex post* premium only by a random error. These conclusions supported a consensus view that sterilized central bank intervention, which changes the mix of outside assets available to private holders, would have little influence on exchange rates. This view coincided with the dominant political opinion in the US Treasury during the first Reagan Administration.

On the other hand, efforts to show that the risk premium is zero or is uncorrelated with any past information also failed (Hansen and Hodrick 1983), leading to a widespread opinion that assets denominated in different currencies may not be perfect substitutes. An alternative interpretation suggests that apparent risk premia may be due to a small sample problem, specifically the absence of an important expected future event in the sample in question (Kaminsky 1990).

However, substantial evidence has been brought forward in contradiction of the rational expectations hypothesis, making use of *survey* based expectations data. These data show that there are substantial extrapolative and adaptive components to expectations (Frankel and Froot 1987) and that there are systematic differences in the expectations of groups of investors with different net asset positions, e.g. exporters and importers (Ito 1990).

Further evidence has also appeared on the effectiveness of sterilized intervention by central banks in foreign exchange markets (Dominguez 1990, Dominguez and Frankel 1993). By changing the definition of the risk premium to one based on the survey expectations, as well as using actual intervention data from the Federal Reserve and the Deutsche Bundesbank, Dominguez and Frankel are able to detect measurable effects of intervention on the exchange rate, particularly through a signaling effect when central bank activity is publicly detected.

In the light of the evidence, this paper seeks to take another look at the portfolio theory, comparing the survey-based and rational expectations definitions of the risk premium and measuring the portfolio variable by the net stock of foreign assets as well as by total stocks of

¹ The first version of this paper was completed while the author was a Guest Scholar at the Brookings Institution, Washington, DC. Helpful comments were received from Patrick Conway, Hali Edison, Dale Henderson, and Kathryn Dominguez.

outside assets. In section 2, the portfolio approach based on net foreign assets is laid out and contrasted with the approach based on outside assets. Related equations for the current account and central bank intervention are specified. In section 3 presents the data and empirical model. Section 4 estimates the model. Section 5 examines forecasting behavior and policy multipliers. Section 6 offers conclusions.

2. Portfolio Theory

The basic insight of the portfolio theory of asset holding, as developed by Markowitz and Tobin, is that diversification of the portfolio maximizes a utility function depending on both risk and expected return. How is the relevant portfolio to be defined? One international version of this theory, developed by Black (1973) and Girton and Henderson (1976) and presented by Branson and Henderson (1985, section 2) postulates the behavior of a domestic investor whose financial wealth is to be allocated over domestic and foreign assets: domestic financial wealth is the relevant portfolio. Another version developed by Solnik (1974), Kouri (1977), Frankel (1979) and Dornbusch (1982) is based on an international version of the Capital Asset Pricing Model, in which homogeneous expectations of global investors lead to a common holding of the "world market portfolio". In Dornbusch, the investor's consumption pattern is independent of country of residence. This assumption carries over to Frankel's tests of the model. Thus the relevant asset stocks to be held are the total available stocks of "outside" assets issued by national governments, adjusted for central bank purchases and sales of foreign assets.

In Appendix 1.1 it is shown that the domestic investor version of the portfolio model yields the prediction that the share of world financial wealth ($\hat{W} = W + SW^*$) held as net foreign assets of the domestic economy $V = SF - B^*$ is positively related to the foreign currency risk premium $rp = i^* + \Delta s^e - i$. Inverted, this becomes

$$rp = \rho \sigma_e^2 V / (W + SW^*) \quad (1)$$

Given the asset stocks and interest rates, the exchange rate S and the expected change in the exchange rate $\Delta s^e = \log(S^e/S)$ must adjust to maintain this relationship.

The model may be closed as in Branson and Henderson (1985) by assuming a goods market or balance of payments equilibrium condition, specifying that the accumulation of net foreign assets through the current account is the outcome of joint equilibria in the domestic and foreign goods markets. In a world with slowly adjusting prices and wages, determined for example by contracts with a one-period lag, the excess of domestic output over expenditure can be expected to depend on the real exchange rate SP^*/P and domestic and foreign output levels Y and Y^* . Earnings on the net stock of foreign assets V should also affect the current account. The nonfinancial balance comprises the current account balance and the balance of non-financial assets (net foreign direct investment):

$$\begin{aligned} \text{NFB}/\hat{W} &= \beta((SP^*/P), Y^*, Y, V/\hat{W}), \\ \beta_1 &> 0, \beta_2 > 0, \beta_3 < 0, \beta_4 > 0 \end{aligned} \quad (2)$$

We assume the domestic and foreign central banks engage in sterilized net purchases of foreign exchange according to

$$\Delta G/\hat{W} = -\gamma(s - \bar{s}) - \mu \Delta s, \quad (3)$$

where \bar{s} is the target exchange rate, assumed equal to $\log(P/P^*)$ for long-run equilibrium to exist. The accumulation of net foreign assets by the private sector *and* the central banks is equal to the nonfinancial surplus:

$$\Delta V + \Delta G = \text{NFB} \quad (4)$$

The usual portfolio model of exchange rates is closed by assuming rational expectations for the exchange rate, so that equations (1) to (4) yield two differential or difference equations in the exchange rate and the stock of net foreign assets with a saddle path solution (Branson and Henderson 1985, section 2, or Black and Salemi 1988). Here, I will instead follow Frankel and Froot and assume that expectations combine adaptive and extrapolative components, plus a term for news about central bank intervention.

$$\Delta s_{+1}^e = \delta_1 \Delta s + \delta_2 (s^e - s) + \delta_3 \text{news} \quad (5)$$

As pointed out by Kouri (1976) and recently explored by De Grauwe (1993), these nonrational expectations simply exacerbate short-run fluctuations of the exchange rate around the long-run equilibrium, as long as we impose consistency with long-run equilibrium.

The implications of this model based on the solution in Appendix 1.2 may be seen in Figure 1. First substitute from (2) and (3) into (4), obtaining an equation for the accumulation of net foreign assets by the home country. Next, solve (5) for the expected change in the exchange rate Δs_{+1}^e , substitute into (1) and solve for the actual change in the exchange rate, which depends on the interest differential $i - i^*$ and the stock of net foreign assets. Setting $\Delta V = 0$ yields the VV curve in Figure 1 with a slope close to vertical if $\delta_1 \approx \delta_2$. Setting the change in the exchange rate $\Delta s = 0$ yields the SS curve with slope $-(\beta_4 + 1 - \delta_2)/(\beta_1 + \gamma) < 0$.

An increase in the foreign interest rate would shift the VV curve right. The exchange rate would first rise and then fall over time, raising the net stock of foreign assets. A rise in the domestic price level would shift the SS curve up, leading to a gradual rise in the price of foreign currency.

A fiscal expansion abroad that led to a decline in the foreign nonfinancial balance at a given real exchange rate would cause a rightward shift in the VV curve as the foreign interest rate rises and an upward shift in the SS curve as the domestic nonfinancial balance rises. The result would be a gradual depreciation of the exchange rate, accompanied by an accumulation of net foreign assets.

Now let us contrast this theory with the global investor version. Instead of net foreign assets $SF - B^*$, we consider the total demand for foreign assets, both domestic and foreign, $F + F^*$ and the total supply \mathfrak{S} .

In the notation of Appendix 1.1, this can be written as

$$f(i, i^* + \Delta s^e)W/S + f^*(i - \Delta s^e, i^*)W^* = \mathfrak{S}$$

Proceeding with similar assumptions on f and f^* as in Appendix 1.1, we arrive at

$$\alpha(i^* + \Delta s^e - i) = S\mathfrak{S}/(W + SW^*) \quad (6)$$

It is this version of the portfolio theory that has repeatedly been tested and found wanting by Frankel (1982), Dooley and Isard (1983), and Frankel and Engel (1984). The independent variable

on the right-hand side of equation (6) is the total stock of outside foreign assets as a share of world wealth. One reason for the difficulty in testing equation (6) as compared to equation (1) is that the substitution possibilities available to identify the *foreign* demand for foreign government bonds f^* are too broad to be easily captured in the set of variables usually included in the analysis². In addition, the changes in net foreign assets are directly related to changes in international competitiveness through the nonfinancial balance of payments, while changes in the total stocks of outside assets depend on government fiscal policies.

3. Data

The empirical part of this paper tests the proposition that the major fluctuations in dollar exchange rates of the 1980's can be explained by fluctuations in the external position of the United States versus the rest of the industrialized countries, mainly Europe and Japan. Therefore the focus is on changes in the United States balance of payments and US versus German and Japanese prices, interest rates, and exchange rates. Weekly data are used to capture the short-run variability of exchange rates and risk premia. Appendix 2 gives details on the data. Because of nonstationarity in the stock of net foreign assets, the empirical form of the risk premium equation (7) relates $RP = i^* - i + DSE_{+1}$ to the *change* in net foreign assets relative to wealth $DNFA/\hat{W}$. Equation (8) reproduces the expectations equation, (9) the equation for central bank purchases of dollars $DFXR$, (10) the equation for the nonfinancial surplus NFB , and (11) the identity connecting the change in assets to the surplus and intervention.

$$RP = a_0 + a_1 VAR + a_2 VAR * DNFA/\hat{W} + a_3 PLAZA + a_4 DUM3MO + u_1 \quad (7)$$

$$DSE_{+1} = b_0 + b_1 DS + b_2 (SE - S) + b_3 NEWS + u_2 \quad (8)$$

$$DFXR/\hat{W} = c_0 + c_1 (S - S^*) + c_2 DS + c_3 PLAZA1 + c_4 CRASH + u_3 \quad (9)$$

$$u_3 \sim N(0, \sigma_3^2), \sigma_3^2 > \sigma_1^2$$

$$NFB/\hat{W} = d_0 + d_1 \sum (SP^*/P)_{-k} - d_2 Y + d_3 Y^* + d_4 POIL + u_4 \quad (10)$$

$$DNFA = NFB - DFXR \quad (11)$$

Preliminary examination of the data suggests that the mean risk premium for the three-month subsample may differ from the one-month subsample, suggesting a dummy variable $DUM3MO$ for the three-month sample period. In addition, the shifts in government intervention policy at the Plaza Agreement in September 1985 and the Louvre Agreement in February 1987 between the Group of Seven industrial countries to intervene in exchange markets may have

² If there is a nontraded asset G^* in the foreign country with yield r^* which is a substitute for F^* but not for B^* , then r^* will enter equation (6) but not equation (1).

changed the mean risk premium as well as the behavior of the intervention equation (9); the Plaza is represented in the risk premium equation by a dummy variable which is equal to one on and after September 25, 1985. The Plaza Agreement enters the intervention equation as a one-period dummy, the Louvre Agreement is modeled as a change in the residual variance, due to much more active intervention after that date [See Figure 3], and the effect of the October 1987 stock market crash enters as a dummy variable for three weeks.

Since the model (7)-(11) is a system of five equations determining the five endogenous variables S , SE , $DFXR$, $DNFA$, NFB , an instrumental variables approach is called for, except for equation (10), which is estimated at the *monthly* level and therefore involves only pre-determined variables on the right-hand-side. The instruments used were lagged values of right-hand-side variables as well as VAR , $NEWS$, NFB , $INTDIFF$, and the relevant dummy variables. When necessary, the Fair IV procedure is used to correct for first-order autocorrelation in the residuals. In order to test separately the effects of central bank intervention in the risk premium equation, the change in net foreign assets $DNFA/\hat{W}$ is broken up into its two components the nonfinancial balance NFB/\hat{W} and central bank intervention $DFXR/\hat{W}$.

To improve the efficiency of estimation, the residuals in the risk premium and expectations equations are assumed to follow an autoregressive process that is conditionally heteroscedastic based on recently observed noise.

$$\begin{aligned} y_t &= b_0 + b_1 x_t + u_t \\ u_t &= \rho u_{t-1} + e_t \\ h_t &= a_0 + a_1 VAR_t + a_2 h_{t-1} \end{aligned} \quad e_t \sim N(0, h_t)$$

The equation is then estimated by maximum likelihood, where the typical element of the likelihood function is

$$\ell_t = -.5 \log(h_t) - .5 e_t^2 / h_t.$$

4. The Empirical Model

Risk Premium

The results of the unrestricted regression for the risk premium equation (7) using the Fair procedure for autocorrelation are shown in the first column of Table 1. All coefficients enter significantly with correct signs. The Q statistic suggests that the correction for first-order autocorrelation has not completely eliminated all forms of serial dependence. A Breusch-Pagan test using VAR to measure heteroscedasticity rejects homoscedastic residuals, with a chi square of 5.75, significance level of 1.65 percent, calling for the nonlinear procedure shown in column two. The residual in the risk premium equation appears to have a combination of heteroscedasticity based on recent noise in the risk premium (A_1) and a time-varying mean that regresses towards zero (A_2). By comparison with Dominguez and Frankel the coefficient on VAR is larger, as is the coefficient on the current and lagged intervention $VAR*DFXR/\hat{W}$. The addition of the non-financial balance, $VAR*NFB/\hat{W}$, and the dummy variables has added considerable to the explanatory power of the equation.

A major implication of the portfolio theory requires that the coefficients on NFB and DFXR should add up to zero. A chi square statistic of 0.1068 does not reject that the sum of the coefficients is zero, supporting the portfolio interpretation of the equation. In column three the restricted regression shows considerably improved statistical significance.

During the period from 1983 to the end of 1988, the average risk premium on the dollar was -0.50 percent per month, or about -6.2 percent per annum, but it varied from -3.81 percent per month to 3.05 percent per month. The average weekly standard deviation of the dollar/mark exchange rate was 0.54 percent, varying from 0.027 percent to 6.00 percent. Using the regression coefficient $36.35 \cdot \text{VAR} / \hat{W} = 0.23$ at the 1983-88 mean, an expansion of the US current account deficit from its weekly average of \$2 billion to \$2.23 billion raises the risk premium on the dollar by 0.05 percent per month (about 10 percent of its average level), or 0.6 percent per annum. An equivalent sale of dollars by a central bank would have a similar effect.

The effect of a 10 percent increase in perceived risk (the square root of VAR) has an effect on the risk premium equal to $(-1.156 + 36.35 \cdot \text{DNFA} / \hat{W})(.11) = .077$ percent per month. This is equal to a 14 percent increase in the risk premium at the mean. It would be larger if foreign assets were increasing more than average, smaller if less.

During the subsample with the three-month horizon, prior to November 1984, the risk premium on the dollar was negative. The dummy variable estimates that it was larger in absolute value by 1.84 percent per month because of the longer horizon. The Plaza Agreement in September 1985 is estimated to have reduced the risk premium on the dollar by 1.29 percent per month for the remainder of the sample. Figure 2 shows the actual and estimated risk premium over the sample period.

Alternative Specifications

As noted above, earlier tests of the portfolio theory by Frankel and others measured the relevant asset stocks by the amounts of outside assets supplied by the issuers of the major currencies. They also measured the risk premium by the *ex post* observed excess return on the foreign asset. Here I compare the equations based on the stock of net foreign assets and the survey measure of the risk premium with alternative specifications based on the *ex post* risk premium and the stock of outside assets.

Beginning with the *ex post* definition of the risk premium, let us define RP30 as the risk premium based on the realized spot exchange rate 30 days after the current spot rate $i^* - i + (s_{t+30} - s_t)$ [90 days in case of the three-month portion of the sample]. Then it is a simple matter to compare regressions of the *ex ante* and *ex post* risk premia on the same set of independent variables. The *ex post* premium is available to me only for the sample from February 2, 1982 to January 8, 1988. In this case, only one coefficient is significant in the unrestricted instrumental variables regression using the Fair procedure for autocorrelation shown in the first column of Table 2, compared with three coefficients in the comparable *ex ante* equation. An F test of 3.04 with 6 and 176 degrees of freedom concludes the *ex post* regression is significant, but it compares

with an F of 5.45 for the *ex ante* equation. After adjustment for conditional heteroscedasticity according to the procedure outlined above with results in column two of Table 2, a chi-square test of 0.92 with 4 degrees of freedom cannot reject the hypothesis that none of the non-dummy independent variables enter the *ex post* equation significantly.

In order to compare the two versions of the portfolio variable, based on net foreign assets and the share of outside assets, both variables were entered into the same equation. The measurement of outside assets based on government debt is described in Appendix 2. As seen in the unrestricted instrumental variables equation in column three of Table 2, net foreign assets retained its significance, while the outside asset variable was not significant at the 5% level.

Expectations

The behavior of expectations, in equation (8), is estimated by the instrumental variables Fair procedure with results in column one of Table 3. Again the residuals appear to have remaining serial dependence according to the Q statistic and a Breusch-Pagan test. The results of the nonlinear procedure for autocorrelation and heteroscedasticity are shown in column two.

Strong extrapolative and adaptive effects on expectations are observed. The News variable reflecting information about central bank intervention also affects expectations significantly, as previously found by Dominguez and Frankel. The results suggest that survey expectations reflect "chartist" behavior, as also found by Frankel and Froot.

Intervention

The central bank intervention equation (9) was estimated by a nonlinear procedure allowing for a shift in variance after the Louvre Agreement in Table 4. The dependent variable is total purchases of dollars by the three central banks combined, as a percent of wealth, and is related to the percentage change in the average value of the dollar in terms of the deutschemark and yen, and to the difference between the level of the average exchange rate and its four-week lagged moving average. Thus a 1 percent fall in the weekly value of the dollar was associated with a purchase of $.00329 \times 11,456$ billion/100 = \$377 million by the group of central banks, at the end of the sample period. Figure 3 shows that the model captures actual intervention behavior rather well.

Current Account

Equation (10) for the monthly nonfinancial balance [as defined in Appendix 2] relative to wealth was estimated with a 15-month polynomial lag structure on the real exchange rate $RER = SP^*/P$ and 3-month distributed lags on domestic and foreign output, as shown in Table 5. According to this equation, a one percent rise in the value of the dollar will lead to a \$160 million worsening of the monthly US nonfinancial deficit after a fifteen month lag. At an annual rate, this is equal to \$1.9 billion. One percent faster growth in Germany and Japan would reduce the monthly deficit by \$1.28 billion, or \$15 billion per year, while one percent faster growth in the United States

would increase it by an equal amount. This simplified equation neglects some improvements that could be obtained by modeling nonoil imports and exports separately in real terms, as in Helkie and Hooper (1987).

5. Model Properties

Forecasting

In order to examine the appropriateness of the model in describing the relationships among the data, the model was refit to the sample ending September 30, 1988 and simulated over the following thirteen weeks out of sample, taking the monthly nonfinancial balance as given. Table 6 gives the one-step-ahead forecast statistics for the main variables in the model. Actually, the root mean square errors out of sample are smaller than the within sample standard errors equation by equation. According to the Theil U statistics, the one-step ahead forecasts handily beat a random walk for the exchange rate and all of the other variables.

Policy Multipliers

The model can be simulated within the sample period to examine its response to changes in interest rates and other variables. Figure 4 shows the response of the model to a temporary one quarter percent per month fall in the dollar interest rate (or rise in the mark interest rate) for four weeks. The value of the mark rises 2.2 percent, but the rise is slowed by intervention purchases of dollars that total \$1.9 billion over the four weeks. The risk premium on the dollar falls by an average of 0.03 percentage points as long as the dollar interest rate is low.

Figure 5 shows the effect of a central bank intervention purchase of one billion dollars, both with and without public information (news). Without news, the mark falls by about 0.25 percent, and the dollar risk premium .05 percent. This is the direct portfolio effect of the intervention. Adding "convincing" public information makes a big difference, as the mark now falls by as much as 1.2 percent. The risk premium on the dollar falls by about the same amount as before and then rebounds more rapidly. Without news, the expected change in the mark remains small, but public information about the intervention leads to an 0.2 percent expected decline in the mark, which helps push the mark down as noted. The sustained effect of the intervention occurs because of its simultaneous effect on expectations.

Figure 6 shows the effects of a temporary \$1 billion increase in the US nonfinancial deficit (\$250 million per week for four weeks). The two lines in each figure show the results of simulating the model with and without intervention by the central bank. It is assumed that intervention is known to the public to the same degree as was true on average in the sample. As can be seen, without intervention, the value of the mark increases 0.15 percent, whereas with central bank intervention the value of the mark increases only by 0.13 percent, or 13 percent less. The amount of intervention required to achieve this 13 percent smoothing is \$134 million in the first five weeks. The risk premium on the dollar rises 0.026 percent, slightly more without intervention.

6. Conclusions

This paper has reexamined the portfolio model of exchange rate determination to compare the exchange risk premium as measured by survey data and by *ex post* observed exchange rates and compared net foreign assets with outside assets as the portfolio variable. Equations for the risk premium, the endogenous behavior of expectations, central bank intervention, and the response of the nonfinancial balance to the exchange rate have been estimated by instrumental variables.

The resulting model appears reasonable in terms of its fit to the data within sample and its elasticities. When used to forecast six months beyond the end of the sample, it is better than a random walk for the exchange rate. Of course it might not do as well in other sample periods. When simulated in response to various shocks, it displays behavior that appears reasonable. According to the model, central bank intervention can have an effect on exchange rates for periods of up to twelve weeks, because of its simultaneous effects on asset stocks and expectations. Intervention also changes the dynamic response of the model to shocks, by dampening the movement of the exchange rate. These effects are sustained over time because of the close interdependence between actual and expected exchange rate behavior.

Several shortcomings in this paper should be noted. The risk premium on the yen could be built into the same framework in order to improve the overall fit of the model. Since it is highly correlated with the risk premium on the mark used here, major changes should not be expected. It would be desirable to integrate an equation for the nonfinancial surplus into the weekly model of the risk premium, expectations, and central bank intervention. Nevertheless, the results appear supportive of a reformulated portfolio model of the exchange rate.

Appendix 1.1

Portfolio Model

Let us consider the Branson-Henderson version of the portfolio theory. Domestic financial wealth consists of holdings of domestic money and domestic and foreign government bonds, with foreign wealth defined symmetrically.

$$W = M + B + SF \quad (A1.1)$$

$$W^* = N^* + F^* + B^*/S \quad (A1.2)$$

where domestic (foreign) money is M (N), domestic (foreign) bonds are B (F), S is the price of foreign currency, and the asterisk denotes foreign holdings. Note that money is assumed not to be held internationally, for simplicity. The total stocks of domestic and foreign government bonds are

$$B = B + B^*$$

$$\mathfrak{S} = F + F^*$$

Since domestic government bonds and money are liabilities of the domestic government, *net private wealth* for the domestic economy is

$$V = W - M - B = SF - B^* \quad (A1.3)$$

and for the foreign economy is

$$V^* = W^* - N^* - \mathfrak{S} = B^*/S - F \quad (A1.4)$$

Now assume that for reasons of portfolio diversification the demands for the domestic and foreign assets depend on the domestic and foreign interest rates on bonds i and i^* , the expected rate of change of the exchange rate Δs^e , and wealth. Following Dornbusch (1982) or Black and Salemi (1988) the coefficient on the domestic demand for foreign assets F should be $1/\rho\sigma_e^2$, where ρ is the coefficient of relative risk aversion and σ_e^2 is the perceived variance of the exchange rate. A similar argument applies to the coefficient of the foreign demand for domestic assets B^* .

$$B = b(i, i^* + \Delta s^e) W, \quad b_1 > 0, \quad b_2 < 0 \quad (A1.5)$$

$$SF = f(i, i^* + \Delta s^e) W, \quad f_1 < 0, \quad f_2 > 0 \quad (A1.6)$$

Similarly,

$$B^*/S = b^*(i - \Delta s^e, i^*) W^*, \quad b_1^* > 0, \quad b_2^* < 0$$

$$F^* = f^*(i - \Delta s^e, i^*) W^*, \quad f_1^* < 0, \quad f_2^* > 0$$

Assume domestic and foreign prices P and P^* are determined in the short run by wage contracts that were set in the previous period and that domestic and foreign output Y and Y^* are also pre-determined. If the demands for domestic and foreign money depend only on the own interest rate and nominal output, the monetary authorities can then control their respective nominal interest rates.

$$m(i, PY) = M, \quad n(i^*, P^*Y^*) = N \quad (A1.7)$$

The private demand for net foreign assets V can be expressed as

$$V = SF - B^* = f(i^* + \Delta s^e - i) W - b^*(i - \Delta s^e - i^*)SW^* \quad (A1.8)$$

Finally, for simplicity assume that domestic and foreign investors have the same degree of risk aversion and perceived risk. Then the f and b^* functions each have the *same* coefficient $\alpha = 1/\rho\sigma_e^2$. Then we can express the demand to hold net foreign assets as a function of the risk premium and world wealth:

$$V = \alpha(i^* + \Delta s^e - i) (W + SW^*) \quad (A1.9)$$

Appendix 1.2

Solution of Model

$$\text{Let } v \equiv (\text{SF-B}^*)/(\text{W} + \text{SW}^*), \Delta s_{t+1}^e \equiv s_{t+1}^e - s_t$$

$$\text{Then (1) is} \quad \Delta s_{t+1}^e + i^* - i = \rho \sigma_e^2 v_t \quad (\text{A2.1})$$

Substituting (2) and (3) into (4) gives

$$\Delta v_t = \beta_1(s_t + p^* - p) + \beta_4(v_{t-1}) + \gamma(s_t - \bar{s}) + \mu \Delta s_t \quad (\text{A2.2})$$

$$\beta_1 > 0, \beta_4 > 0$$

$$(5) \text{ is} \quad \Delta s_{t+1}^e = \delta_1 \Delta s_t + \delta_2(s_t^e - s_t) + \delta_3 \text{news}_t \quad (\text{A2.3})$$

with solution:

$$(1 - \delta_2 L) s_{t+1}^e = (1 - \delta_2 + \delta_1 \Delta) s_t + \delta_3 \text{news}_t \quad (\text{A2.4})$$

$$\Delta s_{t+1}^e = (1 - \delta_2 L)^{-1} [(\delta_1 - \delta_2)(1-L)s_t + \delta_3 \text{news}_t] \quad (\text{A2.5})$$

For simplicity, assume news $\equiv 0$ and substitute (A2.5) in (A2.1).

$$(1 - \delta_2 L)^{-1} [(\delta_1 - \delta_2) \Delta s_t] + i^* - i = \rho \sigma_e^2 v_t \quad (\text{A2.6})$$

Note that long run $i^* - i = \rho \sigma_e^2 \bar{v}$ and from (A2.2) $\bar{s} = p - p^* - (\beta_4/\beta_1)\bar{v}$.

Also $1 - \delta_2 L = 1 - L + L - \delta_2 L = \Delta + (1 - \delta_2)L$.

Therefore (A2.6) can be written as

$$(\delta_1 - \delta_2) \Delta s_t = \rho \sigma_e^2 \Delta v_t + (1 - \delta_2) \rho \sigma_e^2 (v_{t-1} - \bar{v}) \quad (\text{A2.7})$$

and (A2.2) can be written as

$$\Delta v_t = \beta_1(s_t - \bar{s}) + \beta_4(v_{t-1} - \bar{v}) + \gamma(s_t - \bar{s}) + \mu \Delta s_t \quad (\text{A2.8})$$

Again using $1 = 1 - L + L$, we have

$$\Delta v_t = (\beta_1 + \gamma)(\Delta s_t + s_{t-1} - \bar{s}) + \beta_4(v_{t-1} - \bar{v}) + \mu \Delta s_t \quad (\text{A2.9})$$

Therefore we can write (A2.7) and (A2.9) in matrix form as

$$\begin{bmatrix} (\delta_1 - \delta_2) & -\rho\sigma_e^2 \\ -(\beta_1 + \gamma + \mu) & 1 \end{bmatrix} \begin{bmatrix} \Delta S_t \\ \Delta V_t \end{bmatrix} = \begin{bmatrix} 0 & (1 - \delta_2)\rho\sigma_e^2 \\ \beta_1 + \gamma & \beta_4 \end{bmatrix} \begin{bmatrix} S_{t-1} - \bar{S} \\ V_{t-1} - \bar{V} \end{bmatrix} \quad (\text{A2.10})$$

Let $\alpha = (\delta_2 - \delta_1)/[\rho\sigma_e^2(\beta_1 + \gamma + \mu)]$. Then (A2.10) is equivalent to

$$\begin{bmatrix} \Delta S_t \\ \Delta V_t \end{bmatrix} = -\frac{1}{1 + \alpha} \begin{bmatrix} (\beta_1 + \gamma) / (\beta_1 + \gamma + \mu) & (1 - \delta_2 + \beta_4) / (\beta_1 + \gamma + \mu) \\ -\alpha(\beta_1 + \gamma) & 1 - \delta_2 - \alpha\beta_4 \end{bmatrix} \begin{bmatrix} S_{t-1} - \bar{S} \\ V_{t-1} - \bar{V} \end{bmatrix} \quad (\text{A2.11})$$

In case $\delta_1 = \delta_2 = \delta$, then $\alpha = 0$ and the system has one root $\mu/(\beta_1 + \gamma + \mu)$ and one root $0 < \delta < 1$. If $\delta_1 \approx \delta_2$, the roots will be similar. The system will be damped, with the larger root δ quickly dominating behavior.

The dynamics of the system can be seen in Figure 1 of the text, where the slope of the $\Delta S = 0$ curve is, from (A2.11) $-(\beta_4 + 1 - \delta_2)/(\beta_1 + \gamma) < 0$ and the slope of the $\Delta V = 0$ curve is $(1 - \delta_2 - \alpha\beta_4)/\alpha(\beta_1 + \gamma) \approx \infty$ if $\alpha \approx 0$.

Capital Gains

To allow for the effects of capital gains and losses, approximate the effects on v as follows:

$$\Delta V_t = \left(\frac{SF}{W + SW^*} \right)_{t-1} \frac{\Delta S_t}{S_{t-1}} - \left(\frac{SF - B^*}{W + SW^*} \right)_{t-1} \cdot \left(\frac{SW^*}{W + SW^*} \right)_{t-1} \cdot \frac{\Delta S_t}{S_{t-1}} = \epsilon \Delta S_t$$

Thus an extra term can be added to equation (A2.2), with the sign of ϵ depending on the existing stocks of assets. Given total wealth, ϵ can be expected to be small.

Appendix 2

Data

Data for the US nonfinancial deficit (including US official capital outflows) on a quarterly basis have been taken from *International Financial Statistics*. These data have been adjusted to the annual benchmarks of the OECD measure of the nonfinancial deficit given in Barenco (1990) and then interpolated on a monthly basis using a regression on the monthly trade balance via the Chow and Lin (1975) approach, which follows the monthly pattern and preserves the quarterly totals. The procedure adds to the monthly trade deficit the non-trade items, such as services, direct investment, and government capital flows. The weekly nonfinancial balance is obtained from the monthly by linear interpolation, allowing for 4 and 5 week months.

Reported monthly changes in foreign exchange reserves of the German, Japanese, and US central banks ($DFXR = DFXRGR + DFXRJP - DFXRUS$) are regressed on weekly US central bank intervention and weekly news reports of intervention by the three central banks to obtain weekly changes in foreign currency assets, again preserving the monthly totals via the Chow and Lin method. See Figure 3 for the results. A measure of the change in *private* financial assets ($DNFA = NFB - DFXR$) is then constructed by subtracting intervention from the nonfinancial balance. The cumulated change in private financial assets is then taken as a measure of net private foreign assets ($NFA = B^* - SF$). The dollar value of the sum of total private financial wealth in the United States, as given in the Flow of Funds Statistics, and total private financial wealth in Germany, as given in the Monthly Report of the Deutsche Bundesbank, is used as the deflator \hat{W} .

For the alternative measure of the relevant stock of assets, the stocks of outside assets supplied by the two governments are measured as the net stock of US Federal debt and the net stock of German Federal debt, both on a monthly basis. These were then interpolated to a weekly basis as indicated above for the net stock of financial assets. The deutschemark relative share was then defined as $S^*DMDEBT / (DOLDEBT + S^*DMDEBT)$. Dickey-Fuller tests were unable to reject a unit root in the relative share, so as with net foreign assets, its first difference was used.

The risk premium RP is measured by the one-month interest differential between the dollar and the deutschemark less the expected one-month change in the dollar price of the deutschemark, as given in the Money Market Services survey data on a weekly basis. Prior to November 1984, the data refer to three-month interest rates and expected changes in the exchange rate, and prior to August 1985 the observations are biweekly rather than weekly. An additional variable, the lagged daily variability of the exchange rate over the week prior to the MMS survey, is used as in Dominguez and Frankel (1991) to capture the effect of changes in the perceived degree of risk. News is represented by the number of stories in the *Wall Street Journal* or the *Financial Times* about dollar purchases (negative if sales). These data were kindly provided by Kathryn Dominguez and Jeffrey Frankel. The monthly real exchange rate entering equation (10) is taken from the IMF's measure of relative unit labor costs, corrected for exchange rates. The monthly domestic and foreign output variables are measured by US industrial production IPUS and the average of

German and Japanese industrial production FIP. The monthly price of oil, which also enters the empirical version of equation (10) is measured by the IMF's index of world crude oil prices.

Before seeking to estimate the relationships represented by equations (7)-(10), it is important to consider whether their variables can be represented by stationary stochastic processes. To that end, Dickey-Fuller tests were run on the risk premium RP, the actual and expected changes in the spot exchange rate DS and DSE, the lagged variance of the exchange rate VAR, and the level of net private foreign assets relative to wealth $NFLP/\hat{W}$. The results of those tests shown in Appendix Table 1 strongly reject unit roots in the risk premium and the variance of exchange rates, but do not reject a unit root in net foreign assets. For the first difference of net foreign assets $DNFA/\hat{W}$, the tests do reject a unit root.

Appendix Table 1. Dickey-Fuller Tests

Variable\Lags	0	1	2
RP	-138.05**		
$NFLP/\hat{W}$	-0.38	-.61	
$DNFA/\hat{W}$	-64.61**	-2.96*	-5.94**
VAR	-140.56**		

* significant at the five percent level to reject unit root.

** significant at the one percent level to reject unit root.

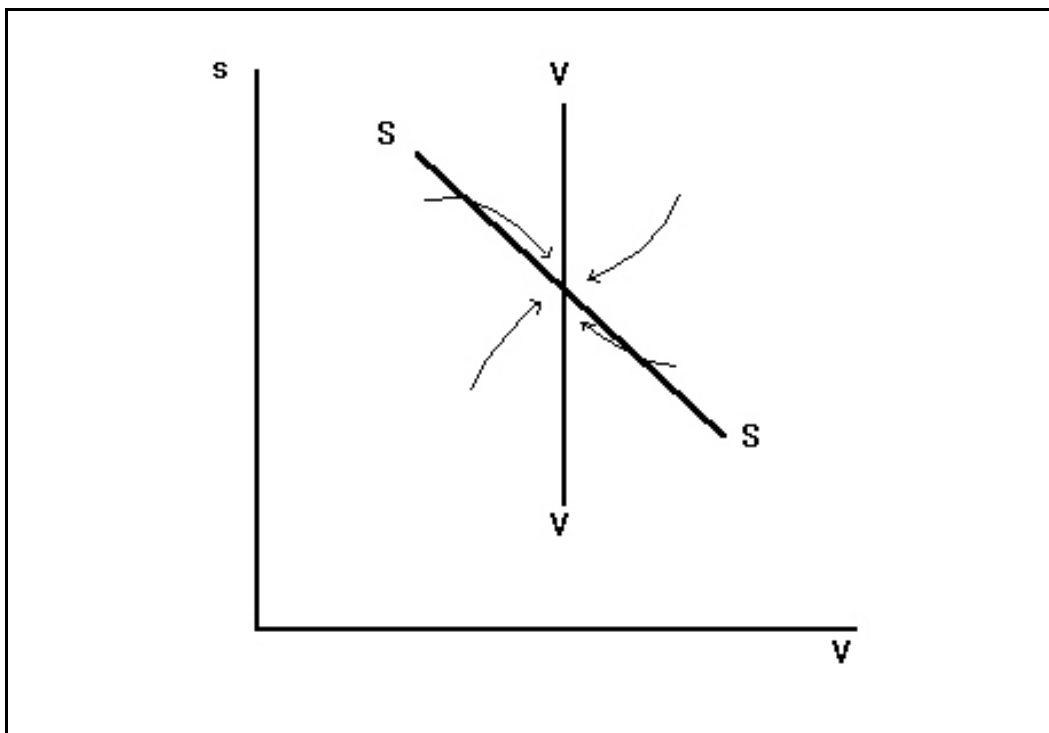


Figure 1. Long Run Equilibrium

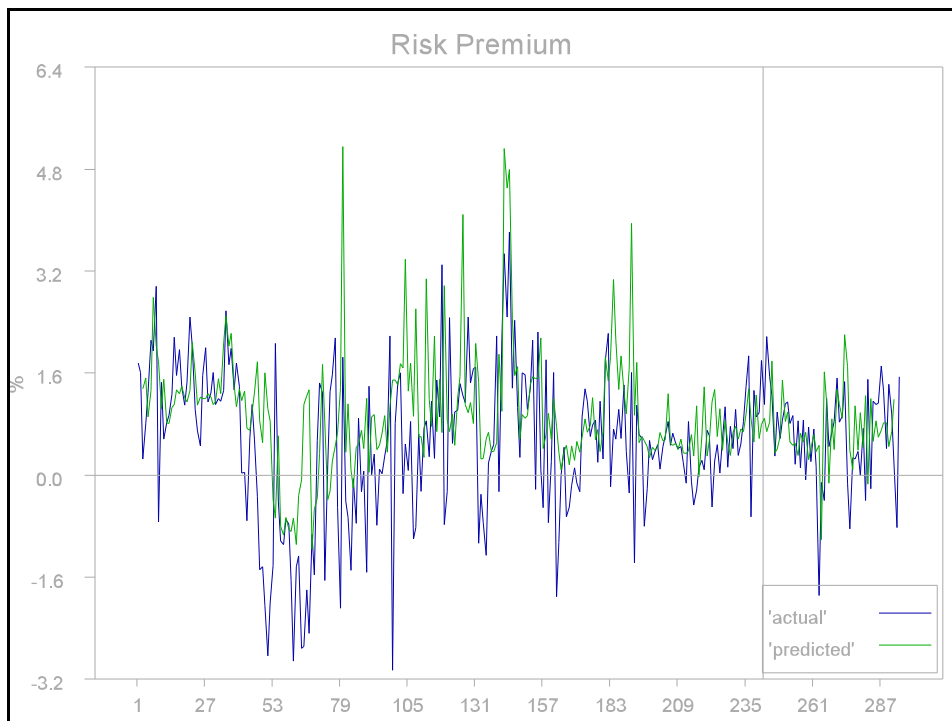


Figure 2. Predicted and Actual Risk Premium.
Sample 1-242, 11/17/82-12/30/88.

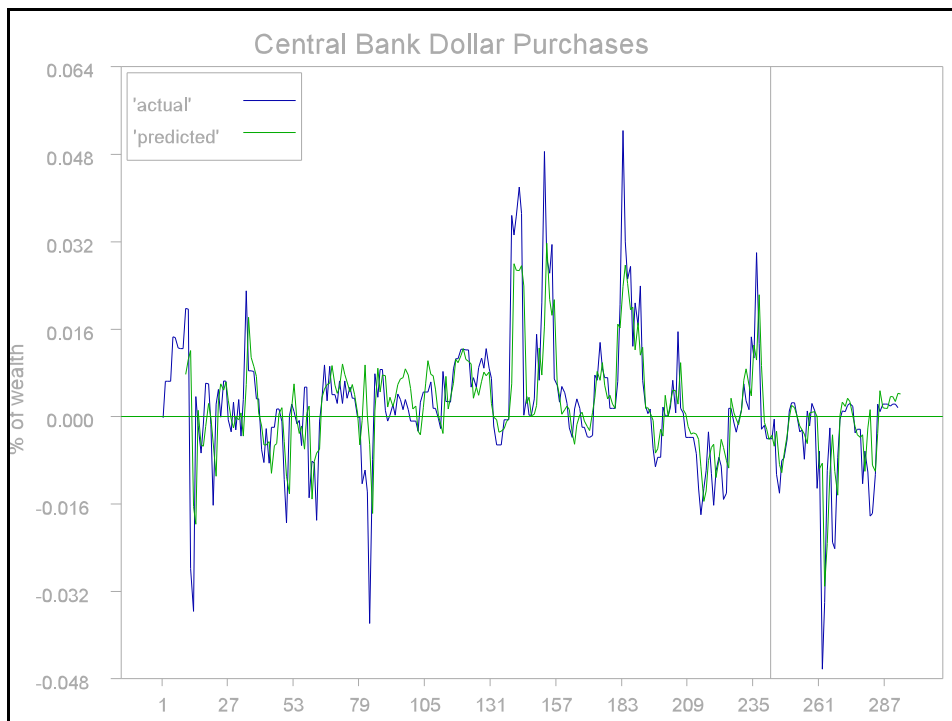


Figure 3. Predicted and Actual Central Bank
Intervention. Sample 1-242, 11/17/82-12/30/88.

Figure 4. Effect of One Percent Fall in US Interest Rate

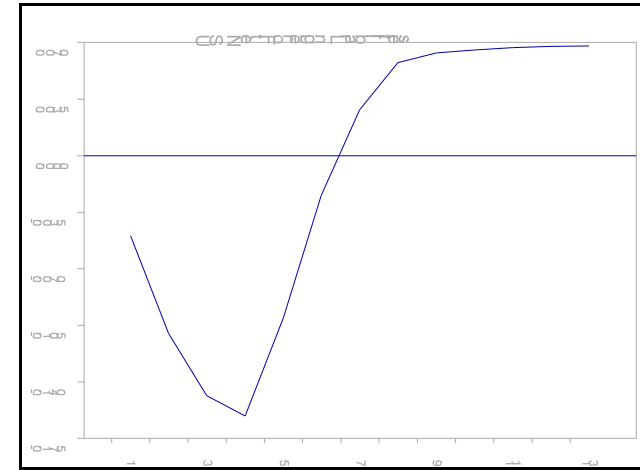
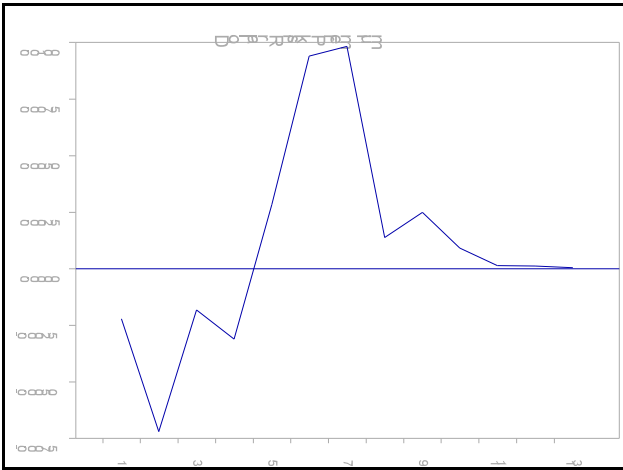
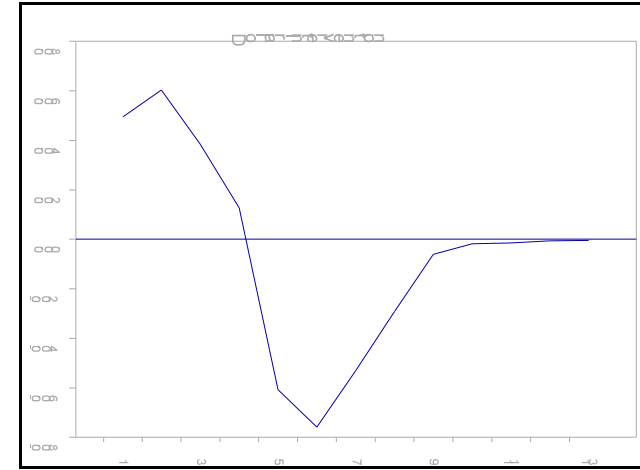
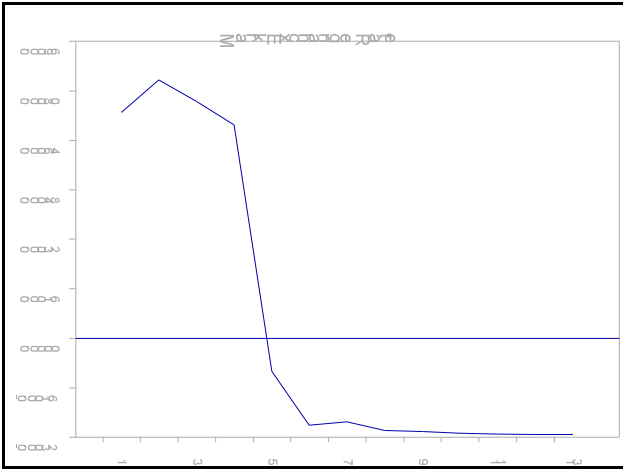


Figure 5. Effect of \$1 Billion Intervention with & without News

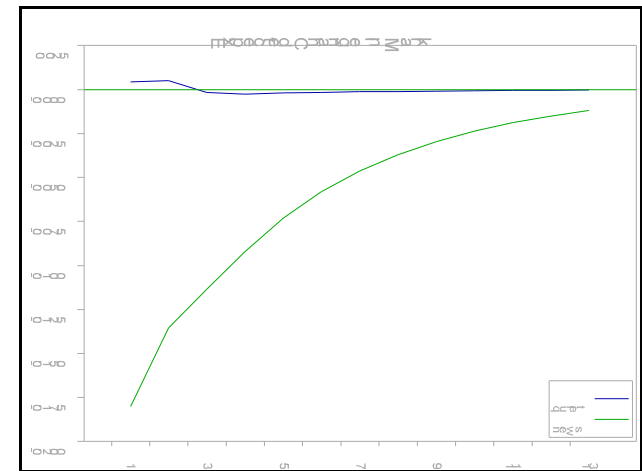
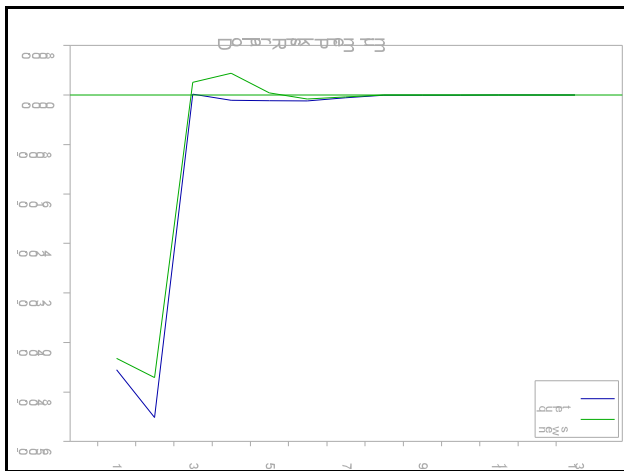
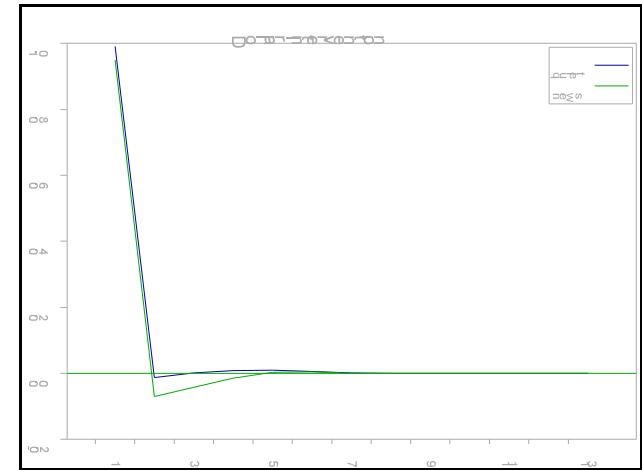
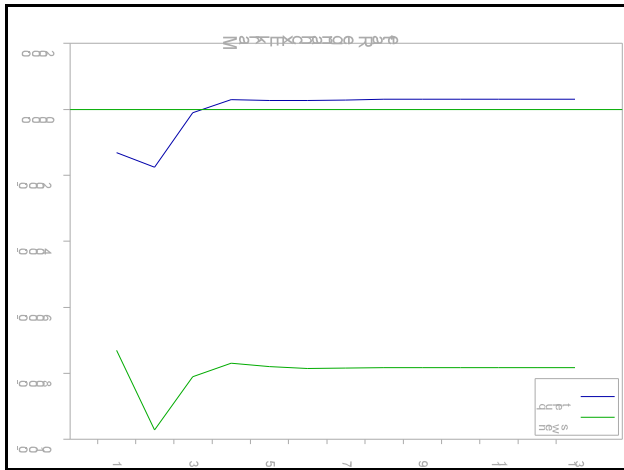


Figure 6. Effect of \$1 Billion Increase in US Deficit with & without Intervention

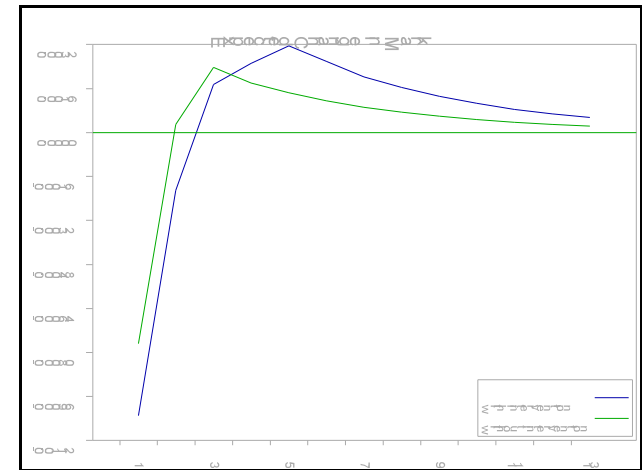
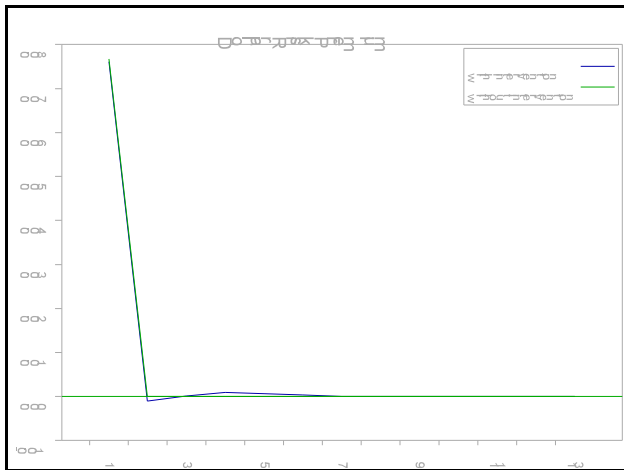
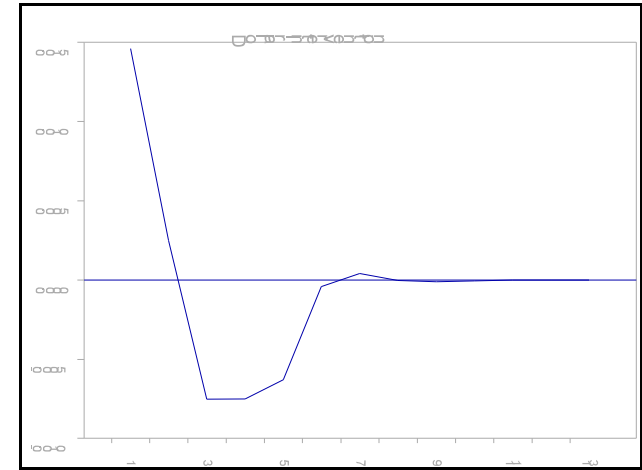
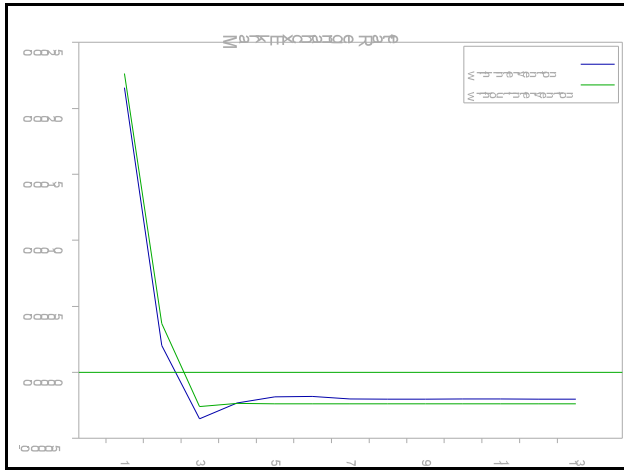


Table 1. Risk Premium Equations*

Variable	IV	NONLINEAR	NL-RESTRICTED
CONSTANT	0.889(3.13)	0.956(3.77)	0.956(3.826)
VAR	-.918(-2.66)	-1.13(-1.84)	-1.16(-3.24)
VAR*NFB/ \hat{W}	30.66(2.15)	36.50(1.81)	36.35(3.482)
VAR*DFXR/ \hat{W}	-14.0(-1.61)	-21.90(-2.27)	-21.72(2.38)
(VAR*DFXR/ \hat{W}) ₋₁	-18.3(-2.83)	-15.82(-1.52)	-14.63**
DUM3MO	-1.53(-4.40)	-1.85(-6.19)	-1.84(-6.18)
PLAZA	-1.23(-4.18)	-1.29(-5.00)	-1.29(-5.11)
RHO	0.283(4.19)	0.236(3.943)	0.237(3.949)
A ₀	-	-0.035(-0.62)	-0.035(-0.62)
A ₁	-	0.902(4.784)	0.902(4.816)
A ₂	-	0.610(7.302)	0.610(7.376)
R ²	0.297		
See	1.029		
D-W	2.066		
Q-statistic	63.06(.039)		

*t-ratios in parentheses, except significance level for Q-statistic

**calculated from restriction, $\chi^2 = 0.1068$.

Table 2. Alternative Risk Premium Equations

Variable	RP30-IV	RP30-NONLIN	RP-DMRELSHR
CONSTANT	0.188(0.198)	0.234(0.215)	-0.81(-2.95)
VAR	-1.60(-0.90)	-0.278(-.16)	0.874(2.532)
VAR*NFB/ \hat{W}	52.7(0.90)	14.41(0.242)	-35.4(-2.46)
VAR*DFXR/ \hat{W}	63.8(2.99)	15.42(0.704)	31.88(2.372)
(VAR*DFXR/ \hat{W}) ₋₁	1.47(0.081)	-10.78(-.43)	15.55(2.320)
DUM3MO	-2.11(-1.78)	-2.38(-1.86)	1.508(4.560)
PLAZA	-0.19(-0.19)	-0.03(-0.03)	1.161(4.119)
VAR*DMRELSHR	-	-	0.116(1.911)
RHO	0.522(4.317)	0.572(9.87)	0.237(3.346)
A ₀	-	3.39(3.84)	-
A ₁	-	3.97(2.18)	-
R ²	0.384	-	0.291
See	2.468	-	1.035
D-W	1.732	-	2.058
Q-statistic	38.49(0.49)	-	65.62(0.024)

RP30: Regression $F_{6,176} = 3.042$, Signif. Level = 0.0074; RP30 - Nonlin: Regression $\chi_4^2 = 0.904$, Signif. Level = 0.924;

RP-DMrelshr: exclude VAR*DMRELSHR $F_{1,227} = 3.654$, Signif. Level = 0.057; exclude VAR*NFB/ \hat{W} $F_{1,227} = 6.038$, Signif. Level = 0.015

Table 3. Expectations Equations

Variable	DSE ₊₁	DSE ₊₁ NONLINEAR
CONSTANT	0.147(2.32)	0.225(3.67)
DS	0.949(13.3)	0.752(14.4)
SE - S	0.814(19.0)	0.789(18.5)
NEWS	-0.178(-3.1)	-0.217(-4.7)
RHO	-0.419(-6.5)	-0.358(-5.3)
A ₀	-	0.636(8.42)
A ₁	-	0.432(3.45)
R ²	0.349	
See	1.059	
D-W	2.088	
Q-statistic	71.12	

Table 4. Intervention Equation

Variable	DFXR/ \hat{W}	DFXR/ \hat{W}
CONSTANT	0.077(0.55)	0.138(0.79)
DNER	0.237(3.08)	0.138(3.88)
LSBAR	0.215(4.76)	0.191(4.66)
PLAZA1	-.013(-1.63)	-.008(-1.65)
CRASH	0.012(1.77)	0.013(3.35)
RHO	0.594(10.95)	0.605(17.98)
D ₀	.0071(15.14)	
D ₁	-.0017(-2.19)	
R ²	0.52	0.54
See	0.008	0.008
D-W	1.96	
Q-statistic	37.06(0.37)	90.98(0.08)

Table 5. Monthly Nonfinancial Balance Equation

Variable	NFB/ \hat{W}
CONSTANT	-.0070(-1.09)
ΣRER_i	.0014(5.25)
ΣFIP_{-i-3}	-.0112(-4.14)
$\Sigma IPUS_i$	0.0113(6.80)
POIL	-.0002(1.04)
R ²	0.851
See	0.0002
D-W	1.578
Q-statistic	27.30(0.16)

Table 6. Out of Sample Model Forecasts - 10/7/88 to 12/30/88

VARIABLE	MEAN ERROR	ABS.ERROR	RMS ERROR	THEIL U
DS	-0.130719	0.970001	1.194972	0.803526
DFXR	0.133244	0.727951	1.011496	0.947516
RP\$	-0.015027	0.061955	0.094562	0.516079
DSE	0.159387	0.616887	0.772769	0.755576
DM\$	-0.001307	0.009700	0.011950	0.939877
SE	0.000287	0.011925	0.014092	1.083996

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