NBER WORKING PAPER SERIES

EXCHANGE-RATE POLICY AFTER A DECADE OF "FLOATING"

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Working Paper No. 909

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge MA 02138

June 1982

This is a revision of a paper presented at the NBER Conference on Exchange Rates, January 25-29, 1982, Bellagio, Italy. Not for quotation; comments welcome. The research reported here is part of the NBER's research program in International Studies. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

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ABSTRACT

This paper integrates exchange-rate policy into a model of exchange-rate behavior, and examines the data econometrically to infer hypotheses about policy behavior in the 1970s. The model shows how unanticipated movements in money, the current account, and relative price levels will cause first a jump in the exchange rate, and then a movement along a "saddle path" to the new long run equilibrium. Here the role of "news" in moving the exchange rate is clear. The model is used to analyze the options available to the central bank that wants to reduce the jump in the exchange rate following a real or monetary disturbance. The distinction is made between monetary policy and sterilized intervention, and a regime in which the domestic interest rate is used as the policy variable is also studied. Systems of vector autoregressions (VARs) for each of four countries--the U.S., the U.K., Germany, and Japan--are estimated, and the correlations among their residuals are studied. These represent the "innovations," or "news" in the time series. A clear pattern emerges in these correlations, in which policy in the U.S. and to a lesser extent Japan, drives exchange rates, and policy in Germany and the U.K. reacts. It appears that U.S. monetary policy is essentially determined by domestic considerations, with the exchange rate moving as a consequence. In Japan, interest rates are varied in response to movement in the current-account and relative price levels, and the effects on the exchange rate are partially neutralized by sterilized intervention. Germany and the U.K. react to movements in their exchange rates by moving interest rates, and sterilized intervention.

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12/27/81

I. Introduction and Summary

During the 1970s an extensive theoretical literature has developed analyzing market determination of freely floating exchange rates. At the same time, there has been extensive and continuous intervention in the market by central banks. Exchange rates have not been floating freely; they have been managed, or manipulated, by central banks. However, most of the description of exchange rate policy, as actually practiced has been informal, or "literary," not integrated with the formal theoretical literature. Recent examples are the surveys in Branson (1980) and Mussa (1981).

Rather than reproduce Mussa's excellent review, in this paper I integrate exchange-rate policy into a model of exchange-rate behavior, and examine the data econometrically, to infer hypotheses about policy behavior in the 1970s. I focus on four major currencies, the U.S. dollar, the Deutschemark, Sterling, and the Japanese yen, and analyze movements in their effective (weighted) exchange rates as calculated by the IMF for their relative cost and price data.

In section II a model of market determination of a floating exchange-rate is laid out. It is a rational-expectations version of the model in Branson (1977), and it draws on the model of Kouri (1978). The model shows how unanticipated movements in money, the current account, and relative price levels will cause first a jump in the exchange rate, and then a movement along a "saddle path" to the new long run equilibrium. Here the role of "news" in moving the exchange rate, as recently emphasized by

Dornbusch (1980) and Frenkel (1981) is clear. The model emphasizes imperfect substitutability between domestic and foreign bonds, in order to prepare for the analysis of intervention policy in section III.

Exchange-rate policy is introduced in section III. We analyze the options available to the central bank that wants to reduce the jump in the exchange rate following a real or monetary disturbance--"news" about the current account, relative prices, or money. This is the policy characterized as "leaning against the wind" in Branson (1976). The distinction is made between monetary policy and sterilized intervention. We also study a regime in which the domestic interest rate is used as the policy variable.

In sections IV and V we turn to the data. These are described systematically in section IV, where we investigate the time-series properties of the exchange rate, money, realtive prices, and the current account, the short-term interest rate, and reserves for each of the four countries. It is difficult to summarize these data, but the time-series behavior of exchange rates, money, relative prices, and current-account balances are roughly consistent with the model of section II.

In section V we estimate systems of vector autoregressions (VARs) for each of the countries, and study the correlations among their residuals. These represent the "innovations," or "news" in the time series. A clear pattern emerges in these correlations, in which policy in the U.S. and to a lesser extent Japan, drives exchange rates, and policy in Germany and the U.K. reacts. It appears that U.S. monetary policy is essentially determined by domestic considerations, with the exchange rate moving as a consequence. In Japan, interest rates are varied in response to movement in the current-account and relative price levels, and the effects on the exchange rate are partially neutralized by sterlized intervention. Germany and the U.K. react to movements in their exchange rates by moving interest rates, and sterlized intervention.

II. An Asset-Market Model with Rational Expectations

II.A. Introduction

The purpose of this section is to lay out a simple asset-market model of exchange-rate determination within which, in the next section, monetary policy reaction to movements in the exchange rate can be analyzed. The literature of the 1970s has identified three principal macroeconomic variables that influence movements in exchange rates. These are money supplies, relative price levels, and current-account balances. Here I develop a representative model that explicitly includes all three elements. The model is an extension of the asset-market model sketched in Branson (1975), and developed in full in Branson (1977). It is a close relative of Kouri (1978). In the early versions of this model the focus was on the roles of relative prices and asset markets, and static expectations were assumed. Here the model is extended to study the effects of underlying "real" disturbances influencing the current account and to include explicitly policy intervention in a rational expectations framework.

II.B. Asset-market specification.

To make the analysis manageable, let us consider one country in a many-country world. We can aggregate the assets available in this country into a domestic money stock M, which is a nonearning asset, holdings of domestically-issued assets B, which are denominated in home currency, and net holdings of foreign-issued assets F, which are dominated in foreign exchange.[1] B^P (for bonds) is government debt held by the private sector, and B^c is government debt held by the central bank. Total government debt $B = B^p + B^c$. F^p (for foreign assets) is the net claims on foreigners held by the domestic private sector and R is central bank foreign reserves. Total national net claims on foreigners $F = F^p + R$. The money stock M is equal to $R + B^c$, with a 100% reserve system. I assume the initial exchange rate is indexed to unity, and that the central bank does not permit capital gains or losses on R to influence M. Similarly, interest income on the central bank's holding of R is assumed to be turned over to the Treasury so that it does not affect M. The current account in the balance of payments gives the rate of accumulation of F over time. The rate of accumulation of B is the government deficit. M is controlled by central bank purchases (or sales) of B or F from (or to) the domestic private sector.

The rate of return on F is given by $\bar{r}$, fixed in the world capital market, plus the expected rate of increase in the exchange rate, $\hat{e}$. The rate of return on B is the domestic interest rate r, to be determined in domestic financial markets. Total private-sector wealth, at any point in time, is given by $W = M + B^p + eF^p$, so here the exchange rate e, in home currency per unit of foreign exchange (e.g. $0.50 per DM), translates the foreign-exchange value of F into home currency.

The total supplies of B and F to the national economy are given at each point in time. Each can be accumulated only over time through foreign or domestic investment.[2] Given the existing stocks of B and F at any point in time, the central bank can make discrete changes in M by swapping either B or F with the domestic private sector; these are open-market operations in government debt or foreign assets.

The demand for each asset by the private sector depends on wealth, $W = M + B^p + eF^p$, and both rates of return, r and $\bar{r} + \hat{e}$. As wealth rises, demands for all three assets increase. The demands for B and F depend positively on their own rates of return and negatively on those of the other assets. The demand for money depends negatively on both r and $\bar{r} + \hat{e}$; as either rises, asset-holders attempt to shift from money into the asset whose return has gone up.

These asset-market equilibrium conditions are summarized in equations (1) - (6).

(1) $M \equiv R + B^c = m(r, \bar{r} + \hat{e})\cdot W.$

(2) $B^p = b(r, \bar{r} + \hat{e})\cdot W.$

(3) $eF^p = f(r, \bar{r} + \hat{e})\cdot W.$

(4) $W = M + B^p + eF^p.$

(5) $B^c + B^p = \bar{B}.$

(6) $F^p + R = F.$

Equation (4) is the balance sheet constraint, which insures that $m + b + f = 1$. The three demand functions give the desired distribution of the domestic wealth portfolio W into the three assets. Specifying the asset demand functions as homogeneous in wealth eliminates the prive level from the asset-market equilibrium conditions. Given the balance sheet constraint (4), and gross substitutability of the three assets, we have the constraints on partial derivatives of the distribution functions:

$$m_r + f_r = b_r < 0: \qquad m_{\bar{r}} + b_{\bar{r}} = f_{\bar{r}} < 0.$$

Here a subscript denotes a partial derivative. The three market equilibrium conditions (1)-(3) contain two independent equations given the balance sheet constraint (4). In equation (5) the bar over B indicates that the total supply of government debt is fixed.

II.C. Asset accumulation and the current account.

Equations (1)-(6) provide the specification of asset markets in the model. The other main building block of the model is the current-account equation. The balance-of-payments accounts provide the identity

$$\dot{F} \equiv \dot{F}^p + \dot{R} \equiv X + \bar{r}(F^p + R) \equiv X + \bar{r}F.$$

where X is net exports of goods and non-capital services in terms of foreign exchange. Net exports depend on the real exchange rate e/p, private sector wealth W, (given by equation (4) above), and an exogenous shift factor z which represents real events such as changes in tastes in technology, oil discoveries, etc., which increase net exports for given values of e/p and W. Thus we can write

$$X = X(e/P, W, z); \; X_e > 0, \; X_W < 0; \; X_z > 0.$$

The sign of X_e assumes the Marshall-Lerner condition holds; X_W reflects wealth effects on import demand.

Substitution of the function for net exports into the balance-of-payments identity gives us the equation for accumulation of national net foreign assets:

(7) $\dot{F} = X(e/p, W, z) + \bar{r}F.$

It is important to note that open-market swaps between the central bank and the domestic private sector have no direct effect on W or F in (7). And the effect of accumulation of national net foreign assets through a current-account surplus ($\dot{F} > 0$) on W and F is the same regardless of the distribution of $\dot{F}$ between $\dot{F}^P$ and $\dot{R}$. Since an increase in R, ceteris paribus, increases the money stock, which is part of W, any increase in F will raise W by dF independently of the split between $\dot{F}^P$ and $\dot{R}$. Thus the central bank's intervention policy will have no effect on how a current-account balance moves F and W in (7).

The effect of an increase in F on $\dot{F}$ in (7) is unclear.

$$\frac{\partial \dot{F}}{\partial F} = X_W + \bar{r},$$

with $X_W < 0$ and $\bar{r} > 0$. Below we will conveniently assume that $\partial\dot{F}/\partial F = 0$; it will quickly become apparent why this is convenient. In Branson (1981), the case where $\partial\dot{F}/\partial F < 0$ is analyzed.

Equations (1)-(7) plus the assumption of rational expectations (or, more precisely, perfect foresight in this non-stochastic model) give us a complete dynamic model in $\dot{F}$ and $\hat{e}$. Price dynamics are suppressed, but we will discuss below exogenous price movements as delayed response to monetary shocks.

II.D. Solution of the model.

Solution of the model proceeds as follows. First, the rational expectations assumption is that $\hat{e}$ is the rate of change of e. Then two equations of (1)-(3), with wealth substituted from (4) can be used to solve for r and $\hat{e}$ as functions of M, W, eF^P. The $\hat{e}$ and $\dot{F}$ equations then are two dynamic equations in e and F that can be solved for the movement in these two variables.

Divide equations (1) and (3) by W and differentiate totally, holding $\bar{r}$ constant:

$$(8) \qquad d(\frac{M}{W}) = m_r dr + m_{\hat{e}} d\hat{e} \; ;$$

$$d(\frac{eF^P}{W}) = f_r dr + f_{\hat{e}} d\hat{e} \; .$$

These can be solved in matrix form as:

$$(9) \qquad \begin{pmatrix} dr \\ d\hat{e} \end{pmatrix} = \frac{1}{(m_r f_{\hat{e}} - f_r m_{\hat{e}})} \begin{bmatrix} f_{\hat{e}} & -m_{\hat{e}} \\ -f_r & m_r \end{bmatrix} \begin{pmatrix} d(\frac{dF^P}{W}) \\ d(\frac{M}{W}) \end{pmatrix} .$$

The solution for $d\hat{e}$ is then

$$(10) \qquad d\hat{e} = \frac{1}{m_r f_{\hat{e}} - f_r m_{\hat{e}}} [-f_r d(\frac{M}{W}) + m_r d(\frac{eF^P}{W})]$$

The coefficients of eF^P/W and M/W are the partial derivatives of the $\hat{e}$ adjustment function,

$$(11) \qquad \hat{e} = \phi(\frac{eF^P}{W}, \frac{M}{W}) ; \; \phi_1 > 0; \; \phi_2 < 0.$$

This is the dynamic equation to be solved along with (7) for $\dot{F}$ to obtain equilibrium e and F^P.

In the e, F^P space of Figure 1, the $\hat{e} = 0$ locus is a rectangular hyperbola. This can be seen by observing that in ϕ, eF^P enter multiplicatively (in W as well as the numerator eF^P), so changes in e and F^P that

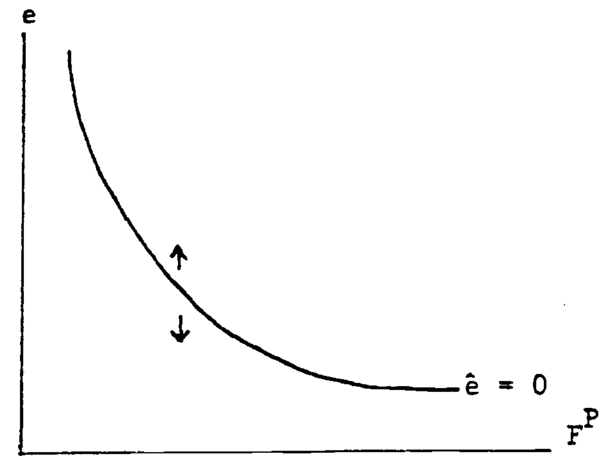

Figure 1: Locus where $\hat{e} = 0$

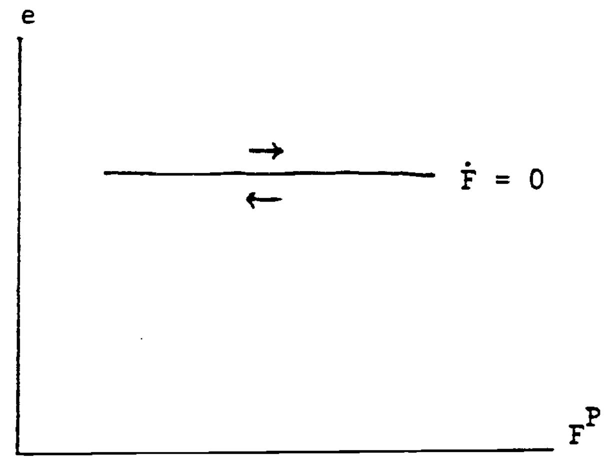

Figure 2: Locus where $\dot{F} = 0$

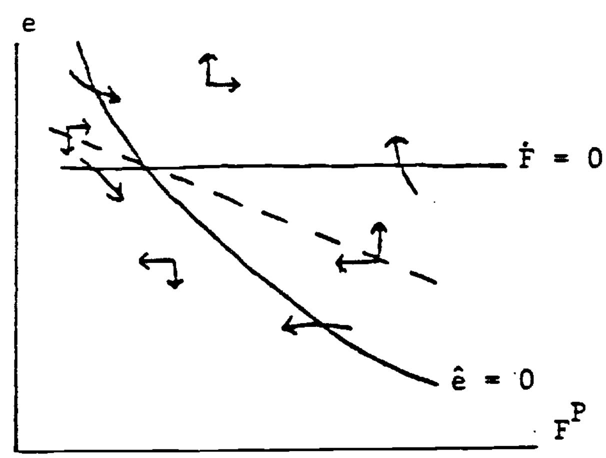

Figure 3: Equilibrium path for e, F^P

hold the product eF^p constant will hold $\hat{e}$ constant. Combinations of e and F^p off the locus move e away from it, as the arrows show. For example, since $\phi_1 > 0$ an increase in e or F^p from a point on the locus makes $\hat{e} > 0$.

An increase in M/W, holding eF^p/W constant, would shift the $\hat{e} = 0$ locus in Figure 1 up. This would be the result of an expansionary open-market operation in the government debt market with $dB^c = dM > 0$, and no change in R or F^p. An increase in eF^p/W, holding M/W constant, will shift $\hat{e} = 0$ down; this could result from an open-market swap between F and B. An expansionary open-market operation in the foreign asset market, with the central bank altering reserves by exchanging M for F with the private sector, would shift $\hat{e} = 0$ up both by increasing M/W and reducing eF^p/W. This will provide the difference between intervention in the bond or foreign-asset markets in the model.

For given values of z and P in the $\dot{F}$ equation (7), the $\dot{F} = 0$ locus in e, F^p space is a horizontal line at the e value where $X = -\bar{r}F$. This is shown in Figure 2. If e is above this value, the current-account is in surplus and $\dot{F} > 0$. In section III we will introduce a "leaning against the wind" exchange-rate policy in which the authorities attempt to reduce the extent of jumps in the exchange rate, but not to reverse them. Thus we rule out here the possibility that the monetary authority "over-intervenes," and assume that the sign of $\dot{F}^p$ is the same as the sign of $\dot{F}$; this is the same as assuming $|\dot{R}| < |\dot{F}|$. This essentially assumes that the authorities permit the market to guide the system towards its long-run equilibrium, but perhaps slow the movement. The assumption gives the arrows showing movement in Figure 2; above $\dot{F} = 0$, $\dot{F}^p > 0$, below it is negative.

An increase in z in (7) will shift the $\dot{F} = 0$ locus down. Given the assumption that $X_W + \bar{r} = 0$, the extent of the shift is simply given by the effect of a change in e on X:

$$\left.\frac{de}{dz}\right|_{\dot{F} = 0} = -\frac{1}{X_e} .$$

If z rises, increasing X and giving a current account surplus, e must fall (currency appreciate) enough to restore the original value of X. An increase in P will shift $\dot{F} = 0$ up, with

$$\left.\frac{de}{dp}\right|_{\dot{F} = 0} = 1 .$$

Equilibrium of the system is shown in Figure 3. There is one saddlepath into the equilibrium shown by the dashed line. For a given value of F^P, it is assumed that following a disturbance, the market will pick the value for e that puts the system on the saddlepath toward equilibrium. The system would have quite different properties under a policy regime of "over-intervention" that reversed the pattern of movement in the horizontal direction.

II.E. Reaction to Exogenous Shocks.

II.E.1 Monetary disturbance.

Consider an (unanticipated) expansionary open-market operation in government debt. This initially leaves W and F^P unchanged. There are two extreme assumptions on price adjustment to consider: no change in P, or $dP/P = dM/M$ immediately.

With no change in P as M increases, the $\dot{F} = 0$ locus in Figure 4 does not shift, but $\hat{e} = 0$ shifts up. With F^P initially given, the exchange

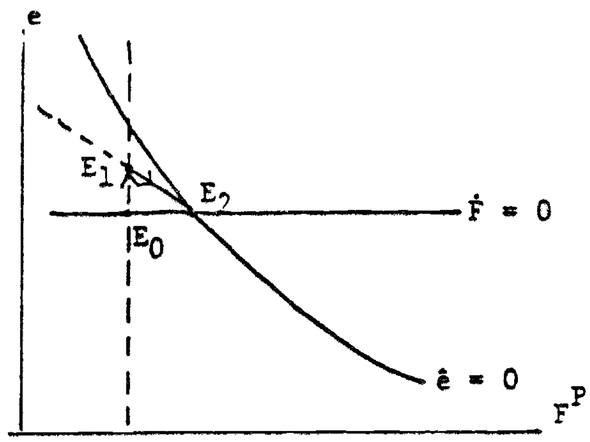

Figure 4: Open-market operation in B, no change in F^P

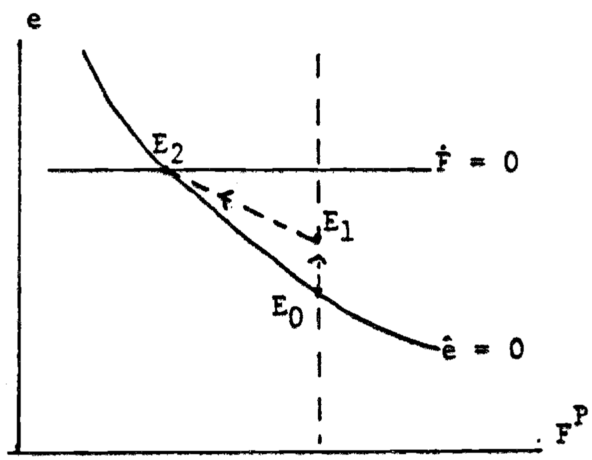

Figure 5: Deterioration in competitiveness

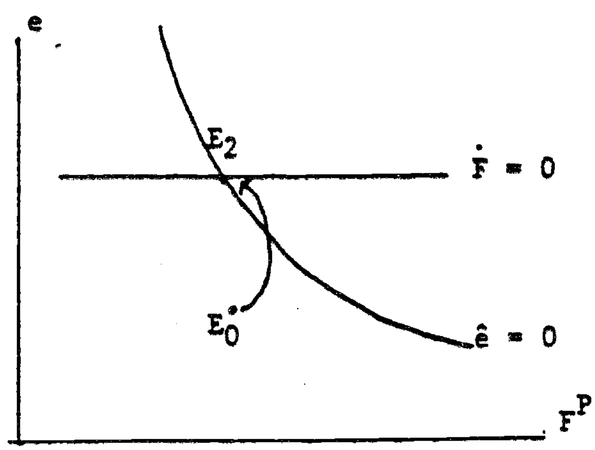

Figure 6: Sluggish price adjustment

rate jumps (currency depreciates) from initial equilibrium E_0 to E_1 on the new saddlepath. This establishes $\hat{e} < 0$ as needed for asset-holders to hold the existing stock of F^P given the lower interest rate. The rise in e/P generates a current-account surplus, and F^P rises with e falling toward E_2. This is an extreme form of "overshooting."

Suppose the domestic price level immediately reacts by rising by the same proportion as the money stock. Then $\dot{F} = 0$ also shifts up by that same proportion. The extent of the upward shift in $\hat{e} = 0$ depends on initial portfolio distribution and the degree of substitutability among F, M, and B. One borderline case would be $M = eF^P$ and $m_r = f_r$. It can be seen in the expression for $d\hat{e}$ in equation (10) that in this can a propartial increase in e will maintain $\hat{e} = 0$. To the extent that $M > eF^P$ or $|f_r| > |m_r|$, the $\hat{e} = 0$ curve would shift up more than $\dot{F} = 0$, requiring "overshooting" and $\hat{e} < 0$, $\dot{F}^P > 0$ moving to equilibrium. The reverse initial conditions would yield "undershooting" with $\hat{e} > 0$, $\dot{F}^P < 0$ in the movement to equilibrium.

II.E.2. Real disturbance.

The effect of an unanticipated fall in z (or an increase in P) is shown in Figure 5. The decrease in competitiveness shifts $\dot{F} = 0$ up from its initial intersection with $\hat{e} = 0$ at E_0. The exchange rate jumps (currency depreciates) from E_0 to E_1, and then gradually rises to E_2 as F^P falls. The depreciation of the currency restores current-account balance ($\dot{F} = 0$). The model "undershoots" in response to real disturbances.

II.E.3. Sluggish price adjustment.

A limiting case of sluggish price adjustment could be modelled as a combination of Figures 4 and 5. Expansionary monetary policy would begin this process illustrated in Figure 4. The delayed price response would then resemble Figure 5. To the extent that the price response is logged and unanticipated, the e, F^P point would follow a path illustrated in Figure 6. Quicker price response or anticipation would straighten the path to E_2, which may be to the right or left of E_0 depending on initial portfolio distribution and substitutability.

II.F. Conclusions and empirical implications.

It is convenient to summarize here the basic conclusions from the analysis so far.

1. Unanticipated changes in money, the price level, or underlying real conditions should cause a jump in the exchange rate toward the new rational-expectations saddle path.

2. Thus we should expect to see correlation between unanticipated movements in e and M, X, and P in the data. Some initial evidence was presented in Branson (1981); more is presented below.

3. Movement of the exchange rate following a real disturbance is likely to be monotonic, while monetary disturbances are likely to produce "overshooting." Lagged price adjustment makes "multiple overshooting" possible. This can be seen in a combination of Figures 4 and 6.

II.G. Interest-rate control as an alternative to money-supply control.

In interpreting the empirical results on exchange-rate policy in section V below, it will be convenient to have a version of the model in which the monetary authority manipulates its holdings of government debt in order to hit an interest-rate target, and uses the interest rate as the instrument of monetary policy. Here we take r as exogenous, fixed by policy, and permit B^P/W and M/W to vary as necessary to hold r at its target value.

To solve the model under a regime of interest-rate control, we make r exogenous and M/W endogenous in equations (8) above, and then solve for $d\hat{e}$ and d(M/W). This yields an $\hat{e}$ equation in the form

$$(12) \quad \hat{e} = \psi(\frac{eF^P}{W}, r), \ \psi_1 > 0 \ ; \ \psi_2 > 0 \ .$$

The interest rate simply replaces M/W here.

The $\hat{e} = 0$ locus is still a rectangular hyperbola in e, F^P space. A reduction in r, implying an increase in M/W and decrease in B^P/W, shifts the $\hat{e} = 0$ locus up. Thus Figure 4 provides a qualitative description of the effect of a reduction of the interest-rate target in a regime of monetary control. The effects of movement in the interest rate on the path of the exchange rate are clearly the same as the effects of the corresponding change in M/W in the model with monetary control.

III. "Leaning Against the Wind" as Exchange Rate Policy

III.A. Introduction.

There is already ample evidence that monetary authorities have generally tried to slow the movement of exchange rates. This type of intervention has long been characteristic of U.S. domestic monetary policy; in Branson (1976) I labelled this "leaning against the wind" as exchange rate policy. Artus (1976) and Branson, Halttunen and Masson (BHM) (1977) presented evidence that German monetary policy responded to movements in the exchange rate in this fashion. BHM (1977) estimated a reaction function of the form $\Delta M = \alpha \Delta e + \ldots$, with $\alpha < 0$ for Germany. As the exchange rate rose (DM depreciated), the money supply was reduced (relative to its trend). Amano (1979) describes Japanese monetary policy as attempting to stabilize the exchange rate similarly. U.K. exchange rate policy was discussed briefly in OECD (1977), where a regression of the form $\Delta r_m = \beta \Delta e + \ldots$, with r_m the minimum lending rate (MLR) and $\beta > 0$ is reported. This suggests that when sterling depreciated (e rose), the MLR was increased as a policy reaction. More recently, Mussa (1981) has presented a thorough review of exchange-rate intervention which is consistent with a "leaning-against-the-wind" model.

The purpose of this section of the paper is to characterize policy intervention in terms of the model of section II, to prepare for interpretation of the empirical results in section V below. The objective is not to evaluate policy; it is to describe it. The main difference from the previous models is the description of intervention as instantaneous and discrete changes in asset stocks via open-market operations to reduce the size of discontinuous jumps in exchange rates. This type of policy behavior is discernable in the "innovation" correlations in section V below.

We will begin with the description of monetary policy reaction to real disturbances via open-market operations in government debt or foreign assets. Then we study sterilized intervention in the foreign asset market.

III.B. Monetary policy.

Consider a real disturbance to the current account that shifts $\dot{F} = 0$ up, (rise in e) to restore equilibrium. This is illustrated in Figure 7, where in the absence of policy intervention, the exchange rate would jump from the initial equilibrium E_0 to E_1 and then depreciate further to E_2. If the central bank tightened money by selling bonds to the public, holding F^p initially constant, the $\hat{e} = 0$ curve in Figure 7 would shift down as shown by the dashed $\hat{e} = 0$. This would shift the saddle path down to the path running to E_2', and reduce the exchange-rate jump to E_1'. Thus instantaneous intervention would reduce the initial jump in e. This would be an unexpected change in M, since the originating shift in z and X was unexpected. So this type of intervention could reduce the variability of e over time.

If the open-market operation were done in the foreign asset market, a smaller quantitative intervention would give the same shift in $\hat{e} = 0$ and in the saddle path in Figure 7, because eF^p/W in equation (8) would rise. In addition, since F^p would rise, the initial jump would be to a point on the new saddle path below E_1'. Thus intervention on the foreign-asset market would, in a sense, be more efficient than open-market operations in the bond market. This is essentially the same result that is obtained by Branson (1977) and Kenen (1982) under static expectations.

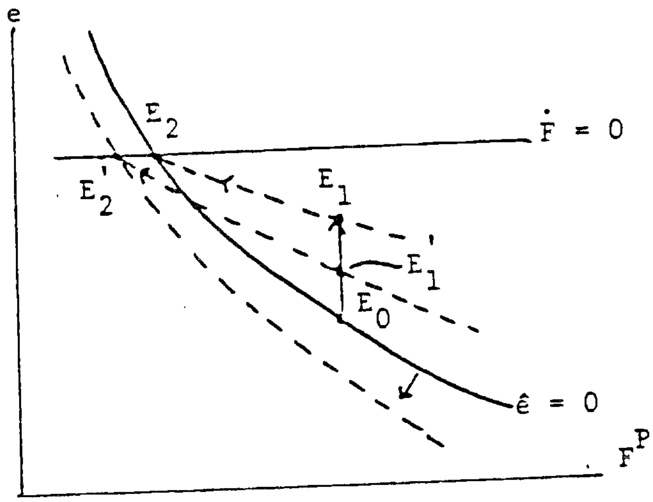

Figure 7: Monetary policy reaction

In a model with interest-rate control, the same result as the bond-market open-market operation of Figure 7 could be obtained by an appropriate increase in the interest rate target. The necessary increase in r could be reduced by performing the open-market operation in the foreign asset market.

III.C. Sterilized Intervention.

There is by now ample evidence that central banks intervene in the foreign exchange markets but attempt to prevent the intervention from changing the path of M. The literature was cited in Whitman (1975); more recent results are discussed in Obstfeld (1980) (1982). In terms of the model of section III, this is an open-market exchange of foreign assets for bonds by the central bank, with $\Delta B^P = -e\Delta F^P$ initially. The result is again a downward shift in $\hat{e} = 0$, as in Figure 7, plus an outward shift in F^P. Thus the jump in the exchange rate is to a point below E_1', since F^P increases. This presents the possibility for intervention that does not move the path of the money supply.

III.D. Monetary disturbances.

Shifts in asset demand functions on the foreign interest rate would shift the $\hat{e} = 0$ locus, and the exchange rate would follow a path such as that of Figure 4, at least initially. Either monetary or sterilized intervention could reduce the extent of the shift in $\hat{e} = 0$, reducing the jump in e. The central bank would vary the supplies of the three assets to meet, at least partially, shifts in their demands by the public. Again, this is a straight-forward extension of "leaning-against-the-wind" policy reaction from the domestic to the international markets.

III.E. Empirical implications.

The principal empirical implication of the present model of policy intervention is that we should observe the intervention in the correlation of unexpected movements or "innovations" in exchange rates with innovations in money and/or reserves. Monetary intervention would give a negative correlation between exchange-rate and money innovations. Intervention with interest-rate control would give a positive correlation between exchange-rate and interest-rate innovations. If the monetary intervention is done in the foreign-asset market, a positive correlation between exchange-rate innovations and reserves would result. Sterilized intervention would give the reserve-exchange rate correlation without a money-exchange rate correlation. Thus we can study the correlation matrix of innovations in section V below to infer hypotheses about policy behavior.

IV. The Data

IV.A. Introduction.

The asset-market model of section II implies that unanticipated exogenous movements in the money stock, the current-account balance, and relative price levels will cause unanticipated jumps in the exchange rate.

The intervention model of section III implies that unanticipated jumps in exchange rates can cause unanticipated changes in the money stock, reserves, or interest rates. Thus innovations in money or interest rates may have a positive or negative correlation with innovations in exchange rates. If the correlation is negative, the inferred hypothesis would be that the underlying model is a monetary reaction function. A negative correlation between reserve and exchange-rate innovations would indicate exchange-market intervention. In this and the following section of the paper we see that the quarterly data for the U.S., Germany, Japan, and the U.K. can be interpreted in this framework. We are inferring testable hypothesis from the data in this exercise.

In this and the next section, we study relationships of movements in the exchange rate of each country, measured by the effective exchange rate as defined by the IMF, with movements in money stocks, current-account balances, relative prices, reserves, and interest rates. The purpose is to see what policy stance is implied by the data. The data are described in detail in Table 1.

The first step in analyzing the data is to investigate their time-series properties. This provides a compact description of the "facts," and an initial indication of whether the facts are roughly consistent with the theory. The time-series analysis of the data is done in this section. Then in section V we study systems of vector autoregressions, one for each country, to test the relations between unanticipated changes, or "innovations," in the variables.

IV.B. Time series analysis.

In this section the autoregressive structure of each time series is described by regression equations of the form:

$$X_t = \alpha_0 + \sum_{i=1}^{I} \alpha_i X_{t-i} + \sum_{j=1}^{3} \beta_j D_j + \gamma t + u_t \,, \tag{12}$$

Table 1: VARIABLE DEFINITIONS AND DATA

I. Variable Name

e	effective nominal exchange rate, in units of foreign currency per unit of home currency as computed by the IMF. Note that this definition is the inverse of e in sections II and III.
$P/\bar{P}$	relative wholesale prices (ratio of home to competitors indices).
M1	narrow money, as defined by the IMF in the International Financial Statistics (IFS).
M3	broad money, as defined by the IMF (M1 plus quasi-money) in the IFS .
CAB	current account balance .
IS	short-term interest rate, from IFS .
R	reserves, from IFS .

II. Countries

United States
United Kingdom
Federal Republic of Germany
Japan

III. Data

1. All data are quarterly, from IMF sources (in most cases from IFS) and cover 1973:IV to 1980:IV.

2. Exchange Rates: e_t is the log of the average effective exchange rate during quarter t. The units are foreign currency per unit of domestic currency. The index is based on a geometrically weighted average of bilateral rates between the home and 13 other industrial countries. The weights are the same as those used to calculated $P/\bar{P}$. Base: 1975 = 100. Source: IMF. Note that these are not the MERM rates published in IFS.

3. Relative Prices: The index is a log of the ratio of home to foreign quarterly wholesale prices indices. $\bar{P}$ is a composite and uses the same weights as e does (see above). Base = 1975. Source: IMF. This index is not the same as that published in the IFS. Our data is based on indices in local (not a common) currency.

4. Money: This is the log of the end of the quarter money stock. Source: IFS, line 34 ("money") for M1, lines 34 and 35 ("money" + "quasi-money") for M3.

5. Current Account: This is the dollar value of the flow during the quarter (not measured in logs). Source: IFS, Lines: 77aa (Merchandise: Exports, fob); 77ab (Merchandise: Imports, fob); 77ac (Other Goods, Services, and Income: Credits): 77ad (Other Goods, Services, and Income: Debits); 77ae (Private Unrequited Transfers); 77ag (Official Unrequited Transfers).

6. Short-term interest rate: Data are taken from IFS as indicated in the Table on "Money Market and Euro Dollar Rates." Source: IFS country pages: U.S. and U.K., line 60c; Germany and Japan, line 60b.

7. Reserves: These are the dollar value of reserves measured at end of period. Source: IFS line 1d.d. These series did not vary significantly from the series adjusted for valuation changes provided by the IMF.

where X_t is the log of the time series under consideration, X_{t-i} is its value lagged i quarters, D_i is a seasonal dummy, and t is time. Equation (12) is a univariate autoregression of the variable X on its own past values, and the estimated values of the α coefficients give the pattern of response of the time series to a disturbance u_t. The two cases that will prominently appear in our data are first-order autoregression, where only α_1 is significant, and second-order autoregression, where α_1 and α_2 are significant. One purpose of the analysis is simply to describe the data; the second is to see if the time-series structure of the exchange-rate data is consistent with that of the other data.

For each variable we began with a regression on four lags, seasonal dummies, and a time trend. We then shortened the lags by eliminating insignificant variables at the far end of the lag. The results are shown in Tables 2 through 5, one for each country. Each column in the tables shows the results of a regression of the indicated variable on lagged values of itself. Coefficients of the time trend and seasonal dummies are not shown. The regressions are performed on quarterly data for the period 1973-IV to 1980-IV. The beginning date was chosen because it was after the major period of disequilibrium adjustment in 1971-73, including a major real devaluation of the U.S. dollar, and the last date was the most recent for which data were available when we began the study in June 1981. The regressions were run using the logs of exchange rates, relative prices, and money, and the levels of the current-account balance, interest rates, and reserves. The current-account and reserves are both time series that pass through zero in some cases.

IV.C. Country results.

IV.C.1. United States

The results for the U.S. are instructive, and serve as an illustration of the technique. In the first two columns of Table 2, we show the regressions for the log of the U.S. nominal effective exchange rate e, weighted by the IMF, in foreign currency per dollar. The first column shows the regression with four lags on the exchange rate; only the lag at t-1 is significant with a coefficient of 0.86. When the lags at t-2 through t-4 are eliminated, the standard error of the estimated equation falls a bit, and the coefficient of e_{t-1} is 0.78. Thus the U.S. effective rate, measured as a quarterly average, can be described as a stable first-order autoregression (AR1). The coefficient of 0.78 in e_{t-1} indicates that a given disturbance u_t will eventually disappear from the time series as its effect is given by increasing powers of .78: $e_t = .78u_t$; $e_{t+1} = .78^2u_t$, etc.

The third and fourth columns of Table 2 show the results for the log of the U.S. relative price index $P/\bar{P}$. This is an index of the U.S. WPI relative to a weighted average of the WPI's of thirteen other industrial countries. The variable $P/e\bar{P}$ is the IMF's measure of relative cost, published in the International Financial Statistics. It is the inverse of the "real exchange rate" of section II.

TABLE 2: UNITED STATES AUTOREGRESSIONS (STD. ERRORS IN PARENTHESES)

LAGS	TIME SERIES: e		$P/\bar{P}$		M1		M3		CAB		IS			R	
t-1	0.86* (.21)	.78* (.10)	1.71* (.21)	1.36* (.17)	0.33 (.24)	0.55* (.18)	0.70* (.24)	0.78* (.14)	0.92* (.21)	0.80* (.14)	1.21* (.17)	0.82* (.24)	0.82* (.12)	1.31* (.26)	0.87* (.15)
t-2	-0.24 (.29)	----	-1.41* (.38)	-0.60* (.16)	0.31 (.27)	----	0.33 (.27)	----	-0.19 (.30)	----	-1.19* (.26)	0.00 (.24)	----	-0.75 (.40)	----
t-3	0.37 (.28)	----	0.74 (.38)	----	-0.16 (.29	----	-0.22 (.30)	----	0.13 (.30)	----	1.49* (.30)	----	----	0.28 (.40)	----
t-4	-0.24 (.19)	----	-0.20 (.21)	----	0.22 (.24)	----	-0.08 (.24)	----	-0.20 (.22)	----	-0.65* (.25)	----	----	0.09 (.27)	----
STATISTICS															
R^2	0.86	0.85	.92	.90	.99	.99	.99	.99	.76	.74	.92	.79	.79	.88	.84
D-W	1.89	1.82	2.16	1.51	1.57	1.96	1.98	2.15	1.86	1.66	2.24	1.68	1.68	1.78	1.28
SE	0.027	.026	.008	.009	.012	.012	.009	.008	1.96	1.91	0.82	1.28	1.26	36.7	38.8

Notes: (1) Sample period: 1973:IV to 1980:IV for dependent variable.

(2) All regressions include constant, seasonal dummies, and time trend.

(3) A '*' indicates the coefficient is significant at the 5% level.

(4) Source for all data is IMF (but e is not merm, $P/\bar{P}$ is WPI).

The first regression for $P/\bar{P}$ in Table 2 gives significant coefficients to the lags at t-1 and t-2. Elimination of the longer lags results in the second equation, with a standard error only slightly larger than the first. The result for $P/\bar{P}$ is a second-order autoregression (AR2), with a stable cyclical response to a disturbance.[3]

The next two pairs of columns in Table 2 show the univariate autoregression results for the two U.S. money stocks. In both cases only the lag at t-1 is significant. Both are stable first-order autocorrelations.

The next two columns in Table 2 show the autoregressions for the current-account balance. These are run on the level of CAB, rather than its log, since the time series passes through zero. The result is similar to that for the money stocks.

The next three columns in Table 2 show the autoregressions for the U.S. short-term interest rate. All four lag coefficients are significant in the first column. In the second regression, with just lags at t-1 and t-2, the second is completely insignificant. Beyond t-1, the important lags are at t-3 and t-4. The last of the three regressions includes only the lag at t-1; the standard error is clearly higher than in the four-lag regression. Rather than include in the VAR system for the U.S. in section

V four (or more) lags on the interest rate, which would greatly reduce degrees of freedom, I decided to include only the lag at t-1. The last two columns of Table 2 show the regressions for U.S. reserves. Only the lag at t-1 is significant, giving a stable first-order autoregression.

In the case of the U.S., then, money stocks, the balance on current account, reserves, and the nominal effective exchange rate all follow stable AR1 processes. This suggests that the behavior of money stocks, the current-account balance, reserves, and the exchange rate are consistent, at this level, with the theoretical model of section II and III.

The relationships between interest rates and relative prices, and the exchange rate is more complicated. With relative prices following an AR2, there is at best a loose relationship to the exchange rate. This is consistent with the evidence of high variability in PPP in Frenkel (1981). The higher-order process for the interest rate suggests that it is being moved by all the exogenous variables simultaneously, rather than reacting systematically to, or causing directly, the exchange rate.

IV.C.2. West Germany.

Table 3 shows the univariate autoregression results for Germany. The format is exactly the same as for the U.S., so the discussion can be brief.

As in the U.S. case, the nominal effective rate, the money stocks, and the balance on current account all follow AR1 processes in Germany. All but M3 are stable. German M3 has a lag coefficient of unity, indicating that it is a "random walk": the change in M3 is (roughly) white noise.

TABLE 3: GERMANY UNIVARIATE AUTOREGRESSIONS

LAGS	e		$P/\bar{P}$		M1		M3		CAB		IS		R	
t-1	0.71* (.20)	0.67* (.18)	----[a]	1.15* (.19)	0.67* (.21)	0.86* (.15)	1.08* (.20)	1.02* (.11)	0.56* (.22)	0.69* (.15)	0.74* (.21)	0.90* (.07)	0.70* (.19)	0.75* (.11)
t-2	-0.15 (.23)	----	----	-0.58* (.19)	0.23 (.25)	----	-0.10 (.30)	----	0.30 (.27)	----	0.27 (.26)	----	-0.19 (.23)	----
t-3	0.37 (.23)	----	----	----	0.24 (.24)	----	0.24 (.30)	----	-0.15 (.28)	----	-0.04 (.22)	----	0.56* (.23)	----
t-4	-0.29 (.18)	----	----	----	-0.32 (.19)	----	-0.50* (.24)	----	0.05 (.24)	----	-0.15 (.16)	----	-0.33 (.17)	----
STATISTICS														
R^2	.96	.96		.99	.99	.99	.99	.99	.82	.81	.89	.88	.95	.93
D-W	1.11	1.43		2.50	2.11	2.20	2.06	1.73	1.64	1.95	1.90	2.25	1.80	2.01
SE	.024	.024		.003	.020	.020	.009	.009	1.33	1.28	1.02	1.01	2.36	2.52

[a] With more than two lags, the autoregression for $P/\bar{P}$ would not invert due to collinearity.

The German relative price series is AR2 with a stable cyclical response to disturbances.[4] The German interest rate is AR1 with a lag coefficient close to unity. Reserves have a barely significant lag at t-3, but but can be approximated by a stable AR1. Thus the impression from the German data is similar to the U.S., except for the additional possibility that the interest rate is used as a policy instrument to control movements in the exchange rate.

IV.C.3. United Kingdom

The U.K. results are summarized in Table 4. Both the nominal effective rate and the M1 money stock in the U.K. have coefficients of unity on the t-1 lag, indicating that they follow a random walk. The relative price series is AR2, as in the U.S. and Germany, but with a stable monotonic adjustment response to disturbances.

In the first regression for the current-account balance, there are no significant lag terms. Thus the U.K. CAB is best described as random around the path described by the trend and seasonal dummy terms. This suggests that the innovations in the CAB in the U.K. should not be interpreted as conveying information about future movements in the exchange rate.[5]

Both the interest rate and reserves in the U.K. follow second-order autoregressions, with stable cyclical responses to disturbances. This would be consistent with interest rate policy being used to control reserves.

TABLE 4 : UNITED KINGDOM UNIVARIATE AUTOREGRESSIONS

LAGS	e		$P/\bar{P}$		M1		M3		CAB		IS		R	
t-1	1.10* (.22)	1.04* (.07)	1.41* (.22)	1.53* (.17)	1.08* (.21)	0.95* (.12)	0.91* (.24)	.85* (.16)	0.12 (.23)	0.12 (.21)	1.21* (.21)	1.28* (.18)	1.14* (.22)	1.22* (.19)
t-2	0.01 (.31)	----	-0.48 (.36)	-0.57* (.19)	0.21 (.25)	----	-0.04 (.29)	----	-0.02 (.26)	----	-0.29 (.32)	-0.52* (.18)	-0.23 (.33)	-0.45* (.18)
t-3	-0.02 (.30)	----	0.19 (.35)	----	-0.62* (.22)	----	-0.03 (.29)	----	0.02 (.27)	----	-0.23 (.31)	----	-0.20 (.34)	----
t-4	-0.10 (.23)	----	-0.20 (.19)	----	0.08 (.20)	----	-0.14 (.19)	----	0.06 (.24)	----	0.04 (.22)	----	0.02 (.23)	----
STATISTICS														
R^2	.94	.94	.99	.99	.99	.99	.99	.99	.50	.50	.83	.83	.95	.95
D-W	1.7	1.64	1.96	2.09	2.11	1.59	2.11	1.69	1.92	1.96	1.99	2.15	1.95	2.10
SE	.035	.033	.012	.012	.019	.024	.016	.016	912.71	853.07	1.33	1.30	1.80	1.74

IV.C.4. Japan

The results for Japan are summarized in Table 5. There we see major differences from the other three countries. The nominal effective exchange rate, the relative price series, the current-account balance, and the interest rate are all AR2 with stable cyclical response patterns. The two money stocks are AR1 with unitary lag coefficients. Reserves in Japan follow a complex autoregression of at least the fourth degree. Comparison of the first two reserve regressions in Table 5 shows the importance of the lag at t-4. To conserve degrees of freedom in the Japanese VAR system reported in section V, I used the first-order approximation.[6] Thus in the Japanese case the time-series behavior of the exchange rate is consistent with that of relative prices, the current account, and the interest rates, but the exchange rate does not follow the random-walk pattern of money.

IV.D. Summary on the data.

The univariate autoregressions of Tables 2 through 5 provide a useful and compact description of the "facts." Comparing the country results, we see several common points.

1. All weighted relative price series are second-order autoregressions with stable responses to shocks. All but the U.K. series are cyclical.
2. All the money stocks are first-order autoregressions, many with unitary lag coefficients.

TABLE 5: JAPAN UNIVARIATE AUTOREGRESSIONS

	e		P/P		M1		M3		CAB		IS		R		
t-1	1.18*	1.33*	1.24*	1.21*	0.79*	1.03*	1.03*	1.10*	1.25*	1.50*	1.32*	1.56*	1.06*	1.07*	0.
	(.22)	(.18)	(.20)	(.14)	(.22)	(.14)	(.22)	(.08)	(.22)	(.16)	(.23)	(.16)	(.16)	(.22)	(.
t-2	-0.37	-0.55*	-0.85*	-0.62*	-0.56	---	0.26	---	-0.32	-0.67*	-0.39	-0.72*	-0.55*	-0.30	-
	(.34)	(.18)	(.32)	(.12)	(.30)		(.32)		(.37)	(.16)	(.38)	(.17)	(.24)	(.31)	
t-3	0.12	---	0.45	---	-0.04	---	-0.21	---	0.10	---	0.05	---	0.74*	- .05	-
	(.34)		(.32)		(.31)		(.32)		(.38)		(.56)		(.25)	(.21)	
t-4	-0.26	---	-0.27	---	-0.24	---	-0.01	---	-0.34	---	-0.23	---	-0.72*	---	-
	(.22)		(.16)		(.28)		(.23)		(.25)		(.34)		(.17)		
STATISTICS															
R^2	.91	.90	.99	.99	.99	.99	.99	.99	.91	.90	.93	.92	.92	.86	.
D-W	1.74	2.06	1.82	1.81	1.77	2.42	1.79	1.96	1.85	2.17	2.00	2.34	1.47	2.01	[illegible]
SE	.044	.044	.014	.014	.023	.023	.008	.008	.97	1.00	1.00	1.00	1.86	2.48	2

3. The U.S. and German exchange-rate and current-account series are first-order autoregressions, and the Japanese are second-order. Thus these movements in exchange rate are consistent with movements in the current-account balance, while the U.K. CAB contains no information about its future path.

4. The U.S. and German exchange-rate and reserves follow AR1 processes that could reflect intervention. The U.K. and Japanese interest rates and exchange rates follow consistent processes, AR1 and AR2 respectively.

V. Empirical Results Using Vector Autoregression

V.A. Introduction.

A useful technique for studying the relationships between the innovations in money, the current account balance, relative price levels, interest rates, reserves, and the exchange rate is vector autoregression (VAR). Here each variable of a system is regressed against the lagged values of all variables (including itself) in the system, to extract any information existing in the movements of these variables. The residuals from these "vector autoregressions" are the innovations -- the unanticipated movements -- in the variables. We can study the correlations of the residuals to see if they are consistent with the hypotheses implied by the theory of sections II and III. The vector autoregression technique is introduced and justified by Sims (1980). A clear exposition is presented in Sargent (1979). Interesting and instructive applications are discussed in Taylor (1980), Ashenfelter and Card (1981), and Fischer (1981).

Here I estimate systems of VARs for each of the four countries, the U.S., the U.K., Germany, and Japan. Two systems were estimated for each country. Both include the effective exchange rate e, the current account balance CAB, and the effective relative price $P/\bar{P}$, the interest rate IS, and reserves R; the difference between the two is that one includes M1 and the other M3. An obvious extension of the research would be to include cross-country effects, particularly of money stocks, but also the other variables. The difficulty in proceeding in this direction comes from the limited number of quarterly observations: 29 from 1973-IV to

1980-IV. Each VAR includes lagged values of four variables, a time trend, and three seasonal dummies. In order to expand the analysis, I am presently moving to a monthly data base.

Before estimating the VARs, one must consider the issue of the timing of the data. The effective exchange rate can be computed from public information on a daily basis. In fact, a UK effective rate is published daily in the Financial Times. Our data are averages during the quarter. The effective rate used here is the inverse of e as defined in sections II and III. Money stock data are available on a weekly basis, so they are roughly contemporaneous with the exchange rage data. Our money data are end-of-period. We would expect from section II that the weekly changes in M would generate nearly simultaneous movements in e. Thus the innovation of the average e over a quarter would be most closely connected in our data with the innovation of the end-of-quarter money stock, which is the cumulation of the weekly innovations. Reserves are also end-of-period data, so that intervention to slow an unanticipated jump in e would appear as an innovation in reserves.

The relative price data are quarterly averages of monthly data, which become known soon after the month finishes. Thus in our data set, the innovation in e_t would be most closely connected to the innovation in $P/\bar{P}_t$. Interest rates are also quarterly averages, so that if the interest rate were used to control the exchange rate we would see a correlation between the innovations in e_t and in IS_t.

On the other hand, the data on the quarterly balance in current account are not announced until well into the following quarter. Thus to the extent that the innovation in CAB signals a change in the equilibrium real exchange rate, it is the innovation in CAB_{t-1} that moves e_t.

The VAR residuals to be correlated, then, are those of e_t, M_t, $(P/\bar{P})_t$, CAB_{t-1}, IS_t, and R_t. We will use a ∿ to designate residuals from the VARs. The variables in each VAR system are listed in Table 6. The number of lags included in each variable was determined by the univariate autoregression of Table 2 through 5. This constraint provides a convenient way to limit the number of regressors and conserve degrees of freedom. A next step in research would be to re-estimate the VAR systems with additional lags to see how much information is lost by application of this constraint.

After the VAR systems are estimated, we correlate their residuals to study the relationship among innovations. The correlations are given for the systems with M1 and M3 in Tables 7-14 below, two for each country. Each table includes the correlation coefficients among the VAR "innovations" and in parentheses the probability of that correlation occurring under the null hypothesis that the true correlation is zero.

In discussing the correlations, we will focus on the correlations particularly relevant for analyzing exchange-rate determination and policy. Detailed discussion of all the results would be far too tedious.

V.B. United States

The correlations of VAR innovations for the U.S. are shown in Tables 7 and 8. Remember that here the effective nominal exchange rate is defined in units of foreign exchange per unit of home currency, the inverse of the theoretical definition of sections II and III. So here an increase in e is an appreciation.

Table 6: Variables Included in Vector Autoregression Systems

U.S., Germany	U.K.	Japan
$\ln e_{t-1}$	$\ln e_{t-1}$	$\ln e_{t-1}$
$\ln M_{t-1}$	$\ln M_{t-1}$	$\ln e_{t-2}$
$\ln P/\overline{P}_{t-1}$	$\ln P/\overline{P}_{t-1}$	$\ln M_{t-1}$
$\ln P/\overline{P}_{t-2}$	$\ln P/\overline{P}_{t-2}$	$\ln P/\overline{P}_{t-1}$
CAB_{t-2}	CAB_{t-2}	$\ln P/\overline{P}_{t-2}$
IS_{t-1}	IS_{t-1}	CAB_{t-2}
R_{t-1}	IS_{t-2}	CAB_{t-3}
	R_{t-1}	IS_{t-1}
	R_{t-2}	IS_{t-2}
		R_{t-1}

Note: Two VAR systems were estimated for each country, one with M1, one with M3. The equations are estimated on data 1973 IV – 1980 IV (described in Table 1).

Table 7: Correlations of Innovations From U.S. Vector Autoregression System With M1

	$\tilde{e}$	$\tilde{M1}$	$\widetilde{P/\bar{P}}$	$\widetilde{CAB}$	$\widetilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	−.30 (.11)	−.42 (.03)	−.12 (.55)	−.09 (.65)	.14 (.46)
$\tilde{M1}$		1.00	−.35 (.06)	−.41 (.03)	−.03 (.87)	−.56 (.00)[a]
$\widetilde{P/\bar{P}}$			1.00	.44 (.02)	.24 (.20)	.26 (.17)
$\widetilde{CAB}$				1.00	−.11 (.58)	.55 (.00)[a]
$\widetilde{IS}$					1.00	.35 (.07)
$\tilde{R}$						1.00

a. An entry of .00 indicates the number was less than .005.

Table 8: Correlation of Innovations From U.S. Vector Autoregression System With M3

	$\tilde{e}$	$\tilde{M3}$	$\tilde{P/\bar{P}}$	$\tilde{CAB}$	$\tilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	-.48 (.01)	-.37 (.05)	-.08 (.68)	-.02 (.92)	.24 (.22)
$\tilde{M3}$		1.00	.23 (.24)	.05 (.81)	.50 (.01)	.07 (.73)
$\tilde{P/\bar{P}}$			1.00	.38 (.04)	-.03 (.89)	.03 (.90)
$\tilde{CAB}$				1.00	-.24 (.21)	.47 (.01)
$\tilde{IS}$					1.00	.30 (.12)
$\tilde{R}$						1.00

The first rows of Tables 7 and 8 give the correlations of exchange-rate innovations. The negative signs for relative prices and money are consistent with innovations in those variables driving e, as in the model of section II. There is a weak correlation with reserves, consistent with intervention. Innovations in reserves, shown in the last columns of Tables 7 and 8, are positively correlated with innovations in CAB, but not in money. It is useful here to recall that the CAB is lagged one period, so that the correlation is between the residual $\tilde{CAB}_{t-1}$ and $\hat{R}_t$. Thus the indication in Table 7 and 8 is that intevention comes at the point where the CAB announcement would move the exchange rate, not during the period in which the actual CAB occurs.

The underlying vector autoregression for e (not shown here) also shows a strong Granger-causal role for lagged CAB. Thus the hypothesis I would infer from the U.S. data is as follows. The current account, money, and relative prices all move the exchange rate, the latter two through market expectations and innovations. Monetary policy is essentially oriented toward domestic targets; movement in the exchange rate is a side effect. The U.S. monetary authorities intervene and sterilize, but do not follow a tight rule. This shows up in the strong correlation be- $\bar{R}$ and $\bar{CAB}$, and in the correlation between $\bar{R}$ and $\bar{e}$.

V.C. Germany

The innovation correlations for Germany are shown in Tables 9 and 10. In the first row of both tables we see a very strong negative correlation between exchange-rate and relative price innovations. This could come from exchange rates causing prices or vice versa, but through innovations and market expectations rather than a tight PPP relationship. The correlations of exchange-rate innovations with short-term interest rates and reserves (in the M1 system) must reflect leaning-against-the-wind policy both in terms of

Table 9: Correlation of Innovations From German Vector Autoregression System With M1

	$\tilde{e}$	$\tilde{M1}$	$\tilde{P}/\bar{P}$	$\tilde{CAB}$	$\tilde{IS}$	R
$\tilde{e}$	1.00	.17 (.37)	−.44 (.02)	.27 (.15)	−.48 (.01)	.40 (.03)
$\tilde{M1}$		1.00	.02 (.94)	.25 (.19)	−.47 (.01)	.28 (.14)
$\tilde{P}/\bar{P}$			1.00	.23 (.22)	.07 (.73)	.28 (.14)
$\tilde{CAB}$				1.00	−.33 (.08)	.43 (.02)
$\tilde{IS}$					1.00	−.13 (.49)
$\tilde{R}$						1.00

Table 10: Correlation of Innovations From German Vector Autoregression System With M3

	$\tilde{e}$	$\widetilde{M3}$	$\widetilde{P/\bar{P}}$	$\widetilde{CAB}$	$\widetilde{IS}$	R
$\tilde{e}$	1.00	-.09 (.63)	-.59 (.00)	.03 (.90)	-.52 (.00)	-.26 (.17)
$\widetilde{M3}$		1.00	.18 (.34)	.20 (.30)	-.53 (.00)	-.04 (.84)
$\widetilde{P/\bar{P}}$			1.00	.25 (.20)	.05 (.79)	.45 (.01)
$\widetilde{CAB}$				1.00	-.29 (.13)	.25 (.19)
$\widetilde{IS}$					1.00	-.01 (.96)
$\tilde{R}$						1.00

interest rates and intervention. The negative correlation of the interest rate and CAB innovations suggests that interest-rate policy may respond to the state of the CAB as well as to the exchange rate. The lack of correlation between money and reserves or exchange rates indicates sterilized intervention. The correlation between $\overline{CAB}$ and $\bar{R}$ also supports the intervention hypothesis.

Thus the German data suggest fairly strongly a situation in which (a) price and exchange-rate innovations go together, and (b) the authorities react to exchange-rate and current-account movements through changes in interest rates and sterilized intervention. This is consistent with the earlier results of BHM (1977) and of Herring-Marston (1977) for the fixed-rate regime.

V.D. <u>United Kingdom</u>

The U.K. correlations are shown in Tables 11 and 12. The exchange-rate correlations with interest rates and reserves are a strong indication of leaning-against-the-wind intervention and interest-rate policy. This effects M1 but not M3, as can be seen in the correlations of $\bar{M}$ with $\bar{e}$ and $\bar{R}$. Innovations in the current-account balance have the positive correlation with e that would come from the theory of section II. Perhaps this suggests that while from the unnivariate autoregressions of section IV, CAB innovations have no predictive content, the market thinks they do.

In both tables there is a strong negative correlation between the CAB innovation and the interest rate. This would be consistent with interest-rate policy determined by CAB as well as the exchange rate, similar to the German case. The U.K. data thus show influence of CAB on e,

Table 11: Correlations of Innovations From United Kingdom Vector Autoregression System With M1

	$\tilde{e}$	$\widetilde{M1}$	$\widetilde{P/\bar{P}}$	$\widetilde{CAB}$	$\widetilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	.46 (.01)	-.05 (.81)	.29 (.12)	-.59 (.00)	.53 (.00)
$\widetilde{M1}$		1.00	.09 (.62)	-.34 (.07)	-.37 (.05)	.52 (.00)
$\widetilde{P/\bar{P}}$			1.00	-.02 (.91)	.06 (.74)	-.03 (.89)
$\widetilde{CAB}$				1.00	-.44 (.02)	-.14 (.48)
$\widetilde{IS}$					1.00	-.29 (.12)
$\tilde{R}$						1.00

Table 12: Correlations of Innovations From United Kingdom Vector Autoregression System With M3

	$\tilde{e}$	$\widetilde{M3}$	$\widetilde{P/\bar{P}}$	$\widetilde{CAB}$	$\widetilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	-.04 (.82)	-.04 (.85)	.47 (.01)	-.55 (.00)	.44 (.02)
$\widetilde{M3}$		1.00	.05 (.79)	.46 (.01)	-.30 (.10)	-.15 (.43)
$\widetilde{P/\bar{P}}$			1.00	.05 (.80)	-.05 (.81)	-.04 (.85)
$\widetilde{CAB}$				1.00	-.61 (.00)	.08 (.67)
$\widetilde{IS}$					1.00	-.27 (.15)
$\tilde{R}$						1.00

with interest-rate and intervention policy reacting to innovations in e and CAB with M1 unsterilized.

V.E. Japan

The results for Japan are shown in Tables 13 and 14. Let us focus on Table 13 first. The correlation of innovations in the exchange rate and interest rate suggest a system of interest rate control with policy targets other than the exchange rate, rather than reaction to exchange rates as in the U.K. and Germany. The correlations of the interest rate with relative prices and the CAB suggest that these might be the targets.

The reserve correlations with the exchange rate and $\overline{\text{CAB}}$ strongly suggest "leaning-against-the-wind" intervention, with the central bank obsorbing part of the CAB innovations to reduce movement in the exchange rate. The lack of correlation of $\overline{\text{M1}}$ with reserves on the exchange rate indicates sterlization.

An interesting story emerges from the Japanese correlations. They suggest that policy sets interest rates with CAB and $P/\bar{P}$ among the objectives. The interest rate moves the exchange rate, as in section II, and the authorities intervene to, in a sense, neutralize this effect. They also attempt to sterilize M1 from all of this.

The VAR system with M3 is consistent with this story in terms of signs of correlations, although significance levels vary from the M1 system (in both directions — see the correlation of $\overline{\text{IS}}$ and $\overline{\text{CAB}}$).

V.F. Summary of VAR Results on Policy

An interesting view of how the monetary system and interdependence have worked in the 1970s emerges from the VAR innovation correlations.

Table 13: Correlations of Innovations From Japan Vector Autoregression System With M1

	$\tilde{e}$	$\widetilde{M1}$	$\widetilde{P/\bar{P}}$	$\widetilde{CAB}$	$\widetilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	-.06 (.77)	-.08 (.68)	-.03 (.89)	.55 (.00)	.33 (.08)
$\widetilde{M1}$		1.00	-.10 (.59)	-.07 (.71)	-.18 (.36)	.23 (.24)
$\widetilde{P/\bar{P}}$			1.00	-.32 (.09)	.42 (.02)	-.05 (.81)
$\widetilde{CAB}$				1.00	-.25 (.19)	.48 (.01)
$\widetilde{IS}$					1.00	.31 (.10)
$\tilde{R}$						1.00

Table 14: Correlations of Innovations From Japan Vector Autoregression System With M3

	$\tilde{e}$	$\widetilde{M3}$	$\widetilde{P/\bar{P}}$	$\widetilde{CAB}$	$\widetilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	.00 (.98)	-.20 (.30)	.05 (.81)	.18 (.35)	.12 (.52)
$\widetilde{M3}$		1.00	.02 (.93)	.12 (.52)	-.28 (.14)	.18 (.34)
$\widetilde{P/\bar{P}}$			1.00	-.36 (.05)	.43 (.02)	-.10 (.61)
$\widetilde{CAB}$				1.00	-.60 (.00)	.33 (.07)
$\widetilde{IS}$					1.00	.14 (.46)
$\tilde{R}$						1.00

My interpretation, or inferred set of hypotheses is as follows. The U.S. sets monetary policy, largely by controlling quantities, with domestic objections most in mind. The market looks to innovations in money and relative prices, and levels of the current-account balance, to set the U.S. exchange rate. The monetary authority attempts sterilized intervention occasionally.

In Japan, interest rates are set with relative prices (or rates of inflation) and the current-account balance among the leading objectives. Interest-rate innovations move the exchange rate, but an attempt is made to neutralize this effect through sterilized intervention.

Movements in the U.S. and Japanese effective rates, caused partly by fundamentals and partly by policy, are mirrored instantaneously in the U.K. and German effective rates, and their policy reacts. The reaction appears as "defensive" interest-rate movements sensitive to exchange-rate and CAB innovations, and largely sterilized intervention in the foreign exchange market. Thus a consistent story in which domestically-oriented policy in the U.S. and Japan is transmitted in the U.K. and Germany is consistent with the VAR innovation results.

One final issue appears in the relations among exchange-rate and interest-rate innovations. The correlation in the U.S. is negligible, while in the U.K. and Germany it is strongly negative. An implication is that innovations in the dollar prices of the DM and Sterling should be negatively correlated with innovations in the U.S.-German and U.S.-U.K. interest differentials, as noted by Frenkel (1981). The hypothesis advanced there was that nominal interest rates and exchange rates were both reacting to changes in inflation rates. The alternative hypothesis provided here is that U.K. and German interest rate innovations are policy reactions.

FOOTNOTES

1. Since the analysis here applies to any single country in the international financial system, I use the terms 'home' and 'foreign' to denote the country being discussed and the rest of the system, respectively. At the level of generality of this discussion no damage would be done if the reader substituted U.S. for 'home country', 'dollar' for 'home currency' and 'Fed' for 'central bank'.

2. Since F is home claims on foreigners less home liabilities to foreigners, an asset swap which exchanges a claim and a liability with a foreign asset-holder is a transaction within F, changing claims and liabilities by the same amount. This transaction would leave F and B unchanged. The reason for using this particular aggregation will become clear when we study dynamic adjustment below. Basically, we want to define net foreign assets consistently with the balance of payments and national income and product accounts, which record the capital account balance as the change in U.S. private holdings of net foreign assets. The assumptions outlined above make M and B non-traded assets. This implies that the total stocks of M, B, and F in domestic portfolios are given at any point in time.

3. The characteristic equation is given by

$$P/\bar{P}_t - 1.36\ P/\bar{P}_{t-1} + 0.60\ P/\bar{P}_{t-2} = 0.$$

The roots of this equation are $.68 \pm .37i$, with a modulus of $0.77 = 0.6^{1/2}$.

4. Note that the German price equation would not invert due to multicollinearity with more than two lags.

5. A moving average specification of the equation for the U.K. CAB was also experimented with, with no improvement in results. The U.K. CAB does seem to be random about its trend.

6. The Japanese VAR results were re-estimated using a four-quarter lag on reserves, without much change.

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