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2 Exchange Rate Policy after a Decade of "Floating"

William H. Branson

2.1 Introduction and Summary

During the 1970s an extensive theoretical literature 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. Examples are the surveys in Branson (1980) and Mussa (1981).

Rather than reproduce Mussa's excellent review (1981), 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 United States dollar, the deutschemark, sterling, and the Japanese yen, and analyze movements in their effective (weighted) exchange rates as calculated by the International Monetary Fund for their relative cost and price data.

In section 2.2 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 2.3.

Exchange rate policy is introduced in section 2.3. 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 2.4 and 2.5 we turn to the data. These are described systematically in section 2.4, where we investigate the time series properties of the exchange rate, money, relative 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 2.2.

In section 2.5 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 United States and to a lesser extent Japan drives exchange rates, and policy in Germany and the United Kingdom reacts. It appears that United States 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 United Kingdom react to movements in their exchange rates by moving interest rates and sterilized intervention.

2.2 An Asset Market Model with Rational Expectations

2.2.1 Introduction

The purpose of this section is to lay out a simple asset market model of exchange rate determination within which 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.

2.2.2 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] Bonds, B^p, is government debt held by the private sector, and B^c is government debt held by the central bank. Total government debt $B = B^p + B^c$. Foreign assets, F^p, 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

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 United States 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 United States private holdings of net foreign assets. The assumptions outlined above make M and B nontraded assets. This implies that the total stocks of M, B, and F in domestic portfolios are given at any point in time.

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 increased.

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) $$B^c + B^p = \overline{B}.$$

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

Equation (4) is the balance sheet constraint, which ensures 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 price 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:

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

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.

2.2.3 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 indentity.

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

where X is net exports of goods and noncapital 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, and so on, 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:

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

It is important to note that open-market swaps between the central bank and the domestic private sector have no direct effect on either W or F in (7). And the effect of accumulation of national net foreign assets through a current account surplus ($\dot{F} > 0$) on both 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; $\partial\dot{F}/\partial F = X_W + \bar{r}$, 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 nonstochastic 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.

2.2.4 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:

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

$$d\left(\frac{eF^p}{W}\right) = f_r dr + f_{\hat{e}} d\hat{e}.$$

These can be solved in matrix form as

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

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

$$(10) \qquad d\hat{e} = \frac{1}{m_r f_{\hat{e}} - f_r m\hat{e}} \left[-f_r d\left(\frac{M}{W}\right) + m_r d\left(\frac{eF^p}{W}\right) \right].$$

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

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

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 2.1, the $\hat{e} = 0$ locus is a rectangular hyperbola. This can be seen by observing that in ϕ, eF^p enters multiplicatively (in W as well as the numerator eF^p), so changes in e and F^p that 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 2.1 upward. 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 $\hat{e} = 0$ downward; this could result from an open-market swap between

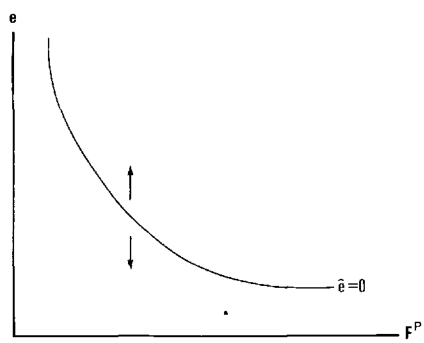

Fig. 2.1 Locus where ê = 0

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 2.2. If e is above this value, the current account is in surplus and $\dot{F} > 0$. In section 2.3 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 overintervenes 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 toward its long-run equilibrium, but perhaps slow the movement. The assumption gives the arrows showing movement in figure 2.2; 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 $\dot{F} = 0$ upward, with

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

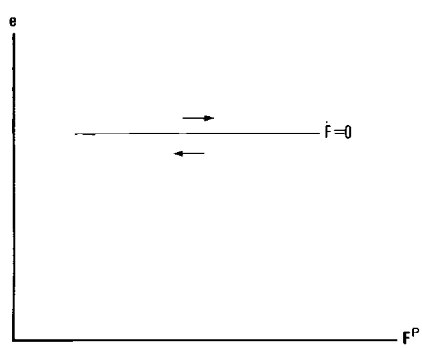

Fig. 2.2 Locus where $F = 0$

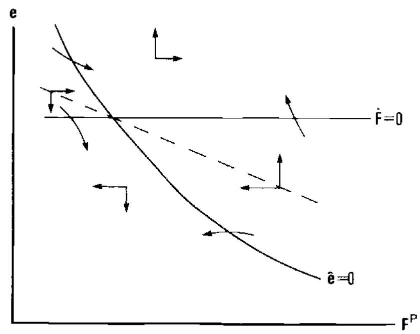

Fig. 2.3 Equilibrium path for e, F^P

Equilibrium of the system is shown in figure 2.3. There is one saddle path 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 saddle path toward equilibrium. The system would have quite different properties under a policy regime of overintervention that reversed the pattern of movement in the horizontal direction.

2.2.5 Reaction to Exogenous Shocks

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 2.4 does not shift, but $\hat{e} = 0$ shifts upward. With F^p initially given, the exchange rate jumps (currency depreciates) from initial equilibrium E_0 to E_1 on the

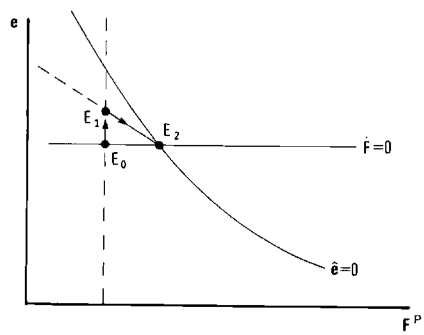

Fig. 2.4 Open-market operation in B, no change in F^P

new saddle path. 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 upward 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 case a proportional 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 upward 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.

Real Disturbance

The effect of an unanticipated fall in z (or an increase in P is shown in figure 2.5. The decrease in competitiveness shifts $\dot{F} = 0$ upward 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.

Sluggish Price Adjustment

A limiting case of sluggish price adjustment could be modeled as a combination of figures 2.4 and 2.5. Expansionary monetary policy would begin this process illustrated in figure 2.4. The delayed price response would then resemble figure 2.5. To the extent that the price response is lagged and unanticipated, the e, F^p point would follow a path illustrated in figure 2.6.

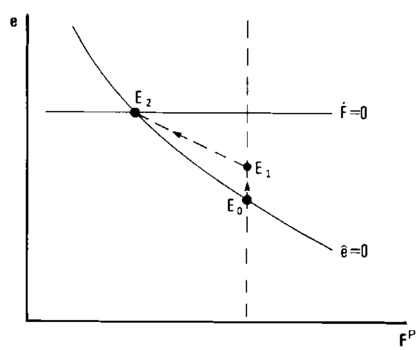

Fig. 2.5 Deterioration in competitiveness

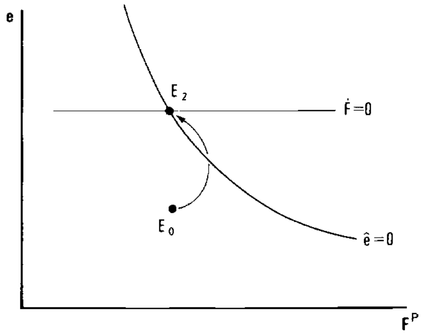

Fig. 2.6 Sluggish price adjustment

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.

2.2.6 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 2.4 and 2.6.

2.2.7 Interest Rate Control as an Alternative to Money Supply Control

In interpreting the empirical results on exchange rate policy in section 2.5 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

$$(12) \qquad \hat{e} = \psi\left(\frac{eF^p}{W}, r\right), \; \psi_1 > 0; \; \psi_2 > 0.$$

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 upward. Thus figure 2.4 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.

2.3 "Leaning against the Wind" as Exchange Rate Policy

2.3.1 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 United States domestic monetary policy; in Branson (1976) I labeled 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. United Kingdom 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.

In this section I shall characterize policy intervention in terms of the model of section 2.2., to prepare for interpretation of the empirical results in section 2.5 below. The objective is to describe policy, not evaluate 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 discernible in the "innovation" correlations in Section 2.5 below.

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

2.3.2 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 2.7, where, in

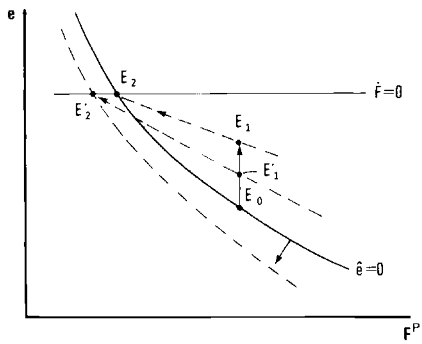

Fig. 2.7 Monetary policy reaction

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 2.7 would shift downward as shown by the dashed $\hat{e} = 0$. This would shift the saddle path downward 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 2.7, 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.

In a model with interest rate control, the same result as the bond market open market operation of figure 2.7 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.

2.3.3 Sterilized Intervention

There is 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 2.3, 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 2.7, 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.

2.3.4 Monetary Disturbances

Shifts in asset demand functions or the foreign interest rate would shift the $\hat{e} = 0$ locus, and the exchange rate would follow a path like that of figure 2.4, 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 public demand for them. Again, this is a straightforward extension of leaning-against-the-wind policy reaction from the domestic to the international markets.

2.3.5 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 2.5. below to infer hypotheses about policy behavior.

2.4 The Data

2.4.1 Introduction

The asset market model of section 2.2 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 2.3 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 United States, Germany, Japan, and the United Kingdom can be interpreted within this framework. We are inferring testable hypotheses from the data in this exercise.

In this section and the next, 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 2.1.

Table 2.1 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 2.2 and 2.3.
- $P/\bar{P}$ = 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 causes from *IFS*) and cover 1973:IV–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 calculate $P/\bar{P}$. 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 price indices. $\bar{P}$ is a composite and uses the same weights as does e (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 (Merchandises: 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: United States and United Kingdom, 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.

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 2.5 we study systems of vector autoregressions, one for each country, to test the relations between unanticipated changes, or "innovations," in the variables.

2.4.2 Time Series Analysis

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

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

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 appear prominently 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 2.2–2.5, 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 United States 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.

2.4.3 Country Results

United States

The results for the United States are instructive and serve as an illustration of the technique. In the first two columns of table 2.2, we show the regressions for the log of the United States nominal effective exchange rate e,

Table 2.2 **United States Univariate Autoregressions (Standard Errors in Parentheses)**

	Time Series														
	e		$P/\bar{P}$		M1		M3		CAB		IS			R	
Lags:															
t-1	.86*	.78*	1.71*	1.36*	.33	0.55*	.70*	.78*	.92*	.80*	1.21*	.82*	.82*	1.31*	.87*
	(.21)	(.10)	(.21)	(.17)	(.24)	(.18)	(.24)	(.14)	(.21)	(.14)	(.17)	(.24)	(.12)	(.26)	(.15)
t-2	.24	—	−1.41*	−60*	.31	—	.33	—	−.19	—	−1.19*	.00	—	−.75	—
	(.29)		(.38)	(.16)	(.27)		(.27)		(.30)		(26)	(24)		(.40)	
t-3	.37	—	0.74	—	−.16	—	−.22	—	.13	—	1.49*	—	—	.28	—
	(.28)		(.38)		(.29)		(.30)		(.30)		(.30)			(.40)	
t-4	−.24	—	−.20	—	.22	—	−.08	—	−.20	—	−.65*	—	—	.09	—
	(.19)		(.21)		(.24)		(.24)		(.22)		(.25)			(.27)	
Statistics:															
R^2	.86	.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	.027	.026	.008	.009	.012	.012	.009	.008	1.96	1.91	.82	1.28	1.26	36.7	38.8

Notes: (1) Sample period: 1973:IV–1980:IV for dependent variable.
(2) All regressions include constant, seasonal dummies, and time trend.
(3) An * 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).

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 .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 .78. Thus the United States effective rate, measured as a quarterly average, can be described as a stable first-order autoregression (AR1). The coefficient of .78 on 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: $e_t = .78\ u_t$; $e_{t+1} = .78^2\ u_t$, and so on.

The third and fourth columns of table 2.2 show the results for the log of the United States relative price index $P/\bar{P}$. This is an index of the United States WPI relative to a weighted average of the WPIs of 13 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 2.2.

The first regression for $P/\bar{P}$ in table 2.2 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 distrubance.[3]

The next two pairs of columns in table 2.2 show the univariate autoregression results for the two United States 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 2.2 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 2.2 show the autoregressions for the United States 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 United States in section 2.5 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 2.2 show the regressions for United States reserves. Only the lag at $t-1$ is significant, giving a stable first-order autoregression.

In the case of the United States, then, money stocks, the balance on current account, reserves, and the nominal effective exchange rate all follow

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 $.68 + .37i$, with a modulus of $0.77 = 0.6^{1/2}$.

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 sections 2.2 and 2.3.

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 purchasing power parity (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.

West Germany

Table 2.3 shows the univariate autoregression results for Germany. The format is exactly the same as for the United States, so the discussion can be brief.

As in the United States 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. 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 can be approximated by a stable AR1. Thus the impression from the German data is similar to the United States, except for the additional possibility that the interest rate is used as a policy instrument to control movements in the exchange rate.

United Kingdom

The United Kingdom results are summarized in table 2.4. Both the nominal effective rate and the M1 money stock in the United Kingdom 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 United States 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 United Kingdom 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 United Kingdom should not be interpreted as conveying information about future movements in the exchange rate.[5]

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

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

Table 2.3 **Germany Univariate Autoregressions**

	e		$P/\bar{P}$		M1		M3		CAB		IS		R	
Lags:														
t-1	.71*	.67*	—[a]	1.15*	.67*	.86*	1.08*	1.02*	.56*	.69*	.74*	.90*	.70*	.75*
	(.20)	(.18)		(.19)	(.21)	(.15)	(.20)	(.11)	(.22)	(.15)	(.21)	(.01)	(.19)	(.11)
t-2	−.15	—	—	−.58*	.23	—	−.10	—	.30	—	.27	—	−.19	—
	(.23)			(.19)	(.25)		(.30)		(.27)		(.26)		(.23)	
t-3	.37	—	—	—	.24	—	.24	—	−.15	—	−.04	—	.56*	—
	(.23)				(.24)		(.30)		(.28)		(.22)		(.23)	
t-4	−.29	—	—	—	−.32	—	−.50*	—	.05	—	−.15	—	−.33	—
	(.18)				(.19)		(.24)		(.24)		(.16)		(.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	74.5	79.8

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

Table 2.4 United Kingdom Univariate Autoregressions

	e		P/$\bar{P}$		M1		M3		CAB		IS		R	
Lags:														
t-1	1.10*	1.04*	1.41*	1.53*	1.08*	.95*	.91*	.85*	.12	.12	1.21*	1.28*	1.14*	1.22*
	(.22)	(.07)	(.22)	(17)	(.21)	(.12)	(.24)	(.16)	(.23)	(.21)	(.21)	(.18)	(.22)	(.19)
t-2	.01	—	−.48	−.57*	.21	—	−.04	—	−.02	—	−.29	−.52*	−.23	−.45*
	(.31)		(.36)	(.19)	(.25)		(.29)		(.26)		(.32)	(.18)	(.33)	(.18)
t-3	−.02	—	.19	—	−.62*	—	−.03	—	.02	—	−.23	—	−.20	—
	(.30)		(.35)		(.22)		(.29)		(.27)		(.31)		(.34)	
t-4	−.10	—	−.20	—	.08	—	−.14	—	.06	—	.04	—	.02	—
	(.23)		(.19)		(.20)		(.19)		(.24)		(.22)		(.23)	
Statistics:														
R^2	.94	.94	.99	.99	.99	.99	.99	.99	.50	.50	.83	.83	.95	.95
D-W	1.70	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	56.8	55.1

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

Japan

The results for Japan are summarized in table 2.5. 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 2.5 shows the importance of the lag at $t-4$. To conserve degrees of freedom in the Japanese VAR system reported in section 2.5, 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.

2.4.4 Summary on the Data

The univariate autoregressions of tables 2.2–2.5 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 United Kingdom series are cyclical.
2. All the money stocks are first-order autoregressions, many with unitary lag coefficients.
3. The United States 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 United Kingdom CAB contains no information about its future path.
4. The United States and German exchange rate and reserves follow AR1 processes that could reflect intervention. The United Kingdom and Japanese interest rates and exchange rates follow consistent processes, AR1 and AR2, respectively.

2.5 Empirical Results Using Vector Autoregression

2.5.1 Introduction

A useful technique for studying the relationships among the innovations in money, the current account balance, relative price levels, interest rates,

[6] The Japanese VAR results were reestimated using a 4-quarter lag on reserves, without much change.

Table 2.5 **Japan Univariate Autoregressions**

	e		$P/\bar{P}$		M1		M3		CAB		IS		R		
Lags:															
t-1	1.18*	1.33*	1.24*	1.21*	.79*	1.03*	1.03*	1.10*	1.25*	1.50*	1.32*	1.56*	1.06*	1.07*	.80*
	(.22)	(.18)	(.20)	(.14)	(.22)	(.14)	(.22)	(.08)	(.22)	(.16)	(.23)	(.16)	(.16)	(.22)	(.12)
t-2	−.37	−.55*	−.85*	−.62*	−.56	—	.26	—	−.32	−.67*	−.39	−.72*	−.55*	−.30	—
	(.34)	(.18)	(.32)	(.12)	(.30)		(.32)		(.37)	(.16)	(.38)	(.17)	(.24)	(.31)	
t-3	.12	—	.45	—	−.04	—	−.21	—	.10	—	.05	—	.74*	−.05	—
	(.34)		(.32)		(.31)		(.32)		(.38)		(.56)		(.25)	(.21)	
t-4	−.26	—	−.27	—	−.24	—	−.01	—	−.34	—	−.23	—	−.072*	—	—
	(.22)		(.16)		(.28)		(.23)		(.25)		(.34)		(.17)		
Statistics:															
R^2	.91	.90	.99	.99	.99	.99	.99	.99	.91	.90	.93	.92	.92	.86	.84
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	1.40
SE	.044	.044	.014	.014	.023	.023	.008	.008	.97	1.00	1.00	1.00	58.8	78.5	80.4

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 2.2 and 2.3. 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 United States, the United Kingdom, 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 included 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 United Kingdom 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 2.2 and 2.3. Money stock data are available on a weekly basis, so they are roughly contemporaneous with the exchange rate data. We use end-of-period money data. 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 ends. 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 on current account

Table 2.6 Variables Included in Vector Autoregression Systems

United States, Germany	United Kingdom	Japan
$\ln e_{t-1}$	$\ln e_{t-1}$	$\ln e_{t-1}$
$\ln M_{t-1}$	$\ln M_{t-1}$	$\ln e_{t-2}$
$\ln P/\bar{P}_{t-1}$	$\ln P/\bar{P}_{t-1}$	$\ln M_{t-1}$
$\ln P/\bar{P}_{t-2}$	$\ln P/\bar{P}_{t-2}$	$\ln P/\bar{P}_{t-1}$
CAB_{t-2}	CAB_{t-2}	$\ln P/\bar{P}_{t-2}$
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 2.1).

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 tilde to designate residuals from the VARs. The variables in each VAR system are listed in table 2.6. The number of lags included in each variable was determined by the univariate autoregression of tables 2.2–2.5. 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 reestimate 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 2.7–2.14 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.

2.5.2 United States

The correlations of VAR innovations for the United States are shown in tables 2.7 and 2.8. 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 2.2 and 2.3. So here an increase in e is an appreciation.

The first rows of table 2.7 and 2.8 give the correlations of exchange rate innovations. The negative signs for relative prices and money are consistent

Table 2.7 **Correlations of Innovations from United States Vector Autoregression System with M1**

	$\tilde{e}$	$\tilde{M}1$	$\tilde{P}/\bar{P}$	$C\tilde{A}B$	$\tilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	−.30	−.42	−.12	−.09	.14
		(.11)	(.03)	(.55)	(.65)	(.46)
$\tilde{M}1$		1.00	−.35	−.41	−.03	−.56
			(.06)	(.03)	(.87)	(.00)[a]
$\tilde{P}/\bar{P}$			1.00	.44	.24	.26
				(.02)	(.20)	(.17)
$C\tilde{A}B$				1.00	−.11	.55
					(.58)	(.00)[a]
$\tilde{IS}$					1.00	.35
						(.07)
$\tilde{R}$						1.00

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

with innovations in those variables driving *e*, as in the model of section 2.2. There is a weak correlation with reserves, consistent with intervention. Innovations in reserves, shown in the last columns of tables 2.7 and 2.8, 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 $C\tilde{A}B_{t-1}$ and $\hat{R}_t$. Thus the indication in tables 2.7 and 2.8 is that intervention 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 United States data is as follows. The current account, money, and relative prices all move the exchange rate, the latter two through market

Table 2.8 **Correlation of Innovations from United States Vector Autoregression System with M3**

	$\tilde{e}$	$\tilde{M}3$	$\tilde{P}/\bar{P}$	$C\tilde{A}B$	$\tilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	−.48	−.37	−.08	−.02	.24
		(.01)	(.05)	(.68)	(.92)	(.22)
$\tilde{M}3$		1.00	.23	.05	.50	.07
			(.24)	(.81)	(.01)	(.73)
$\tilde{P}/\bar{P}$			1.00	.38	−.03	.03
				(.04)	(.89)	(.90)
$C\tilde{A}B$				1.00	−.24	.47
					(.21)	(.01)
$\tilde{IS}$					1.00	.30
						(.12)
$\tilde{R}$						1.00

expectations and innovations. Monetary policy is essentially oriented toward domestic targets; movement in the exchange rate is a side effect. The United States monetary authorities intervene and sterilize, but do not follow a tight rule. This shows up in the strong correlation be $\tilde{R}$ and $\tilde{CAB}$, and in the correlation between $\tilde{R}$ and $\tilde{e}$.

2.5.3 Germany

The innovation correlations for Germany are shown in tables 2.9 and 2.10. 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

Table 2.9 **Correlation of Innovations from German Vector Autoregression System with M1**

	$\tilde{e}$	$\tilde{M}1$	$\tilde{P}/\bar{P}$	$C\tilde{A}B$	$\tilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	.17	−.44	.27	−.48	.40
		(.37)	(.02)	(.15)	(.01)	(.03)
$\tilde{M}1$		1.00	.02	.25	−.47	.28
			(.94)	(.19)	(.01)	(.14)
$\tilde{P}/\bar{P}$			1.00	.23	.07	.28
				(.22)	(.73)	(.14)
$C\tilde{A}B$				1.00	−.33	.43
					(.08)	(.02)
$\tilde{IS}$					1.00	−.13
						(.49)
$\tilde{R}$						1.00

Table 2.10 **Correlation of Innovations from German Vector Autoregression System with M3**

	$\hat{e}$	$\tilde{M}3$	$\tilde{P}/\bar{P}$	$C\tilde{A}B$	$\tilde{IS}$	R
$\tilde{e}$	1.00	−.09	−.59	.03	−.52	−.26
		(.63)	(.00)	(.90)	(.00)	(.17)
$\tilde{M}3$		1.00	.18	.20	−.53	−.04
			(.34)	(.30)	(.00)	(.84)
$\tilde{P}/\bar{P}$			1.00	.25	.05	.45
				(.20)	(.79)	(.01)
$C\tilde{A}B$				1.00	−.29	.25
					(.13)	(.19)
$\tilde{IS}$					1.00	−.01
						(.96)
$\tilde{R}$						1.00

M1 system) must reflect leaning-against-the-wind policy in terms of both 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 $\tilde{CAB}$ and $\tilde{R}$ also supports the intervention hypothesis.

Thus the German data suggest fairly strongly a situation in which (1) price and exchange rate innovations go together, and (2) 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 and Marston (1977) for the fixed rate regime.

2.5.4 United Kingdom

The United Kingdom correlations are shown in tables 2.11 and 2.12. 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 $\tilde{M}$ with $\tilde{e}$ and $\tilde{R}$. Innovations in the current account balance have the positive correlation with e that would come from the theory of section 2.2. Perhaps this suggests that while from the univariate autoregressions of section 2.4, 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 United Kingdom data thus show influence of CAB on e, with interest rate and intervention policy reacting to innovations in e and CAB with M1 unsterilized.

Table 2.11 Correlations of Innovations from United Kingdom Vector Autoregression System with M1

	$\tilde{e}$	$\tilde{M}1$	$\tilde{P}/\bar{P}$	$\tilde{CAB}$	$\tilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	.46	−.05	.29	−.59	.53
		(.01)	(.81)	(.12)	(.00)	(.00)
$\tilde{M}1$		1.00	.09	−.34	−.37	.52
			(.62)	(.07)	(.05)	(.00)
$\tilde{P}/\bar{P}$			1.00	−.02	.06	−.03
				(.91)	(.74)	(.89)
$\tilde{CAB}$				1.00	−.44	−.14
					(.02)	(.48)
$\tilde{IS}$					1.00	−.29
						(.12)
$\tilde{R}$						1.00

Table 2.12 **Correlations of Innovations from United Kingdom Vector Autoregression System with M3**

	$\tilde{e}$	$\tilde{M}3$	$\tilde{P}/\bar{P}$	$C\tilde{A}B$	$\tilde{IS}$	R
$\tilde{e}$	1.00	−.04	−.04	.47	−.55	.44
		(.82)	(.85)	(.01)	(.00)	(.02)
$\tilde{M}3$		1.00	.05	.46	−.30	−.15
			(.79)	(.01)	(.10)	(.43)
$\tilde{P}/\bar{P}$			1.00	.05	−.05	−.04
				(.80)	(.81)	(.85)
$C\tilde{A}B$				1.00	−.61	.08
					(.00)	(.67)
$\tilde{IS}$					1.00	−.27
						(.15)
$\tilde{R}$						1.00

2.5.5 Japan

The results for Japan are shown in tables 2.13 and 2.14. Let us focus on table 2.13 first. The correlation of innovations in the exchange and interest rates suggests a system of interest rate control with policy targets other than the exchange rate, rather than the reaction to exchange rates as found in the United Kingdom 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 $C\tilde{A}B$ strongly suggest leaning-against-the-wind intervention, with the central bank absorbing part of the CAB innovations to reduce movement in the exchange rate. The lack of correlation of $\tilde{M}1$ with reserves or the exchange rate indicates sterilization.

An interesting picture emerges from the Japanese correlations. They sug-

Table 2.13 **Correlations of Innovations from Japan Vector Autoregression System with M1**

	$\tilde{e}$	$\tilde{M}1$	$\tilde{P}/\bar{P}$	$C\tilde{A}B$	$\tilde{IS}$	$\tilde{R}$
$\tilde{e}$	1.00	−.06	−.08	−.03	.55	.33
		(.77)	(.68)	(.89)	(.00)	(.08)
$\tilde{M}1$		1.00	−.10	−.07	−.18	.23
			(.59)	(.71)	(.36)	(.24)
$\tilde{P}/\bar{P}$			1.00	−.32	.42	−.05
				(.09)	(.02)	(.81)
$C\tilde{A}B$				1.00	−.25	.48
					(.19)	(.01)
$\tilde{IS}$					1.00	.31
						(.10)
$\tilde{R}$						1.00

Table 2.14 Correlations of Innovations from Japan Vector Autoregression System with M3

	$\tilde{e}$	$\tilde{M3}$	$\tilde{P}/\bar{P}$	$C\tilde{A}B$	$I\tilde{S}$	$\tilde{R}$
$\tilde{e}$	1.00	.00	−.20	.05	.18	.12
		(.98)	(.30)	(.81)	(.35)	(.52)
$\tilde{M3}$		1.00	.02	.12	−.28	.18
			(.93)	(.52)	(.14)	(.34)
$\tilde{P}/\bar{P}$			1.00	−.36	.43	−.10
				(.05)	(.02)	(.61)
$C\tilde{A}B$				1.00	−.60	.33
					(.00)	(.07)
$I\tilde{S}$					1.00	.14
						(.46)
$\tilde{R}$						1.00

gest that policy sets interest rates with CAB and $P/\bar{P}$ among the objectives. The interest rate moves the exchange rate, as in section 2.2, 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 picture in terms of signs of correlations, although significance levels vary from the M1 system (in both directions—see the correlation of $I\tilde{S}$ and $C\tilde{A}B$).

2.5.6 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. My interpretation, or inferred set of hypotheses, is as follows. The United States sets monetary policy, largely by controlling quantities, with domestic objectives most in mind. The market looks to innovations in money and relative prices, and levels of the current account balance, to set the United States 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.

Movement in the United States and Japanese effective rates, caused partly by fundamentals and partly by policy, are mirrored instantaneously in the United Kingdom 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 United States and Japan is transmitted in the United Kingdom 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 United States is negligible, while in the United Kingdom and Germany it is strongly negative. An implication is that innovations in the dollar prices of the deutsche mark and sterling should be negatively correlated with innovations in the United States–German and United States–United Kingdom 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 United Kingdom and German interest rate innovations are policy reactions.

Comment Willem H. Buiter

This interesting paper develops a theoretical open economy model that suggests certain associations between innovations in the exchange rate, the money stock, the current account, relative price levels, interest rates, and international reserves. The empirical part of the paper studies these correlations between innovations for the United States, the United Kingdom, the Federal Republic of Germany, and Japan. I shall discuss the theoretical and empirical sections in turn.

The Theoretical Model

The paper develops a model of a single open economy. The country is specialized in the production of its exportable and has some market power in the world market for the exportable. It consumes both its exportable good and an import whose world price in foreign currency is given. There are perfect international financial markets in the sense that instantaneous stock-shift portfolio reshuffles between domestic and foreign assets are possible. Domestic and foreign bonds are, however, imperfect substitutes. The interest rate on the foreign bond is exogenous. Exchange rate expectations are rational. Assumptions about price-level flexibility range from a fixed domestic currency price of the exportable to a freely flexible exportables price. External wealth adjustment through current account deficits and surpluses is allowed for. The model can be viewed as a flexible exchange rate version of Obstfeld (1980) or an imperfect asset substitutability version of Branson and Buiter (1983).

The decision to conduct the analysis conditional on the level of output and thus to avoid the need to consider the goods market or IS equilibrium condition certainly has expository advantages. However, the empirical observations have presumably been generated by a complete model in which output is endogenous. To infer what kinds of correlations between real world innovations are to be anticipated on the basis of the model, output would have to be endogenized. If output or income is an argument in the money demand function, some of the predictions of the complete model are likely to be different from those of the asset markets model, at any rate as regards the fixed and sluggish price adjustment versions.

The monotonic movement of the exchange rate following a real disturbance holds true, even in the fixed price and perfectly flexible price versions of the model, only for unanticipated permanent disturbances. Anticipated future shocks are likely to give rise to nonmonotonic adjustment patterns. With lagged price adjustment the adjustment process is likely to be cyclical, even in response to unanticipated shocks. If, for example, sluggish price adjustment is modeled by $\frac{\dot{p}}{p} = \phi(y - \bar{y}) + \pi, \dot{\pi} = \eta\left(\frac{\dot{p}}{p} - \pi\right)$ where y is real output, $\bar{y}$ is capacity output, and π is core inflation (ϕ, $\eta > 0$), a cyclical adjustment process is virtually guaranteed. Adding sluggish price adjustment increases the dimensionality of the state vector by at least one. The example just given adds two state variables.

The implicit assumption is made throughout, that F^p and W are positive. From equation (11) we find that the $\dot{e} = 0$ locus can be given by either branch of the rectangular hyperbola in figure 2.C.1 depending on whether the stationary value of F is positive or negative. (It is assumed that while F^p can be negative as well as positive, W is positive throughout.)

Assuming with Branson that the $\dot{F}^p = 0$ locus is horizontal, the phase diagram is as figure 2.C.1. If there is a unique stationary solution for W and the domestic interest rate r, then there is a unique solution for F^p. If this

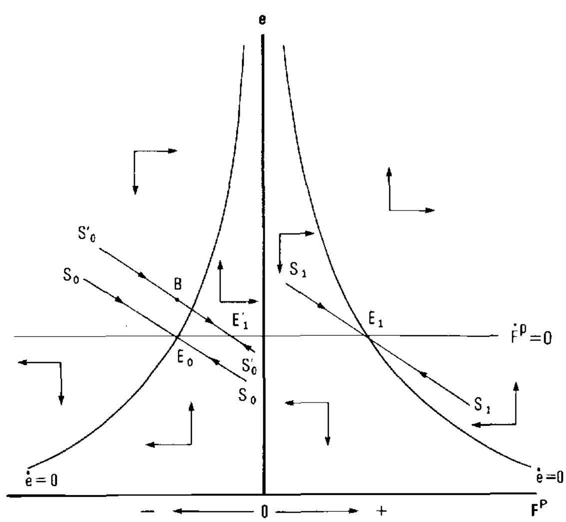

Fig. 2.C.1

solution is negative we are at E_0; if it is positive E_1 will be the stationary equilibrium.

The qualitative response of e and F^p to an unanticipated increase in M will be the same, whether the stationary equilibrium is at E_0 or E_1. From an initial position at E_0, the $\dot{e} = 0$ locus shifts down and to the right when M increases. There is a new long-run equilibrium at E_0', say, and a new convergent saddle path $s_0's_0'$ through E_0'. The exchange rate "jump-depreciates" to B and then gradually appreciates toward E_0' along $s_0's_0'$.

Most of the results in the theoretical part of the paper do not require the assumption of imperfect asset substitutability. The distinction between open market operations in domestic bonds and open market operations in foreign bonds would of course disappear if the two bonds were perfect substitutes.

The Empirical Work

The data analysis starts by estimating univariate autoregressions for money stocks, current account balances, effective exchange rates, relative prices, and interest rates. For the United States, the money supply, the current account balance, reserves, and the nominal exchange rate are found to follow stable AR1 processes. Branson argues that this suggests the behavior of these variables is "consistent, at this level, with the theoretical model of sections 2.2 and 2.3." However, the theoretical model only suggests that the innovations should be correlated. Consider, for illustrative purposes, the following structural model.

(1a) $$m_t = \alpha_1 m_{t-1} + \epsilon_t^m,$$

(1b) $$e_t = \beta_1 e_{t-1} + \beta_2 e_{t-2} + \beta e_{t-3} + \beta_4[m_t - E(m_t \mid I_{t-1})] + \epsilon^e t.$$

In this equation, ϵ_t^m and ϵ_t^e are white noise disturbances. Clearly the innovation in the univariate autogression for m_t, ϵ_t^m and the innovation in the univariate autogression for e_t, $\epsilon_t^e + \beta_4\epsilon_t^m$, are correlated even if ϵ_t^m and ϵ_t^y are independently distributed. Yet m_t will follow an AR1 process and e_t an AR3 process. Conversely, even if m_t and e_t were each to follow "similar" AR1 processes, this by itself can tell us nothing about the correlation between the innovations in the two processes. That issue can only be settled by estimating a bivariate ARIMA process for m_t and e_t.

I am also unconvinced of the validity of the criterion for selecting the number of lags to be included in the vector autogressions. In the paper, the number of lags included for each variable was determined by the univariate autogressions. Assume for purposes of illustration that e_t and m_t follow a first-order vector autogressive process:

(2a) $$e_t = \alpha_1 e_{t-1} + \alpha_2 m_{t-1} + \epsilon_t^e,$$

(2b) $$m_t = \beta_1 e_{t-1} + \beta_2 m_{t-1} + \epsilon_t^m.$$

Repeated substitution in (2b) yields $m_t = \beta_1 \sum_{i=0}^{\infty} \beta_2^i e_{t-1-i} + \sum_{i=0}^{\infty} \beta_2^i \epsilon_{t-i}^m$. That is,

(3a) $$e_t = \alpha_1 e_{t-1} + \alpha_2 \beta_1 \sum_{i=0}^{\infty} \beta_2^i e_{t-2-i} + \alpha_2 \sum_{i=0}^{\infty} \beta_2^i \epsilon_{t-1-i}^m + \epsilon_t^e.$$

Similarly,

(3b) $$m_t = \beta_2 m_{t-1} + \beta_1 \alpha_2 \sum_{i=0}^{\infty} \alpha_1^i m_{t-2-i} + \beta_1 \sum_{i=0}^{\infty} \alpha_1^i \epsilon_{t-1-i}^e + \epsilon_t^m.$$

If in (2a)–(2b) α_1, α_2, β_1, and β_2 are all nonzero, then the univariate autoregressions would be characterized by an infinite lag distribution. If ϵ_t^e and ϵ_t^m are white noise, the disturbances in the univariate autogressions would be infinite-order MA processes. Clearly, (2a) and (2b) are only consistent with univariate autoregressive representations for e_t and m_t if $\alpha_2 = \beta_1 = 0$.

Finally, a remark about the interpretation of any observed contemporaneous correlation between the innovations in a vector autoregression. Branson argues, for example, that a positive correlation between innovations in the money supply and the exchange rate reflects the response of the exchange rate to unanticipated open market operations, while a negative correlation suggests monetary ("leaning against the wind") intervention aimed at stabilizing the exchange rate in response, say, to current account disturbances.

While I have no quarrel with Branson's interpretation of the correlations contained in the paper, it is important to realize that the stochastic properties of the data themselves cannot establish whether m responds to innovations in e, e responds to innovations in m, or both respond to each other's innovations. The effect of unanticipated e on m is observationally equivalent with the effect of unanticipated m on e (Buiter 1983). Consider the following example:

(4a) $$e_t = a_1 + b_1[m_t - E(m_t \mid I_{t-1})] + \epsilon_t^e,$$

(4b) $$m_t = a_2 + b_2[e_t - E(e_t \mid I_{t-1})] + \epsilon_t^m.$$

The reduced form of this model is given by

(5a) $$e_t = a_1 + (1 - b_1 b_2)^{-1}(\epsilon_t^e + b_1 \epsilon_t^m) = a_1 + u_t^e,$$

(5b) $$m_t = a_2 + (1 - b_1 b_2)^{-1}(\epsilon_t^m + b_2 \epsilon_t^e) = a_2 + u_t^m.$$

Let ϵ_t^e and ϵ_t^m be white noise disturbances that are also contemporaneously uncorrelated.

The covariance between the reduced-form disturbances u^e and u^m in (5a) and (5b) is given by

$$E(u^e u^m) = (1 - b_1 b_2)^{-2}(b_1 \sigma_{\epsilon}^2 m + b_2 \sigma_{\epsilon}^2 e) \tag{6}$$

If we know on a priori grounds that money does not respond to exchange rate surprises ($b_2 = 0$), then $E(u^e u^m) = b_1 \sigma_{\epsilon}^2{}^m$ and b_1 can be identified and estimated using the estimated variance-covariance matrix of the reduced-form disturbances since $b_1 = E(u^e u^m)/E(u^m)^2$. If instead the exchange rate does not respond to money surprises ($b_1 = 0$), then $E(u^e u^m) = b_2 \sigma_{\epsilon}^2{}^e$, $E(u^e u^m)/E(u^m)^2 = b_2 \sigma_{\epsilon}^2 e/(\sigma_{\epsilon}^2{}^m + b_2^2 \sigma_{\epsilon}^2 e)$ and $b_2 = E(u^e u^m)/E(u^e)^2$. The data themselves cannot tell us whether $b_1 = 0$, $b_2 = 0$, or both b_1 and b_2 are nonzero.

Prior information must be used to overcome this identification problem. If it can be assumed, for example, that $b_1 \geqslant 0$ and $b_2 \leqslant 0$, then a negative value for $E(u^e u^m)$ is (from [6]) only consistent with a (negative) policy response of m to e. Even if we accept the constraint $b_1 \geqslant 0$, one may well be able to imagine policy scenarios under which $b_2 > 0$. "Leaning with the wind" in the foreign exchange market can be shown to be optimal under certain conditions (Buiter and Eaton 1981). In that case the positive correlation between u^e and u^m reflects both any positive structural effect of m on $e(b_1 \geqslant 0)$ and the positive policy response of m to $e(b_2 > 0)$. Only detailed prior knowledge of the actual form of the policy response rules will enable us to extract useful information from correlations between the innovations in vector autoregressions.

Comment Peter B. Kenen

If I had read only the summary of findings at the start of Branson's paper, I would have had no quarrel with him. His descriptions of national policies seem eminently sensible. Having read his whole paper carefully, I find myself in difficulty. I agree with most of his conclusions but have many doubts about the way that he obtains them.

I do not have much trouble with the model that Branson uses to define the questions he wants to investigate. It is a standard asset market model of exchange rate determination that is made forward looking by introducing rational expectations. (If I understand the model, most of the comparative static results could be obtained with stationary expectations. The rational expectations form serves mainly to draw the distinction between anticipated and unanticipated shocks—a distinction Branson needs later to treat his regression residuals as proxies for unanticipated shocks.)

I do have one small complaint and one unanswered question. It would have been easier for me to follow his presentation if Branson had told us from the start that "reserves" held by the central bank do not differ in character from the foreign assets held by the public (that R is part of F); this is why reserve use for official intervention is the same as an open market sale of foreign assets to domestic asset holders. My question has to do with the assumption that $(\delta\dot{F}/\delta F) = 0$. In most asset market models, this term or one like it must be negative for the model to be stable; an increase in F is an increase in wealth, and it must reduce $\dot{F}$, the capital outflow or current account surplus, if the economy is to reach a stationary state. I wonder, then, whether Branson's assumption could impair the stability of his model.

I have somewhat more serious questions about the use of this standard model for the main purpose of the paper—empirical work on exchange rate determination and official intervention. The model describes a small country facing a homogeneous world. There is one exchange rate and one foreign asset. The countries with which Branson deals in his empirical work are large in every sense, and the outside world is not homogeneous. Branson does not face this problem squarely, and when the numbers force him to do something about it, whether he wants to or not, he tries to make the countries fit his model rather than making his model fit the countries.

Let me add right away that it would be very difficult to make the model fit the countries. It would be necessary to deal simultaneously with a number of interdependent economies, each one holding assets in the others' currencies and affecting by its policies all of the bilateral exchange rates for its currency. One could, of course, determine the effects of policies, domestic and foreign, on the behavior of the effective exchange rate. But one would have to begin with the effects on the relevant bilateral exchange rates and to take account of the foreign repercussions relevant to each such rate. One could thus measure the influence of United States monetary policy on the effective exchange rate for the dollar by determining its impact on the mark-dollar rate, the yen-dollar rate, and so on, allowing fully for the German and Japanese responses, including both endogenous and policy responses.

What has Branson done? He has tried to fit four large countries into his small-country model by working directly with effective exchange rates and making no allowance for foreign repercussions or for the effects of other countries' policies. His vector autoregressions for the United States include the effective exchange rate for the dollar, the ratio of domestic to foreign prices corresponding conceptually to the effective rate, and the current account balance. They also include United States reserves, the United States money supply, and the United States short-term interest rate. The price ratio and current account balance may take some account implicitly of events in other countries, including endogenous responses to events in the United States, but they are far from adequate for this purpose.

When I made these observations at Bellagio, during the discussion of Branson's paper, several participants came to his defense. It would be impossible, they said, to execute the strategy implied by my criticism. To capture the impact of official intervention on the effective exchange rate for the dollar, one would have to estimate vector autoregressions for all of the relevant bilateral exchange rates and include a larger number of variables in *every* vector autoregression. Each equation would have to include all of the bilateral exchange rates, all of the current account balances, and all of the other variables for the foreign countries. Branson does not have enough degrees of freedom. I was at first inclined to accept this defense, but I am increasingly dissatisfied with it. If one cannot do things right, one should perhaps refrain from doing them at all.

What are the practical consequences of following Branson's procedure? Two examples lead me to believe that it must misrepresent the influence of official intervention. My first example illustrates the need to disaggregate—to work separately with the bilateral exchange rates for each currency. For most of the period covered by this study, exchange rate arrangements in Western Europe pegged bilateral rates between the mark and certain other European currencies. The German authorities had to intervene whenever the relevant bilateral rates reached the limits of the bands set first by the "snake" and then by the EMS. I have not worked carefully through the implications, but I venture a conjecture. When the effective exchange rate for the mark is used to "explain" the behavior of German reserves, the vector autoregression will be unsatisfactory. The coefficients of the German reaction function implicit in its coefficients will not be unbiased, and the residuals will not represent the "innovations" needed later on. To measure the effects of intervention accurately, one has to disaggregate—to separate the two types of intervention residing in the German data and link each type of intervention to the relevant bilateral exchange rates.[1]

My second example illustrates the need to include foreign variables in each country's vector autoregressions. During most of the period covered by this study, the United States authorities did not intervene regularly on foreign exchange markets. When they did intervene, moreover, they concentrated on two or three bilateral exchange rates. But foreign central banks intervened extensively. To capture the effects of intervention on the effective exchange rate for the dollar, one should thus try to estimate the effects of United States intervention on the two or three bilateral exchange rates and, simultaneously, the effects of foreign intervention on those and the other bilateral rates that make up the effective rate.

For reasons given earlier, it would be difficult to do this correctly. If

1. One would expect both types of intervention to affect both types of rates—those that are pegged by intra-European arrangements and those that are not—and the "cross effects" may be quite strong. (Some of the intervention undertaken to defend the pegged rates is done in dollars rather than in European currencies, and therefore it should affect the bilateral exchange rate between the mark and dollar directly.) But the correlations between the two types of intervention and two types of rates are apt to be different, and they should be identified instead of being "averaged" into a single correlation between "innovations" in total intervention and in the effective exchange rate.

intervention is not exogenous but can and should be described by a reaction function, we should include in the vector autoregressions for the United States all variables for all foreign countries, and this is not possible. But there may be rough and ready ways to take account of foreign intervention:

1. Using the small-country approach adopted by Branson (i.e., using only United States variables) but working with bilateral exchange rates for the dollar, not with the effective rate, we could obtain new sets of exchange rate residuals. We could then calculate the simple correlations between German reserves and the mark-dollar residuals, between Japanese reserves and the yen-dollar rate, and so on.

2. If we were to look at Branson's vector autoregressions for reserves, we would probably find that very few of the right-hand-side variables are significant. In this event, it would be possible to run three new equations—one for the mark-dollar exchange rate containing all of the United States and German variables, one for German reserves containing the mark-dollar rate (or the effective exchange rate for the mark) and one or two other variables, and an equation for United States reserves containing the mark-dollar rate (or the effective exchange rate for the dollar) and one or two other variables. We could then run simple correlations between the residuals from the exchange rate equation and the residuals from the reserve equations.

These methods are imperfect. The second, for example, runs afoul of my earlier objection—that some German intervention is mandated by intra-European monetary arrangements. But they may take us farther than Branson's approach.

As I have concentrated heavily on intervention, let me continue in that vein. I have two more problems. In Branson's paper, intervention is identified with quarter-to-quarter changes in official foreign exchange holdings (in the series on line 1.d.d of *International Financial Statistics*). If these are the figures he has used, he is wrong to say that they can turn negative. Furthermore, Branson mentions the valuation problem but says that it is small. He does not mention a much larger problem: changes in the figures are not necessarily due to intervention. During the fourth quarter of 1978, when the United States began to intervene heavily to keep the dollar from depreciating, it sold large quantities of foreign exchange. Nevertheless, its official foreign exchange holdings rose by $4.34 billion. Why? Because the United States drew on its reserve position in the IMF and issued the Carter bonds. It borrowed more foreign exchange than it used. There are other instances of this sort, and one must make careful corrections for them before using changes in foreign exchange holdings to represent official intervention. We cannot correct them completely, but we should do what we can. There is no excuse for running data from a tape into a regression program without inspecting, let alone correcting them.

My last point has to do with the reliability of the results reported in Branson's paper. For example, the results in table 2.13, which deals with Japan, come from vector autoregressions that use M1 to represent the Japanese money supply. The correlation between innovations in reserves and in the exchange rate is .33 and is significant. The results in table 2.14, also dealing with Japan, come from vector autoregressions that use M3 to represent the money supply. The correlation between the same sets of "innovations" is .12 and is not signficant. What conclusion should we draw about the effectiveness of intervention? It may be best to render the old Scottish verdict—not proven—until we can discriminate decisively between the reduced forms implicit in alternative specifications. I have grave doubts about the validity of the rational expectations hypothesis. Even those who think that it is valid, however, should entertain doubts about using residuals from reduced-form regressions to represent the unexpected.

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