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Exchange Rate Economics: A Survey

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Abstract

We survey the literature on the two main views of exchange rate determination that have evolved since the early 1970s: the monetary approach to the exchange rate (in flex-price, sticky-price and real interest differential formulations) and the portfolio balance approach. We then go on to discuss the extant empirical evidence on these models and conclude by discussing how the future research strategy in the area of exchange rate determination is likely to develop. We also discuss the literature on foreign exchange market efficiency, on exchange rates and 'news' and on international parity conditions.

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Summary

Asset-market models of exchange rate determination are distinguished by their stress on stock equilibrium effects. Monetary models can be distinguished from more general portfolio-balance models by the assumed degree of substitutability between domestic and foreign assets. Early monetary models assumed flexible prices and continuous purchasing power parity (PPP), although this was remedied in the second generation, "overshooting" monetary models.

The broad conclusion which emerges from the empirical evidence is that while the asset-approach models have performed reasonably well for some periods, such as the interwar period and the first few years of the recent float (1973-78), they have largely failed to explain the behavior of the major exchange rates since 1978.

A number of hypotheses have been put forward to explain this phenomenon, including views concerning the effect of "non-fundamentals," such as chart analysis and political factors, on exchange rate behavior. Other researchers have argued that standard exchange rate equations may be misspecified in one or more ways and have suggested, for example, the use of structural, rather than reduced form, models.

Under the efficient-markets hypothesis (EMH), it should be impossible for a trader to earn excess returns to speculation. The EMH is, in fact, a joint hypothesis consisting of rational expectations and an assumption concerning the attitude of agents toward risk. Methods of testing the EMH include testing the profitability of simple trading rules ("filter rules"), testing the implication of the EMH that (under risk neutrality) the forward rate should be an optimal predictor of the future spot rate, and testing for the statistical independence of exchange rate forecast errors with respect to past information. There is now overwhelming evidence to suggest that the forward foreign exchange rate is a biased and inefficient predictor of the future spot rate. The simple EMH (i.e., one assuming risk neutrality) thus appears to have been decisively rejected. Evidence for the existence of a time-varying risk premium is, at best, mixed, while tests using data on surveys of expectations in the foreign exchange market tend to reject the rational-expectations hypothesis.

The empirical evidence on the various international parity conditions suggests the following. First, the covered-interest-parity condition (that the nominal-interest-rate differential is just equal to the forward exchange rate premium) receives fairly strong support, especially for Eurodeposit interest rates. The uncovered-interest-parity condition (that the expected rate of exchange rate depreciation is just equal to the nominal interest rate differential) is resoundingly rejected. Similarly, real interest rate parity is often easily rejected. The empirical literature on PPP rejects the hypothesis of continuous PPP, while the hypothesis of long-run PPP receives mixed support.

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I. Introduction

The past two decades have seen an enormous growth in the literature on exchange rate economics. Given the importance attached to the exchange rate in the success or otherwise of an open economy, it is not surprising that exchange rate economics is one of the most heavily researched areas of the discipline. The period since the advent of generalized floating exchange rates in 1973 has generated a wealth of data on exchange rates and on the factors which supposedly determine them, giving econometricians and applied economists an unprecedented opportunity to test a number of propositions relating to foreign exchange markets. Exchange rate economics remains, however, an extremely challenging area in the sense that, despite this extensive research, there still remains a large number of unresolved issues.

The intense research activity in this area has generated a vast literature which this paper attempts to survey. In particular, we examine the two main views of exchange rate determination that have evolved since the early 1970s: the monetary approach to the exchange rate (in flex-price, sticky-price and real interest differential formulations) and the portfolio balance approach to the exchange rate. We then go on to discuss the extant empirical evidence on these models and conclude by discussing how the future research strategy in the area of exchange rate determination is likely to develop. We also discuss the literature on foreign exchange market efficiency, on exchange rates and 'news' and on international parity conditions.

The present contribution may be viewed as an extension and update of earlier surveys of empirical work on exchange rates by, amongst others, Kohlhagen (1978), Levich (1979, 1985) and Isard (1988) and as a simplification and synthesis of surveys of exchange rate theory by Mussa (1984), Frenkel and Mussa (1985), and Obstfeld and Stockman (1985).

II. Theories of Exchange Rate Determination

Early contributions to the postwar literature on exchange rate economics include Nurske (1944) and Friedman (1953). Both of these contributions are to a large extent concerned with the role of speculation in foreign exchange markets. Nurske warns against the dangers of 'bandwagon effects' which may generate market instability. 1/ Friedman's classic apologia of floating exchange rates (Friedman, 1953) is remarkable in its anticipation of much of the foreign exchange literature of the following two decades, and is still cited as the seminal article on stabilizing speculation.

Meade (1951a, Part III) laid the foundations for simultaneous analysis of internal and external balance in an open economy which were built upon a

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1/ See Bilson (1981), Frankel and Froot (1987), Allen and Taylor (1990) for recent discussions of bandwagon effects in foreign exchange markets.

decade later in the path breaking contributions of Mundell (1961, 1962, 1963, 1968) and Fleming (1962). In his verbal exposition of his capital account theory, Meade (ibid.) had worked through the stock equilibrium implications of a movement in international interest rate differentials, but did not faithfully represent this feature in his mathematical exposition (1951b, p. 103). Mundell (ops. cit.) and Fleming (op. cit.) followed Meade's mathematical representation and thus abstracted from the stock-flow implications of interest rate differential changes. Thus, although the integration of asset markets and capital mobility into open-economy macroeconomics was an important contribution of the Mundell-Fleming model, the model was largely rejected on a priori grounds as a serious contender for the explanation of exchange rate movements at the beginning of the recent float. This was because it was judged to contain a fundamental flaw: it is cast almost entirely in flow terms. In particular, the model allows current account imbalances to be offset by flows across the capital account without any requirement of eventual stock equilibrium in the holding of net foreign assets.

As well as Meade's (1951a) contribution in this respect, in papers dating from the 1950s, Polak (1957) and Johnson (1958) had stressed the distinction between stock and flow equilibria in the open economy context, and this was to become a hallmark of the monetary approach to balance of payments analysis (see e.g., Frenkel and Johnson, 1976) and subsequently, the monetary approach to the exchange rate (see e.g., Frenkel and Johnson 1978). More generally, work done in the late 1960s by Oates (1965), McKinnon and Oates (1966), McKinnon (1969) and Ott and Ott (1965, 1968) began an integration of open economy macroeconomic analysis and financial portfolio balance analysis by imposing stock equilibrium constraints. Slightly later work by Branson (1968), Willet and Forte (1969) and Kouri and Porter (1974) built on this work by by incorporating more general features of financial portfolio choice (Tobin, 1965). 1/

1. The flexible price monetary model

Since an exchange rate is, by definition, the price of one country's money in terms of that of another, it is perhaps natural to analyze the determinants of that price in terms of the outstanding stocks of and demand for the two monies. This is the basic rationale of the monetary approach to the exchange rate (Frenkel, 1976; Kouri, 1976; Mussa 1976, 1979).

The early, flexible-price monetary model (FLPM) relies on the twin assumptions of (continuous) purchasing power parity (PPP) and the existence of stable money demand functions for the domestic and foreign economies. The (logarithm of the) demand for money may be assumed to depend on (the logarithm of) real income, y, the (logarithm of the) price level, p, and the level of the interest rate, r (foreign variables are denoted by an

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1/ The history of thought on open economy macroeconomics is analyzed in more detail in Taylor (1990).

asterisk). Monetary equilibria in the domestic and foreign country respectively are given by

$$m_t^s = p_t + \phi y_t - \lambda r_t \tag{1}$$

$$m_t^{s*} = p^* + \phi^* y_t^* - \lambda^* r_t^* \tag{2}$$

Equilibrium in the traded goods market ensues when there are no further profitable incentives for trade flows to occur--that is, when prices in a common currency are equalized and PPP holds. The PPP condition is:

$$s_t = p_t - p_t^* \tag{3}$$

where s_t is the nominal exchange rate (domestic price of foreign currency). Thus, if PPP holds continuously, the logarithm of the real exchange rate, q_t say ($q_t = s_t - p_t + p_t^*$), is a constant. The world price, p^*, is exogenous to the domestic economy, being determined by the world money supply. The domestic money supply determines the domestic price level and hence the exchange rate is determined by relative money supplies. Algebraically, substituting (1) and (2) into (3) gives, after rearranging

$$s_t = (m^s - m^{s*})_t - \phi y_t + \phi^* y_t + \lambda r_t - \lambda^* r_t^* \tag{4}$$

which is the basic FLPM equation. From (4), we can see that an increase in the domestic money supply, relative to the foreign money stock, will lead to a rise in s_t--i.e., a fall in the value of the domestic currency in terms of the foreign currency. This seems intuitive enough. On the other hand, an increase in domestic output <u>appreciates</u> the domestic currency (s_t falls). Similarly, a rise in domestic interest rates depreciates the domestic currency (in the Mundell-Fleming model, this would lead to capital inflows and hence an <u>appreciation</u>).

In order to resolve these apparent paradoxes, one has to remember the fundamental role of relative money demand in the FLPM model. A relative rise in domestic real income creates an excess demand for the domestic money stock. As agents try to increase their (real) money balances, they reduce expenditure and prices fall until money market equilibrium is achieved. As prices fall, PPP ensures an appreciation of the domestic currency in terms of the foreign currency. An exactly converse analysis explains the response of the exchange rate to the interest rate--an increase in interest rates reduces the demand for money and so leads to a depreciation.

It is instructive to write the FLPM equation in two alternative but equivalent formulations. Assuming the domestic and foreign money demand coefficients are equal ($\phi = \phi^*, \lambda = \lambda^*$), (4) reduces to:

$$s_t = (m - m^*)_t - \phi (y - y^*)_t + \lambda (r - r^*)_t \tag{5}$$

A further assumption underlying the FLPM model is that uncovered interest parity holds continuously--i.e., the domestic-foreign interest differential is just equal to the expected rate of depreciation of the domestic currency. Thus, using a superscript e to denote agents' expectation formed at time t, we may substitute Δs^e_{t+1} for $(r-r)^*_t$ in (5) to get

$$s_t = (m-m^*)_t - \phi(y-y^*)_t + \lambda\Delta s^e_{t+1} \tag{6}$$

Thus, the expected change in the exchange rate and the interest differential, which reflects inflationary expectations, are interchangeable in this model. Some researchers relax the constraint that the income and interest rate elasticities are equal or, as a sort of hybrid,

$$s_t = (m-m^*)_t - \phi y_t + \phi^* y^*_t + \lambda\Delta s^e_{t+1} \tag{7}$$

Note also that (7) can be expressed as

$$s_t = (1+\lambda)^{-1}(m-m^*)_t - (1+\lambda)^{-1}\phi y_t + (1+\lambda)^{-1}\phi^* y^*_t + \lambda(1+\lambda)^{-1}s^e_{t+1} \tag{8}$$

If expectations are assumed to be rational, 1/ then by iterating forward, it is easy to show that (7) can be expressed in the 'forward solution' form

$$s_t = (1+\lambda)^{-1}\sum_{i=0}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^i\left[(m-m^*)^e_{t+i} + \phi y^e_{t+i} + \phi^* y^{*e}_{t+i}\right] \tag{9}$$

where it is understood that expectations are conditioned on information at time t. Equation (9) makes clear that the monetary model, with rational expectations, involves solving for the expected future path of the 'forcing variables', i.e., relative money and income. As is common in rational expectations models, the presence of the discount factor $\lambda/(1+\lambda) < 1$ in (9) implies that expectations of the forcing variables need not, in general, be formed into the infinite future--so long as the forcing variables are expected to grow at a rate less than $(1/\lambda)$.

2. The sticky price and real interest differential monetary models

A problem with the early, flexible price variant of the monetary approach, however, is that it assumes continuous purchasing power parity (PPP)--equation (3). Under continuous PPP, the real exchange rate--that is to say, the exchange rate adjusted for differences in national price levels--cannot vary, by definition. Yet, a major characteristic of the recent experience with floating has been the wide gyrations in the real rates of exchange between many of the major currencies, bringing with it the very

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1/ The application of rational expectations to exchange rates was first considered by Black (1973).

real consequences of shifts in international competitiveness (see e.g., Dornbusch, 1987). Clearly, therefore, the simple, flexible-price monetary approach does not fit the facts of observation. An attempt to rehabilitate the monetary model in this respect led to the development of a second generation of monetary models, due originally to Dornbusch (1976). The 'sticky price' monetary model (SPM) allows for substantial overshooting of the nominal and real, price-adjusted exchange rate above their long-run, equilibrium (PPP) levels as the 'jump variables' in the system--exchange rates and interest rates--compensate for sluggishness in other variables--notably goods prices. 1/

The intuition underlying the overshooting result in the SPM model is relatively straightforward. Imagine the effects of a cut in the nominal U.K. money supply. Since prices are sticky in the short run, this implies an initial fall in the real money supply and a consequent rise in interest rates in order to clear the money market. The rise in domestic interest rates then leads to a capital inflow and an appreciation of the nominal exchange rate (i.e., rise in the value of domestic currency in terms of foreign currency), which given sticky prices, also implies an appreciation of the real exchange rate. Foreign investors are aware that they are artificially forcing up the exchange rate and that they may therefore suffer a foreign exchange loss when the proceeds of their investment are reconverted into their local currency. 2/ However, so long as the expected foreign exchange loss (expected rate of depreciation) is less than the known capital market gain (i.e., the interest differential), risk-neutral investors will continue to buy sterling assets. A short-run equilibrium is achieved when the expected rate of depreciation is just equal to the interest differential (uncovered interest parity holds). Since the expected rate of depreciation must then be non-zero for a non-zero interest differential, the exchange rate must have overshot its long-run equilibrium (PPP) level. In the medium-run, however, domestic prices begin to fall in response to the fall in money supply. This alleviates pressure in the money market (the real money supply rises) and domestic interest rates begin to decline. The exchange rate then depreciates slowly in order to converge on the long-run PPP level. This model therefore explains the paradox that countries with relatively high interest rates tend to have currencies whose exchange rate is expected to depreciate. The initial rise in interest rates leads to a step appreciation of the exchange rate after which a slow depreciation is expected in order to satisfy uncovered interest parity.

1/ In fact, the main features of the SPM model would be captured in a framework in which the domestic currency price of domestic goods are sticky but domestic currency prices of foreign goods can move with the exchange rate.

2/ Even if investors effect forward cover--i.e., sell the proceeds of their investment against their local currency in the forward market--the cost of this cover will be close to the expected rate of depreciation of the domestic currency (and exactly equal if the forward market is efficient and agents are risk-neutral--see Section 3).

The Dornbusch overshooting model has been further developed by Buiter and Miller (1981) who, inter alia, allow for a non-zero rate of core inflation and consider the impact of natural resource discoveries on output and the exchange rate.

Frankel (1979a) argues that a shortcoming of the Dornbusch (1976) formulation of the SPM monetary model is that it does not allow a role for differences in secular rates of inflation. His model is therefore an attempt to allow for this defect and the upshot is an exchange rate equation which includes the real interest rate differential as an explanatory variable--the real interest differential (RID) variant of the monetary model.

The sticky-price monetary model is clearly an advance over the simple (continuous PPP) monetary model in that it more closely explains the facts of observation. It is, however, fundamentally monetary in that attention is focused on equilibrium conditions in the money market. Monetary models of the open economy are able to do this by assuming perfect substitutability of domestic and foreign non-money assets (but non-substitutability of monies--see Calvo and Rodriguez, 1977, and Girton and Roper, 1981, for a relaxation of this assumption). The markets for domestic and foreign non-money assets can then be aggregated into a single extra market ('bonds') and excluded from explicit analysis by application of Walras' Law. This 'perfect substitutability' assumption is relaxed in the portfolio balance model of exchange rate determination. In addition, the portfolio balance model is stock-flow consistent in that it allows for current account imbalances to have a feedback effect on wealth and hence on long-run equilibrium (see e.g., Branson 1977, 1983, 1984; Isard, 1980; Dornbusch and Fisher, 1980).

3. The portfolio balance model

In common with the FLPM and SPM models, the level of the exchange rate in the portfolio balance model (PBM) is determined, at least in the short run, by supply and demand in the markets for financial assets. The exchange rate, however, is a principal determinant of the current account of the balance of payments. Now, a surplus (deficit) on the current account represents a rise (fall) in net domestic holdings of foreign assets which in turn affects the level of wealth, which in turn affects the level of asset demand, which again affects the exchange rate. Thus, the PBM is an inherently dynamic model of exchange rate adjustment which includes in its terms of reference asset markets, the current account, the price level and the rate of asset accumulation. Although, as we noted above, a number of researchers had, in the late 1960s, discussed the implications of open economy portfolio balance in the context of fixed exchange rate balance of payments theory, the seminal contributions to the literature on the portfolio balance approach to exchange rate determination were: Kouri (1976), Allen and Kenen (1977), Branson (1977), Dornbusch and Fischer (1980) and Isard (1980).

Another feature of the PBM is that it allows one to distinguish between short-run equilibrium (supply and demand equated in asset markets), and the dynamic adjustment to long-run equilibrium (a static level of wealth and no tendency of the system to move over time). Although this is also a characteristic of the sticky price monetary model, the latter does not attempt to allow for the full interaction between the exchange rate, the balance of payments, the level of wealth and stock equilibrium.

In the short run (on a day-to-day basis), the exchange rate is determined in the PBM purely by the interaction of supply and demand in asset markets. During this period, the level of financial wealth (and the individual components of that level) can be treated as fixed. In its simplest form, the PBM divides net financial wealth of the private sector (W) into three components: money (M), domestically issued bonds (B) and foreign bonds denominated in foreign currency (F). B can be thought of as government debt held by the domestic private sector; F is the level of net claims on foreigners held by the private sector. Since, under a free float, a current account surplus on the balance of payments must be exactly matched by a capital account deficit (i.e., capital outflow and hence an increase in net foreign indebtedness to the domestic economy), the current account must give the rate of accumulation of F over time.

With foreign and domestic interest rates given by r and r^* as before, we can write down our definition of wealth and simple domestic demand functions for its components as follows: 1/

$$W = M + B + SF \tag{10}$$

$$M = M(r,r^*)W \qquad M_r < 0,\ M_{r^*} < 0 \tag{11}$$

$$B = B(r,r^*)W \qquad B_r > 0,\ B_{r^*} < 0 \tag{12}$$

$$SF = F(r,r^*)W \qquad F_r < 0,\ F_{r^*} > 0 \tag{13}$$

Relation (10) is an identity defining wealth. The major noteworthy characteristics of equations (11)-(13) are that, as is standard in most expositions of the PBM, the scale variable is the level of wealth, W, and the demand functions are homogeneous in wealth; this allows them to be written in nominal terms (assuming homogeneity in prices and real wealth, prices cancel out). 2/

This provides a simple framework for analyzing the effect of, for example, monetary and fiscal policy on the exchange rate. Thus, a contractionary monetary policy (M down) reduces nominal financial wealth (through (10)) and so reduces the demand for both domestic and foreign bonds (through

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1/ We use the notation $X_w = \partial X/\partial w$.
2/ See Tobin (1969).

(12) and (13)). As foreign bonds are sold, the exchange rate appreciates (the foreign price value domestic currency rises). The effects of fiscal policy (operating through changes in B) on the exchange rate are more ambiguous, depending on the degree of substitution between domestic and foreign bonds.

Masson (1981), Branson (1983, 1984) and Dooley and Isard (1982) have also extended this model to incorporate rational expectations. Branson (1984), for example, demonstrates that under rational expectations, real disturbances will generate monotonic adjustment of the exchange rate in the PBM, while monetary disturbances will generate exchange rate overshooting. Masson (1981) and Buiter (1984) also consider the stability of the PBM when net domestic holdings of foreign assets are negative.

III. Empirical Evidence on Exchange Rate Models

We shall divide our discussion of the empirical evidence on exchange rate models into three parts. The first part deals with the evidence on the various monetary exchange rate models using interwar data and data from the recent float before 1978. The second part relates to the empirical evidence on monetary models including more recent data from the current float. The third part deals with the empirical evidence on the portfolio balance model of the exchange rate.

1. The first period tests of the monetary models

The empirical evidence on the various formulations of the monetary exchange rate model--the flexible-price (FLPM), sticky-price (SPM) and real interest differential (RID) specifications--can be divided into two periods. The 'first period' evidence relates to studies of the interwar period and of the recent float up until about 1978. This first period evidence is largely supportive of the monetary model. The 'second period' evidence covers the period of the recent float extending beyond the late 1970s and is not so supportive of the monetary model.

One of the first tests of equation (7) was conducted by Frenkel (1976) for the German mark-U.S. dollar exchange rate over the period 1920-23. Since this period corresponds to the German hyperinflation, Frenkel argues that domestic monetary impulses will overwhelmingly dominate equation (7) and thus domestic income and foreign variables can be dropped, and attention focused simply on the effects of German money and the expected inflation (operating through expected depreciation). Frenkel reports results supportive of the FLPM during this period. A number of researchers have estimated FLPM equations for the more recent experience with floating exchange rates. For example, Bilson (1978a) tests the FLPM for the German mark-U.K. pound exchange rate (with the forward premium, fp_t, substituted for Δs^e_{t+1} and without any restrictions on the coefficients on domestic and

foreign money), over the period January 1972 through April 1976. Bilson incorporates dynamics into the equation and uses a Bayesian estimation procedure; results in broad accordance with the monetary approach are reported. Hodrick's (1978) tests of the FLPM for the U.S. dollar-German mark and U.K. pound-U.S. dollar over the period July 1972 to June 1975 are highly supportive of the FLPM. Putnam and Woodbury (1979) estimate equation (5) for the sterling-dollar exchange rate over the period 1972-74, and report that most of the estimated coefficients are significantly different from zero at the 5 percent significance level and all are correctly signed according to the FLPM. However, the money supply term is significantly different from unity.

Dornbusch (1979) also reports results broadly supportive of the FLPM for the mark-dollar exchange rate over the period March 1973 to May 1978, in a specification incorporating the long-term interest rate differential. Although Dornbusch (1979) introduces the long-term interest rate differential as an econometric expedient, an interpretation may be placed on this term which is consistent with Frankel's RID equation, which we discussed above. Thus Frankel (1979a), in his implementation of the RID model for the mark-dollar exchange rate over the period July 1974-February 1978, uses a long bond interest differential as an instrument for the expected inflation term, on the assumption that long-term real rates of interest are equalized. Frankel argues that since the coefficients on the interest rate and expected inflation terms are both significant, the extreme FLPM and SPM models are both rejected in favor of his RID model.

2. The second period tests of the monetary models

Although the monetary approach appears reasonably well supported for the period up to 1978, the picture alters dramatically once the sample period is extended. For example, estimates of the RID model reported by Dornbusch (1980), Haynes and Stone (1981), Frankel (1984) and Backus (1984) cast serious doubt on its ability to track the exchange rate in-sample: few coefficients are correctly signed (many are wrongly signed) the equations have poor explanatory power as measured by the coefficient of determination, and residual autocorrelation is a problem. In particular, estimates of monetary exchange rate equations for the German mark-US dollar for this period often report coefficients which suggest that a relative increase in the domestic money supply leads to a rise in the foreign currency value of the domestic currency (exchange rate appreciation). This latter phenomenon, of the price of the mark rising as its supply is increased, has been labelled by Frankel (1982) as the "mystery of the multiplying marks".

How can one explain this poor performance of the monetary approach equations for the second half of the floating sample? Rasulo and Wilford (1980) and Haynes and Stone (1981) have suggested that the root of the problem may be traced to the constraints imposed on relative monies, incomes and interest rates. The imposition of such constraints may be justified on the grounds that if multicollinearity is present, constraining the variables

will increase the efficiency of the coefficient estimates. However, Haynes and Stone (1981) show that the subtractive constraints used in monetary approach equations are particularly dangerous because they may lead to biased estimates and sign reversals.

An alternative explanation for the poor performance of the monetary model in the second period has been given by Frankel (1982a). He attempts to explain the mystery of the multiplying marks by introducing wealth into the money demand equations. The justification for this inclusion is that Germany was running a current account surplus in the late 1970s which was redistributing wealth from U.S. residents to German residents, thus increasing the demand for marks, and reducing the demand for dollars, independently of the other arguments in the money demand functions. By including home and foreign wealth (defined as the sum of government debt and cumulated current account surpluses) in his empirical equation, and by not constraining the income, wealth and inflation terms to have equal and opposite signs, Frankel (1982a) reports a monetary approach equation which fits the data well and in which all variables, apart from the income terms, are correctly signed and most are statistically significant.

As noted by Boughton (1988a), a further explanation for the failure of the monetary approach equations may be traced to the relative instability of the underlying money demand functions and the simplistic functional forms which are normally implicitly assumed for money demand. Indeed, a number of single-country money demand studies strongly indicate that there have been shifts in velocity for the measure of money utilized by the above researchers (see Artis and Lewis, 1981 for a discussion). In Frankel (1984) shifts in money demand functions are incorporated into the empirical equation by introducing a relative velocity shift term $(v-v^*)$, which is modeled by a distributed lag of $[(p+y-m)-(p^*+y^*-m^*)]$. Including the $(v-v^*)$ term in the estimating equation for five exchange rates leads to most of the monetary variable coefficients becoming statistically significant and of the correct signs. However, significant first-order residual autocorrelation remains a problem in all of the reported equations.

Driskell and Sheffrin (1981) argue that the poor performance of the monetary model can be traced to the failure to account for the simultaneity bias introduced by having the expected change in the exchange rate (implicitly) on the right-hand side of the monetary equations. One potential method of circumventing such simultaneity is offered by the rational expectations solution of the monetary model, which effectively gives an equation purged of the interest differential-forward exchange rate effect. Recently a number of researchers have begun to test this version of the model, with some degree of success. For example, Hoffman and Schlagenhauf (1983) implement a version of the 'forward solution' FLPM formulation (equation (9)) by specifying a time-series model for the stochastic evolution of the fundamentals. The equation is estimated jointly with time series models for relative money and income for the French franc, the German mark and the U.K. pound against the U.S. dollar. Hoffman and

Schlagenhauf compute likelihood ratio tests for the validity of the rational expectations hypothesis and the validity of this hypothesis plus the coefficient restrictions implied by the FLPM (such as the unit coefficient on relative money supplies). Although the expectations restrictions are not rejected for any of the countries, the FLPM restrictions are rejected for Germany. Kearney and MacDonald (1987) carry out a similar procedure for the Australian dollar-U.S. dollar and cannot reject the restrictions implied by the rational expectations-FLPM model.

MacDonald and Taylor (1991a), using multivariate cointegration techniques (Engle and Granger, 1987; Johansen, 1988), test the validity of the monetary model as a long-run equilibrium relationship for the U.S. dollar-German mark, dollar-sterling and dollar-yen exchange rates over the period January 1976 through December 1990. They find that an unrestricted version of equation (4) cannot be rejected as a long-run equilibrium for these exchange rates and that, for the dollar-mark rate, none of the coefficient restrictions implicit in equation (5) can be rejected. Note that, since all of the monetary models collapse to an equilibrium condition of the form (4) or (5) in the long-run, these tests have no power to discriminate between them. They do suggest, however, that while short-run exchange rate behavior may be difficult to model, economic fundamentals should not be rejected out of hand as a description of long-run exchange rate behavior.

The rational expectations solution to the FLPM has spawned further empirical work which seeks to test for the presence of speculative bubbles. It is well known from the rational expectations literature that equation (9) is only one solution to (7) from a potentially infinite sequence. 1/ If we denote the exchange rate given by (9) as $\hat{s}_t$ then it is straightforward to demonstrate 2/ that equation (7) has multiple rational expectations solutions, each of which may be written in the form

$$s_t = \hat{s} + b_t \tag{14}$$

where b_t--the 'rational bubble' term--satisfies

$$b^e_{t+1} = \lambda^{-1}(1+\lambda)b_t$$

Meese (1987) attempts to test for bubbles by applying a version of the Hausman (1978) specification test suggested by West (1985) for present value models. The test involves estimating a version of equation (7) (which produces consistent coefficient estimates regardless of the presence or otherwise of rational bubbles) and a closed-form version of (9) (which produces consistent coefficient estimates only in the absence of bubbles). Hausman's specification test is used to determine if the two sets of coefficient estimates are significantly different. If they are, then this

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1/ See, for example, Blanchard and Watson (1982).
2/ See MacDonald and Taylor (1989) for a fuller discussion.

is suggestive of the existence of a speculative bubble. For the dollar-yen, dollar-mark and dollar-sterling exchange rates (monthly data over the period October 1973 to November 1982), Meese in fact finds that the two sets of coefficient estimates are significantly different and therefore rejects the no-bubbles hypothesis. Kearney and MacDonald (1987) apply a version of this methodology to the Australian dollar-U.S. dollar exchange rate and cannot reject the no-bubbles hypothesis.

An alternative way of testing for bubbles has been to adopt the variance bounds test methodology originally proposed by Shiller (1979) in the context of interest rates. This may be illustrated in the following way. If we define the ex post rational or perfect foresight exchange rate as that given by replacing expected future values of money and income in (9) with their actual values:

$$s_t^* = (1+\lambda)^{-1}\sum_{i=1}^{\infty}\left(\frac{\lambda}{1+\lambda}\right)^i\left[(m-m^*)_{t+i} - \phi y_{t+1} + \phi^* y_{t+i}\right]$$

then s_t^* will differ from $\hat{s}_t$ given by (9) by a rational forecast error, u_t say (i.e., $s_t^* = \hat{s}_t + u_t$). Given that u_t is a rational expectations forecast error, $\hat{s}_t$ and u_t must be orthogonal to one another, so we have

$$\text{var}(s_t^*) = \text{var}(\hat{s}_t) + \text{var}(u_t) \qquad (15)$$

which implies

$$\text{var}(s_t^*) \geq \text{var}(\hat{s}_t) \qquad (16)$$

In the absence of bubbles the inequality given by (16) should hold. However, in the presence of bubbles (16) is likely to be violated since on using (14) we have $s_t^* = s_t - b_t + u_t$ and the relationship corresponding to (15) is

$$\text{var}(s_t^*) = \text{var}(s_t) + \text{var}(b_t) + \text{var}(u_t) - 2\text{cov}(s_t, b_t) \qquad (17)$$

Since, in the presence of bubbles, s_t and b_t may be positively correlated, we cannot derive (16) from (17). Thus, violation of (16) ("excess volatility") could be taken as evidence of the presence of rational bubbles.

Huang (1981) tests versions of (16) for the dollar-mark, dollar-sterling and sterling-mark for the period March 1973 to March 1979. His results are supportive of excess volatility and by inference he finds

against the no-bubbles hypothesis. Kearney and MacDonald (1987) implement tests of (16) for the Australian-U.S. dollar over the period January 1984-December 1986 and generally find in favor of the no-bubbles hypothesis.

There are, however, a number of problems with this kind of approach. First, it is conditional on an assumed model of the exchange rate: violation could be due to an inappropriate choice or specification of model. Second, and perhaps more importantly, there may be other possible explanations for the presence of bubbles such as measurement error in computing the perfect foresight exchange rate, inappropriate stationary-inducing transformations, or small-sample bias.

Evans (1986) tests for bubbles in the dollar-sterling exchange rate over the period 1981-84 by testing for a non-zero median in excess returns from forward market speculation (the forward rate forecasting error adjusted for risk). Evans designs and applies non-parametric tests for a non-zero median in returns which are similar in nature to runs tests. He decisively rejects the zero-median hypothesis and infers that this provides evidence of speculative bubbles. Note, however, that Evans may, in fact, be detecting peso problems 1/ and, moreover, there is no guarantee that his method of risk adjusting the excess returns (based on real interest differentials) is correct.

We now turn to the empirical evidence on the SPM reduced form. Driskell (1981) presents an estimate of an equation representative of the Dornbusch (1976) overshooting model for the Swiss franc-U.S. dollar rate for the period 1973-77 (quarterly data), and reports results largely favorable to the SPM model. Other tests of the SPM reduced form have been conducted by Backus (1984), Hacche and Townend (1981) and Wallace (1979). Results supportive of the SPM are presented by Wallace (1979) for the 1950s Canadian float against the U.S. dollar. Backus (1984) also tests the SPM model using the Canadian-U.S. dollar but for the recent floating experience (1971 quarter I to 1980 quarter IV). However, Backus's estimation results differ from those of Wallace in that he finds few statistically significant coefficients.

Estimates of a more dynamic version of the SPM model, provided by Hacche and Townend (1981) for the U.K. pound effective exchange rate, May 1972-February 1980, are suggestive of exchange rate overshooting. But in other respects the estimated equation is unsatisfactory: many coefficients are insignificant and wrongly signed and the equation does not exhibit sensible long-run properties.

1/ The peso problem (Krasker, 1980) refers to the situation where agents attach a small probability to a large change in the economic fundamentals, which does not occur in sample. This will tend to produce a skew in the distribution of forecast errors even when agents are rational, and thus may generate evidence of non-zero excess returns from forward speculation. See MacDonald and Taylor (1989) for further analysis of the peso problem.

Pappel (1988) argues that the price and exchange rate dynamics underlying the Dornbusch SPM model cannot be captured by single-equation estimation methods. To capture such dynamics, he argues, it is necessary to use a systems method of estimation which incorporates the cross-equation constraints derived from the structural equations and the assumption of rational expectations. His procedure allows domestic income and interest rates to be modeled endogenously, but not the money supply. Effectively, Pappel reduces the structural model to a reduced form vector autoregressive moving average model with nonlinear parameter constraints. He estimates this jointly with equations for income and the interest rate, for the effective exchange rates of Germany, Japan, the United Kingdom, and the United States, 1973 quarter II to 1984 quarter IV. Pappel notes: "The results of the estimation are moderately successful. Most of the structural coefficients have the expected sign, are of reasonable magnitude, and are *significant....Our results...show that Dornbusch's model and its* extensions provide a solid empirical, as well as theoretical, basis for understanding the functioning of the flexible exchange rate system."

A version of the SPM model due to Buiter and Miller (1981) has been empirically implemented by Barr (1989) and (using a structural model) by Smith and Wickens (1988, 1990) for the sterling-pound exchange rate and both sets of authors report favorable in-sample estimates of the model. The results reported in these papers are likely to be fairly robust since care has been taken in specifying the model dynamics and also Smith and Wickens estimate the model structurally. In simulating their model, Smith and Wickens (1988) find that the exchange rate overshoots by 21 percent in response to a 5 per cent change in the money supply.

Wadhwani (1984) uses the SPM model to generate s^* and to test for excess volatility and finds that the inequality (16) is violated for the dollar-sterling rate, over the period 1973, quarter I to 1982, quarter III. His results are therefore supportive of those generated by Huang (1981) using the FLPM model.

3. Empirical evidence on the portfolio balance model

Compared to the monetary approach to the exchange rate, relatively less empirical work has been conducted on the PBM, perhaps due to the limited availability of good, disaggregated data on non-monetary assets. The research that does exist on the PBM may be broadly divided into two types of test. The first concentrates on solving the short-run portfolio model as a reduced form (assuming expectations are static), in order to determine its explanatory power. The second, indirect type of test exploits the fact that the portfolio balance model rests on the assumption of imperfect substitutability between domestic and foreign assets. An alternative way of expressing this assumption is to view the return on domestic and foreign assets as being separated by a risk premium. Thus, an indirect test of the PBM is to test for the significance of such risk premia. In addition, Branson (1984) examines the time series behavior of a number of

financial variables for several countries to see if they are consistent with the predictions of the PBM.

The reduced form exchange rate equation derived from a system such as (10)-(13) may be written as (see Branson, Halttunen and Masson, 1977--the assumed short-run nature of the relationship allows income and prices to be assumed exogenous and constant):

$$S_t = g(M_t, M_t^*, B_t, B_t^*, fB_t, fB_t^*) \quad (18)$$

where fB and fB^* denote foreign holdings of domestic and foreign bonds respectively. Branson, Halttunen and Masson (1977) estimate a log-linear version of an equation similar to this for the German mark-U.S. dollar exchange rate over the period August 1971-December 1976. However, Branson et al drop the terms relating to domestic and foreign bond holdings because of the ambiguous effect they have on the exchange rate, depending on the degree of substitutability between traded and non-traded bonds. But as Bisignano and Hoover (1982) point out, this rather arbitrary exclusion will generally result in biased regression coefficients. Although the estimates reported by Branson et al. are deemed supportive of the PBM, once account is taken of acute first-order residual autocorrelation, only one coefficient, that on the U.S. money supply, is statistically significant. After specifying a simple reaction function which is purported to capture the simultaneity between the exchange rate and the money supply, Branson et al. re-estimate their equation using two-stage least squares and report more satisfactory estimates of the portfolio balance empirical model; however, residual autocorrelation remains a problem (the estimated first-order autocorrelation coefficient is 0.87, which suggests that unexplained shocks have persistent effects on the exchange rate and hence that this version of the PBM does not fully explain the mark-dollar exchange rate). In Branson, Halttunen and Masson (1979), a log-linear PBM exchange rate equation is estimated for the longer period August 1971-December 1978, for the mark-dollar, but the results are shown not to differ significantly from the earlier ones; again, persistent autocorrelation is a problem. In a further paper, Branson and Halttunen (1979) estimate the equation for five currencies (the Japanese yen, the French franc, the Italian lira, the Swiss franc, and the U.K. pound) against the German mark for a variety of different sample periods over the 1970s. Although Branson and Halttunen report equations which seem supportive of the PBM, in terms of statistically significant and correctly signed coefficients, a note of caution must again be sounded since the residuals in their OLS equations are all highly autocorrelated.

One problem with the Branson et al. implementation of the PBM lies in their use of cumulated current accounts for the stock of foreign assets. Such an approximation will, of course, include <u>third country</u> items which are not strictly relevant to the determination of the <u>bilateral</u> exchange rate in question. Bisignano and Hoover (1982) pick up on this point and argue that the PBM approach should be implemented using only bilateral data for foreign

assets and also, to be consistent, domestic and foreign bond holdings should be included in the PBM reduced form (see above). Incorporating such modifications in their estimates of the PBM equation for the Canadian dollar-U.S. dollar, over the period March 1973 to December 1978, Bisignano and Hoover (1982) report moderately successful econometric results; in particular, they show that it is wrong to neglect domestic and foreign non-monetary asset stocks in exchange rate reduced forms.

Dooley and Isard (1982) were the first to attempt to construct data on domestic and foreign bond holding without assuming that the current account deficit is financed entirely in one of the two currencies under consideration. For example, in an analysis of the dollar-mark exchange rate, the U.S. demand for US bonds is viewed as one component of the total demand (the other demand components being attributed to private German wealth holders, private and official OPEC 1/ residents, and private and official residents of the rest of the world). The total demand is then assumed equal to the supply of outside dollar-denominated bonds, viewed as equal to the cumulative U.S. budget deficit, less the stock of bonds removed from private circulation through Federal Reserve open-market operations, and less cumulative U.S. and foreign official intervention purchases of dollar-denominated bonds. Dooley and Isard estimate their model for the dollar-mark exchange rate over the period May 1973 through June 1977 using an iterative estimation procedure to impose model consistent (i.e., broadly speaking, rational) expectations and compare the predictions of the model to naive forecasts using the forward rate and the lagged spot rate. They summarize the performance of the model as follows (1982, p. 273):

> The model is better than the forward rate as a predictor of the change in the exchange rate...however,..., the model fails to explain the major portion of observed changes in exchange rates; the coefficient of correlation between predicted and observed changes is 0.4, and the model incorrectly predicts the direction of one out of every three changes.

Dooley and Isard point out that the ability of the model to outperform the forward rate as a spot rate predictor challenges the view that exchange risk premia are non-existent. On the other hand, the empirical shortcomings of the model suggest either that their simplifications of the theoretical model are too severe or that observed exchange rate movements are predominantly unexpected.

Boughton (1988b) introduces term structure effects into an empirical portfolio balance model and estimates jointly a "semi-reduced form" consisting of a real exchange rate portfolio balance equation which includes long- and short-term interest rates, an equation for the short-term rate (essentially an inverted LM curve) and a forecasting equation for the long-short term interest rate spread. He uses data on the real effective

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1/ That is, oil producing and exporting countries.

exchange rates for the U.S. dollar and on real bilateral dollar-yen and dollar-mark exchange rates for the period May 1973 through December 1985. He reports estimation results that are broadly satisfactory in terms of the sign and statistical significance of the estimated coefficients. Boughton then uses these results in a number of counterfactual simulations in an analysis of the strong appreciation of the dollar over the 1980-85 period. He concludes that a major contributory factor to the rise of the dollar over the period, according to his model, was a failure of the "rest of the world" (Germany, Japan, the United Kingdom, and France) sufficiently to tighten monetary policy, as measured by the significance of the short-term interest rate differential in explaining the swings in the dollar: in December 1980 the weighted average short-term rate for the four countries outside the United States would have had to have risen from 11.2 percent to 21.3 percent in order to have prevented the subsequent appreciation of the dollar.

In an attempt to improve on the estimates of monetary approach and portfolio balance equations and, in particular, to overcome the model misspecification suggested by the typically high value of the first-order residual autocorrelation coefficient in such equations, a number of researchers have attempted to combine features of both the monetary and portfolio balance approaches into a reduced form exchange rate equation. Thus, if risk is important the monetary approach reduced form will be misspecified to the extent that it ignores the imperfect substitutability of non-money assets. In the PBM with rational expectations, agents would be expected to revise their estimates of the expected real exchange rate as new information about the future path of the current account reaches the market: the spot exchange rate in a portfolio balance reduced form should include news about the current account as an explanatory variable. We now turn to some empirical attempts to synthesize the portfolio and monetary approaches, with emphasis being placed on the modeling of the risk premium and news about the current account.

Versions of hybrid models with characteristics such as these have been estimated by a number of researchers (Hooper and Morton, 1982; Frankel, 1983, 1984; Isard, 1980; and Hacche and Townend, 1981). In Hooper and Morton's implementation, the risk premium is assumed to be a function of the cumulated current account surplus net of the cumulation of foreign exchange market intervention. Their equation is estimated for the dollar effective exchange rate 1973 quarter II-1978 quarter IV using an instrumental variables estimator. Hooper and Morton report mixed results with only some of the coefficients (mainly those relating to the monetary approach variables) appearing significant and of the correct sign.

Using Hooper and Morton's specification, Hacche and Townend (1981) test the PBM with an additional term to allow for the impact of oil prices on the sterling effective exchange rate, over the period June 1972 to December 1981. The results are largely disappointing: few coefficients are significant and of those that are, the estimated risk premium coefficient is

wrongly signed and the point estimate of the oil price coefficient correctly signed.

In Frankel's (1984) implementation of the portfolio-monetary hybrid reduced form model, the current account news term is not considered and the risk premium is derived as the solution to the PBM. Frankel estimates a hybrid equation for five currencies against the dollar for the period 1974-1981 (monthly data, with the exact beginning and end points currency specific). In general, Frankel finds that the estimated coefficients of the monetary approach variables are statistically insignificant, and some wrongly signed.

As noted earlier, an alternative, indirect method of testing the PBM is to model the exchange risk premium--the deviation from uncovered interest rate parity--as a function of the relative stocks of domestic and foreign debt outstanding. The Dooley and Isard (1982) study discussed above can be interpreted as a test of this kind. Direct attempts to model deviations from uncovered interest parity as a function of relative international debt outstanding have been made by Frankel (1982, 1983, 1985) for the German mark-U.S. dollar rate, and by Rogoff (1984) for the Canadian dollar-U.S. dollar exchange rate. In each case, however, statistically insignificant relationships are reported. Fisher et al. (1990) report that an exchange rate equation in which the deviation from uncovered interest rate parity (for the sterling effective rate, with both the exchange rate and interest rate expressed in real terms) is modeled as a function of the ratio of the current account balance to GDP outperforms other exchange rate equations used in major econometric models of the U.K. economy in terms of beating a random walk in out-of-sample forecast tests. 1/

4. The out of sample forecasting performance of exchange rate models

Hitherto, we have considered only the in-sample properties of the asset approach reduced forms. A stronger test of the models' validity would be to determine how well they perform out-of-sample compared to an alternative, such as the naive random walk model. Meese and Rogoff (1983) (hereafter MR) have conducted such a study for the dollar-pound, dollar-mark, dollar-yen and trade-weighted dollar exchange rates using data running from March 1973 through June 1981. The exchange rate models tested by MR correspond to the *FLPM, the RID and the portfolio-monetary synthesis equation of Hooper and* Morton (1982). The out-of-sample performance of these equations is compared to the forecasting performance of the random walk model, the forward exchange rate, a univariate autoregression of the spot rate and a vector autoregression. MR compute their forecasts in the following way. First, the equations are estimated using data from the beginning of the sample to November 1976 and four forecasts are made for one, three, six and twelve months ahead. The data for December 1976 is then added to the original

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1/ See the next section. Note that this study uses quarterly data, as does Boughton (1988).

data set, the equations re-estimated and a further set of forecasts are made for the four time horizons. This 'rolling regression' process is then continually repeated. The statistics used to gauge the out-of-sample properties of the models are the mean error (ME), mean absolute error (MAE) and the root mean square error (RMSE). A sample of MR's RMSE results (for the six-month forecast and excluding the forward rate, univariate and vector autoregression forecasts) are reported in Table 1, where the reduced forms derived from structural models have been estimated using the Fair (1970) procedure.

Table 1. Root Mean Square Forecast Errors for Selected Exchange Rate Equations

Exchange Rate	Forecast Horizon	Random Walk	FLPM	RID	Monetary/Portfolio Synthesis
	(In months)				
$/Mark	6	8.71	9.64	12.03	9.95
$/Yen	6	11.58	13.38	13.94	11.94
$/Pound	6	6.45	8.90	8.88	9.08
Trade-Wtd. Dollar	6	6.09	7.07	6.49	7.11

Source: Meese and Rogoff (1983).

The devastating conclusion which emerges from the Meese-Rogoff study is that none of the asset approach exchange rate models considered outperform the simple random walk model. This result is all the more striking when it is remembered that the reduced form forecasts are computed using actual values of the various independent variables.

In an attempt to improve on the poor performance of the asset reduced forms, MR alternatively attempt estimating the models in first differences, allow home and foreign magnitudes to enter unconstrained, include price levels as additional explanatory variables, use different definitions of the money supply and replace long term interest rates with other proxies for inflationary expectations. But all to no avail: the modified reduced form equations still fail to outperform the simple random walk.

In a further paper, MR (1984) consider possible explanations as to why the reduced form asset models fail to beat the random walk model out-of-sample. In particular, MR (1984) show--using the vector autoregressive

methodology--that the instruments used in simultaneous estimates of asset reduced forms may not be truly exogenous and thus the estimated parameter estimates may be extremely imprecise. To overcome this problem MR impose coefficient constraints, culled from the empirical literature on money demand equations, in the asset reduced forms and re-estimate the RMSE's for the same period as their 1983 paper. Interestingly, MR find that although the coefficient constrained asset reduced forms still fail to outperform the random walk model for most horizons up to a year, they find that in forecasting beyond a year (which was not possible, due to degrees of freedom problems, with the unconstrained estimates in MR,1983) the asset reduced forms do outperform the random walk model in terms of RMSE. As Salemi (1984) points out, this tends to suggest that the exchange rate acts like a pure asset price in the short term (i.e., approximately a random walk--see, e.g., Samuelson, 1965) but that in the longer term its equilibrium is systematically related to other economic variables. One important point to bear in mind about MR's work is that their comparison of the random walk model with the structural models is a little unfair because the random walk predictions are one-step-ahead and therefore use information not available to the multi-step ahead forecasts.

A large section of the literature has been devoted to determining whether MR's specification of the asset reduced form equations, their estimation strategy, or the models themselves are at fault. Woo (1985) and Finn (1986) estimate versions of the rational expectations form of the FLPM (equation (9)) with the addition of a partial adjustment term in money demand and perform a MR forecasting exercise. Finn reports that this model forecasts as well as the random walk model (but fails to outperform a random walk) whilst Woo finds that his formulation outperforms the random walk model in terms of both the MAE and RMSE, for the mark-dollar. Somanath (1986) also utilizes money demand partial adjustment terms in his formulation of various asset reduced form equations (such as FLPM, RID, and Hybrid) for the German mark-U.S. dollar. Interestingly, he finds, for the period studied by MR, that this modification results in the structural exchange rate models outperforming the random walk model in terms of the standard criteria, and that for a sample period extending beyond that of MR the basic (i.e., without any additional dynamics) FLPM, RID and hybrid equations outperform a random walk. 1/

A time-varying parameter model has been used by Wolff (1987) and Schinasi and Swamy (1987) as the preferred estimation technique for econometric implementation of the RID and FLPM equations. Both Wolff (1987) and Schinasi and Swamy (1987) argue that the poor forecasting performance noted by MR may be due to the failure of these authors to account for parameter instabilities. There are in fact a number of reasons why the parameters in empirical exchange rate equations are unlikely to be constant for the recent floating experience. For example, instabilities

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1/ The forecasting performance of these equations is even better for the extended sample period when money market dynamics are allowed for.

in the underlying structural equations (money demand and PPP equations), policy regime changes (Lucas, 1976) and heterogeneous beliefs by agents (leading to a diversity of responses to macroeconomic developments over time) could all impart parameter instabilities over time. Using the Kalman filter methodology, Wolff (1987) reworks MR's results (same currencies and time period), for the FLPM and RID reduced forms, assuming that the parameters follow a random walk process. However, Wolff reports that this strategy only results in the FLPM and RID models beating a random walk in the case of the dollar-mark exchange rate (for both the dollar-yen and the dollar-pound the random walk has a better forecasting performance across all forecast horizons and indeed if one takes the average across all currencies and forecast horizons the random walk model dominates). Schinasi and Swamy (1987) use a less restrictive time-varying model than Wolff and find that their model results in consistently better forecasts (than a random walk) for the FLPM, RID and hybrid equations (for the mark, yen, and pound dollar bilateral exchange rates). However, it is not entirely clear if the improved performance of the structural models is due to the use of time-varying parameters or simply to the fact that a multi-step random walk forecast is used rather than the one-step forecast used by MR. In a further experiment, Schinasi and Swamy add a lagged dependent variable to the various monetary reduced forms and compare their forecasting performance to a one-step ahead random walk. It is demonstrated for all cases that the time-varying parameter version are always superior to the fixed coefficients version and, furthermore, out-perform the one-step-ahead random walk in almost all cases.

Finally, Boughton (1984) tests the out of sample forecasting performance of a preferred habitat version of the portfolio balance model (using fixed coefficient methods), for a variety of currencies, against a random walk model. It is demonstrated that in every case that this out-performs the random walk model. However, it seems likely that this result reflects Boughton's use of quarterly data (all the other studies use monthly data) since his estimates of the hybrid equation also generally outperform the random walk model.

5. Empirical exchange rate models: new directions

The broad conclusion which emerges from our survey of the empirical evidence on exchange rate models is that the asset approach models have performed well for some time periods, such as the interwar period, and, to some extent, for the first part of the recent floating experience (i.e., 1973-1978) but have largely broken down as an adequate explanation of the behavior of the major exchange rates during latter part of the recent float.

The failure of simple asset approach equations to perform satisfactorily for the latter period may be due to misspecification. Such misspecification may be of an econometric nature insofar as the dynamic properties of the asset equations have, in relation to the Hendry et al. (1984) dynamic modeling methodology, been very poorly specified (the

persistent indication of first-order autocorrelation is supportive of this view). Simple asset- approach equations may also be misspecified from an economic point of view. Thus the 'breakdown' in the performance of the monetary model could be a consequence of the omission of important variables such as the current account, wealth and risk factors. However, when such additions are made to the simple asset models little improvement in equation performance is reported.

Some authors, (e.g., Pappel, 1988; Isard, 1988) have argued that a useful way of ensuring that exchange rate models are correctly specified (in terms of the correct set of variables to include, the exogeneity assumptions made and the dynamic specification) is to estimate the models structurally, and this seems to be a useful avenue for future research. 1/ Examples of existing studies which have applied the structural model approach to modeling the exchange rate--with some degree of success--would include Kearney and MacDonald (1985), Blundell-Wignall and Masson (1985), Masson (1988), Pappel (1988) and Smith and Wickens (1988, 1990). Note, however, that the systems approach raises a set of further issues concerning the assumed structure of the whole economy--see, for example, Fisher et al. (1990) on the econometric evaluation of the exchange rate in large-scale models of the U.K. economy.

Other explanations which have variously been put forward to explain the poor empirical performance of asset approach exchange rate equations include the following.

Some authors have stressed the idea that foreign exchange rates may have consistently deviated from their underlying 'fundamental' levels (i.e., as predicted by economic theory) due to the presence of rational bubbles, as discussed above (see, e.g., Flood and Hodrick, 1989).

Other researchers have concentrated on the influence of foreign exchange analysts who do not base their predictions on economic theory but on the identification of supposedly recurring patterns in graphs of exchange rate movements--i.e., 'technical' or 'chart' analysts. Frankel and Froot (1986, 1990), for example, suggest a model of the foreign exchange market in which traders base their expectations partly on the advice of fundamentalists (i.e., economists) and partly on the advice of non-fundamentalists (ie chartists). They argue that such a model would seem to explain the heavy overvaluation of the U.S. dollar during the mid-1980s.

Some support for the view that non-fundamentalist advice may be an important influence in foreign exchange markets is provided by Taylor and

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1/ Thus, Isard (1988, p. 197) writes: 'Strong support exists for the view that simultaneous-equation frameworks are preferable to single-equation semi-reduced-form models for capturing the associations between exchange rates, interest differentials, and actual or expected inflation differentials in response to different types of exogenous shocks.'

Allen (1991) who conducted a survey among chief foreign exchange dealers in the London foreign exchange market and found that a high proportion of chief dealers use some form of chart analysis in forming their trading decisions, particularly at the shorter horizons. At the shortest horizons (intraday to one week) Taylor and Allen find that over 90 percent of their survey respondents reported using some form of chart analysis and around 60 percent judged charts to be at least as important as fundamentals at this horizon. As the time horizon is lengthened, however, the weight given by dealers to fundamental analysis increases. At the longest forecast horizons considered (one year or longer), nearly 30 percent of chief dealers reported relying on pure fundamental analysis and 85 percent judged fundamentals to be more important than chart analysis at this horizon. In addition, Allen and Taylor (1990) analyze the accuracy of a number of individual chart analysts' one-week and four-week ahead forecasts of the dollar-sterling, dollar-mark and dollar-yen exchange rates and find that some of them consistently outperform a whole range of alternative forecasting procedures, including the random walk model, vector autoregressions and univariate autoregressive moving average time series models. Given this evidence, it seems hardly surprising that empirical models based on pure, 'fundamental' economic theory fail to provide an adequate explanation of short-term movements in exchange rates, although the finding that foreign exchange participants focus more on fundamentals at longer horizons suggests that more attention might fruitfully be given to modeling the fundamental determinants of long-term exchange rates. This is consistent with evidence in favor of the monetary model as a long-run equilibrium condition reported by MacDonald and Taylor (1991a).

Masson and Knight (1986, 1990) and Frenkel and Razin (1987) emphasize the role of shifts in fiscal policy stance among the major OECD countries as important determinants of exchange rate behavior (see also Dornbusch, 1987). These authors argue that the large autonomous changes in national saving and investment balances--in particular those influenced by shifts in public sector fiscal positions in the largest industrial countries--must exert a very strong influence on current account positions, real interest rates and hence exchange rates.

Dooley and Isard (1989, 1991) focus their attention on factors affecting the choice of where to locate tangible assets and other 'taxable' forms of wealth. In support of this view, Dooley and Isard point to the experience of a number of debt-burdened developing countries during the 1980s who experienced substantial depreciations of their real exchange rate around the time of the outbreak of the international debt crisis in 1982. Dooley and Isard (1989) argue that '... these depreciations can be attributed primarily to a set of events that considerably reduced the attractiveness of owning assets located in the debt-burdened countries, thus giving rise to a "transfer problem" in which real depreciation played an important role in the adjustment to substantially smaller net capital inflows and current account deficits.' Dooley, Isard, and Taylor (1991) suggest that changes in relative country preferences should be systematically reflected

in the price of gold, which can be viewed as "an asset without a country." Hence, if the effects of monetary shocks on gold prices can be isolated, evidence that residual changes in the price of gold are capable of explaining or predicting residual changes in exchange rates might be regarded as indirect evidence that exchange rate behavior largely reflects changes in country preferences. Dooley et al., in fact, provide econometric evidence which is largely supportive of this view for a number of major exchange rates during the percentage change in the gold price is a highly significant additional explanatory variable in a simple RID monetary model, and also improves the dynamic modeling techniques, Dooley et al. also demonstrate that the price of gold is a crucial factor in beating a random walk in post-sample prediction tests.

Dornbusch (1987) stresses the importance of analyzing a country's industrial structure in attempting to explain the behavior of its exchange rate. For example, the effect of an exchange rate change on a firm's pricing decisions (and hence on further changes in the exchange rate) will depend upon whether the industry faces competition from imports which are close substitutes for their goods, whether the market is characterized by oligopoly, imperfect competition, etc., and the functional form of the specific market demand curve. After demonstrating these points with a number of concrete examples, Dornbusch concludes: 'Even though this application of industrial organization ideas to the effects of exchange rate movements does not emerge with firm results, it is quite apparent that it offers a major avenue for theoretical research and for applied studies'.

Which of these directions is likely to lead us towards a better understanding of exchange rate behavior? In our view, the rational bubbles explanation is perhaps the least attractive, not least because a growing amount of empirical research now suggests that asset market participants may not be endowed with fully rational expectations (Frankel and Froot, 1987; Taylor, 1988a). The Taylor and Allen (1991) evidence on the prevalence of non-fundamentalist analysis in foreign exchange markets suggests that, as a guide to the <u>short-run</u> behavior of exchange rates, the fundamentals versus non-fundamentals approach seems promising. Unfortunately, this road is likely to be difficult to tread in terms of developing reliable models of exchange rate behavior. For example, Allen and Taylor (1990), after analyzing survey data on chartists' exchange rate forecasts, report a significant degree of heterogeneity amongst chartist forecasts--not all chartists see the same patterns (or draw the same conclusions from them) at the same points in time. They argue, moreover that the degree of consensus is likely to shift significantly over time in a fashion which may be hard to model empirically. Thus, while this approach may help us to rationalize the <u>past</u> behavior of exchange rates (e.g., Frankel and Froot, 1990), it may prove rather more difficult to apply it to predicting <u>future</u> short-term exchange rate behavior.

Given the Taylor-Allen evidence that foreign exchange market participants rely more on fundamental economic analysis at longer horizons,

it would seem that more attention ought to be focused on attempting to model the long-run equilibrium exchange rate, and it is perhaps in this area that the new approaches involving accounting for fiscal policy stance, locational decisions and industrial organization might be most fruitfully applied. In addition, the recent development of econometric techniques which aid in the identification of long-run relationships using short-run data (see e.g., Engle and Granger, 1987) is likely to provide a further impetus in this direction. (See MacDonald and Taylor, 1991a)

IV. The Efficient Markets Hypothesis

In this section we present a brief review of the literature on the efficient markets hypothesis (EMH) as applied to the spot and forward markets for foreign exchange.

Under the hypothesis of market efficiency it should be impossible for a trader to earn excess returns to speculation. In order to test this hypothesis, it is necessary to have a model of the equilibrium expected return. Early tests of spot market efficiency (e.g., Poole, 1967) tested for randomness of exchange rate changes. As pointed out by Levich (1985), however, efficiency only implies randomness of returns if the equilibrium expected return is constant. If the underlying fundamental determinants of the exchange rate (such as relative money and output according to the monetary approach) are serially correlated, then so will the equilibrium exchange rate be. Thus, contrary to popular belief, efficiency does not necessarily imply that the exchange rate should follow a random walk. This is most easily seen by recalling the uncovered interest parity condition: under risk neutrality and rational expectations, the expected rate of depreciation of one currency against another will be just equal to the interest rate differential between the currencies of appropriate maturity, so that the expected profit from arbitraging between them is zero. Thus, only if the interest differential is identically zero will the spot rate follow a random walk. 1/ The analysis of Cumby and Obstfeld (1981) can be seen as a logical extension of the literature on the randomness of exchange rate changes since they test for randomness of deviations from uncovered interest rate parity (see the section on international parity conditions below).

Another method of testing spot market efficiency is to test for the profitability of filter rules (e.g., Poole, 1967; Dooley and Shafer, 1983). A simple x percent filter rule implies the following trading strategy: buy a currency whenever it rises x percent above its most recent trough; sell the currency and take a short position whenever the currency falls x percent below its most recent peak. If the market is efficient and uncovered interest rate parity holds, the interest rate costs of such a strategy

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1/ If the interest differential were identically equal to a constant, the logarithm of the spot rate would follow a random walk with drift.

should on average eliminate any profit. Poole's (1967) study does not in fact allow for interest rate costs, but Dooley and Shafer's (1983) analysis not only includes interest rate costs but also allows for transactions costs using bid and asked exchange rate quotations. After examining a number of filter rules using daily data on nine exchange rates for the 1970s, they report that small filters--1, 2, and 3 percent--would have systematically generated profit for all exchange rates over the sample period. As noted by Levich (1985), however, it is not clear that the optimal filter rule size could have been chosen ex ante, and there also appears to be an important element of riskiness in that substantial sub-period losses are often generated.

The literature on forward foreign exchange market efficiency has generally utilized some form of regression-based analysis of spot and forward exchange rates. As is clear from the preceding discussion, the EMH can be seen as a joint hypothesis of a view of equilibrium returns and the contention that agents are endowed with rational expectations. For our purposes, the latter proposition can be stated as:

$$\Delta s_{t+k} = \Delta s^e_{t+k} + \eta_{t+k}, \qquad \Delta s^e_{t+k} = E[\Delta s_{t+k} | I_t] \tag{19}$$

where $\Delta s_{t+k} = s_{t+k} - s_t$, $\Delta s^e_{t+k} = s^e_{t+k} - s_t$, s denotes the logarithm of the spot rate (home currency price of foreign currency), s^e_{t+k} denotes the expected value of s_{t+k} at time t, E is the mathematical conditional expectation operator, I_t is the information set on which agents base their expectations and η_{t+k} is a random forecast error, orthogonal to the information set. Relationship (19) is normally expressed in logarithms in order to circumvent the so-called 'Siegel paradox' (Siegel, 1972) that, because of a mathematical relationship known as Jensen's inequality, one cannot have, simultaneously, an unbiased expectation of, say the mark-dollar exchange rate (marks per dollar) and of the dollar-mark exchange rate (dollars per mark) because $1/E(S) \neq E(1/S)$. This problem does not arise if agents are assumed to form expectations of the logarithm of exchange rates, however, since $E(-s)=-E(s)$. McCulloch (1975), however, has investigated the empirical importance of this phenomenon (using 1920s data) and shown the operational importance of the Siegel paradox to be slight. Nevertheless, the literature has continued to work with logarithmic transformations of the data.

If agents are risk-neutral, then since a profit can be expected to be made when the forward rate differs from the expected future spot rate (by taking open forward positions), one might expect the forward rate for maturity k periods ahead to be forced into equality with the market's expectation of the spot rate at time t+k:

$$f_t = s^e_{t+k} \tag{20}$$

If agents are risk-averse, however, then the forward rate will not be driven to full equality with the expected future spot rate because of the

risk involved in taking open forward positions. Thus, a risk premium, λ_t say, might be expected to drive a wedge between f_t and s^e_{t+k}. Under this assumption, (20) can be rewritten, after subtracting s_t from both sides:

$$fp_t = \Delta s^e_{t+k} + \lambda_t, \tag{21}$$

where fp_t denotes the logarithm of the forward premium ($fp_t = f_t - s_t$) and λ_t represents a risk premium which is required to compensate agents from exposure to the risk involved in running open positions in the currency in question.

From (19) and (21) we can obtain a statement of the efficient markets hypothesis under risk aversion as follows:

$$fp_t = \Delta s_{t+k} + \epsilon_{t+k} + \lambda_t. \tag{22}$$

where $\epsilon_{t+k} = -\eta_{t+k}$. As we shall see, in trying to interpret the often quoted finding that the forward premium is a biased predictor of the exchange rate depreciation, researchers tend to either assume that λ_t is zero, and conclude that rejection is attributable to 'irrationality', or to assume agents are rational and conclude that rejection is due to the presence of a statistically significant risk premium.

A popular way of testing the joint EMH is to regress the actual change in the exchange rate on the forward premium,

$$\Delta s_{t+k} = \alpha + \beta\ fp_t + u_{t+k} \tag{23}$$

and if agents are risk neutral and rational, we would expect $\alpha=0$, $\beta=1$ and, if non-overlapping data is being used (k=1), the disturbance term to be serially uncorrelated. If, however, agents are either risk averse or 'irrational' (or both) then such conditions will be violated.

An alternative test of the optimality of the forward rate as a predictor of the exchange rate change has been to conduct forecast error orthogonality tests. More specifically, a number of researchers estimate an equation of the form:

$$s_{t+k} - f_t = \Gamma X_t + \omega_{t+k} \tag{24}$$

where X_t is a vector of variables known at time t, which is the econometricians' observed portion of the 'true' information set, I, available to agents; Γ is a vector of parameters and ω_{t+k} is an error term. The null hypothesis of rational expectations and risk neutrality is equivalent to the hypothesis that Γ should equal the null vector, so that the error in forecasting the exchange rate using the current forward rate should be unforecastable using current information--i.e., it should be

orthogonal to elements of the information set available at time t. If this condition is significantly violated then information available to agents at time t has remained unexploited, contradicting rationality.

1. Tests of the forward premium as an optimal predictor of the rate of depreciation

A large number of researchers have implemented (23), using a variety of currencies and time periods, for the recent floating experience, and report results which are unfavorable to the EMH under risk neutrality. For example, Bilson (1981), Longworth (1981), Fama (1984), Gregory and McCurdy (1984), Taylor (1988b) and Kearney and MacDonald (1988) all report a result which seems to suggest a resounding rejection of the unbiasedness hypothesis: a significantly negative point estimate of β. This result seems particularly robust given the variety of estimation techniques used by researchers and the mix of overlapping and non-overlapping data sets. A typical example of the kind of result obtained by researchers is reported here as equation (25) (from Fama, 1984), where standard errors are in parenthesis:

$$\Delta s_{t+k} = \underset{(0.42)}{0.81} - \underset{(0.50)}{1.15}(f-s)_t \tag{25}$$

Currency: Swiss franc-U.S. dollar, August 1973-December 1982

A large amount of research effort has been expended in trying to rationalize this finding. Perhaps the most popular explanation is that there is a non-zero, time-varying risk premium which drives a wedge between the forward rate and future spot rate (see Fama, 1984; Hodrick and Srivastava, 1986).

2. Error orthogonality tests of the efficient markets hypothesis

Alternative tests of the efficiency hypothesis have relied on testing the orthogonality of forward rate forecasting errors to information available at the time of the forecast. Orthogonality tests of efficiency may be split into those which include only lagged forecast errors in the conditioning information set (in terms of Fama's 1976 taxonomy, such tests are weak form tests, which we categorize as type A tests) and those which include information additional to lagged forecast errors in the information set (semi-strong form tests, which we label type B tests).

Type A tests have been conducted by, inter alios, Cumby and Obstfeld (1984), Geweke and Feige (1978), Frankel (1979b), Gregory and McCurdy (1984), MacDonald (1983) and MacDonald and Taylor (1991b). These authors use a variety of different sample periods (i.e., recent float and interwar float), exchange rates (usually bilateral dollar rates) and estimation techniques--ordinary least squares (OLS), generalized least squares,

Zellner's 'seemingly unrelated regressions' technique and generalized method of moments (GMM). Their basic finding is that the EMH is rejected for a number of currencies for the recent and interwar floating experiences. For example, Hansen and Hodrick (1980) estimate equation (24) using a weekly data base, for part of the recent float and find that the orthogonality property is violated for three currencies (the Swiss franc, the Italian lira and the German mark). Hansen and Hodrick estimate their version of equation (24) using OLS (since it is consistent), but correct the covariance matrix of standard errors for the implied moving average error structure which is implied by overlapping data (k>1) using Hansen's (1982) generalized method of moments procedure. 1/ MacDonald and Taylor (1991b) also use Hansen's GMM technique to conduct type A tests for the inter-war period, but, in contrast to HH, MacDonald and Taylor use the GMM procedure to correct for both the implied moving average error and conditional heteroscedasticity (HH assume conditional homoscedasticity); they find very strong rejection for dollar- sterling, franc-sterling and franc-sterling (this result contrasts with other tests of the EMH for this period).

Given the rejections of the null reported when researchers conduct type A tests, it is hardly surprising to find that type B tests result in even stronger rejections. Thus, Geweke and Feige (1978), Hakkio (1981), Hansen and Hodrick (1980), Hsieh (1984) and MacDonald and Taylor (1991) all test the orthogonality of the forward rate forecast error with respect to own lagged forecast errors and lagged forecast errors from other foreign exchange markets and find that the null hypothesis $\Gamma=0$ is resoundingly rejected.

3. Rationalizing inefficiency findings

The rejection of the EMH is usually explained in one of two ways. As noted above, the EMH is a joint null hypothesis of rational expectations and an assumption concerning the attitude of agents toward risk. Often, it has been tested under the assumption of risk neutrality. Thus, the first, and by far the most popular explanation of the inefficiency finding is to argue that agents are risk averse and therefore that λ_t is non-zero in (21). For examples of attempts to model or test for the foreign exchange risk premium econometrically see, inter alia, Fama (1984); Hansen and Hodrick (1983); Domowitz and Hakkio (1985); Wolff (1987); and Taylor (1988b, 1991a). By and large, however, the risk premium has proved elusive in that few of these authors report satisfactory estimates of it. 2/

Alternatively, researchers have sought to explain rejection in terms of a failure, in some sense, of the expectations component of the joint hypothesis. Examples in this group are: the 'peso problem' suggested by

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1/ See MacDonald and Taylor (1989) for an explanation and discussion of the moving average structure of overlapping forecast errors.

2/ For extensive surveys of this issue see Hodrick (1987); MacDonald and Taylor (1992).

Krasker (1980); 1/ the rational bubbles phenomenon, originally suggested by Flood and Garber (1980); or inefficient information processing, as suggested by Bilson (1981), (see MacDonald and Taylor 1992 for a more detailed survey).

A problem with each of these possible rationalizations of the inefficiency finding is that in order to test for a failure in one leg of the EMH, the researcher must must normally assume that the other component of the joint hypothesis is valid. For example, all of the investigations of foreign exchange risk premia cited above are conducted conditional on the assumption of rational expectations. Clearly one would like to be able to conduct tests of each component of the joint hypothesis in order to discern which component joint is at fault. The recent availability of survey data on exchange rate expectations, from a variety of sources, has allowed researchers to do just that. For example, Frankel and Froot (1987, and 1990), MacDonald and Torrance (1988b, 1990) and Taylor (1989a) all use the median of various exchange rate surveys to this end. The broad conclusion to emerge from this research is that the joint hypothesis fails both because agents are risk-averse and because their expectations do not conform to the rational expectations hypothesis (Takagi, 1991; MacDonald and Taylor, 1992). Furthermore, Ito (1990) demonstrates, using a highly disaggregated survey data base that exchange rate expectations appear to be highly heterogeneous. 2/

4. The efficient markets hypothesis: anything left?

There is now overwhelming evidence to suggest that the forward foreign exchange rate is a biased and inefficient predictor of the future spot rate. The simpler version of the EMH (i.e., assuming risk neutrality) thus seems to have been decisively rejected for the foreign exchange market. 3/ This result is commonly explained either in terms of a time-varying risk premium or in terms of some problem with the expectations leg of the joint hypothesis of market efficiency. The time-varying risk premium story, although intuitively extremely plausible, receives rather mixed support from the data, and at best we must conclude that the jury is still out on this as an explanation. Furthermore, a number of researchers have argued that the use of a time-varying risk premium is a rather vacuous device which "has no

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1/ See footnote 1, page 13.

2/ Froot and Ito (1988) test the "consistency" of the median response of survey data. Such tests amount to testing whether the long-term forecast implied by a short-term forecast is consistent with the survey-based long-term forecast. Such a test is effectively an application of the cross equation restrictions tested in the context of a vector autoregressive model of the forward and spot rates. Froot and Ito demonstrate that the survey forecasts are inconsistent.

3/ The London Financial Times noted (April 5, 1988, p. 16): 'In the hurly-burly of City dealing rooms, where anomalous price movements are exploited daily, the [efficient markets] theory has always been dismissed as the product of remote academic theorising.'

function but tautologically to save the theory." (Mankiw and Summers, 1984). 1/ Perhaps then the failure of the joint efficiency hypothesis should be traced to the expectations leg of the joint hypothesis. The reported profitability of some simple trading rules would certainly seem to point in this direction. Indeed MacDonald and Young (1986), Frankel and Froot (1987), Goodhart (1988) and Allen and Taylor (1990) have recently argued that combining a chartist view of exchange rate determination with an equilibrium, or fundamentalist, view, offers a much more realistic view of how exchange rates are actually determined and helps to explain why the forward rate is such a poor predictor of the future exchange rate. 2/ Combining this view with a fresh approach to the underlying fundamentals (e.g., Dooley, Isard, and Taylor, 1991) is an approach which we believe offers a great deal of potential for future research on exchange rate economics.

V. "News" and Exchange Rates

One important implication of the rational expectations hypothesis is that it is unanticipated events or 'news' that drive asset prices like the exchange rate. For example, although the strict EMH requires the forward exchange rate to be an unbiased forecast of the future spot rate, it does not predict that the forward rate will be a particularly good forecast (although it may be the best available) of the future spot rate in periods which contain a great deal of new information. Thus, in the preceding discussion, the error made in forecasting the spot rate at time t+k using information at time t(η_{t+k} in (19)) can be thought of as due to new information arriving in periods t+1 through t+k. If such news elements are small and insignificant then clearly the EMH predicts that s_{t+k} should be very close to f_t, but if a researcher is examining an equation such as (23) a period in which there has been a great deal of new information, the sample variance of the prediction error could be substantial.

Let the vector z include all variables relevant for the process of exchange rate determination, and thus our equation for the determination of the exchange rate is

$$s_t = \gamma' z_t + \eta_t \tag{26}$$

1/ Frankel and Froot (1990) present the most complete and formal statement of this view.

2/ Both Hakkio (1978) and MacDonald (1988) report some success in estimating PPP relationships for the recent floating experience using systems estimators; however, certain features of the estimation strategy adopted by these authors (in particular their use of a serial correlation correction) indicate that PPP deviations are important.

where η_t is a white-noise error. Under the rational expectations hypothesis, agents use the true model in forming their exchange rate expectations agents, so

$$s_t^e = \gamma' z_t^e \tag{27}$$

where $s_t^e = E(s_t | I_{t-1})$, $z_t^e = E(z_t | I_{t-1})$. Thus on subtracting (27) from (26) and assuming risk-neutrality (so that $s_t^e = f_{t-1}$), we can see that the forward rate forecast error is composed of a news term and a purely random term

$$s_t - f_{t-1} = \gamma(z_t - z_t^e) + \eta_t \tag{28}$$

where the term in parentheses represents the 'news'.

This highlights two factors which face a researcher in attempting to test the news approach empirically. First, a specific model of the process of exchange rate determination must be chosen. In terms of equation (28) a choice has to be made as to which variables should enter the z vector. Second, having decided on the appropriate model of exchange rate determination, the researcher must decide on an appropriate method of generating the expected values of the determining variables. As we demonstrate below, researchers have used essentially three methods to generate expected values: regression analysis, time series analysis and the use of survey data.

Frenkel (1981) uses time series methods (univariate autoregressions) to generate news on nominal interest rate differentials which he then uses to explain the forward rate forecast error for the U.S. dollar-U.K. pound, U.S. dollar-French franc and U.S. dollar-German mark exchange rates, over the period June 1973 through June 1979. Although Frenkel finds that all of the estimated news coefficients have signs in accordance with the monetary model of the exchange rate, this coefficient is statistically significant only for the U.S. dollar-U.K. pound. Edwards (1983) and MacDonald (1983) provide similar mixed support for the FLPM-news approach, using a seemingly unrelated regressions estimation technique. MacDonald (1985) extends this analysis to the interwar period. Copeland (1984) incorporates oil price surprises into his news analysis of the sterling-dollar exchange rate. Bomhoff and Korteweg (1983) use a multi-state Kalman filter technique to generate news on relative money, output and oil prices and test the news approach for six exchange rates over the period 1973-79. Again, their results provide some support for the approach. Branson (1984) tests the implications of the rational expectations portfolio balance model for the effect of news on current account balances and other variables on the exchange rate using a vector autoregressive technique to generate news terms. He reports results broadly in accordance with the predictions of the portfolio balance model. In contrast to the above researchers, Dornbusch (1980) generates the news variables from OECD survey data (a survey based news approach has also been adopted by Engel and Frankel, 1984, and MacDonald and Torrance, 1988b).

Other researchers have also used survey data on money supplies and other variables to test for the effect of news on exchange rates (see MacDonald and Taylor, 1992 for a discussion).

VI. International Parity Conditions

In this survey we have repeatedly referred to various international parity conditions. In this section we bring together these parity conditions and briefly survey the extant empirical evidence on their validity (a comprehensive account is given in MacDonald and Taylor, 1990,1992; see also Isard, 1988).

If foreign exchange markets are operating efficiently then arbitrage *should ensure that the covered interest differential on similar assets be* continuously equal to zero--covered interest parity (CIP) should hold:

$$(i-i^*)_t - (f-s)_t = 0 \qquad (29)$$

In any computation of CIP it is clearly important to consider home and foreign assets which are comparable in terms of maturity, and also in terms of other characteristics such as default and political risk (Aliber, 1973; Dooley and Isard, 1980b; Frankel and MacArthur, 1988).

Essentially two types of tests of CIP have been conducted. The first relies on computing the actual deviations from interest parity to see if they differ 'significantly' from zero. The significance is usually defined with respect to the neutral band, which is determined by transactions costs. For example, Frenkel and Levich (1975, 1977), for a selection of currencies, demonstrate that around 80 percent of apparent profit opportunities lie within the neutral band when treasury bills are used and almost 100 percent when Euro-rates are considered. Furthermore, in Frenkel and Levich (1977) it is demonstrated that in periods of turbulence a much smaller percentage of deviations from CIP may be explained by transactions costs; this is interpreted as reflecting higher financial uncertainty in such periods. Clinton (1988) demonstrates that deviations from covered interest parity should be no greater than the minimum transaction costs in one of three markets: the two underlying deposit markets (e.g., Euro-marks and Euro-dollars) and the foreign exchange swap market (i.e., the market in which a currency can be simultaneously bought spot and sold forward against another currency). On the basis of analysis of data for five major currencies against the U.S. dollar "taken from mid morning quotes on the Reuter Money Rates Service from November 1985 to May 1986", Clinton finds that the neutral band should be within ±0.06 percent per annum from parity and that although the hypothesis of zero profitable deviations from parity can be rejected, "empirically, profitable trading opportunities are neither large enough nor long-lived enough to yield a flow of excess returns over time to any factor".

By questioning the quality of the data used by Frenkel and Levich, various researchers have arrived at different conclusions. For example, McCormick (1971) finds on using higher quality data that most of the deviations from CIP (70-80 percent) lie <u>outside</u> the neutral band for U.K.-U.S. Treasury bills. Taylor (1988c, 1989b), however, goes further than McCormick and argues that in order to provide a true test of CIP it is important to have data on the appropriate exchange rates and interest rates recorded at the same instant in time at which a dealer could have dealt. On using high quality-high frequency, contemporaneously sampled data for spot and forward dollar-sterling and dollar-mark exchange rates and corresponding Euro-deposit interest rates for a number of maturities, Taylor finds, inter alia, that there are few profitable violations of CIP, even in periods of market uncertainty and turbulence. One interesting feature of Taylor's work is the finding of a maturity effect--the frequency, size and persistence of arbitrage opportunities appear to be an increasing function of the length of maturity of underlying financial instruments. A rational is offered for this in terms of banks' prudential credit limits. These findings receive further support in Taylor and Fraser (1991), in which high-frequency, contemporaneous data sampled around a series of news releases (such as trade figures) is employed to test CIP.

A second method for testing the validity of CIP has been the use of regression analysis. Thus, if CIP holds, and in the absence of transaction costs, estimation of the following equation

$$f_t - s_t = \alpha + \beta(i-i^*)_t + u_t \tag{30}$$

should result in estimates of α and β differing insignificantly from zero and unity respectively and a non-autocorrelated error. Equation (30) has been tested by a number of researchers for a variety of currencies and time periods (see, for example, Branson, 1969, Marston, 1981, Cosandier and Liang, 1981, and Fratianni and Wakeman, 1982). The main conclusion to be drawn from this line of research is that, broadly speaking, CIP is supported in that although there are significant deviations of α from zero (reflecting perhaps non-zero transactions costs) the estimates of β differ insignificantly from unity in the majority of cases. As noted by Taylor (1988c, 1989b), however, it is not clear what regression-based analyses of CIP are actually testing. For example, it may be that a researcher cannot reject the hypothesis that α=0 and β=1 in equation (30) but that the fitted residuals themselves represent substantial arbitrage opportunities. Put another way, such a test may suggest strongly that CIP held <u>on average</u> over a period when in fact it did not hold at <u>any instant</u> during the period. Thus although regression-based tests may be useful for testing the broad stylized fact of CIP (which may be of interest, for example, in exchange rate modeling) they can say virtually nothing about market efficiency. However, in spite of this caveat we summarize the above evidence as suggesting that CIP does appear to be reasonably well supported by the data, especially if Euro-deposit interest rates are considered.

Uncovered interest parity (UIP) is the proposition that the interest differential should be exactly equal to the expected rate of depreciation of the exchange rate:

$$(i-i^{*})_t = \Delta s^e_{t+k} \tag{31}$$

Given CIP, this means that that the forward premium should, in fact, be equal to the expected currency depreciation, a condition that will only hold if agents are risk neutral. In the absence of a direct measure of expectations, it is necessary to formulate an auxiliary hypothesis concerning expectations formation before UIP becomes testable, and it is usual to assume that expectations are formed rationally. In this case, given covered interest parity, uncovered interest parity implies that the forward rate should act as an optimal predictor of the future spot rate. But this of course takes us back to the literature on forward market efficiency which is discussed in the previous section. Thus, tests of efficiency of the forward exchange market can be viewed as indirect tests of UIP--indirect because they rely on a maintained hypothesis of CIP.

For reasons not immediately clear, direct tests of UIP occur relatively infrequently in the literature. Under rational expectations and risk neutrality, such a test would amount to testing the interest differential as an optimal predictor of the rate of depreciation. Such a test might, for example, involve estimating an equation of the form:

$$s_t = \alpha_0 s_{t-k} + \alpha_1 (r-r^{*})_{t-k} + \varphi_t \tag{32}$$

where the joint hypothesis of risk neutrality and rational expectations implies that α_0 and α_1 should equal minus and plus unity respectively, and that φ_t should be orthogonal to past information.

Equation (32), or variants thereof, has been tested by, inter alios, Hacche and Townend (1981), Cumby and Obstfeld (1981), Davidson (1985), Loopesko (1984) and Taylor (1987b), and the message to emerge from this work is that UIP is very strongly rejected. In common with the literature on the optimality of the forward rate as a predictor of the future spot rate, such rejection is usually interpreted as indicating the presence of a (time-varying) risk premium. MacDonald and Torrance (1990), however, demonstrate, using survey expectations data, that rejection is most likely caused by both risk and expectations factors. Interestingly, numerous papers which attempt to model deviations from UIP in terms of a risk premium are largely unsuccessful (see, inter alia, Dooley and Isard, 1982; Frankel, 1982b, 1983, 1985b; and Rogoff, 1984).

Another international parity condition which has received attention in the literature is that of real interest rate parity. This may be derived using UIP (31), ex ante PPP (33) and Fisher closed conditions for the home and foreign country (34) and (35):

$$\Delta s^e_{t+k} = \Delta p^e_{t+k} - \Delta p^e_{t+k} \tag{33}$$

$$i_t = r_t - \Delta p^e_{t+k} \tag{34}$$

$$i^*_t = r^*_t - \Delta p^{e*}_{t+k} \tag{35}$$

where i denotes the real interest rate, r the nominal interest rate, and p the logarithm of the price level. By combining (31) and (33)-(35) we obtain:

$$i_t = i^*_t \tag{36}$$

Thus, given the stated assumptions, real interest rates must be equalized across countries and the scope for the policy maker to alter real economic activity by changing the real interest rate is limited. Is condition (36) supported empirically? The real interest rate parity condition has been tested by a number of researchers for the U.S. against other OECD countries (see e.g., Mishkin, 1981, 1984; Friedman and Schwartz, 1982; von Furstenberg, 1983; Cumby and Obstfeld, 1984; Cumby and Mishkin, 1984; MacDonald and Taylor, 1990; and Fraser and Taylor, 1990) and the results indicate a resounding rejection of real interest rate parity. For example, Cumby and Obstfeld (1984) empirically implement (33) by running the following regression

$$\Delta p_{t+1} - \Delta p_{t+1} = \alpha + \beta(r-r^*)_t + v_{t+1} \tag{37}$$

which is obtained by using (33)-(35) in (31) and by assuming expected inflation rates are formed rationally. A test of $\alpha = 0$, $\beta = 1$ (the null hypothesis) is a test of the equality of expected real interest rates. A sample of Cumby and Obstfeld's results is reported here as equation (38):

$$\Delta p_{t+1} - \Delta p^*_{t-1} = \underset{(0.01)}{0.028} + \underset{(0.23)}{0.503}(r-r^*)_t\text{; US-Germany, Jan. 76-Sept. 81} \tag{38}$$

where standard errors are in parenthesis, the price terms are consumer price indices and the interest rates are Euro-deposit interest rates. For this equation, and for others reported by Cumby and Obstfeld, the null hypothesis is easily rejected. Cumby and Obstfeld summarize their battery of tests thus: 'The tests demonstrate that ex ante real interest rate equality is often rejected decisively over the recent floating period.'

Tests of purchasing power parity (PPP) have often involved estimates of equations (39) and (40)

$$s_t = \alpha + \beta p_t - \beta^* p^*_t + \varphi_t \tag{39}$$

$$\Delta s_t = \beta \Delta p_t - \beta^* \Delta p^*_t + \varphi_t \tag{40}$$

Thus a test of (39) would be interpreted as a test of absolute PPP--the hypothesis that the level of the exchange rate is determined by relative price levels--whilst a test of (40) would be interpreted as a test of relative PPP--the proposition that the rate of exchange rate depreciation is driven by relative inflation differentials. In Frenkel (1978), estimates of (39) and (40) are presented for the interwar experience with floating rates and in Frenkel (1981), for the recent floating experience. Frenkel's interwar estimates of (39) and (40) are highly supportive of PPP; however his results for a variety of currencies for the recent floating experience are not (PPP in both its absolute and relative forms is resoundingly rejected by the data). In further tests of PPP for the interwar and recent floating experience, Krugman (1978) reports estimates of (39) and (40) which are largely unfavorable to PPP (he uses a longer sample period for the interwar period than Frenkel, 1978). Krugman (1978) concludes: 'There is some evidence that the deviations of exchange rates from PPP are large, fairly persistent, and seem to be larger in countries with unstable monetary policy'.

Further evidence against the traditional view of PPP has been provided by the efficient markets view of PPP (EMPPP), which posits that the real exchange rate should follow a random walk. This may be seen in the following way. From the Fisher equations (34) and (35), and the UIP condition, (31) we have:

$$i_t - i_t^* = \Delta p_{t+1}^{e*} - \Delta p_{t+1}^{e} + \Delta s_{t+1}^{e} \tag{41}$$

and by assuming the expected values in (41) are formed rationally, we have:

$$i_t - i_t^* = \Delta p_{t+1}^{*} - \Delta p_{t+1} + \Delta s_{t+1} + a_{t+1} \tag{42}$$

where a_{t+1} is the rational forecast error. Thus, if the real interest rate differential is constant over time, the logarithm of the real exchange rate should follow a random walk. As is well known, if a variable follows a random walk process, any change in the variable will be permanent and mean-reverting behavior is ruled out. Such a view is disturbing to a proponent of PPP because although few would deny that there are shocks which in the short run may lead to a change in the real exchange rate, such shocks are generally thought to be temporary phenomena: over time the real exchange rate eventually returns to its equilibrium value. The majority of evidence reported to date does in fact find in favor of EMPPP. Thus, Roll (1979), Darby (1980), Frenkel (1981), Adler and Lehmann (1983), Mishkin (1984), and MacDonald (1985 a,b) find in favor of the model whilst Cumby and Obstfeld (1984), Frankel (1985b) and Frankel and Froot (1986) are able to reject the hypothesis.

Further evidence in favor of the EMPP may be gleaned from studies which utilize cointegration analysis (Engle and Granger, 1987) to test for mean reversion in the real exchange rate or in the residual of an equation such as (39). Such studies (see, for example, Taylor, 1988) generally report a

failure of significant mean reversion of the exchange rate towards PPP for the recent floating experience (see also Huizinga, 1987). In a recent paper, however, Abuaf and Jorion (1990), using systems estimation methods in which the first-order autoregressive coefficient of the real exchange rate is constrained to be equal across a range of real exchange rates, are able to reject the unit root (random walk) hypothesis. For the interwar period the unit root hypothesis may be rejected for the major exchange rates using univariate unit root tests, implying that this period is characterized by long-run PPP (Taylor and McMahon, 1988; Taylor, 1991b).

Other tests of PPP are more descriptive in their nature. Thus, a number of researchers (e.g., Dornbusch and Krugman, 1978; Dornbusch, 1979; and MacDonald and Taylor, 1990) have sought to gauge the validity of PPP by plotting the real exchange rate alongside the nominal rate for a number of currencies: if PPP holds the real exchange rate should be independent of the nominal rate. Such plots clearly indicate that both real and nominal rates are closely tied together. All the above studies have utilized aggregate price indices in their tests of PPP. Given that the absolute PPP condition is simply the sum of parity conditions for individual goods, it may be more appropriate to test PPP at a disaggregated level. This in fact has been the strategy of Isard (1977), Kravis and Lipsey (1978) and Fraser, Taylor and Webster (1991). In all of these papers strong rejections of the PPP hypothesis have been reported.

The conclusions which we draw from this section are as follows. First, the covered interest parity condition seems to receive fairly strong support from the data, especially when it is implemented with Euro-deposit interest rates and data which properly reflect the trading opportunities open to arbitrage. A less sanguine conclusion, however, emerges from our discussion of uncovered interest parity: UIP is resoundingly rejected for the recent experience with floating exchange rates. This conclusion clearly has important implications for exchange rate models which rely on UIP in their derivation. A major challenge facing researchers is to try to determine whether such failure is due to a violation of risk neutrality or a failure of rational expectations. Studies which have attempted to capture a risk premium, by regressing the deviation from UIP on determinants of risk, have not been successful and this perhaps suggests that it is the expectations leg of the joint hypothesis which is at fault. Indeed, single hypothesis tests using survey data indicate that both components of the null are at fault (see, for example, MacDonald and Torrance, 1988b). In common with tests of UIP, empirical tests of real interest rate parity have most often tended to reject the null hypothesis. Our summary of the battery of tests which have been used to test for the existence of PPP, support the view that continuous PPP has not held for the recent floating period, while the evidence in favor of long-run convergence of real exchange rates towards PPP is at present mixed. Taylor and McMahon (1988) produce evidence which strongly suggests that a form of long-run PPP may have held during the interwar period. Perhaps the difference in performance of PPP between the two periods reflects the greater number of factors (such as productivity

changes) requiring equilibrium real exchange rate changes for the recent experience with floating.

The findings of this section are important since they suggest that at least three types of international parity conditions used by a number of researchers to build the type of exchange rate models discussed previously are not unequivocally validated by the data. Future modeling should therefore take account of this and, at the very least, take proper account of the time series properties of UIP and PPP. Proper recognition of the limitations of certain parity conditions should help to improve our understanding of how foreign exchange rates are determined.

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