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MACROECONOMIC DETERMINANTS OF REAL EXCHANGE RATES

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Abstract

This paper presents a model that integrates money, relative prices, and the current account balance as factors explaining movements in nominal (effective) exchange rates. Thus money and the current account are the proximate determinants of changes in real (effective) rates. The basic model is first analyzed under static expectations. It is an extension of Branson (1977) to include explicitly exogenous disturbances to the current account. Next, rational expectations are introduced, and it is shown that the nominal (and real) rate should be expected to jump instantaneously in response to new information or "innovations" in money, the current account, and relative prices.

The model is applied to the quarterly data on effective exchange rates, relative prices, money and the current account for four countries--the U.S., the U.K., Germany and Japan--since 1973. First the time-series properties of the data are described. All are approximately first-order autocorrelations <u>except</u> all relative prices and Japan's effective exchange rate and current account balance. These are second-order autocorrelations. Then vector autoregressions (VARs) are estimated among the four variables for each country. The residuals from these equations are the "innovations" in the data--the current movements not predicted by the past. The correlations amongst these innovations are consistent with the theory.

Thus the broad conclusion from the paper is that the theoretical model which integrates money, the balance on current account and relative prices, is consistent with movements in these variables since 1973. Real exchange rates adjust to real disturbances in the current account, and time-series innovations in the current account seem to signal the need for adjustment.

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Macroeconomic Determinants of Real Exchange Rates

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October 16, 1981

I. Introduction and Summary

In 1973 the international monetary system began a period of continuous movement of exchange rates among major currencies. Rather than moving smoothly following the paths of relative national price levels, exchange rates have exhibited the volatile movements that are generally associated with asset market prices. This has been amply documented by Jacob Frenkel (1981a,b). Sharp movements of the exchange rate relative to relative price levels are fluctuations in "real exchange rates." This term is defined here to mean the nominal exchange rate adjusted for relative price movements.

During the period since 1973 theory about the determinants of exchange rate fluctuations has undergone a transformation. We began with alternative models in which rates moved to clear the current account balance (the "elasticities" approach) or responded to movements in relative money stocks (the "monetary" approach). These have been integrated into a more general framework in which exchange rates are determined in the short run by conditions of asset-market equilibrium, in the same way as asset prices or interest rates, and in the long run by real conditions affecting the current account. This integrated theoretical view is expressed, for example, in Dornbusch (1980). In this view, monetary disturbances generally do not change the equilibrium real exchange rate, but real disturbances to the current account do. This theoretical view has been accepted widely enough that the OECD Economic Outlook reports it as the conventional wisdom:

> The main economic variables generally thought to explain exchange rates are monetary conditions (and especially interest rate differentials), current account developments, and relative price performance. But over recent months the influence of inflation differentials has been uncharacteristically small, or operated with considerable delay, the dominant role being played by monetary conditions and current account developments.[1]

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[1] OECD, Economic Outlook no. 29, July 1981, p. 59.

Since the variables cited in the quote are generally thought to determine movements in exchange rate, one would expect new information about these variables to move exchange rates in the short run through expectations. Some initial evidence that "news" or "innovations" in the relevant variables moves exchange rates is reported in Dornbusch (1980) and Frenkel (1981b). More evidence is presented in section VI below.

This paper presents a model that integrates money, relative prices, and the current account balance as factors explaining movements in nominal (effective) exchange rates. Thus money and the current account are the proximate determinants of changes in real (effective) rates. In section II we present the basic model with static expectations. It is an extension of Branson (1977) to include explicitly exogenous disturbances to the current account.[1] The result is gradual adjustment of the real exchange rate following a current account disturbance. In section III we introduce (rational) expectations, and see that the nominal (and real) rate should be expected to jump instantaneously in response to new information or "innovations" in money, the current account, and relative prices.

In sections IV - VI we study the quarterly data on effective exchange rates, relative prices, money and the current account for four countries -- the U.S., the U.K., Germany and Japan -- since 1973. Section IV describes the time-series properties of the data. All are approximately first-order autocorrelations <u>except</u> all relative prices and Japan's effective exchange rate and current account balance. These are second-order autocorrelations. We see in section V that purchasing power parity does not hold in the short run. This confirms evidence presented, for example, by Frenkel (1981a).

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[1] Readers familiar with that model can easily skip the first seven pages of section II.

Finally, in section VI we see the results of estimation of vector autoregressions (VARs) among the four variables for each country. The residuals from these equations are the "innovations" in the data -- the current movements not predicted by the past. The correlations amongst these innovations provide a test of the theory; we would expect a systematic relationship between innovations in money, current account balance, relative prices and the effective exchange rate. These correlations are shown in Tables 10 and 11. They are generally consistent with the theory of sections II and III.

Thus the broad conclusion from the paper is that the theoretical consensus expressed by the OECD, which integrates money, the balance on current account and relative prices, is consistent with movements in these variables since 1973. Real exchange rates adjust to real disturbances in the current account, and time-series innovations in the current account seem to signal the need for adjustment.

II. The Asset-Market Model with Static Expectations.

II.A. Introduction

The literature of the 1970s has identified three 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. We begin by specifying the underlying economic structure with static expectations. Then in section III below rational expectations concerning movements in the exchange rate are introduced.

The model is an extension of the asset-market model sketched in Branson (1975), and developed in full in Branson (1977, 1979a). There the focus was on the roles of relative prices and asset markets, mainly in the short run. Here the model is extended to study the effects of underlying "real" disturbances influencing the current account balance, with price dynamics specified explicitly.

II.B. Asset-market equilibrium in the short run.

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, net holdings of domestically-issued assets B, which are denominated in home currency, and net holdings of foreign-issued assets F, which are denominated in foreign exchange._/ B (for bonds) is essentially government debt held

_/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 "US" for 'home country', 'dollar' for 'home currency' and 'Fed' for 'central bank'.

by the domestic private sector. F (for foreign assets) is the net claims on foreigners held by the domestic private sector. The current account in the balance of payments gives the rate of accumulation of F over time. The rate of accumulation of B is new government debt issue sold to the private sector, and the rate of accumulation of M is given by home central bank (Fed) purchases of government debt.

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 $W = M + B + eF$, 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 the three assets, M, B and F, to domestic holders are given at each point in time. Each can be accumulated only over time through foreign or domestic investment.[/] These interact with demands for the three assets in determining equilibrium values for the home interest rate r and exchange rate e. The demand for each asset

[/] 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.

depends on wealth, $W = M + B + eF$, 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) - (4).

(1) $M = m(r, \bar{r} + \hat{e})\cdot W.$

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

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

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

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 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:

$$m_1 + f_1 = b_1 < 0: \qquad m_2 + b_2 = f_2 < 0.$$

Here a subscript denotes a partial derivative. The three market equilibrium conditions (1)-(3) contain two independent equations in e and r, given the balance sheet constraint. Any pair of (1)-(3), with W substituted from (4), can be used to determine short-run equilibrium values for e and r.

In this section the assumption of static expectations means $\hat{e} = 0$. In section III we will see the important difference that expectations make for the dynamic path to the long-run equilibrium.

We can study short-run equilibrium determination of the exchange rate and the interest rate holding $\bar{r} + \hat{e}$ constant, using Figure 1. There we show the pairs of interest rate r and exchange rate e that alternatively hold the demand for money equal to its supply (MM), the demand for domestic assets equal to their supply (BB), and the demand for foreign assets equal to their supply (FF). To obtain the slopes of MM and BB, consider what happens as e rises. This increases the home currency value of wealth W, increasing the demand for both M and B. As the demand for money rises, the equilibrium r that maintains demand for money equal to the fixed supply rises, giving the positive slope to MM. As the demand for domestic assets rises, this pulls up their price, depressing the equilibrium interest rate. This gives the negative slope to BB.

For the slope of FF, consider what happens as the home rate of return r rises. As the domestic r rises, the demand for foreign assets falls, and e falls as asset-holders attempt to sell F. This gives FF a negative slope. Since a given increase in r reduces the demand for F by

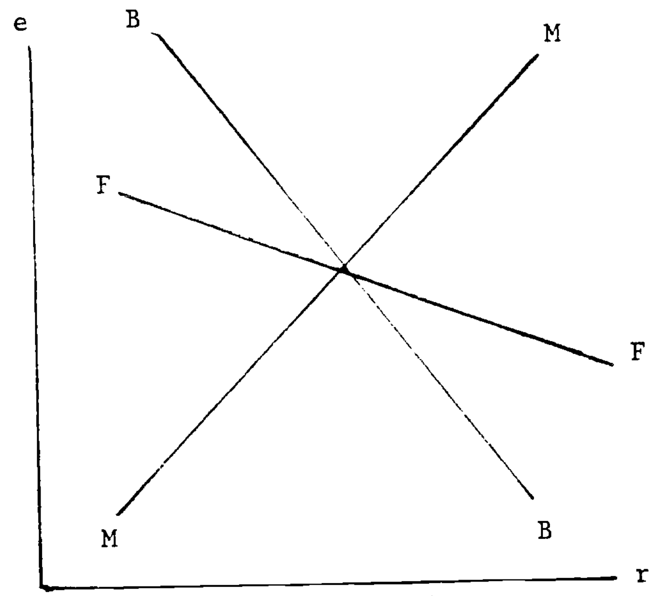

Figure 1: Short-run equilibrium in asset markets.

less than it increases the demand for B, a smaller drop in the exchange rate is required to restore equilibrium in the foreign asset market than would restore equilibrium in the domestic asset market. This makes BB steeper than FF.

Movements of equilibrium r and e can be analyzed by asking how the market-equilibrium curves of Figure 1 shift as monetary policy or the world rate $\bar{r} + \hat{e}$ or F shift for example. This analysis can be done by using any two of the three curves. Since the three assets sum to total wealth, if a given change in e and r restores equilibrium in two markets, it must in the third. Thus, since all three curves go through the same equilibrium r, e point (the one that yields equilibrium in all three markets simultaneously), we need to use only two to analyze changes in short-run equilibrium; the third will follow implicitly.

Short-run stability and comparative statics of the asset-market model in (1)-(4) are discussed in detail in Branson (1979a). There we see the effects of changes in the stocks of M, B, or F on equilibrium e and r using Figure 1.[/] The comparative static results are summarized in Table 1.

Table 1. Effects of increases in asset stocks on short-run equilibrium interest rate (r) and exchange rate (e).

	Effects of Accumulation of stocks			Effects of open-market operations	
Effects on	ΔM	ΔB	ΔF	$\Delta B = -\Delta M$	$e\Delta F = -\Delta M$
r	-	+	0	-	-
e	+	?	-	+	+

[/]Technically, we can put (4) for W into (1)-(3), totally differentiate any pair of these three, and solve for de and dr. This is done in the Appendix in Branson (1979a).

The entries in Table 1 give the direction of change of the interest rate and the exchange rate following (a) an increase in any one of the asset stock, holding the others constant, in the first three columns, and (b) an expansionary open-market operation, with M exchanged for B or for F, in the last two columns. One important implication of Table 1 is that an increase in the domestic money stock M, either through a budget deficit or an open-market operation, directly raises the exchange rate e. The increase in e is required for financial market equilibrium and should come quickly before any effects on the price level are seen. Thus, in the short run the exchange rate is determined by financial market equilibrium, not only by relative prices. A second important implication of Table 1 is that if the country is running a surplus on current account, so that net foreign assets F are increasing, this tends to reduce the exchange rate; a deficit in current account, with F falling, raises the exchange rate. This is the key to dynamic adjustment of the exchange rate as we move from short run to long run.

The short-run comparative statics of Table 1 yield an implicit reduced-form equation for the exchange rate:

(5) $e = e\ (F, M; B);\ e_F < 0;\ e_M > 0.$

This gives the <u>instantaneous</u> equilibrium value for e as a function of the supplies of the relevant assets. The partial derivatives e_M and e_F <u>are</u> comparative-static solutions de/dM and de/dF.—/ An increase in M raises

—/The precise equation for de from the comparative statics can be obtained by total differentiation of (1) and (2) and inversion to solve for de:

$$(5') \qquad de = [F(bm_1 - mb_1)]^{-1} \cdot \left\{ \begin{array}{l} -\ [b_2(1-m) - m_1 b]dM \\ +\ [b_2 m - m_1 b]edF \\ +\ [b_2 m + m_1(1-b)]dB \end{array} \right\}$$

e_F from (5) is the coefficient of dF in (5'), and e_M is the coefficient of dM. See Branson (1979a), Appendix equation (A.11).

instantaneous equilibrium e, and an increase in F reduces it. Inspection of the system (1)-(4) with $\hat{e} = 0$ (static expectations) shows that the elasticity of e with respect to F, $e_F \cdot F/e$, is -1. The variables e and F enter only multiplicatively.

II.C. Dynamics and Long-run Equilibrium

II.C.1 The Adjustment Mechanism

In the short run the exchange rate is determined by requirements of asset-market equilibrium, giving existing stocks of money, domestic assets, and foreign assets. But this is not the end of the story. The value of the exchange rate at one point in time, t(0), given income, the domestic price level, and other real variables, may yield a nonzero balance on current account. With flexible exchange rates and no central bank intervention in foreign exchange markets, the sum of the balances on capital account and current account is identically zero. Thus, a nonzero current account balance implies an equally nonzero capital account balance of the opposite sign. If the current account shows a surplus, the capital account is in deficit and the private sector is accumulating foreign assets; F is increasing. If the current account is in deficit, F is decreasing. As F changes, the exchange rate changes through the short-run mechanism of subsection B. Thus, if the initial value of the exchange rate e(0), yields a nonzero current account balance, F is either increasing or decreasing, moving e from e(0). The point of this section is to study the dynamic adjustment through the current account, and to show the condition under which it leads to a stable long-run equilibrium value for e where the current account balance is zero and the stock of net foreign assets is not changing.

In addition to the exchange-rate dynamics, the price level presumably responds to changes in the domestic money stock, but with a lag. For price dynamics, we follow Dornbusch (1976) in assuming slow adjustment of the price level to monetary shocks. We also assume that in the long run, the price level changes proportionately to the money stock; the economy is homogeneous in monetary variables. Rather than specify the entire domestic economy, I will assume long-run homogeneity and gradual adjustment of the price level.[/]

[/]Readers interested in the underlying model of the economy might consult Branson (1979b, ch. 7).

The technical analysis of dynamic adjustment will be presented in this subsection. Then in subsections II D and II E we will describe the response of the system to monetary and real shocks.

The assumption on price dynamics is captured simply by

$$\frac{dp}{dt} \equiv \dot{p} = \lambda(m-m^{*}). \tag{6}$$

Here $m = M/p$, and m^{*} is the equilibrium value of real balances corresponding to long-run equilibrium output. Equation (6) says that if it is increased, raising m above m^{*}, the price level will rise to restore $m = m^{*}$.[/]

[/]This is a formalization of the argument on price-level adjustment in Branson (1977, 1979a).

The other dynamic equation is provided by the balance-of-payments identity. With no central bank intervention, and thus zero change in reserves, the capital account and current account must sum to zero:

$$0 \equiv X + \bar{r}\,F - \dot{F}\ .$$

Here X is net exports of goods, $\bar{r}F$ is income on net foreign assets, and $\dot{F} \equiv dF/dt$ is the rate of accumulation of net foreign assets, the rate of capital outflow. This gives us an expression for $\dot{F}$:

$$\dot{F} \equiv X + \bar{r} F .$$

Net exports, in turn, depend on the real exchange rate e/p, and an exogenous shift factor z. The real exchange rate here is the relative price of foreign to home bundles of goods, $e\bar{p}/p$, with the foreign price level $\bar{p}$ set equal to unity. An assumption of purchasing-power-parity (PPP) would impose constancy on $e\bar{p}/p$, as e follows exactly the path of $p/\bar{p}$. This assumption has not held in the 1970s, but we will see below that it may be a reasonable description of the average long-run path of e.[/]

[/] See Katseli (1979) and Frenkel (1981a) for the breakdown of PPP in the 1970s.

The exogenous shift factor z represents real events such as changes in tastes or technology, oil discoveries, etc., that increase net exports (in foreign exchange terms) for a given value of e/p. Thus we write

$$X = X(e/p,z); \; X_e > 0 \; ; \; X_z > 0 .$$

An increase in e/p is a real devaluation; $X_e > 0$ assumes the Marshall-Lerner conditions held in the short run.

With the reduced-form expression for e and the exports function both included, the dynamic equation for $\dot{F}$ is now

$$(7) \quad \dot{F} = X[e(F,M;B)/p,z] + \bar{r} F .$$

The variable B is not of interest here. M and z are exogenous to the dynamic system given by (6) and (7). F and p are the slowly-adjusting state variables, and e can jump in the short-run in response to changes in F and M.

II.C.2 Long-run Equilibrium

The long-run equilibrium conditions are $\dot{p}$ and $\dot{F} = 0$ in equations (6) and (7). The implication for long-run movements in p have already been assumed. The price level moves proportionately to changes in M.

The effect of an increase in z is more interesting. From (7), an increase in z initially generates a current-account surplus, $\dot{F} > 0$. As F accumulates, e falls as shown in the short-run comparative statics. This reduces X and $\dot{F}$. When X has fallen to its initial value, $\dot{F}$ is still positive, since F has increased. Therefore e must fall further, until the reduction in X just outweighs the increase in $\bar{r}F$. Thus because income on foreign assets is part of the current-account balance, the exchange rate must appreciate enough to offset the original increase in z plus the increase in investment income due to accumulation of F between equilibria.

II.C.3. Dynamic Stability

Equations (6) and (7) for $\dot{p}$ and $\dot{F}$ can be combined and linearized into the system:

$$(8)\quad \begin{pmatrix} \dot{F} \\ \dot{p} \end{pmatrix} = \overbrace{\begin{bmatrix} X_e e_F + \bar{r} & -X_e \\ 0 & -\lambda \end{bmatrix}}^{S_M} \begin{pmatrix} F - F_0 \\ p - p_0 \end{pmatrix} + \begin{bmatrix} X_z & X_e e_M \\ 0 & \lambda \end{bmatrix} \begin{pmatrix} z - z_0 \\ M - M_0 \end{pmatrix}$$

A sufficient condition for stability is that $X_e e_F + \bar{r} < 0$. This is the "super Marshall-Lerner" condition in Branson (1977). X_e is positive and e_F is negative. Their product is the effect of F accumulation on X, through the normal Marshall-Lerner effect. This must be large enough to offset the effect of rising F or $\bar{r}F$ to ensure stability.

If this super Marshall-Lerner condition holds, this system moves towards its long-run equilibrium monotonically after a disturbance to M or z. This can be seen from the form of the stability matrix S_M in (8). The roots of the system that govern its dynamics are simply the diagonal elements, both real and negative. This insures monotonic stability.[/]

[/] I did not see this when I said in Branson (1977, 1979a) that adjustment is not necessarily monotonic.

Thus the super-Marshall-Lerner stability condition insures long-run stability. Thus reassured, we can move on to describe adjustment in reaction to monetary shocks on M or real shocks to z.

II.D. The Effect of a Monetary Disturbance

The analysis of short-run comparative statics of section II.B and of the dynamic adjustment in section II.C, can now be combined to study the effect of monetary disturbances. We will follow the path of adjustment of the exchange rate following a one-time shift arising in the monetary sector. Such a disturbance could originate on the supply side, owing to a shift in monetary policy or the supply behaviour of the banking system, or on the demand side, owing to a shift in the public's demand for money. A sudden decrease in the demand for money, at initial values for exchange rates and interest rates, should produce the same results as an increase in the supply of money, due to monetary policy, for example. In the discussion below, we will focus on the example of an increase in the money supply (expansionary open-market operation). The result would be equally applicable in the event of a reduction in money demand.

We begin with the effects on the domestic price path of a monetary shift. This is the underlying path about which the exchage rate is moving as the current account adjusts. Then we move on to study the impact and adjustment effects on the exchange rate, relative to the price path.

Following equation (6), the price level will rise in response to the excess level of real balances, moving to a new equilibrium where the price level has increased proportionately to the increase in the money supply. This is shown in Figure 2. The domestic price level begins at an initial equilibrium value $p^{*}(0)$, indexed to 1.0 at time t(0). It rises to a new equilibrium value p^{**}, where $dp/p = dM/M$. This is the price

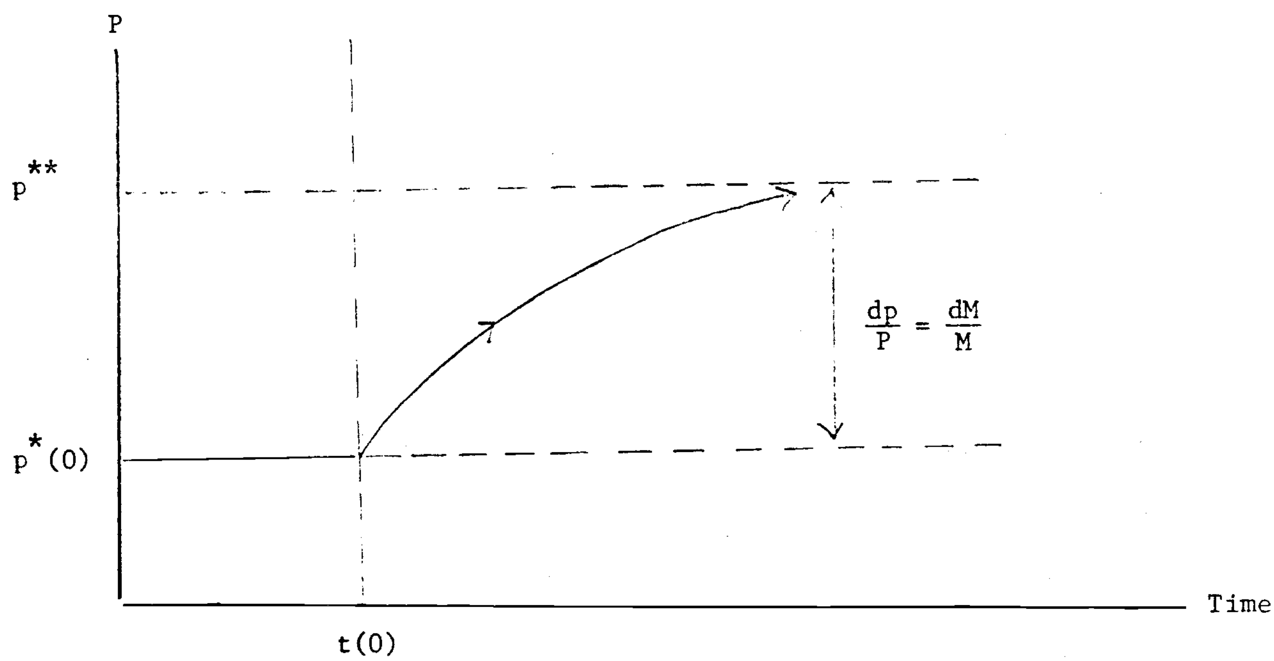

Figure 2: Adjustment of the domestic price level.

path around which the exchange rate e adjusts.

Next we turn to the path of exchange-rate adjustment. We begin with the system in full equilibrium, with the current account balance zero, so that $X(e/p,z) = -\bar{r}F$, with given initial stocks of M, B, and F. We want to trace the path of the exchange rate following an initial increase in the money supply, through an open-market operation. To avoid the second-order complications that came from a reallocation of investment income on foreign assets between the private sector and the government if the open-market operation is done in the foreign exchange market, we will focus on the case where $\Delta B = -\Delta M$: an open-market operation in government debt. Again, the effects of a downward shift in the demand for money would be the same. The result of a contraction of supply or increase in demand would be symmetrically opposite.

The initial effect of the increase in the money stock is an upward jump in the exchange rate, to maintain asset market equilibrium. This is the increase shown in Table 1. Figure 3 shows the adjustment path of the exchange rate, superimposed on the price path of Figure 2. Initially, e^* and P^* are normalized to 1.0. The increase in the money stock pushes the exchange rate up to e_1 instantaneously. The next step is to trace the dynamic adjustment path as net foreign assets accumulate.

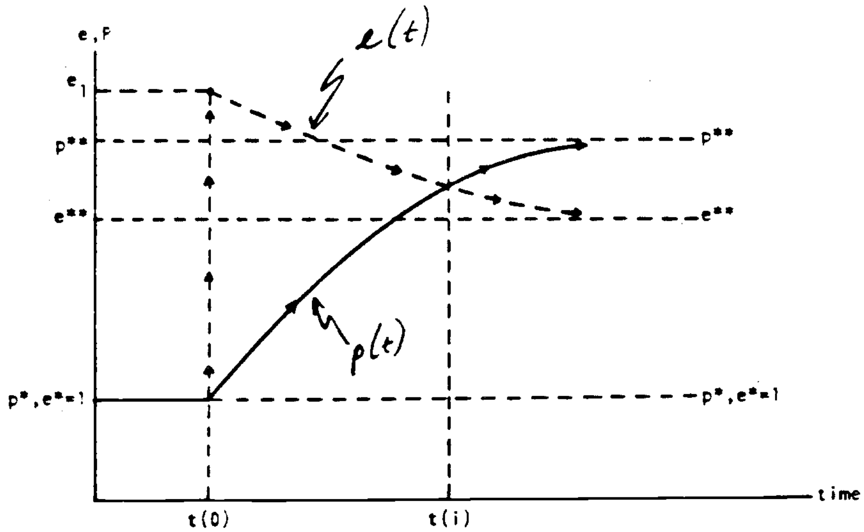

Figure 3: Adjustment of price level and exchange rate to an increase in M.

At e_1 in Figure 3, the price ratio (e/P) has risen above the e^*/P^* value that gave $\dot{F} = 0$ at the original value of F at time t(0). In the initial equilibrium at t(0), the current account balance was zero. After the increase in the money supply, with F still at F(0), the price ratio rises to $e_1/P^*) > (e^*/P^*)$. Assuming the Marshall-Lerner condition holds, the movement on the price ratio increases net exports, so that the current account becomes positive at t(0), and net foreign assets F begins to accumulate. As F increases, e falls and X falls, following the dynamic adjustment path discussed in section II.C, and shown in Figure 3.

With F accumulating, at a decreasing rate since the current account surplus is shrinking, the exchange rate follows the e(t) path in Figure 3 converging toward the rising p(t) path. At the point t(i) where the paths cross, the price ratio e/p is the same as the original $e^*/p^* = 1$. This implies that at the crossing point t(i) where e(t) = p(t), net exports have fallen to their original value. But since F has accumulated in the interval between t(0) and t(i), the current account balance is positive at t(i) due to the increase in investment income from $\bar{r}F(0)$ to $\bar{r}F(i)$. Thus, at t(i), where e(i) = p(i), F is still accumulating and e must fall further. It falls until the price ratio e/p reaches the valu- where $X(e/p,z) = -\bar{r}F$ once again. At that point the current account balance is zero, and the adjustment process is completed. There has been an accumulation of foreign assets and a concomitant increase in investment income, and the ratio e/p has decreased so that the net export deficit just offsets the investment income in the balance on current account.

Given the long-run equilibrium value P^{**} in Figure 3, the exchange rate has settled at e^{**}, such that $e^{**}/P^{**} < e^{*}/P^{*}$.

II.E. The Effect of a Real Disturbance (in z)

Let us now consider the effect of an increase in the current-account balance due to exogenous real factors, represented by z in the net export function. Beginning from an initial equilibrium, the current account balance suddenly increases, making $\dot{F}$ positive. Foreign assets accumulate, since the current-account surplus is net foreign investment. The accumulation of F drives e down; the real exchange rate appreciates. This in turn reduces the current account surplus.

Movement of e around the original (and unchanged) equilibrium p^* is shown in Figure 4. The increase in z at time t(0) makes $\dot{F}$ positive. This causes e to begin to fall (an appreciation). At some point t(j), e has fallen enough to restore X to its initial value, but because F has accumulated, e must fall farther. It falls to the new value e^{**} where the current-account balance is again zero. The appreciation of the real exchange rate e/p must reduce X enough to offset the initial impulse from Z plus the accumulation of F between equilibria.

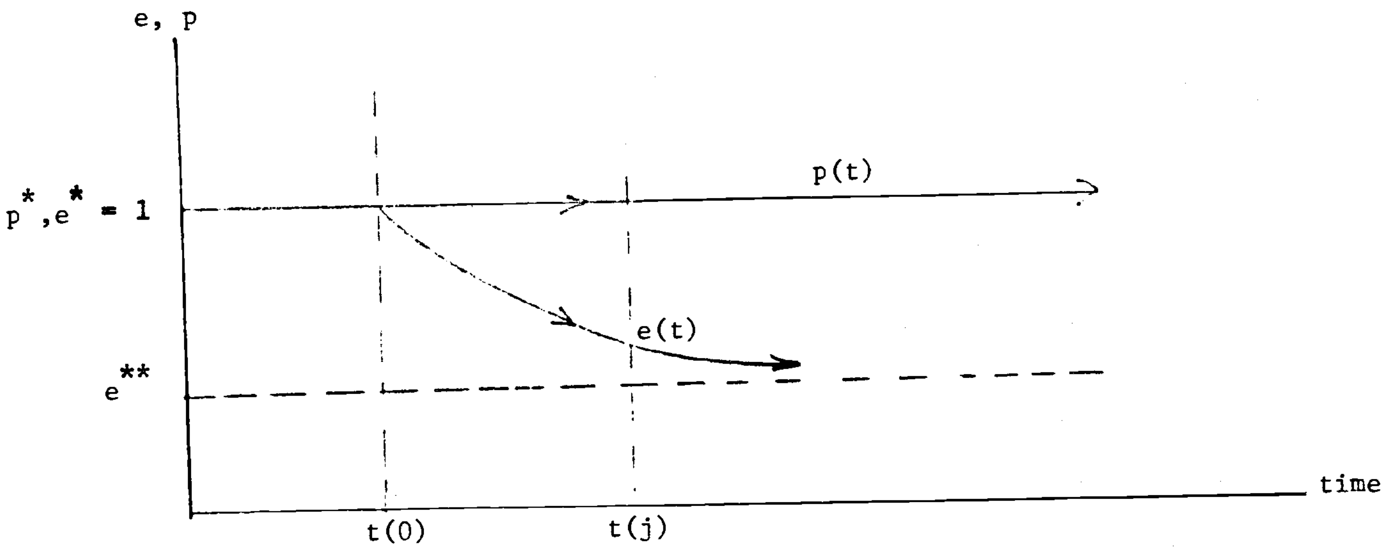

Figure 4: Adjustment of the real exchange rate to an increase in z.

II.F. Conclusions from the Theory with Static Expectations.

The patterns of relationships between the key variables as the system is disturbed by random monetary and real shocks can be summarized easily. Since we are assuming static expectations, it does not matter whether disturbances are anticipated.

1. Monetary disturbances cause an initial jump in the nominal and real exchange rates, which is reversed as the accumulation dynamics take over. The long-run effect of any single shock is a movement in the real exchange rate e/p due to the change in the foreign asset position between equilibria. If monetary shocks are repetitive and random, this will produce random movement in the real exchange rate, related to F.

2. Real disturbances to the current account, represented by z, will cause a gradual adjustment of e relative to p, with static expectations. The adjustment must not only offset the initial effect on X from dz, but also offset the resulting accumulation of F. If real disturbances are repetitive and random, this will also generate random movement in the real exchange rate.

3. Current-account surpluses will generally be associated with an appreciating currency, and deficits with a depreciating currency, under either source of disturbance.

4. The PPP path $\bar{p}/p$ will be the long-run average around which the exchange rate e moves as the system is hit by monetary or real disturbances. The PPP path does _not_ determine short-run movements in e, but may serve as a long-run anchor in the absence of "permanent" structural change.

III. Rational Expectations and the Current Account

III.A. Introduction

In section II we saw that with static expectations the nominal and real exchange rates adjust gradually to a current-account disturbance. The path of the exchange rate follows the accumulation path of net foreign assets. Technically, the exchange rate can be solved in short-run equilibrium as a function of the levels of the asset stocks. This was possible because the assumption of static expectations eliminates the term in expected change in the exchange rate $\hat{e}$ from the asset-demand functions.

When we move to the assumption of rational expectations, we restore the $\hat{e}$ term, and obtain a separate equation for the path of the exchange rate. This will result in a model with two dynamic equations--for $\dot{F}$ and $\hat{e}$. The rational expectations assumption--here literally perfect foresight because the model is non-stochastic--imposes the condition that the expected change in the rate is the actual change.

The main characteristic of the rational expectations version of the model is that since the market looks ahead to the consequences of a current account disturbance, the exchange rate jumps at the time when the change is perceived. Some of the gradual adjustment of e is pulled forward into a jump in the present with rational expectations.

In the next subsection we go through the technical aspects of solution of the rational expectations version of the model. Then, using the basic diagram in Figure 8 below, in subsection III.C we will discuss the implications of the model for the effects of current-account disturbances on the nominal and real exchange rates.

III.B. Solution of the Model

The model begins with the original equations for the financial sector plus the dynamic adjustment equation for $\dot{F}$. These are repeated here for convenient reference.

(1) $M = m(r, \bar{r} + \hat{e})\cdot W$

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

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

(4) $W = M + B + eF$

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

The dynamics with separate equations for $\hat{e}$ and $\dot{F}$ are sufficiently complicated that in this section we will suspend the $\dot{p}$ equation and take p as exogenous. This will permit us to focus on the relationship between the current-account and the exchange rate (real and nominal).

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. 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:

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

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

These can be solved in matrix form as:

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

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

$$d\hat{e} = \frac{1}{(+)} [-m_r d(\frac{eF}{W}) + f_r d(\frac{M}{W})] .$$

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

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

This is the dynamic equation to be solved along with (5) for $\dot{F}$ to obtain equilibrium e and F.

In the e, F space of Figure 5, the $\hat{e} = 0$ locus is a rectangular hyperbola. This can be seen by observing that in ϕ, eF enter multiplicatively (in W as well as the numerator eF), so changes in e and F that hold the product eF constant will hold $\hat{e}$ constant. Combinations of e and F off the locus move e away from it, as the arrows show. for example, since $\phi_1 > 0$ an increase in e or F from a point on the locus makes $\hat{e} > 0$.

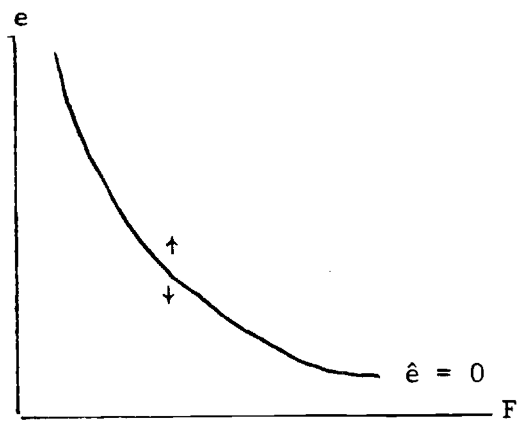

Figure 5: Locus where ê = 0

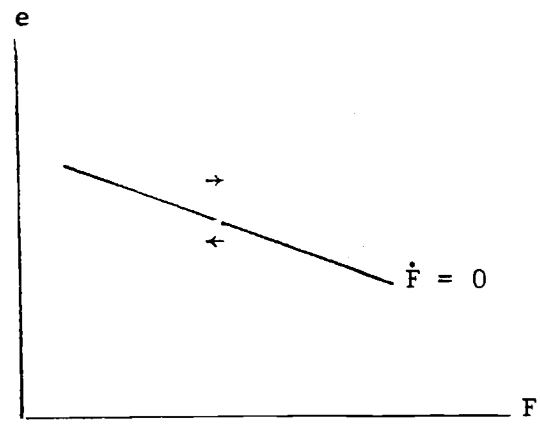

Figure 6: Locus where Ḟ = 0

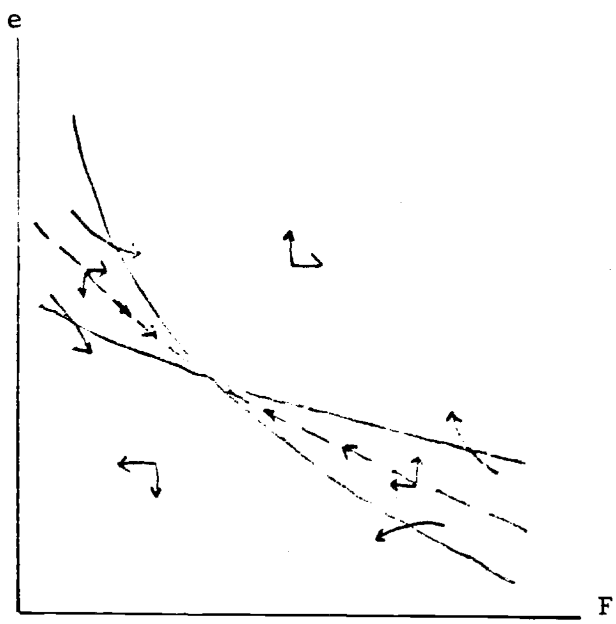

Figure 7: Equilibrium path for e, F

The $\dot{F} = 0$ locus in Figure 6 gives e, F pairs from equation (7) that hold F constant. Total differentiation of (7) gives the slope

$$\frac{de}{dF}\Big|_{\dot{F}=0} = \frac{-\bar{r}}{X_e}$$

Combinations off the F = 0 locus move F away from it. In (7) we see that an increase in F from a point on $\dot{F} = 0$ results in $\dot{F} > 0$.

The equilibrium is shown in Figure 7. With the $\dot{F} = 0$ locus flatter than $\hat{e} = 0$, the equilibrium is a "saddlepoint." There is one path into the equilibrium point, shown as the dotted line. Any initial e, F choice will lead away from equilibrium, as indicated in the figure. A basic assumption in rational-expectations models is that following a disturbance the market will pick the value for e that puts the system on the stable path to the equilibrium.

If the $\dot{F} = 0$ locus is steeper than $\hat{e} = 0$, the system is completely unstable. The slope of $\dot{F} = 0$ is $-\bar{r}/X_e$, and since $\hat{e} = 0$ is a rectangular hyperbola, its slope is given by

$$\frac{de}{dF}\Big|_{\hat{e} = 0} = -\frac{e}{F}\ .$$

Saddle-point equilibrium therefore requires

$$-\frac{e}{F} < -\frac{\bar{r}}{X_e}$$

Since along $\dot{F} = 0$, $\bar{r}F = X$, this condition for stability in the rational-expectations version of the model is the ordinary Marshall-Lerner condition, $eX_e/X > 1$. If this condition holds, following a disturbance the exchange rate will initially move in the right direction.

Now consider the effect of an increase in z, the real current-account disturbance in (5) for $\dot{F}$. In Figure 8 the rise in z shifts the $\dot{F} = 0$ locus down. Why? The rise in z requires an offsetting fall in e or F in equation (5) to hold $\dot{F} = 0$. The new long-run equilibrium is at point E_2, with a saddle path running to it as indicated by the dashed line. To put the system immediately on that path with initial F_0, the market appreciates the currency from E_0 to point E_1 in a jump. Then the e, F dynamics carry the system to E_2, with F accumulating and e appreciating further.

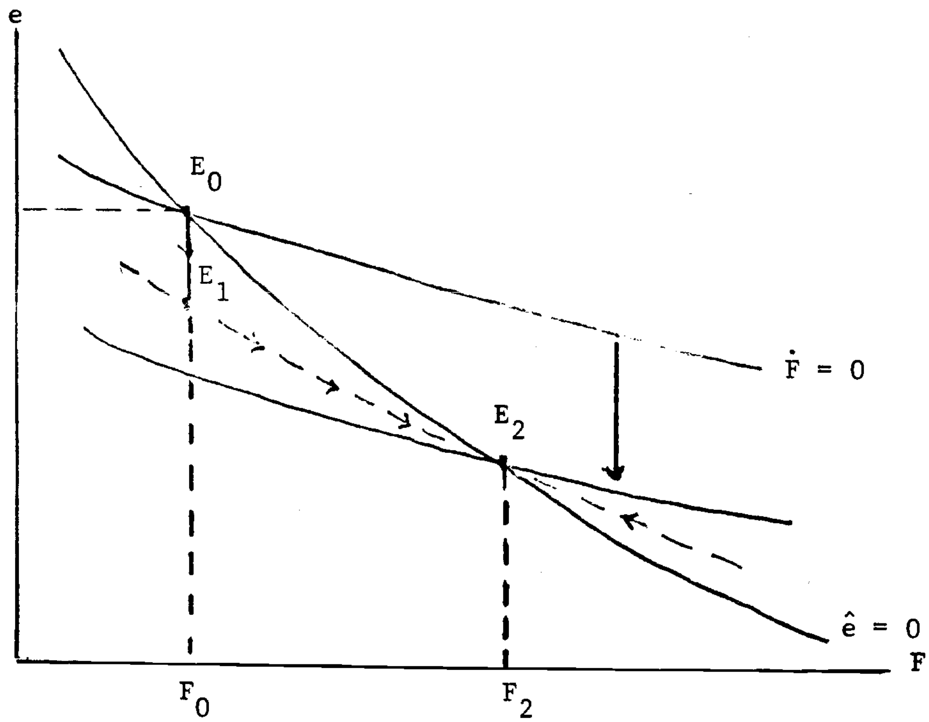

Figure 8: Effect of Current-account Disturbance

Referring back to the financial market equations (1)-(4), we see that the jump in e reduces eF, while the expectation of further appreciation, $\hat{e} < 0$, reduces demand for eF. Thus the jump in e is needed to maintain market equilibrium with (rational) expectations of appreciation of e in the adjustment process.

In the new long-run equilibrium e has fallen relative to p enough to offset the effect of the exogenous disturbance z on net exports X <u>plus</u> the increase in foreign earnings $\bar{r}(F_2-F_0)$. Thus the real disturbance to the current account causes an adjustment in the real exchange rate e/p that comes in an initial jump, then a continued gradual movement to long-view equilibrium.

The same figure can be used to analyze the effects of an (exogenous) change in the domestic price level p. A fall in p (relative to the foreign price level) will shift the $\dot{F} = 0$ locus down by stimulating net exports. This will then give a jump appreciation from E_0 to E_1, and further appreciation to E_2. Again, the value of the real exchange rate at E_2 is lower than it was at the initial equilibrium, in order to increase the trade deficit enough to offset the rise in investment income $\bar{r}(F_2-F.)$.

III.C. Current Account Disturbances and Exchange Rate Fluctuations

The important implication of the rational expectations model is not the necessary precision with which the market chooses the saddle point path. Rather, it is the result that disturbances with foreseeable implications for the exchange rate will cause the rate to jump when the disturbance appears. Thus in addition to jumps when unanticipated changes in monetary policy appear, their rate will jump in reaction to real disturbances to the current-account balance.

This modifies the conclusion from section II concerning real disturbances and the exchange rate. An unanticipated increase in the current account balance creates an expectation of appreciation of the nominal and real exchange rate to move the current account back to equilibrium. The expectation itself causes a jump appreciation of the nominal rate, which is also an appreciation of the real rate. After the jump, there is further movement to long-run equilibrium.

Thus unanticipated changes in the current account balance, as well as the money stock, are likely to generate jumps in the exchange rate. In the case of the current account, the jump is not reversed, however. If disturbances are random, we still expect the exchange rate to fluctuate around the PPP path. This would make the real exchange rate roughly follow a random walk. Jacob Frenkel (1981b) provides evidence supporting this view.

In addition, major structural shifts in the world economy, such as the recovery of Europe and Japan after World War II, or the rise of the newly industrializing countries (NICs) in the developing world, would b- expected to cause permanent shifts in the equilibrium real rate. In Branson (1980) it is argued that the major real devaluation of the U.S. dollar in the 1970s resulted from the change in the structure of the system as Europe and Japan recovered and grew relative to the U.S.

IV. The Data

IV.A. Introduction.

The asset-market model of sections II and III implies that unanticipated movements in the money stock, the current-account balance, and relative price levels will cause unanticipated jumps in the exchange rate. In this and the following two sections of the paper, we show that the model is consistent with the data on these variables for four major currencies--the U.S. dollar, the Deutschemark, sterling, and the yen. We study movements in the effective exchange rate of each of these countries, as calculated by the IMF. For each country, movements in the effective rate are related to movements in M1 or M3, the balance on current account, and an index of relative prices, measured by the Wholesale Price Index and weighted by the IMF. The data are described in detail in Table 2.

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 focus on the PPP relationship between relative prices and exchange rates. In section VI 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:

$$(10) \qquad X_t = \alpha_0 + \sum_{i=1}^{I} \alpha_i X_{t-i} + \sum_{j=1}^{3} \beta_j D_j + \gamma t + u_t \ ,$$

Table 2: VARIABLE DEFINITIONS AND DATA

I. Variable Name

e	effective exchange rate, in units of foreign currency per unit of home currency
$P/\bar{P}$	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

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).

where X_t is the log of the time series under consideration, X_{t-i} is its value lagged i quarters, D_1 is a seasonal dummy, and t is time. Equation (10) 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 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 money, current account, and relative price 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 3 through 6, 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 1974-I 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 [see Branson (1980)], and the last date was the most recent for which data were available when we began the study in June 1981.

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 3, we show the

TABLE 3: UNITED STATES AUTOREGRESSIONS (STD. ERRORS IN PARENTHESES)

	TIME SERIES									
LAGS	e		$P/\bar{P}$		M1		M3		CAB	
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)
t-2	-0.24 (.29)	----	-1.41* (.38)	-0.60* (.16)	0.31 (.27)	----	0.33 (.27)	----	-0.19 (.30)	----
t-3	0.37 (.28)	----	0.74 (.38)	----	-0.16 (.29	----	-0.22 (.30)	----	0.13 (.30)	----
t-4	-0.24 (.19)	----	-0.20 (.21)	----	0.22 (.24)	----	-0.08 (.24)	----	-0.20 (.22)	----
STATISTICS										
R^2	0.86	0.85	.92	.90	.99	.99	.99	.99	.76	.74
D-W	1.89	1.82	2.16	1.51	1.57	1.96	1.98	2.15	1.86	1.66
SE	0.027	.026	.008	.009	.012	.012	.009	.008	1.96	1.91

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, $\dot{P}/\bar{P}$ is WPI).

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 on 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: $\Delta e_t = .78u_t$; $\Delta e_{t+1} = .78^2 u_t$, etc. The "half-life" of the disturbance is just over 3 quarters.[/]

The third and fourth columns of Table 3 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 <u>International Financial Statistics</u>. It is the inverse of the "real exchange rate" of sections II and III.

The first regression for $P/\bar{P}$ in Table 3 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 "half-life" is the time needed for the initial disturbance to be reduced to half its initial size. It can be computed from

$$\ln 0.5 = -0.69 = -(1-\alpha_1)t,$$

where α_1 in this case is .078 and t is the half-life.

The result for $P/\bar{P}$ is a second-order autoregression (AR2), with a stable cyclical response to a disturbance.[/]

The next two pairs of columns in Table 3 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 with half-lives of 1.5 and 3 quarters, respectively.

Finally, the last two columns in Table 3 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: a first-order autocorrelation with a half-life of 3-1/2 quarters.

In the case of the U.S., then, money stocks, the balance on current account, and the nominal effective exchange rate all follow stable AR1 processes, while the relative price series is a cyclical AR2. This suggests that the behavior of money stocks, the current-account balance, and the exchange rate are consistent, at this level, with the theoretical model of sections II and III. These variables all follow stable AR1 processes. However, the relationship between relative price levels and the exchange rate is more complicated. The relative price series exhibits cyclical behavior while the exchange rate is monotonically damped.

_/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 $0.77 = 0.6^{1/2}$.

Thus there is not a one-to-one correspondence between price and exchange rate fluctuations, even in the 1974-80 period.

IV.C.2. West Germany.

Table 4 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. The German relative price series is AR2 with a stable cyclical response to disturbances._/ Thus the German data are quite similar to the U.S.

IV.C.3. United Kingdom

The U.K. results are summarized in Table 5. Again, the results are broadly similar to those for the U.S. and Germany, with one major exception. 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 innovations in the CAB in the U.K. should not be interpreted as conveying information about future movements in the exchange rate._/ This implication is reinforced by the vector autoregression results in section VI below.

_/Note that the German price equation would not invert due to multicolinearity with more than two lags.

_/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.

TABLE 4: GERMANY UNIVARIATE AUTOREGRESSIONS

LAGS	e		$P/\bar{P}$		M1		M3		CAB	
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)
t-2	-0.15 (.23)	----	----	-0.58* (.19)	0.23 (.25)	----	-0.10 (.30)	----	0.30 (.27)	----
t-3	0.37 (.23)	----	----	----	0.24 (.24)	----	0.24 (.30)	----	-0.15 (.28)	----
t-4	-0.29 (.18)	----	----	----	-0.32 (.19)	----	-0.50* (.24)	----	0.05 (.24)	----
STATISTICS										
R^2	.96	.96		.99	.99	.99	.99	.99	.82	.81
D-W	1.11	1.43		2.50	2.11	2.20	2.06	1.73	1.64	1.95
SE	.024	.024		.003	.020	.020	.009	.009	1.33	1.28

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

TABLE 5: UNITED KINGDOM UNIVARIATE AUTOREGRESSIONS

LAGS	e		$P/\bar{P}$		M1		M3		CAB	
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)
t-2	0.01 (.31)	----	-0.48 (.36)	-0.57* (.19)	0.21 (.25)	----	-0.04 (.29)	----	-0.02 (.26)	----
t-3	-0.02 (.30)	----	0.19 (.35)	----	-0.62* (.22)	----	-0.03 (.29)	----	0.02 (.27)	----
t-4	-0.10 (.23)	----	-0.20 (.19)	----	0.08 (.20)	----	-0.14 (.19)	----	0.06 (.24)	----
STATISTICS										
R^2	.94	.94	.99	.99	.99	.99	.99	.99	.50	.50
D-W	1.7	1.64	1.96	2.09	2.11	1.59	2.11	1.69	1.92	1.96
SE	.035	.033	.012	.012	.019	.024	.016	.016	912.71	853.07

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 again AR2, but with a stable monotonic adjustment response to disturbances.

IV.C.4. Japan

The results for Japan are summarized in Table 6. There we see major differences from the other three countries. The nominal effective exchange rate, the relative price series, and the current-account balance are all AR2 with stable cyclical response patterns. The two money stocks are AR1 with unitary lag coefficients. Thus in the Japanese case the time-series behavior of the exchange rate is consistent with that of relative prices and the current account, but the exchange rate does not follow the random-walk pattern of money.

IV.D. Summary on the Data

The univariate autoregressions of Tables 3 through 6 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.
3. All the exchange rate and current-account series except the Japanese are first-order autoregressions; the Japanese are second-order. Thus movements in the exchange

TABLE 6: JAPAN UNIVARIATE AUTOREGRESSIONS

	e		P/P̄		M1		M3		CAB	
t-1	1.18* (.22)	1.33* (.18)	1.24* (.20)	1.21* (.14)	0.79* (.22)	1.03* (.14)	1.03* (.22)	1.10* (.08)	1.25* (.22)	1.50* (.16)
t-2	-0.37 (.34)	-0.55* (.18)	-0.85* (.32)	-0.62* (.12)	-0.56 (.30)	---	0.26 (.32)	---	-0.32 (.37)	-0.67* (.16)
t-3	0.12 (.34)	---	0.45 (.32)	---	-0.04 (.31)	---	-0.21 (.32)	---	0.10 (.38)	---
t-4	-0.26 (.22)	---	-0.27 (.16)	---	-0.24 (.28)	---	-0.01 (.23)	---	-0.34 (.25)	---
STATISTICS										
R^2	.91	.90	.99	.99	.99	.99	.99	.99	.91	.90
D-W	1.74	2.06	1.82	1.81	1.77	2.42	1.79	1.96	1.85	2.17
SE	.044	.044	.014	.014	.023	.023	.008	.008	.97	1.00

rate are all consistent with movements in the current-account balance.

V. Purchasing Power Parity

Before moving on to a vector autoregression analysis of the data for the four countries, it is interesting to look directly at the relationship between exchange rates and relative prices. The IMF data comparing costs and prices provide us with effective exchange rates, e, and weighted relative WPIs using the same weighting system. Thus we can report regressions testing whether exchange rates followed relative price paths for the four countries in the 1974-80 period. These are summarized in Table 7.

In the table, we report regressions of the log of the effective rate on a constant, a time trend, and the log of the effective relative WPI. To allow for simultaneity between prices and exchange rates, the $P/\bar{P}$ term was replaced by an instrumental variable estimate, and the equations were adjusted for first-order serial correlation in the error terms.

If PPP held at all times, the coefficient of time would be zero, and that of $P/\bar{P}$ would be (-1) in Table 7. In no case does this pair of conditions hold. The closest case is the U.S., where the coefficient of $P/\bar{P}$ is - 1.09, but that of time is marginally significant. Even ignoring the difference between the AR1 in the exchange rate and AR2 in $P/\bar{P}$, PPP is violated in the U.S. case during 1974-80 by a divergent trend between e and $P/\bar{P}$. This could be due to measurement biases. In Branson (1980), it was shown that the major jump in the real exchange rate for the U.S. came in 1970-73; after 1974 a steady trend seems to be the dominant factor.

TABLE 7 : PPP REGRESSIONS, 1974-1980

COUNTRY	COEFFICIENTS OF			STATISTICS		
	Const.	Time	$P/\bar{P}$	R^2	ρ	D-W
U.S.	9.71* (2.49)	-0.004 (.002)	-1.09 (.55)	.86	.65* (.15)	1.83
U.K.	14.06* (1.66)	0.035* (.007)	-2.20* (.39)	.91	.58* (.16)	1.52
Germany	13.57 (9.37)	-0.013 (.023)	-1.88 (1.95)	.96	.83* (.11)	1.64
Japan	14.22* (4.10)	-0.007 (.009)	-2.06* (.86)	.91	.71* (.14)	1.43

Note: A Cochrane-Orcutt iterative technique with a two-stage least-squares estimation method was used; the instruments are lagged exchange rates, and lag-one and lag-two $P/\bar{P}$, a constant, time, and seasonal dummies.

In the U.K. and Japan, the coefficients of $P/\bar{P}$ are well above unity, and quite significantly so in the U.K. case. The U.K. also has a very significant time trend. In Germany, neither the time trend nor $P/\bar{P}$ is significant. This is consistent with Frenkel's (1981b) finding that the real exchange rate is AR1.

The regressions of Table 7 thus suggest that since 1974 a deviation-from-trend version of PPP may have held in the U.S., but that the relationship did not hold in the other three countries. This is consistent with the theoretical view of section II that the relative price path is at most a long-run average through the path of nominal exchange rates, even in periods of largely monetary disturbances.

VI. Empirical Results Using Vector Autoregression

A useful technique for studying the relationships between the innovations in money, the current account balance, relative price levels 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 section 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 are 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 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: 28 from 1974 I 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. Money stock data are available on a weekly basis, so they are roughly contemporaneous with the exchange rate 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.

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 $(P/\bar{P})_t$.

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, $(P/\bar{P})_t$, and CAB_{t-1}. We will use a $\sim$ to designate residuals from the VARs. The variables in each VAR system are listed in Table 9. The number of lags included in each variable was determined by the univariate autogression of Tables 3 through 6. 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 of the exchange-

TABLE 9: VARIABLES INCLUDED IN VECTOR AUTOREGRESSION SYSTEMS

US, UK, Germany	Japan
$\ln e_{t-1}$	$\ln e_{t-1}$
$\ln M_{t-1}$	$\ln e_{t-2}$
$\ln P/\bar{P}_{t-1}$	$\ln M_{t-1}$
$\ln P/\bar{P}_{t-2}$	$\ln P/\bar{P}_{t-1}$
CAB_{t-2}	$\ln P/\bar{P}_{t-2}$
	CAB_{t-2}
	CAB_{t-3}

NOTE: Two VAR systems are estimated for each country, one with M1, one with M3. The equations are estimated on data 1974I - 1980IV, described in Table 2.

rate residuals with those of the VARs for money, CAB, and relative prices are shown in Tables 10 and 11 for the systems using M1 and M3 respectively. Each row in the tables gives the correlation coefficient r of the exchange-rate VAR residual with the VAR residuals of the other three variables. Given the definition of the effective exchange rate as foreign exchange per unit of home currency, we expect the money correlations to be negative -- a positive M innovation lends to a depreciation -- the CAB correlations to be positive,and the $P/\bar{P}$ correlations to be negative.

In Table 10, which presents the correlations using M1, the first column shows the correlations of exchange rate and money stock residuals for each country. We see that only for the U.S. is the sign of the correlation negative. The positive correlations for the U.K. and Germany, and the near-zero are for Japan, are consistent with "leaning-against-the-wind" policy behavior, in which money growth slows when the currency depreciates, and vice versa. This type of policy reaction was discussed in Branson (1976), and policy reaction functions of this form were estimated for Germany by Artus (1976) and by Branson, Halttunen and Masson (1977). So the positive correlation in the German case is easy to understand. Similar policy behavior in Japan has been reported in Amano (1979), which could account for the low Japanese M1 correlation. A U.K. policy of moving the minimum lending rates to defend the currency would also be consistent with the positive U.K. M1 correlation in Table 10. When sterling depreciates, interest rates are raised and the rate of money growth is reduced.

The pattern of money correlations in Tables 10 and 11 reflects an asymmetry in policy behavior between the U.S. and the other three countries. If U.S. monetary policy is formulated with domestic targets in mind, then

TABLE 10: CORRELATION OF EXCHANGE RATE RESIDUALS AND OTHER RESIDUALS FROM VECTOR AUTO-REGRESSION SYSTEMS WITH M1

Correlation of $\tilde{e}_t$ of:	with own:	$\tilde{M1}_t$	$\tilde{CAB}_{t-1}$	$\tilde{P/\bar{P}}_t$
U.S.		-0.39	0.36	-0.37
U.K.		0.13	-0.14	-0.29
Germany		0.24	0.54	-0.32
Japan		0.03	0.24	0.11

TABLE 11: CORRELATION OF EXCHANGE RATE RESIDUALS AND OTHER RESIDUALS FROM VECTOR AUTO-REGRESSION SYSTEMS WITH M3

Correlation of $\tilde{e}_t$ of:	with own:	$\tilde{M3}_t$	$\tilde{CAB}_{t-1}$	$P/\bar{P}_t$
U.S.		-0.50	0.34	-0.34
U.K.		0.11	-0.03	-0.27
Germany		0.47	0.20	-0.50
Japan		0.13	0.39	0.28

U.S. money will be exogenous with respect to the exchange rate. This is the model of sections II and III, and gives the negative correlation. But monetary policy in the U.K., Germany, and Japan may be reacting to movements in the exchange rate, which would give a positive correlation. Thus the results are consistent with a view that U.S. monetary policy drives exchange rates, and the others react.

The CAB correlations should be positive, according to the theory of section III. It should be noted that since we are correlating the VAR residuals of e_t with CAB_{t-1}, the positive correlation will not reflect "J-curve" effects in which a current depreciation in e_t causes a reduction in CAB_t due to low trade elasticities. The small negative correlation in the case of the UK CAB is consistent with the univariate autoregression results of Table 5. There we saw that the UK CAB is approximately random about its trend, so that innovations in CAB do not contain any information about future movements in the real exchange rate. Thus the expected correlation for the UK CAB should be zero, which it approximately is.

The $P/\bar{P}$ correlations should be negative from the theory of section III where causation runs from $P/\bar{P}$ to e. However, they would also be negative if causation ran from e to $P/\bar{P}$ through the price of traded goods. Empirical evidence on the importance of this link is presented in Bruno (1978). Thus the negative correlations for $P/\bar{P}$ for the U.S., U.K., and Germany are consistent with the theory of section III, but could also result from reverse causation. Estimation of the relative strengths of the two effects will require more sophisticated econometrics. The positive correlation in the Japanese case is difficult to understand. The explanation may lie in the divergent behavior of export prices and the WPI in Japan, but analysis of that case will also require further work.

The correlation results of the systems using M3 are given in Table 11. They are essentially the same as the M1 results of Table 10. The correlation of the U.K. current-account balance is nearly zero, but the positive correlation for Japanese relative prices is larger than in Table 10.

In summary, it appears that the VAR results are (perhaps surprisingly) quite consistent with the theory of section III, which attempts to integrate money, relative prices, and the current-account balance into one framework explaining movements in exchange rates. The results are clearest for the effects of CAB innovations on exchange rates, supporting Dornbusch (1980). The money causation is less clear because of the plausibility of money reacting continuously to movements in e as suggested in Branson (1976). The relative price results are consistent with the theory but causation remains ambiguous due to dependence of domestic prices of traded goods on the exchange rate as shown by Bruno (1978). Thus the empirical results provide support for the theory, but there is much more econometric research to be done.

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