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EXCHANGE RATE BEHAVIOR UNDER FULL MONETARY EQUILIBRIUM: AN EMPIRICAL ANALYSIS

John H. Makin

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ABSTRACT

This paper aims to remedy difficulties with some extant empirical tests of the monetary approach to exchange rate determination. Four problems are addressed: explication of and allowance for real exchange rate changes; imposition of interest parity; use of the forward rate as an unbiased predictor of the spot rate; and modeling implications of official intervention in foreign exchange markets and of possible efforts to sterilize effects of intervention in the monetary base.

Empirical tests conducted with monthly data on the dollar-DM exchange rate from March, 1973 - December, 1979 do not permit rejection of the complex joint hypothesis represented by equations estimated to test the monetary approach. Still, there remained unexplained a large portion of the behavior of the dollar-DM exchange rate in the 1973-79 monthly sample employed. This result suggests that exchange rates may be viewed as prices determined in asset markets where a large and unsystematic flow of information, not captured by monetary or other variables, produces large, unsystematic movements.

Professor John H. Makin
Department of Economics, DK-30
University of Washington
Seattle, Washington 98195

(206) 543-5955 (5865)

Empirical tests of the monetary approach to exchange rate determination have not so far been very satisfactory. To my knowledge no study has yet attempted to incorporate, either in theory or testing, the fact that exchange rates have not ever been freely flexible and that the most recent episode of "floating" has seen widespread official intervention in foreign exchange markets. Sterilization has, in many instances, been evident as well.

Problems With Empirical Tests of the Monetary Approach

Further difficulties have persisted. Many tests of the monetary approach include an interest differential (or equivalently, given interest parity, a forward premium) among independent, "exogenous" variables which are to explain exchange rate behavior. Included in this group are studies by Bilson (1978, 1979), Hodrick (1978), Bisignano (1980) and Dornbusch (1980). Inclusion of an interest differential as an exogenous variable in an exchange rate equation is not consistent with imposing interest parity and unbiasedness of the forward rate as a predictor of the spot rate. Once these conditions, for which there is considerable empirical support, are imposed, a rational solution for an exchange rate does not involve an interest differential or forward premium. This is well-known and has been demonstrated by Bilson (1978, 1979) for freely flexible exchange rates and extended to the case of limited flexibility of exchange rates by Makin (1980). In fact, inclusion of an interest differential term is likely to cause rejection of the monetary approach. This will be demonstrated below.

One study by Caves and Feige (1980) properly incorporates implications of rationality into proposed empirical tests of the monetary approach. Unfortunately, however, Caves and Feige conduct all of their tests using relative money supplies instead of relative excess money supplies as specified by the monetary approach under rationality.

This study proposes to remedy some of these difficulties. Empirical results obtained so far, which are reported below, are consistent with monetary approach to exchange rate determination, though explanatory power of the estimated equations is not high. While tests of a single exchange rate, the DM-dollar rate, cannot be regarded as definitive, it is clear that, so far, empirical testing fails to contradict the hypothesis that foreign exchange markets are best viewed as securities markets where behavior of asset prices is largely determined by large and steady volume of new information, most of which is impossible to predict ex ante or even to measure systematically, ex post.

Alternatives to the Monetary Approach

An obvious alternative hypothesis to explain results obtained here would be that the monetary approach to exchange rate determination is an inadequate or crucially incomplete theory. Various forms of what may be called an "asset approach" to exchange rate determination are developed in Dornbusch (1980) and Dornbusch and Fischer (1980). While the asset approach embodies a useful extension of the fundamental monetary approach notion that exchange rates are determined by stock equilibrium conditions, it has in some cases been construed to imply abandonment of the monetary approach for what, it will be argued here, may be the wrong reasons. Further, in some cases there are advanced, alternative empirical tests which require fulfillment of a very complex joint hypothesis in order to test primary hypotheses about "asset approach" behavior.

In choosing to refine the monetary approach rather than follow the alternative asset approach this study expands that monetary-equilibrium-rational-expectations (MERE) model of Bilson (1978, 1979). The aim is to derive a MERE model which adequately represents to post-Bretton-Woods system of controlled and varying degrees of permissible flexibility of exchange rates.

Joint Hypothesis Under Monetary Approach

The MERE approach as developed here yields a reduced-form expression for an exchange rate, estimation of which involves testing a joint hypothesis maintaining simultaneous satisfaction of: (1) a stable demand function for money; (2) purchasing power parity (PPP); (3) interest parity; (4) the forward exchange rate as an unbiased predictor of the spot rate; (5) stable intervention and sterilization behavior; (6) representation of real exchange or interest rate changes which may occur and (7) a model employed to project expected future behavior of relevant exogenous variables.

Each of these hypotheses was tested separately using relevant monthly data from March, 1973 through December, 1979 for determinants of the U.S. dollar price of Deutsche Marks (DM). While none of the relationships held perfectly, most glaring inconsistencies arose from, first, the well-known failure of PPP in the presence of persistent real appreciation of the DM against the dollar and second, evidence of distinct episodes of altered intervention and sterilization behavior within the sample period. These matters are given close attention in tests of the MERE joint hypothesis conducted in Section 3.

Risk and "Real" Exchange Rates

Attention to riskiness of nominal assets as a determinant of real interest rates constitutes another part of the attempted extension of MERE under discussion here. Emphasis is placed upon riskiness of financial assets as a store of purchasing power over commodities. A rise in inflation volatility causes risk-averse holders of financial assets to demand a risk premium to compensate for uncertainty of purchasing power over commodities. The result is a rise in the real interest rate which adds to the positive impact upon nominal interest arising from a higher level of inflation. While the higher real rate is required for those whose purchases are largely denominated in local currency, it represents an above-equilibrium return for those (foreigners) whose commodity purchases are largely denominated in some other currency. If, for example, a rise in inflation-volatility in Germany relative to inflation volatility in the U.S. causes inflation level adjusted real returns (for U.S. investors) to rise in Germany relative to the U.S., the DM will appreciate. This proposition is tested with measures of U.S. and German inflation volatility. In effect, changes in relative inflation uncertainty are taken as a proxy for exogenous changes in real interest rates.

Overview

The plan of the paper is as follows. Section 1 presents a brief discussion of the relationship between MERE and the portfolio approach to exchange rate determination. Section 2 outlines the extended MERE theory of exchange rate behavior and derives a testable rational expression for an exchange rate. That expression is incorporated into a theory of international capital flows. Section 3 presents empirical tests of the MERE formulation of exchange rate behavior. Section 4 presents some concluding remarks.

1. MONETARY AND ASSET APPROACHES TO EXCHANGE RATE DETERMINATION

Asset Approach

An extensive comparison of monetary and asset approaches to exchange rate determination is presented in Dornbusch (1980). Offered here are comments on some of the more salient features of the distinction. Clearly, neither approach is superior in every respect. The monetary approach, which really is a restricted form of asset approach is more analytically precise and therefore lends itself more readily to refutation by empirical testing. Therefore, it may be preferable at a time when relatively little is known about explaining a large part of the observable movements in exchange rates.

Distinguishing features of the asset approach are: (1) dependence of money demand (and aggregate demand) on wealth in addition to income; (2) emphasis upon, though not a requirement of, imperfect substitutability of assets; (3) possible movements in real yields on securities traded internationally.

These features deserve some comment. Dependence of money demand on wealth and consideration of "real" yields leads to estimation of exchange rate equations which include proxies for these variables such as current account "surprises" employed by Dornbusch (1980). Both wealth and real yields are notoriously difficult to measure and so one always ends up testing the compound hypothesis that (a) the theory is correct and (b) one has properly measured some concept of wealth or real yields. In many cases this is unavoidable and, indeed, the "proxy-use-syndrome" appears later in this paper. Empirical tests discussed in Section 3 contain a proxy for real interest rates. But this is an "add-on" part of the investigation and not an integral part as it is with most empirical tests of the asset approach.

A basic reservation about the asset approach arises from the fact that an investigator ends up estimating exchange rate equations with numerous prefiltered series on "exogenous" variables on the right-hand-side. Using Dornbusch (1980) as an example, we find that exchange rate depreciation depends on:[1] (1) unanticipated current account imbalances: (2) unanticipated real output growth at home and abroad; (3) unanticipated (from autoregression) home-foreign interest differentials and (4) "residuals from a regression of (home-foreign) short term interest differentials on differentials between (home) and (foreign) country on long-term and short-term interest rates, unemployment rates, and inflation rates, with all explanatory variables lagged one period."[2]

This specification contains a very large number of maintained hypotheses regarding adequacy of various proxies for "news" about current account cyclical movements and interest rates, and requires that "unanticipated" movements, variously defined, of exchange rates and interest rate differentials are not simultaneously determined in a manner defined by the interest parity equation. While the proxy problem is impossible to avoid completely, it is necessary to recognize that use of "unanticipated" variables requires satisfaction of the hypothesis that the investigator has *ex post* measured "anticipated" behavior of variables as seen *ex ante* by decision-makers within the actual sample period under investigation. This may be a questionable assumption in view of the fact that most "unanticipated" filters are estimated using data from the full sample period under investigation which on average was only partially available to those whose expectations formations are being modeled.

Monetary Approach

The monetary approach to exchange rate determination is often rejected on the grounds that the purchasing power parity condition which it imposes is not empirically valid. While empirical failure of PPP is well-documented, this may not be the major difficulty with frequently reported tests of the simple monetary approach. Most descriptions of the monetary approach, like that of Dornbusch (1980), do not impose upon their formulations either interest parity or rationality (which follows from imposition of the condition whereby the forward rate is an unbiased predictor of the spot rate and then solving for the spot rate). As a result the exchange rate ends up being determined by relative excess money supplies and an interest differential (as in equation (3) of Dornbusch (1980)).

$$s = m-m^* - b(r^*-r) - h(y-y^*) \qquad (1)$$

where (all natural logarithms):

s = logarithm of spot exchange rate (home currency price of foreign exchange)

m = logarithm of nominal money

y = logarithm of real income

r = logarithm of one plus nominal interest rate

h = income elasticity of money demand

b = interest elasticity of money demand with respect to "r"

"*" denotes foreign

Note that interest parity implies

$$s - f = r^* - r \qquad (2)$$

where f = logarithm of forward rate. If we let

$$f = \alpha + \varepsilon \qquad (3)$$

where α = a constant

ε = random error term with mean zero and variance σ_ε^2

equations (2) and (3) imply:

$$s_t = \alpha + (r^* - r) + \varepsilon \qquad (4)$$

Equation (4) suggests that estimation of (1) with a constant term will, given interest parity, leave measures of relative excess money as redundant variables in what is really an interest parity equation.

Actual results may differ somewhat if (3) mis-specifies behavior of the forward rate and measures of relative excess money operate on it.[3] The result anticipated here is, however consistent with the finding by Dornbusch (1980) that the interest differential emerges as the only significant variable in an equation like (1) [with nominal interest rates in place of r].

An adequate representation of any theory of exchange rate behavior should impose the interest parity condition which represents steady state arbitrage in asset markets. This condition, with considerable empirical support, enters the forward rate into an equation such as (1). Then, representation of the forward rate as an unbiased predictor of the future spot rate enables a rational solution for the exchange rate exclusively in terms of exogenous determinants of all expected future values of the relative [home versus foreign] excess supply of money. This is the Bilson (1978, 1979) MERE solution which is extended below in Section 2 to include intervention and sterilization behavior.

Eliminating The PPP Problem

The monetary approach still suffers from the assumption of purchasing power parity which is not sustained by the data. An obvious way to deal with this problem, which will be employed in empirical tests of MERE, is to investigate the nature of "real" exchange rate behavior over the sample period under investigation. Write PPP as:

$$s_t = (p_t - p_t^*) + q_t \qquad (5)$$

where q_t is the log of the "real" exchange rate. For the dollar-DM exchange rate during the 1973-79 sample period, q_t follows a random walk (Box-Pierce test for autocorrelations: Q(12) = 17.9; Q(24) = 25.7; Q(36) = 34.6):

$$q_t = q_{t-1} + v_t \qquad (5.a)$$

where v_t = "white noise" residuals from an AR-1 model on q_t $(v \sim n, \sigma_v^2)$.

$$\Delta s_t = \Delta(p-p^*)_t + v_t \qquad (5.b)$$

Equation (5.b) indicates that PPP is satisfied by first differencing logs. All exchange rate equations reported below in Section 3 are estimated in log first-difference form.

2. A RATIONAL MONETARY MODEL OF EXCHANGE RATE DETERMINATION: THE ROLE OF INTERVENTION AND STERILIZATION

Money Demand

The model to be presented here draws on Makin (1980). The log linear money demand function has the form

$$m_t - p_t = k + ay_t - br_t \qquad (6)$$

where:

m = log of money supply $(m_t^s = m_t^d = m_t)$

p_t = log of the price level

y_t = log of real income

r_t = log of (1+i) (i = nominal interest rate)

(a>0) = income elasticity of money demand

(b>0) = minus the negative elasticity of money demand with respect to (i+i).[5]

k = constant.

If an identical "foreign" money demand function is specified with "*" superscripts indicating foreign values, subtracting from (6) the foreign equivalent of (6) gives, setting $k = k^*$:

$$\underline{m}_t = p_t - p_t^* + a\underline{y}_t - b(r - r^*) \tag{7}$$

where

$$\underline{m}_t = (m_t - m_t^*)$$

$$\underline{y}_t = (y_t - y_t^*)$$

<u>Money Supply: Sterilization and Intervention</u>

Money supply is represented by a log linear money "production function" which determines money supply in terms of domestic and foreign assets of the central bank. For country 1, let:

$$M_1^s = D_1^{j_1} X_1^{j_2} \tag{8}$$

where:

M_1^s = money supply

D_1 = domestic assets of central bank in country "1"

X_1 = foreign exchange reserves of central bank in country "1"

j_1 = elasticity of money supply with respect to D_1

j_2 = elasticity of money supply with respect to X_1.

In logs (8) becomes:

$$m_{1_t} = j_1 d_1 + j_2 x_1 \qquad (9)$$

Sterlization links d negatively to reserves

$$d_{1_t} = de_{1_t} - (1-st_1)\ x_{1_t} \qquad (10)$$

where

de_{1_t} = log of autonomous portion of domestic assets of central bank in country 1

st_1 = sterlization coefficient in country 1 [$st_1 = 0$ implies full sterlization; $st_1 = 1.0$ implies zero sterlization and $d_{1_t} = de_{1_t}$].

Intervention links reserves to the exchange rate where:

$$x_1 = -\gamma_1 s \qquad (11)$$

γ_1 measures the elasticity of official reserves with respect to the exchange rate, s. The faster currency 1 depreciates (a rise in s) the faster country one reserves are lost (and the faster "foreign" reserves rise). If analogous expressions apply for country 2, then $\underline{m}_t$, the relative money supply term for countries 1 and 2, can be written as:

$$\underline{m}_t = \underline{de}_t + \phi s_t \qquad (12)$$

where:

$$\underline{de}_t = j_1 \, de_{1_t} - j_1^* \, de_{2_t}$$

$$\phi(\leq 0) \equiv [-\gamma_1(j_2 - j_1(1-st_1)) - \gamma_2(j_2^* - j_1^*(1-st_2))]$$

If intervention dominates sterlization so that currency depreciation lowers x_1 and raises x_2 then ϕ is unambiguously negative. If sterilization eradicates intervention's affect on the monetary base $\phi = 0$. In this case $\underline{m}_t = \underline{de}_t$ and there is no need to take account of either intervention or sterlization in modeling the money supply. The important thing about (12) from the forecasting standpoint is the fact that it links to "ϕ", the value of all reduced-forms describing the impact upon the exchange rate of exogenous variables. And "ϕ" in turn depends upon intervention and sterlization policy parameters γ_i and st_i $(i = 1,2)$ which are likely to change over time.

Equations (7) and (12) along with purchasing power parity, interest parity and the condition that the forward rate is an unbiased measure of the public's expected spot rate enable a rational MERE solution for the exchange rate.

A General Formulation for PPP and "Real" Exchange Rate Changes

Purchasing power parity is expanded here to include systematic and random "real" exchange rate changes.

$$s_t = (p_t - p_t^*) + dz_t + u_t \tag{13}$$

Here z_t represents a vector of real factors which systematically operate to cause deviations from PPP while u_t represents non-systematic divergences of the exchange rate from PPP.

Interest parity is written as:

$$f_t - s_t = r_t - r_t^* \tag{14}$$

where f_t is the log of the forward domestic currency price of foreign currency as of time "t" for time "t+1." Here "r's" refer to one plus nominal interest rates on instruments of term "t" to "t+1." The simple efficient market hypothesis states that under conditions of risk neutrality, zero transactions costs, rational use of information and competitive markets:

$$f_t = E_t\ [s_{t+1} | \text{information}_t] \tag{15}$$

Equation (15) sets the forward rate at "t" for time "t+1" equal to the mathematical expectation of the spot rate at time "t+1" conditional on the information set available at time "t."

A Solution for the Exchange Rate

Equations (14) and (15) imply:

$$_t s^e_{t+1} - s_t = r_t - r_t^* \tag{16}$$

where ${}_{t}s^{e}_{t+1} \equiv E_t[s_{t+1}|\text{information}_t]$. Equation (16) can be substituted into equation (7) for $(r-r^*)$ while PPP (equation (13)) sets $p_t - p^*_t = s_t - hz_t - u_t$. These substitutions along with expresssions for money supply behavior enable a rational solution for the exchange rate of the form:

$$s_t = [\frac{1}{1-\phi}] [(1+W_d) \underline{de}_t - Wd \underline{de}_{t-1}]$$

$$- [\frac{a}{1-\phi}] [(1+W_y) \underline{y}_t - W_y \underline{y}_{t-1}]$$

$$+ [\frac{h}{1-\phi}] [(1+W_z) z_t - W_z Z_{t-1}] \quad (17)$$

where AR-1 processes define growth of exogenous variables

$$\Delta\underline{de}_t = p_d \Delta\underline{de}_{t-1} + u_{d_t} \quad (18.a)$$

$$\Delta\underline{y}_t = p_y \Delta\underline{y}_{t-1} + u_{y_t} \quad (18.b)$$

$$\Delta z_t = p_z \Delta z_{t-1} + u_{z_t} \quad (18.c)$$

and

$$W_j (j = d,y,z) = \frac{bp_j}{(1-\phi)+b(1-p_j)} = \frac{b}{(1-\phi)} \quad (\text{with } p_j=1)$$

With p_j all equal one (growth of exogenous variables a random walk), letting a = 1.0 and ignoring, for now, z_t, the result is a basic form of the extended MERE model useful for elucidating its basic features:

$$s_t = [1/(1-\phi)][(1+b')[RXM]_t - b'[RXM]_{t-1}] \qquad (18)$$

where $b' \equiv [b/(1-\phi)]$.

where $RXM \equiv [\underline{de} - \underline{y}]$ or relative excess money supply.

Equation (18) implies a cyclical response of the exchange rate to relative excess money supply (RXM). If sterlization cancels the impact of intervention on the monetary base ($\phi = 0$), the elasticity of the exchange rate with respect to RXM is (1+b), implying an initial "overshoot" of amount "b" which is subsequently removed at t-1. Sharpness of the cyclical response of the exchange rate to RXM is proportional to the interest elasticity of money demand. This result is most easily understood by first noting that interest parity, PPP and unbiasedness of the forward rate as a predictor of the expected spot rate together imply that Fisher equations describe nominal interest rates in each country.[6] These conditions are all implicit in (18). Given these conditions a rise in RXM is exacerbated by a drop in money demand at home relative to abroad which in turn results from higher nominal interest rates at home relative to abroad. The latter results from a relative increase in expected inflation at home. The size of the additional negative effect on money demand depends on the size of b, the interest elasticity of money demand. In short a rise in RXM feeds on itself by causing anticipated inflation which lowers steady-state money demand. Therefore the exchange rate must depreciate by more than a change in RXM to reduce domestic excess money supply. Once the initial overshoot reduces steady state real money balances at home, the extra pressure on the exchange rate is removed and the overshoot portion of depreciation disappears.

Intervention and Sterilization

These results are modified by intervention and/or sterilization. In the longer run ϕ can not be zero, with intervention not allowed to affect the monetary base. If the base is not affected by balance of payments disequilibria under non-zero intervention reserve gains or losses will persist until some rapid adjustment of exchange rates to perceived equilibrium levels is permitted. This outcome implies that attempts to hold $\phi = 0$ will eventually cause γ (intervention) to fall until exchange rates reach perceived equilibrium levels. In any case, ϕ can be expected to vary over time.

If intervention is heavy and ϕ takes on a large negative value, the "overshoot" may seem to disappear, say over some sample period. The reason will be the market's perception of intervention to prevent exchange rate movement and not any "failure" of the monetary theory of exchange rate determination. A believable announcement of or concrete evidence of a significant change in intervention policy will alter "ϕ" and thereby alter the measured impact upon the exchange rate during some finite sample period of a given change in RXM. The basic MERE theory which postulates a fixed impact would be contradicted by data drawn for that sample period. The reason would not be invalidity of MERE but rather failure to allow for a change in intervention (or sterilization) policy.

3. TESTING THE EXTENDED MERE MODEL

Implications of Theory

The theory developed in Section 2 anticipates some specific forms of observable behavior. The response of exchange rates to components of RXM should be cyclical. Separate components of RXM may produce different cyclical impacts upon exchange rates due to: differences in income elasticity of money demand (impact on response to real income variables)[7]; and different projections of future, expected behavior of determinants of RXM from observable current and lagged values.[8] Over time, estimated parameters may vary due to changes in intervention and/or sterilization policy.

The full sample period runs from March, 1973 through December, 1979. During that time there has been steady "real" depreciation of the dollar against DM. As noted earlier, the log of the real dollar-DM exchange rate follows a random walk during the 1973-79 sample period. Therefore the rate of change of the exchange rate (log-first-difference) obeys PPP. All variables discussed here are in log-first-difference form. Any possible remaining systematic, temporal behavior of the differenced dollar-DM exchange rate is captured by a noise model in the transfer function estimates reported below. Given this formulation, RXM components must explain some part of the white-noise residuals of a prefiltered series on the rate of change of the exchange rate. The measure of relative inflation volatility on real relative risk (hereinafter "σ") described earlier is also included as a possible source of "real" dollar-DM exchange rate movement to be held constant when considering the impact of RXM.[9]

Methodology

Transfer function estimation procedures following Box and Jenkins (1970) were employed to estimate exchange rate equations. This methodology enables parsimonious representation of lengthy, cyclical distributed-lag effects running from exogenous variables to the endogenous variable along with simultaneous pre-filtering of the endogenous variables to "white-noise" by means of an AR, MA or ARMA model. In addition, cross-correlations between the endogenous variable and lagged and leading values of the exogenous variables (pre-filtered to white noise) can be obtained. The cross correlations for lagged exogenous variables enable the investigator to see if any additional explanatory power remains once some relationship between exogenous and endogenous variables has been estimated. Cross correlations between the endogenous variable and leading values of exogenous variables enable a check on feedback running from the endogenous variable to later values of the exogenous variable.

Initial estimation using 82 monthly observations running from March, 1973 through December, 1979 indicated that most impact from exogenous to endogenous variables occurred (via numerator parameters) contemporaneously and with a lag of one month. Further explanatory power appeared to be distributed over a long lag. Therefore a parameter (second order denominator) was included to allow for a cyclical distributed lag impact running from exogenous variables to the endogenous variables.

Estimation Results

Table 1 reports on estimation of a transfer function model with numerator parameters at lags zero and one (0-n. and 1-n.) and a second-order denominator parameters (2-dn.). "Total gain" in Table 1 refers to the full distributed-lag impact of the exogenous variable over a period of damped, cyclical oscillations. The top portion of Table 1 excludes the relative risk (σ) term while the lower portion includes it. The impact of σ is estimated by a numerator parameter at lag 3 only. The estimation program employed estimates a maximum of 15 parameters which left only one parameter attributable to relative risk.[10]

Obviously many alternative formulations including first and third-order denominator parameters and other numerator parameters could produce an oscillatory distributed-lag impact running from RXM variables to the exchange rate. Some were tried. Numerator parameters beyond lag-one-month were generally insignificant (with the notable exception of relative real risk). In most cases third-order denominator parameters resulted in explosive oscillatory distributed lags for one or more RXM variables. The formulation reported in Table 1 has uniformity and relative simplicity to recommend it. However, any significant change in intervention or sterilization policy can and will disturb the appropriate form of the model as we shall see below.

Overall, Table 1 indicates that RXM variables explain some part of dollar-DM exchange rate behavior in a manner predicted by MERE theory. Still, a large part of exchange rate behavior is unexplained as indicated by low R^2's. F-tests of the overall significance of equations (1.1) and (1.2) are very close to crucial values at the 5 percent level.

TABLE 1

TRANSFER FUNCTION ESTIMATION OF THE DOLLAR PRICE OF DM
(t-Statistics in Parentheses)

Equation (1.1) (Real Risk Omitted)
$R^2(\bar{R}^2) = 0.26(0.12)$ $F(13,66) = 1.83$ $[F^{05}13,16 = 1.87]$ Cons.: 0.0150

Exog. Var.	0-n.	1-n.	2-dn.	Total Gain
d_{us} (1,2)	0.1438 (1.04)	0.3696 (2.60)	-0.2286 (0.59)	0.4179
y_{us} (3)	0.2405 (0.61)	-0.2772 (0.72)	-0.8676 (2.96)	-0.0196
d_g	-0.0265 (3.17)	0.0215 (2.21)	-0.5936 (2.86)	-0.0032
y_g	0.0099 (0.13)	0.1800 (2.34)	0.9869 (16.72)	14.49
Noise(MA-6) (4)				.5245 (4.41)

Equation (1.2)(Including Real Risk)
$R(\bar{R}) = 0.28(0.13)$ $F(14,65) = 1.84$ $[F^{05}14,65 = 1.85]$ Cons.: -0.0168

Exog. Var.	0-n.	1-n.	2-dn.	Total Gain
d_{us}	0.1639 (1.23)	0.3805 (2.78)	-0.2795 (0.79)	0.4255
y_{us}	0.3144 (0.79)	-0.3600 (0.90)	-0.8443 (3.23)	-0.0248
d_g	-0.0219 (2.49)	0.0226 (2.41)	-0.6414 (3.06)	0.0004
y_g	0.0262 (0.33)	0.1903 (2.55)	0.9864 (17.75)	15.98
Noise(MA-6)				0.5598 (4.70)
Relative Risk: σ (5)				0.0086 (1.33)

NOTES:
(1) All variables are in log-first-difference.
(2) "d" measures the log of the domestic portion of the monetary base. For both the U.S. and Germany, the domestic portion of the monetary base is measured by "monetary authority reserve money (line 14) less "monetary authority foreign assets" (line 11) in IMF <u>International Financial Statistics</u>.
(3) "y" is "industrial-production" (line 66c of IFS).
(4) The spot exchange rate s is taken from the Harris Bank Tape of international financial statistics. Data are as of the last available reporting day of the month.
(5) Numerator parameter at lag 3 only.

It is clear from Table 1 that a serious mis-specification is very likely to result from the common practice of estimating exchange rate equations which impose the same absolute parameter values on coefficients attached to domestic and foreign money and income variables. Dollar appreciation from U.S. income growth, y_{us}, is far less than DM appreciation implied by German income growth, y_g. This result is consistent with the higher income elasticity of money demand in Germany alluded to earlier. Likewise, dollar depreciation from U.S. money expansion, d_{us}, is considerably above the level of DM depreciation implied by German money expansion, d_g.

Part of the U.S.-German difference in the estimated elasticity of the exchange rate with respect to the domestic portion of the monetary base results from the fact that during the 1973-79 sample period, the elasticity of the U.S. money supply (M-2) with respect to d was about 3 times that for Germany. Even adjusting for this, however, the conclusion remains that U.S. money-base or money growth has resulted in more dollar depreciation than the DM-depreciation resulting from German money-base or money growth.

The estimated impact on the exchange rate of a rise in German money is quite robust. Initial DM depreciation is followed, in 1 month, by almost equal appreciation and subsequent cycling which eventually leaves only a very small net impact on the rate. The total gain changes sign from equation (1.1) to equation (1.2). This is an odd result which is due proximately to the form of the estimated oscillatory distributed-lag impact of d_g on the exchange rate. More fundamentally the small overall response of the exchange rate to d_g, especially when compared to the response to d_{us}, may be due to the tendency of German money growth to revert to a stable mean over the sample period while U.S. money growth rates have tended to accelerate. The latter implies far more anticipated inflation from a given rise in money growth and, therefore, more currency depreciation.

"Relative risk" change is meant to proxy for a real interest rate change in Germany relative to the U.S. Equation (1.2) indicates the anticipated DM appreciation resulting from a rise in σ although the estimated coefficient differs from zero at only about the 20 percent level of significance.

Feedback From Exchange Rates to Exogenous Variables

Table 2 reports Box-Pierce test statistics for autocorrelation and cross correlation of variables in equation (1.2). Perhaps most notable is the indicated feedback running from the exchange rate to the domestic portion of the U.S. monetary base. Examination of the cross correlations between pre-filtered s and pre-filtered d_{us} indicates significant feedback at lags of 2 and 11 months. The indication, in conjunction with estimated intervention equations to be discussed below, is that when dollar depreciation against the DM results in official U.S. "leaning against the wind" and a consequent loss of reserves, part or all of the impact on the monetary base is removed by a rise in d_{us}. Estimated intervention and money supply functions for the United States indicate that during the 1973-79 sample period implied sterilization by the U.S. more than offset the impact of

TABLE 2

CHI-SQUARE TESTS
(Box-Pierce Statistic-Adjusted For Downward Bias)
(For Equation 1.2)

	Degrees of Freedom	P-Value
Autocorrelation:		
Q(12) = 7.09	11	.791
Q(24) = 10.1	23	.990
Cross-Correlation:		
(1) d_{us} on s		
S(0,12) = 7.24	10	.703
S(0,24) = 14.3	21	.857
(2) s on d_{us}		
S(-1,-12) = 30.0	12	.00279
S(-1,-24) = 41.1	24	.0162
(3) y_{us} on s		
S(0,12) = 8.70	10	.561
S(0,24) = 14.0	21	.872
(4) s on y_{us}		
S(-1,-12) = 22.8	12	.0299
S(-1,-24) = 38.3	24	.0324
(5) d_g on s		
S(0,12) = 14.2	10	.164
S(0,24) = 25.9	21	.211
(6) s on d_g		
S(-1,-12) = 18.7	12	.096
S(-1,-24) = 34.0	24	.084
(7) y_g on s		
S(0,12) = 17.7	10	.061
S(0,24) = 22.2	21	.388

(Continued)

TABLE 2 (Continued)

Cross-Correlation: (Cont'd)	Degrees of Freedom	P-Value
s on y_g		
$S(-1,-12) = 13.1$	12	.359
$S(-1,-24) = 23.2$	24	.507
(8) σ on s		
$S(0,12) = 7.76$	12	.803
$S(0,24) = 21.1$	23	.573
(9) s on σ		
$S(-1,-12) = 8.95$	12	.707
$S(-1,-24) = 16.2$	24	.881

intervention on the monetary base. In addition there is some indication of sterilization feedback from s to d_g at lag 3 months. These results suggest a further explanation for the powerful impact of changes in d_{us} on the exchange rate indicated in Table 1. If exchange rate movements are blunted by intervention behavior which is not allowed to produce a stabilizing impact on the monetary base, excess money supply conditions created by a rise in d_{us} can be expected to persist for some time. The powerful response of the exchange rate to a rise in d_{us} that is indicated in Table 1 reflects the expectation that effects upon the U.S. monetary base arising from "leaning against the wind" by U.S. authorities will be overwhelmed by sterilization.

Some feedback from the exchange rate to U.S. industrial production is also indicated in Table 2. Strong positive feedback appears at a lag of 5 months. It may be that dollar depreciation which initially "overshoots" is sharp enough to stimulate a real increase in demand for U.S. exports which in turn requires a rise in industrial production.

Changes in Intervention and Sterilization Policy

The extended MERE model suggests that changes in intervention and sterilization policy within a sample period ought to alter the measured impact upon the exchange rate of changes in money, real income and other disturbances. The first step to check for this possibility was to estimate "leaning against the wind" intervention equations for the U.S. and Germany for the full March, 1973 - December, 1979 sample period.[11] Then the sample period was split after December 1975.

This split, as noted by Bilson (1979), is suggested by the December, 1975 meetings at Rambouillet where major countries attempted to formulate some exchange-rate-policy "rules of the game." Intervention equations of the form obtained for the full sample period were then estimated for the March, 1973 - December, 1975 period and the January, 1976 - December, 1979 period.

For the United States it was not possible to reject the null hypothesis that the intervention model was unchanged. The relevant F-statistic calculated was 1.03, well below the critical value of 1.93 required for rejection of the null hypothesis at the 5 percent level of significance. For Germany, it was possible to reject the null hypothesis of unchanged intervention at the 5 percent level (calculated F = 2.81 versus critical 5 percent F = 2.74).

Inspection of cross correlations of residuals for the sub-periods suggested that sterilization policy for both Germany and the United States was largely unchanged between the two sub-periods.

German intervention became more pronounced during the latter part of the sample period. A one percent change in the exchange rate was accompanied by a nearly one percent change in reserves in the January, 1976 - December, 1979 period. The comparable "elasticity of intervention" in the March, 1973 - December, 1975 period was only about one-third. For the full period [March, 1973 - December, 1979] the estimated "elasticity of intervention" for Germany was about 0.5.

An attempt to estimate equations (1.1) and (1.2) in Table 1 for the shorter sample periods clearly indicated that the fit of the model employed over the full period deteriorated sharply in the sub-periods.

A major difficulty was the implied oscillatory distributed lag impact running from money and income variables to the exchange rate. In a number of cases it became explosive. Another problem is likely the fact that the shorter sample periods afforded few degrees of freedom. Given the need to estimate 15 parameters only 15 degrees of freedom exist for the early period and 29, for the later period. Therefore, these results are far from conclusive. The suggestion which remains is the possibility that significant changes in intervention policy can and may have altered the "true" values of reduced-form parameters within the 1973-79 sample period. The results for the full sample period reflect a composite of distinct intervention policies in each of the sub-periods.

4. CONCLUDING REMARKS

The primary aim of this paper has been to deal with shortcomings of extant empirical tests of the monetary approach to exchange rate determination. Four major difficulties exist: (1) Failure to deal explicitly with real exchange rate changes; (2) Failure to impose interest parity; (3) Failure to represent the forward rate as an unbiased predictor of the spot rate; and (4) Failure to model implications of official intervention in foreign exchange markets and of possible efforts to sterilize effects of intervention on the monetary base.

Theoretical discussion of exchange rate behavior by other investigators has dealt adequately with the first three failures and the fourth has been addressed in Makin (1980). But empirical investigations have tended to incorporate at least one failure and usually, all four, as in the representation by Dornbusch (1980) of an empirical test of the monetary approach. It would be inappropriate, on the basis of poorly formulated empirical tests, to abandon the monetary approach to exchange rate determination, distinguished by its analytical tractability and derivative refutable hypotheses expressed in terms of directly observable variables.

Results of empirical tests conducted here do not permit rejection of the complex joint hypothesis represented by equations estimated to test the monetary approach. In spite of this, there remained unexplained a large portion of the behavior of the dollar-DM exchange rate in the 1973-79 monthly sample employed. This fact is not inconsistent with the view that exchange rates are prices determined in asset markets where a large, unsystematic flow of information, not captured by monetary or other variables, produces large, unsystematic movements of exchange rates.

Results reported here are proximately at variance with those of Caves and Feige (1980). They found that, in the presence of explanatory power of an exchange rate's own past history, monetary variables have no additional explanatory power. They also employed, as this study does, log-first-differences of all variables. They considered a different (U.S.-Canadian dollar) exchange rate. The main difference is their failure to measure excess money supply and to allow for different, reduced-form coefficients measuring the impact of money on exchange rates. In short, the difference between results reported here and those of Caves and Feige may well be due to problems of specification error and omitted variables.

The extended MERE model of exchange rate behavior which includes "leaning against the wind" intervention suggests hypotheses about behavior of international capital flows as well as exchange rates. A basic balance of payments identity which sets the change in official reserves (intervention) equal to the sum of private capital flows and the current account combined with the extended-MERE, exchange rate model yields a theory of international capital flows. Capital flows, like exchange rates, can be shown to depend only on the current expectation of all future, relative excess money supplies. Makin and Nelson (1981) find that a measure of excess money supply produces the predicted cyclical response of U.S. international capital flows over the 1969-80 sample period. Explanatory power of the transfer function is considerably higher than that of the exchange rate equation. This is likely due partly to the fact that the dependent variable is a quantity measure sampled quarterly instead of a price measure sampled over a finer, monthly interval. If asset prices are absorbing a large part of the impact of random information shocks, measured flows which reallocate assets may be more related to behavior of systematic information such as measures of relative excess money.

There remains considerably more work to be done if exchange rate behavior in an era of quasi-floating is to be fully understood. It would be useful to isolate more of the systematic, measurable and testable sources of "real" exchange rate movements. The role of risk premia discussed in Makin (1980) needs to be more fully understood. As more data from the quasi-floating period after March, 1973 become available, it will be necessary to investigate further the implications for exchange rate behavior of any identifiable changes in intervention and/or sterilization policy.

FOOTNOTES

* Thanks are due to Charles Nelson and to students in my seminar on Advanced Macroeconomics for help in distilling ideas presented here. Responsibility for any errors is my own.

1. Dornbusch (1980) uses unanticipated depreciation of the dollar against the yen and DM, but as is clear from his Figure 3 (p. 160) this is almost the same as actual depreciation since most depreciation was unanticipated.

2. Dornbusch (1980), Footnote to Table 4, p. 162.

3. Equation (3) may contain a time trend as in:

$$f_t = \alpha + \beta t + \varepsilon_t$$

In this case some "time" proxy would appear in (4) or a low Durbin-Watson statistic would likely result in differencing.

4. Frenkel (1977) among others provides convincing evidence regarding unbiasedness of the forward rate as a predictor of the spot rate (exchange market efficiency). However, Tryon (1979) finds that the forward market fails to supply an unbiased predictor of the <u>change</u> in the future spot rate in 4 of 6 cases examined. While failure of this more stringent test of market efficiency does not explicitly violate the usual efficiency condition employed here, Tryon's results raise questions worthy of note and further investigation.

5. "b" will be slightly below interest elasticity of money demand with respect to "i", with the difference falling as i rises. The "1 + i" formulation turns out to be particularly convenient for capturing interest parity and introduces no substantive changes in the nature of money demand.

6. This condition holds given a constant ratio of domestic to foreign real interest rates.

7. Estimation of U.S. and German money demand equations for the sample period under investigation revealed German income elasticity of money demand (about 1.5) significantly above that for the U.S. (about 0.4). This implies that real growth in Germany ought to strengthen the DM by more than growth in the U.S. strengthens the dollar.

8. In terms of the model, the "ρ" values describing the (AR-1) growth path of exogenous variables may differ. Alternatively, a more complex ARMA model may imply alternative cyclical response patterns.

9. A measure of σ was obtained as follows. First, an ARMA model was estimated for the producer price index in the U.S. and Germany. A monthly moving average of contemporary and six lagged residuals was calculated for the 1973-79 sample period for each country. The German series less the U.S. series is σ.

The rationale behind σ is simple. The larger are current and past residuals on a forecasting equation for prices, the more uncertainty there is about future price levels and anticipated inflation. More uncertainty requires a risk premium for local country holders of local currency assets who are risk-averse. The higher real return measured in the local currency attracts foreign investors.

10. Some experimentation was conducted with alternative formulations enabling a denominator parameter for relative risk (by dropping

one of the numerator parameters on another variable). Results did not alter conclusions reported here, although in some cases the change in specification caused explosive oscillatory distributed lags to be estimated for RXM variables.

11. Equations estimated were transfer functions with noise models. The dependent variable was the rate of change of monetary authority reserve money (IFS, line 14). The independent variable was a distributed lag on the rate of change of the dollar-DM exchange rate. In the case of the U.S. the dollar-yen exchange rate proved to be highly significant along with the dollar-DM rate unexplaining intervention.

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