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Exchange Rate Economics

A Survey

RONALD MACDONALD and MARK P. TAYLOR*

Two main views of exchange rate determination have evolved since the early 1970s: the monetary approach to the exchange rate (in flexible-price, sticky-price, and real interest differential formulations); and the portfolio balance approach. The literature on these views is surveyed, followed by a discussion of the empirical evidence and likely future developments in the area of exchange rate determination. The literature on foreign exchange market efficiency, exchange rates and "news," and international parity conditions is also reviewed. [JEL F30, F41]

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 failure 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 that supposedly determine them, giving econometricians and applied economists an unprecedented opportunity to test

* Mark P. Taylor, an Economist in the External Adjustment Division of the Research Department, holds master's degrees from the Universities of Oxford and London and a doctorate from London University. He was previously Morgan Grenfell Professor of Financial Markets at the City University Business School, London.

Ronald MacDonald is Robert Fleming Professor of Finance and Investment at Dundee University and holds a bachelor's degree from Heriot Watt University and master's and doctoral degrees from Manchester University. This paper was largely written while he was a Visiting Scholar in the Research Department.

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a number of propositions relating to foreign exchange markets. Despite this extensive research, a large number of unresolved issues remain, and exchange rate economics continues to be an extremely challenging area.

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

This contribution may be viewed as an extension and update of earlier surveys of empirical work on exchange rates by, among 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).

I. Theories of Exchange Rate Determination

Early contributions to the postwar literature on exchange rate economics include Nurkse (1945) and Friedman (1953). Both of these contributions are to a large extent concerned with the role of speculation in foreign exchange markets. Nurkse warns against the dangers of "bandwagon effects," which may generate market instability.[1] Friedman's classic apologia for floating exchange rates (Friedman (1953)) is remarkable in its anticipation of much of the 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 decade later in the pathbreaking contributions of Mundell (1961, 1962, 1963, 1968) and Fleming (1962). In the verbal exposition of his capital account theory, Meade 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 (Meade (1951b, p. 103)). Mundell (1961, 1962, 1963, 1968) and Fleming (1962) followed Meade's mathematical representation and thus abstracted from the stock-flow implications of interest rate differential

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

changes. Therefore, 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.

Other 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, for example, Frenkel and Johnson (1976)), and subsequently, the monetary approach to the exchange rate (see, for example, Frenkel and Johnson (1978)). More generally, work done in the late 1960s by Oates (1966), McKinnon and Oates (1966), McKinnon (1969), and Ott and Ott (1965) began to integrate analyses of open economy macroeconomics and financial portfolio balance by imposing stock equilibrium constraints. Later work by Branson (1968), Willet and Forte (1969), and Kouri and Porter (1974) built on this work by incorporating more general features of financial portfolio choice (Tobin (1965)).[2]

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 makes sense 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), and Mussa (1976, 1979)).

The early, flexible-price monetary model 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 asterisk). Monetary equilibria in the domestic and foreign country, respectively, are given by

[2] Taylor (1990) analyzes in detail the evolution of thinking on open economy macroeconomics.

$$m_t^s = p_t + \phi y_t - \lambda r_t \quad (1)$$

and

$$m_t^{s*} = p_t^* + \phi^* y_t^* - \lambda^* r_t^* . \quad (2)$$

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

$$s_t = p_t - p_t^* , \quad (3)$$

where s_t is the logarithm of the nominal exchange rate (domestic price of foreign currency). Thus, if PPP holds continuously, the logarithm of the real exchange rate, q_t, say ($q_t \equiv s_t - p_t + p_t^*$), is a constant. The world price, p_t^*, 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 equations (1) and (2) into (3) yields, after rearranging

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

which is the basic flexible-price monetary model equation. Equation (4) says that an increase in the domestic money supply, relative to the foreign money stock, will lead to a rise in s_t—that is, a fall in the value of the domestic currency in terms of the foreign currency. This seems intuitive enough. An increase in domestic output, as opposed to the domestic money supply, *appreciates* 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 *appreciation*).

In order to resolve these apparent paradoxes, one has to remember the fundamental role of relative money demand in the flexible-price 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 equation for the flexible-price monetary model in two alternative but equivalent formulations. Assuming that the domestic and foreign money demand coefficients are equal ($\phi = \phi^*$, $\lambda = \lambda^*$), equation (4) reduces to

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

A further assumption underlying the flexible-price model is that uncovered interest parity holds continuously—that is, 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' expectations formed at time t, we may substitute Δs^e_{t+1} for $(r - r)^*_t$ in equation (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 expected change in the interest differential, both of which reflect inflationary expectations, are interchangeable in this model. Some researchers relax the constraint that the income and interest rate elasticities are equal:

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

Note also that equation (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,[3] then by iterating forward, it is easy to show that equation (7) can be expressed in the "forward solution" form:

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

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"—that is, relative money and income. As is common in rational expectations models, the presence of the discount factor, $\lambda/(1 + \lambda) < 1$, in equation (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 $(1/\lambda)$.

[3] The application of rational expectations to exchange rates was first considered by Black (1973).

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* PPP—equation (3). Under continuous PPP, the real exchange rate—that is, 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 them the very real consequences of shifts in international competitiveness (see, for example, Dornbusch (1987)). Clearly, therefore, the simple, flexible-price monetary approach does not fit the observable facts. An attempt to rehabilitate the monetary model led to the development of a second generation of monetary models, beginning with Dornbusch (1976). The sticky-price monetary model allows for substantial overshooting of both the nominal and the real price-adjusted exchange rates beyond their long-run equilibrium (PPP) levels, because the jump variables in the system—exchange rates and interest rates—compensate for sluggishness in other variables—notably goods prices.[4]

The intuition behind the overshooting result in the sticky-price monetary model is relatively straightforward. Imagine the effects of a cut in the nominal U.K. money supply. Sticky prices in the short run imply 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 (that is, a rise in the value of the domestic currency in terms of the 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.[5] However, so long as the *expected* foreign exchange loss (ex-

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

[5] Even if investors effect forward cover—that is, 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 below).

pected rate of depreciation) is less than the *known* capital market gain (that is, 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 nonzero for a nonzero 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 at the long-run PPP level. This model thus 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.

The Dornbusch overshooting model was further developed by Buiter and Miller (1981), who allowed for a nonzero rate of core inflation and considered the impact of natural resource discoveries on output and the exchange rate.

Frankel (1979a) argued that a shortcoming of the Dornbusch (1976) formulation of the sticky-price monetary model was that it did not allow a role for differences in secular rates of inflation. His model was an attempt to allow for this defect, and the upshot was an exchange rate equation that included the real interest rate differential as an explanatory variable.

The sticky-price monetary model is clearly an advance over the simple (continuous PPP) monetary model, in that it more accurately explains the observable facts. 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 maintain this focus by assuming perfect substitutability of domestic and foreign nonmoney 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 nonmoney 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.

Portfolio Balance Model

In common with the flexible-price and sticky-price monetary models, the level of the exchange rate in the portfolio balance model 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 portfolio balance model 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 an open economy in the context of a fixed exchange rate, the seminal contributions to the literature on the portfolio balance approach to exchange rate determination were Kouri (1976), Allen and Kenen (1980), Branson (1977, 1983, 1984), Dornbusch and Fischer (1980), and Isard (1983).

The portfolio balance model, like the sticky-price model, 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). Unlike the sticky-price model, it also allows 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), with the portfolio balance model the exchange rate is determined solely 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 portfolio balance model 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, and 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 (that is, 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 domestic and foreign interest rates given by r and r^* as before, we can write down our definition of wealth and the simple domestic demand functions for its components as follows:[6]

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

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

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

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

Relation (10) is an identity defining wealth. Two noteworthy characteristics of equations (11)–(13) are that, as is standard in most expositions of the portfolio balance model, the scale variable is the level of wealth, W, and the demand functions are homogeneous in wealth; they can thus be written in nominal terms (assuming homogeneity in prices and real wealth, prices cancel out) (see Tobin (1969)).

The model thus provides a simple framework for analyzing the effect of, for example, monetary and fiscal policy on the exchange rate. Thus, a contractionary monetary policy (a fall in M) reduces nominal financial wealth (through equation (10)), and so reduces the demand for both domestic and foreign bonds (through equations (12) and (13)). As foreign bonds are sold, the exchange rate appreciates (the foreign price of 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 portfolio balance model, while monetary disturbances will generate exchange rate overshooting. Masson (1981) and Buiter (1984) also consider the stability of the portfolio balance model when net domestic holdings of foreign assets are negative.

II. Empirical Evidence on Exchange Rate Models

In this section the empirical evidence on exchange rate models is looked at from three perspectives: the monetary exchange rate models using interwar data and data from the recent float before 1978; monetary models including more recent data from the current float; and the portfolio balance model.

[6] We use the notation, $X_j = \partial X / \partial j$.

First-Period Tests of Monetary Models

The empirical evidence on the three formulations of the monetary exchange rate model—the flexible-price, sticky-price, and real interest differential 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 and is largely supportive of the monetary model. The second-period evidence, which covers the period of the recent float extending beyond the late 1970s, is not so supportive of the monetary model.

One of the first tests of equation (7) was conducted by Frenkel (1976) for the deutsche mark-U.S. dollar exchange rate over the period 1920–23. Since this period corresponds to the German hyperinflation, Frenkel argued that domestic monetary impulses will overwhelmingly dominate equation (7), and, thus, the 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 reported results supportive of the flexible-price model during this period.

A number of researchers have estimated flexible-price model equations for the more recent experience with floating exchange rates. For example, Bilson (1978) tested for the deutsche mark-pound sterling 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 incorporated dynamics into the equation and used a Bayesian estimation procedure; his results were in broad accordance with the monetary approach. Hodrick's (1978) tests of the flexible-price model for the U.S. dollar-deutsche mark and pound sterling-U.S. dollar over the period July 1972 to June 1975 were also highly supportive. Putnam and Woodbury (1979) estimated equation (5) for the sterling-dollar exchange rate over the period 1972–74, and reported that most of the estimated coefficients were significantly different from zero at the 5 percent significance level, and all were correctly signed according to the flexible-price model. However, the money supply term was significantly different from unity.

Dornbusch (1979) reported results broadly supportive of the flexible-price model 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 introduced this differential as an econometric expedient, an interpretation may be placed on this term that is consistent with Frankel's real interest differential equation, which we discussed above. Thus, Frankel (1979a), in his implementation of the real interest differential model for the mark-dollar exchange rate over the period July 1974–February 1978, used 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 argued that since the coefficients on the interest rate and expected inflation terms were both significant, both the flexible- and sticky-price models were rejected in favor of the real interest differential model.

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 real interest differential 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 were correctly signed (many were wrongly signed); the equations had poor explanatory power as measured by the coefficient of determination; and residual autocorrelation was a problem. In particular, estimates of monetary exchange rate equations for the deutsche mark-U.S. dollar for the post-1978 period often report coefficients that 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). Frankel (1982a) called this phenomenon—the price of the mark rising as its supply is increased—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 showed that the subtractive constraints used in monetary approach equations were particularly dangerous because they could lead to biased estimates and sign reversals.

Frankel (1982a) provided an alternative explanation for the poor performance. He attempted to explain the mystery of the multiplying marks by introducing wealth into the money demand equations. Germany, he argued, 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 insisting on the constraint that the domestic and foreign income, wealth, and inflation terms had to have equal and opposite signs, Frankel came up with a monetary approach equation that fit the data well and in which all variables, apart from the income terms, were correctly signed and most were 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 that 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 used by the above researchers (see Artis and Lewis (1981) for a discussion). In Frankel (1984), shifts in money demand functions were incorporated into the empirical equation by the introduction of a relative velocity shift term, $(v - v^*)$, which was 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 led to most of the monetary variable coefficients becoming statistically significant and with the correct signs. However, significant first-order residual autocorrelation remained a problem in all of the reported equations.

Driskill and Sheffrin (1981) argued that the poor performance of the monetary model could be traced to a 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 yields an equation purged of the interest differential-forward exchange rate effect. A number of researchers have begun to test this version of the model, with some success. For example, Hoffman and Schlagenhauf (1983) implemented a version of the "forward solution" flexible-price model 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 franc, the deutsche mark, and the pound sterling against the U.S. dollar. Hoffman and Schlagenhauf computed likelihood ratio tests for the validity of the rational expectations hypothesis and the validity of this hypothesis plus the coefficient restrictions implied by the flexible-price model (such as the unit coefficient on relative money supplies). Although the expectations restrictions are not rejected for any of the countries, the coefficient restrictions are rejected for Germany. Kearney and MacDonald (1990) carried out a similar procedure for the Australian dollar-U.S. dollar and could not reject the restrictions implied by the rational expectations hypothesis.

MacDonald and Taylor (1991a), using multivariate cointegration techniques (see Engle and Granger (1987) and Johansen (1988)), tested the validity of the monetary model as a long-run equilibrium relationship for the U.S. dollar-deutsche mark, U.S. dollar-pound sterling, and U.S. dollar-yen exchange rates over the period January 1976 through December 1990. They found that an unrestricted version of equation (4) could not be rejected as a long-run equilibrium for these exchange rates and that, for the U.S. dollar-deutsche mark rate, none of the coefficient restrictions implicit in equation (5) could be rejected. Note that, since all of the monetary models collapse to an equilibrium condition of the form equation (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 flexible-price model has spawned further empirical work that tests for the presence of speculative bubbles. It is well known from the rational expectations literature that equation (9) is only one solution to equation (7) from a potentially infinite sequence (see, for example, Blanchard and Watson (1982)). If we denote the exchange rate given by equation (9) as $\hat{s}_t$, then it is straightforward to demonstrate (see MacDonald and Taylor (1989b)) 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 (1986) tested for bubbles by applying a version of the Hausman (1978) specification test suggested by West (1986) 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 equation (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. Such a difference would suggest 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 found that the two sets of coefficient estimates were significantly different and therefore rejected the hypothesis of no bubbles. Kearney and MacDonald (1986) applied a version of this methodology to the Australian dollar-U.S. dollar exchange rate and could not reject the hypothesis.

An alternative way of testing for bubbles is 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 what results from replacing expected future values of money and income in equation (9) with their actual values:

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

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

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

which implies

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

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

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

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

Huang (1981) tested versions of equation (16) for the dollar-mark, dollar-sterling, and sterling-mark exchange rates for the period March 1973 to March 1979. His results were supportive of excess volatility and, by inference, he rejected the no-bubbles hypothesis. Kearney and MacDonald (1986) implemented tests of equation (16) for the Australian dollar-U.S. dollar over the period January 1984–December 1986 and generally found 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 important, 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) tested for bubbles in the U.S. dollar-pound sterling exchange rate over the period 1981–84 by testing for a nonzero median in excess returns from forward market speculation (the forward rate forecasting error adjusted for risk). Evans designed and applied nonparametric tests for a nonzero median in returns that are similar to runs tests. He decisively rejected the zero-median hypothesis and inferred that this result provided evidence of speculative bubbles. Note, however, that Evans may have been detecting peso problems;[7] 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 reduced form of the sticky-price model. Driskill (1981) presented 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 reported results largely favorable to the sticky-price model. Other tests have been conducted by Backus (1984), Hacche and Townend (1981), and Wallace (1979). Wallace reported results supportive of the model for the float of the Canadian dollar against the U.S. dollar during the 1950s. However, Backus, who tested the model for the float between the two currencies during the recent floating experience (from the first quarter of 1971 to the fourth quarter of 1980), reported different estimation results. Unlike Wallace, he found few statistically significant coefficients.

Estimates of a more dynamic version of the sticky-price model, provided by Hacche and Townend (1981) for the effective exchange rate of the pound sterling from May 1972 to February 1980, do suggest 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.

Papell (1988) argued that the price and exchange rate dynamics underlying the Dornbusch sticky-price model cannot be captured by single-equation estimation methods. To capture such dynamics, he argued, it is necessary to use a systems method of estimation that incorporates the

[7] 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 nonzero excess returns from forward speculation. See MacDonald and Taylor (1989b) for further analysis of the peso problem.

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, Papell reduced the structural model to a reduced-form, vector-autoregressive, moving-average model with nonlinear parameter constraints. He estimated 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 for the period 1973:1 to 1984:4. Papell found that most of the estimated structural coefficients had the expected sign, were of reasonable magnitude, and were statistically significant. He thus concluded that his results supported Dornbusch's model.

Barr (1989) and Smith and Wickens (1988, 1990) empirically implemented a version of the sticky-price model formulated by Buiter and Miller (1981) for the pound sterling exchange rate. All reported favorable in-sample estimates of the model. The results reported in these papers are likely to be fairly robust since both sets of authors took care in specifying the model dynamics; also, Smith and Wickens estimated the model structurally. In simulating their model, Smith and Wickens (1988) found that the exchange rate overshoots by 21 percent in response to a 5 percent change in the money supply.

Wadhwani (1984) used the sticky-price model to generate s^* and to test for excess volatility; he found that the inequality (16) is violated for the U.S. dollar-pound sterling rate over the period 1973:1 to 1982:3. His results are therefore supportive of those generated by Huang (1981) using the flexible-price model.

Empirical Evidence on the Portfolio Balance Model

Compared to the monetary approach to the exchange rate, less empirical work has been conducted on the portfolio balance model, perhaps due to the limited availability of good disaggregated data on nonmonetary assets. The research that has been done may be broadly divided into two types of tests. 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 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 portfolio balance model is to test for the significance of such risk premia. In addition, Branson (1984) examined the time-series behavior of a number of financial variables for several countries to see if they were consistent with the predictions of the model.

The reduced-form exchange rate equation derived from a system such as equations (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):

$$S_t = g(M_t, M_t^*, B_t, B_t^*, fB_t, fB_t^*), \tag{18}$$

where fB and fB^* denote foreign holdings of domestic and foreign bonds, respectively. Branson, Halttunen, and Masson (1977) estimated a log-linear version of an equation similar to this for the deutsche mark-U.S. dollar exchange rate over the period August 1971–December 1976. However, they dropped the terms relating to domestic and foreign bond holdings because of their ambiguous effect on the exchange rate, depending on the degree of substitutability between traded and nontraded bonds. But as Bisignano and Hoover (1982) pointed out, this rather arbitrary exclusion will generally result in biased regression coefficients.

Although the estimates reported by Branson, Halttunen, and Masson (1977) were supportive of the portfolio balance model, 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 that is purported to capture the simultaneity between the exchange rate and the money supply, Branson, Halttunen, and Masson re-estimated their equation using two-stage least squares and reported more satisfactory estimates of the portfolio balance empirical model; however, residual autocorrelation remained a problem (the estimated first-order autocorrelation coefficient was 0.87, which suggests that unexplained shocks have persistent effects on the exchange rate and, hence, that this version of the portfolio balance model does not fully explain the mark-dollar exchange rate).

In Branson, Halttunen, and Masson (1979), a log-linear exchange rate equation was estimated for the longer period August 1971–December 1978, for the mark-dollar, but the results did not differ significantly from the earlier ones; again, persistent autocorrelation was a problem. In another paper, Branson and Halttunen (1979) estimated the equation for five currencies (the yen, the French franc, the lira, the Swiss franc, and the pound sterling) against the deutsche mark for a variety of different sample periods over the 1970s. Although their results seemed supportive of the portfolio balance model, in terms of statistically significant and correctly signed coefficients, a note of caution must again be sounded, since the residuals in their ordinary-least-square equations were all highly autocorrelated.

One problem with the Branson, Halttunen, and Masson (1977, 1979) implementation of the portfolio balance model lies in their use of cumulated current accounts for the stock of foreign assets. Such an approximation will, of course, include *third-country* items that are not strictly relevant to the determination of the *bilateral* exchange rate in question. Bisignano and Hoover (1982) picked up on this point, arguing that the portfolio balance approach should be implemented using only bilateral data for foreign assets, and, to be consistent, domestic and foreign bond holdings should be included in the reduced form of the model (see above). Incorporating such modifications in their estimates of the portfolio balance equation for the Canadian dollar-U.S. dollar over the period March 1973 to December 1978, Bisignano and Hoover reported moderately successful econometric results; in particular, they showed that it is wrong to neglect domestic and foreign nonmonetary 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 U.S. dollar-deutsche mark exchange rate, the U.S. demand for U.S. 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[8] 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 estimated 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 (that is, broadly speaking, rational) expectations, and compared the predictions of the model to naive forecasts using the forward rate and the lagged spot rate. They summarized the performance of the model as follows:

> The model is better than the forward rate as a predictor of the change in the exchange rate. . . . [H]owever . . . 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 (p. 273).

Dooley and Isard pointed out that the ability of the model to outperform the forward rate as a spot rate predictor challenged the view that exchange risk premia were nonexistent. However, the empirical short-

[8] That is, oil producing and exporting countries.

comings of the model suggest either that their simplifications of the theoretical model were too severe or that observed exchange rate movements were predominantly unexpected.

Boughton (1988b) introduced term-structure effects into an empirical portfolio balance model and estimated jointly a "semireduced form" consisting of a real exchange rate portfolio balance equation that 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- and short-term interest rate spread. He used data on the real effective 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. His estimation results were broadly satisfactory in terms of the sign and statistical significance of the estimated coefficients. Boughton then used these results in a number of counterfactual simulations to analyze the strong appreciation of the dollar over the 1980–85 period. He concluded 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) to tighten monetary policy sufficiently, 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 reduced-form monetary approach will be misspecified to the extent that it ignores the imperfect substitutability of nonmoney assets. In the portfolio balance model 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 reached the market: the spot exchange rate in a reduced-form portfolio balance 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 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

(1983), and Hacche and Townend (1981)). In Hooper and Morton's implementation, the risk premium was assumed to be a function of the cumulated current account surplus net of the cumulation of foreign exchange market intervention. Their equation was estimated for the U.S. dollar effective exchange rate 1973:2 to 1978:4, using an instrumental variables estimator. Hooper and Morton reported mixed results, with only some of the coefficients (mainly those relating to the monetary approach variables) significant and of the correct sign.

Using Hooper and Morton's specification, Hacche and Townend (1981) tested the portfolio balance model 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 were largely disappointing: few coefficients were significant and of those that were, the estimated risk premium coefficient was wrongly signed and the point estimate of the oil price coefficient was correctly signed.

In his implementation of the hybrid reduced-form model, Frankel (1984) did not consider the current account news term, and he derived the risk premium as the solution to the portfolio balance model. He estimated a hybrid equation for five currencies against the dollar for the period 1974–81 (monthly data, with the exact beginning and end points currency specific). In general, Frankel found that the estimated coefficients of the monetary approach variables were statistically insignificant, and some wrongly signed.

As noted earlier, an alternative, indirect method of testing the portfolio balance model 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 (1982b, 1983) for the deutsche 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 were reported. Fisher and others (1990) formulated an exchange rate equation, in which the deviation from uncovered interest rate parity (for the pound sterling effective rate, with both the exchange rate and interest rate expressed in real terms) was modeled as a function of the ratio of the current account balance to gross domestic product; this formulation outperformed other exchange rate equations used in major econometric models of the U.K. economy, beating a random walk in out-of-sample forecast tests.[9]

[9] See the next section. Note that this study used quarterly data, as does Boughton (1984b).

Out-of-Sample Forecasting Performance of Exchange Rate Models

So far, 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. Meese and Rogoff (1983) conducted such a study for the dollar-pound sterling, dollar-mark, dollar-yen, and trade-weighted dollar exchange rates using data running from March 1973 through June 1981. The exchange rate models they tested correspond to the flexible-price, the real interest differential, and the portfolio-monetary synthesis of Hooper and Morton (1982). Meese and Rogoff compared the out-of-sample performance of these equations to the forecasting performance of the random walk model, the forward exchange rate, a univariate autoregression of the spot rate, and a vector autoregression. They computed their forecasts as follows. First, the equations were estimated using data from the beginning of the sample to November 1976, and four forecasts were made for 1, 3, 6, and 12 months ahead. The data for December 1976 were then added to the original data set, the equations were re-estimated, and a further set of forecasts were made for the four time horizons. This "rolling regression" process was then repeated continually. 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 Meese and Rogoff'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.

The conclusion that emerges from the Meese-Rogoff study is that none of the exchange rate models using the asset approach outperforms the

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

Exchange Rate	Random Walk	Flexible-Price Model	Real Interest Differential	Monetary/Portfolio Synthesis
US$/DM	8.71	9.64	12.03	9.95
US$/yen	11.58	13.38	13.94	11.94
US$/£ stg.	6.45	8.90	8.88	9.08
Trade-weighted U.S. dollar	6.09	7.07	6.49	7.11

Source: Meese and Rogoff (1983).
Note: The forecast horizon is six months.

simple random walk model—a result that was seen as devastating for research on these models. Moreover, this result is all the more striking when it is remembered that the reduced-form forecasts were computed using *actual* values of the various independent variables.

In an attempt to improve on the poor performance of the asset models, Meese and Rogoff attempted a number of alternate approaches: estimating the models in first differences; allowing home and foreign magnitudes to enter unconstrained; including price levels as additional explanatory variables; using different definitions of the money supply; and replacing long-term interest rates with other proxies for inflationary expectations. But all to no avail: the modified reduced-form equations still failed to outperform the simple random walk.

In a later paper, Meese and Rogoff (1984) considered possible explanations for the failure of the reduced-form asset models to beat the random walk model out-of-sample. In particular, they showed—using the vector autoregressive methodology—that the instruments used in simultaneous estimates of reduced-form asset models may not be truly exogenous, and thus the estimated parameter estimates may be extremely imprecise. To overcome this problem, Meese and Rogoff imposed coefficient constraints, culled from the empirical literature on money demand equations, and re-estimated the RMSEs for the same period, as in their 1983 paper. They found that although the coefficient-constrained reduced forms still failed to outperform the random walk model for most horizons up to a year, in forecasting beyond a year (which had not been possible with the unconstrained estimates in Meese and Rogoff (1983) because of problems with degrees of freedom), the asset reduced forms did outperform the random walk model in terms of RMSE. As Salemi (1984) pointed out, this finding suggests that the exchange rate acts like a pure asset price in the short term (that is, approximately a random walk—see, for example, Samuelson (1965)), but that in the longer term its equilibrium is systematically related to other economic variables.

A large segment of the literature has been devoted to determining whether Meese and Rogoff's specification of the asset reduced-form equations, their estimation strategy, or the models themselves are at fault. Woo (1985) and Finn (1986) estimated versions of the rational expectations form of the flexible-price model (equation (9)), with the addition of a partial adjustment term in money demand, and performed a Meese-Rogoff forecasting exercise. Finn reported that this model forecast as well as the random walk model (but failed to *outperform* it); while Woo's formulation outperformed the random walk model, in terms of both the MAE and RMSE, for the deutsche mark-U.S. dollar exchange rate. Somanath (1986) also used a partial adjustment term in his formulation of various asset reduced-form equations for the mark-dollar exchange rate. Interestingly, for the period studied by Meese and Rogoff, he found that the structural exchange rate models outperformed the random walk model in terms of the standard criteria, and that for a sample period extending beyond that of Meese and Rogoff, the basic (that is, without any additional dynamics) flexible-price, real interest differential, and hybrid equations outperformed the random walk.[10]

Wolff (1987) and Schinasi and Swamy (1989) used a time-varying parameter model as the preferred estimation technique for econometric implementation of the real interest differential and flexible-price equations. Both Wolff and Schinasi and Swamy argued that the poor forecasting performance noted by Meese and Rogoff may have been due to their failure 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 in the underlying structural equations (money demand and PPP equations), changes in policy regime (see Lucas (1976)), and heterogeneous beliefs by agents (leading to a diversity of responses to macroeconomic developments over time) could all impart parameter instabilities.

Using the Kalman filter methodology, Wolff (1987) reworked Meese and Rogoff's results (same currencies and time period), for the reduced forms of the flexible-price and real interest differential models, assuming that the parameters followed a random walk process. However, the two models won out over the random walk only in the case of the U.S. dollar-deutsche mark exchange rate (for both the dollar-yen and the dollar-pound sterling exchange rates the random walk performed better 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 (1989) used a less restrictive time-varying model than Wolff, and their model resulted in consistently better forecasts (than a random walk) for the flexible-price, real interest differential, 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 was due to the use of time-varying parameters or simply to the fact that Schinasi and Swamy used a multistep random walk forecast, rather than the one-step forecast used by Meese and Rogoff. In a further experiment, Schinasi and Swamy added a lagged dependent variable to the various reduced forms of the monetary equations and

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

compared their forecasting performance to a one-step-ahead random walk. For all cases the time-varying parameter version was always superior to the fixed coefficients version and, furthermore, it outperformed the random walk in almost all cases.

Finally, Boughton (1984b) tested 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. In every case, this model outperformed the random walk model. However, this result most likely reflects Boughton's use of quarterly data (all the other studies use monthly data), since his estimates of the hybrid equation also generally outperformed the random walk model.

Empirical Exchange Rate Models: New Directions

The broad conclusion that emerges from our survey 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 (that is, 1973–78); but they have provided largely inadequate explanations for the behavior of the major exchange rates during the latter part of the float.

The failure of simple asset-approach equations may be due to misspecification. This misspecification may be of an econometric nature, insofar as the dynamic properties of the asset equations have (in relation to the Hendry, Pagan, and Sargan (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, even when these additions are made to the simple asset models, little improvement in equation performance is reported.

Some authors (for example, Papell (1988) and Isard (1988)) have argued that a useful way of ensuring that exchange rate models are correctly specified is to estimate the models structurally, and this seems to be a useful avenue for future research.[11] Examples of existing studies that

[11] 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."

have applied this approach to modeling the exchange rate—with some degree of success—include Kearney and MacDonald (1985), Blundell-Wignall and Masson (1985), Masson (1988), Papell (1988), and Smith and Wickens (1988, 1990). Note, however, that the systems approach raises a further set of issues concerning the assumed structure of the whole economy (see, for example, Fisher and others (1990) on the econometric evaluation of the exchange rate in large-scale models of the U.K. economy).

In attempting to explain the poor empirical performance of the asset approach, some authors have suggested that foreign exchange rates may have consistently deviated from their underlying "fundamental" levels (that is, as predicted by economic theory), due to the presence of rational bubbles, as discussed above (see, for example, Flood and Hodrick (1989)). Other researchers have concentrated on the influence of foreign exchange analysts who base their predictions not on economic theory but on the identification of supposedly recurring patterns in graphs of exchange rate movements—that is, "technical" or "chart" analysts. Frankel and Froot (1986, 1990), for example, suggested a model of the foreign exchange market in which traders based their expectations partly on the advice of fundamentalists (that is, economists) and partly on the advice of nonfundamentalists (that is, chartists). They argued that such a model could explain the heavy overvaluation of the U.S. dollar during the mid-1980s.

Some support for the view that nonfundamentalist advice may be an important influence in foreign exchange markets is provided by Taylor and Allen (1992) who conducted a survey of chief foreign exchange dealers in the London foreign exchange market; they found that a high proportion of these dealers used 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 found that over 90 percent of their survey respondents reported using some form of chart analysis, and about 60 percent judged charts to be at least as important as fundamentals at this horizon. As the time horizon was lengthened, however, the weight given by dealers to fundamental analysis increased. 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) analyzed the accuracy of a number of individual chart analysts' one-week and four-week ahead forecasts of the U.S. dollar-pound sterling, U. S. dollar-deutsche mark, and U.S. dollar-yen exchange rates and found that some of them consistently outperformed 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 is hardly surprising that empirical models based on pure, fundamental economic theory fail to provide an adequate explanation of short-term movements in exchange rates. However, the revelation that foreign exchange participants focus more on fundamentals at longer horizons suggests that more attention might fruitfully be paid 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) emphasized the role of shifts in fiscal policy stance among the major Organization for Economic Cooperation and Development (OECD) countries as important determinants of exchange rate behavior (see also Dornbusch (1987)). These authors have argued 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 (1991) focused 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 pointed to the experience of a number of debt-burdened developing countries during the 1980s that experienced substantial depreciations of their real exchange rate around the time of the outbreak of the international debt crisis in 1982. Dooley and Isard (1991) argued that these depreciations could 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" (p. 163). Dooley, Isard, and Taylor (1991) suggested 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, Isard, and Taylor, in fact, provided econometric evidence that is largely supportive of this view for a number of major exchange rates. They also demonstrated that the price of gold is a crucial factor in beating a random walk in post-sample prediction tests.

Dornbusch (1987) stressed the importance of analyzing a country's industrial structure in any attempt 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 on whether the industry faces competition from imports that are close substitutes for its goods and whether the market is characterized by, for example, oligopoly or imperfect competition; another important determinant is the functional form of the specific market demand curve. Although conceding the absence of clear-cut results, Dornbusch nevertheless found this approach promising as an avenue for further research.

Which of these directions is likely to lead us toward 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) and Taylor (1988a)).

The Taylor and Allen (1992) evidence on the prevalence of nonfundamentalist analysis in foreign exchange markets suggests that, as a guide to the *short-run* behavior of exchange rates, the fundamentals versus nonfundamentals approach seems promising. Unfortunately, this road may be rocky because of the difficulties involved in developing reliable models of exchange rate behavior from this approach. For example, Allen and Taylor (1990), after analyzing survey data on chartists' exchange rate forecasts, reported a significant degree of heterogeneity among chartist forecasts—not all chartists see the same patterns (or draw the same conclusions from them) at the same points in time. They argued, moreover, that the degree of consensus is likely to shift significantly over time in a fashion that may be hard to model empirically. Thus, while this approach may help us to rationalize the *past* behavior of exchange rates (for example, Frankel and Froot (1990)), it may prove rather more difficult to apply it to predicting *future* 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 modeling the *long-run equilibrium* exchange rate. It is perhaps in this area that the new approaches that take into account fiscal policy stance, locational decisions, and industrial organization might be most fruitfully applied. In addition, the development of econometric techniques that aid in the identification of long-run relationships using short-run data (see, for example, Engle and Granger (1987)) is likely to provide a further impetus in this direction (see MacDonald and Taylor (1991a)).

III. The Efficient Markets Hypothesis

In this section we present a brief review of the literature on the efficient markets hypothesis 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 (for example, 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 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.[12] 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 (for example, Poole (1967) and 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 should on average eliminate any profit. Poole's study did not, in fact, allow for interest rate costs, but Dooley and Shafer's analysis not only included interest rate costs but also allowed 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

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

reported 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 size could have been chosen ex ante, and there also appears to be an important element of riskiness, in that substantial subperiod losses are often generated.

The literature on forward foreign exchange market efficiency has generally used some form of regression-based analysis of spot and forward exchange rates. As is clear from the preceding discussion, the efficient market hypothesis 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

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

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)).[13] This problem does not arise if agents are assumed to form expectations of the *logarithm* of exchange rates, since $E(-s) = -E(s)$. McCulloch (1975), however, investigated the empirical importance of this phenomenon (using 1920s data) and showed 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 expectations 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,

[13] Because of a mathematical relationship known as Jensen's inequality, one cannot have, simultaneously, an unbiased expectation of, say, the deutsche mark-U.S. dollar exchange rate (marks per dollar) and of the U.S. dollar-deutsche mark exchange rate (dollars per mark) because $1/E(S) \neq E(1/S)$.

say, might be expected to drive a wedge between f_t and s^e_{t+k}. Under this assumption, equation (20) can be rewritten, after subtracting s_t from both sides as

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

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

From equations (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 either to assume that λ_t is zero and conclude that rejection is attributable to "irrationality," or that 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 efficient markets hypothesis 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 nonoverlapping data are being used ($k = 1$), we would expect 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 is to conduct orthogonality tests of forecast errors. More specifically, an equation is estimated 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 cannot be forecast using current information—that is, 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.

Tests of Forward Premium as Optimal Predictor of Rate of Depreciation

Many researchers have implemented equation (23) using a variety of currencies and time periods for the recent floating experience, and report results unfavorable to the efficient markets hypothesis under risk neutrality. For example, Bilson (1981), Longworth (1981), Fama (1984), Gregory and McCurdy (1984), Taylor (1988b), and Kearney and MacDonald (forthcoming) all reported a result suggesting 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 nonoverlapping data sets. Equation (25) below (from Fama (1984)) is a typical example of the result obtained by these researchers (standard errors are in parentheses):

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

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

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

Error Orthogonality Tests of 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 that include only lagged forecast errors in the conditioning information set (in terms of Fama's 1976 taxonomy, such tests are weak form tests, categorized as A-tests) and those that include information additional to lagged forecast errors in the information set (semistrong form tests, labeled B-tests).

A-tests have been conducted by, among others, Cumby and Obstfeld (1984), Geweke and Feige (1979), Frankel (1979b), Gregory and McCurdy (1984), MacDonald (1983), and MacDonald and Taylor (1991b). These authors used a variety of sample periods (that is, recent float and interwar float), exchange rates (usually bilateral dollar rates), and estimation techniques—ordinary least squares (OLS), generalized least squares (GLS), Zellner's "seemingly unrelated regressions" technique, and generalized method of moments (GMM). Their basic finding was that the efficient markets hypothesis is rejected for a number of currencies for the recent and interwar floating experiences. For example, Hansen and Hodrick (1980) estimated equation (24) using a weekly data base for part of the recent float and found that the orthogonality property was violated for three currencies (the Swiss franc, the lira, and the deutsche mark). Hansen and Hodrick estimated their version of equation (24) using OLS (since it is consistent), but corrected 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) GMM procedure.[14] MacDonald and Taylor (1991b) also used Hansen's GMM technique to conduct A-tests for the interwar period, but, in contrast to Hansen and Hodrick, they used the GMM procedure to correct for both the implied moving average error *and* conditional heteroscedasticity (Hansen and Hodrick assumed conditional homoscedasticity); the null hypothesis was strongly rejected for dollar-pound sterling, franc-pound sterling, and franc-dollar exchange rates (this result contrasts with other tests of the efficient markets hypothesis for this period).

Given the rejections of the null hypothesis reported when researchers conduct A-tests, it is hardly surprising to find that B-tests result in even stronger rejections. Geweke and Feige (1979), Hakkio (1981), Hansen and Hodrick (1980), Hsieh (1984), and MacDonald and Taylor (1991b) all tested the orthogonality of the forward rate forecast error with respect to own lagged forecast errors and lagged forecast errors from other foreign exchange markets; in each case, the null hypothesis $\Gamma = 0$ was resoundingly rejected.

Rationalizing Inefficiency Findings

The rejection of the efficient markets hypothesis is usually explained in one of two ways. As noted above, it is a joint null hypothesis of rational expectations and an assumption concerning the attitude of agents toward risk. It has often been tested under the assumption of risk neutrality. Thus, the first, and by far the most popular, explanation of the inefficiency finding is that agents are risk averse and, therefore, λ_t is nonzero in equation (21). For examples of attempts to model or test for the foreign exchange risk premium econometrically, see, among others, Fama (1984), Hansen and Hodrick (1983), Domowitz and Hakkio (1985), Wolff (1987),

[14] See MacDonald and Taylor (1989a) for an explanation and discussion of the moving average structure of overlapping forecast errors.

and Taylor (1988b, 1991a). By and large, however, the risk premium has proved elusive.[15]

Alternatively, researchers have sought to explain rejection in terms of a failure of the expectations component of the joint hypothesis. Examples include the peso problem suggested by Krasker (1980) (see footnote 7 above); the rational bubbles phenomenon, originally suggested by Flood and Garber (1980); and inefficient information processing, as suggested by Bilson (1981) (see MacDonald and Taylor (forthcoming) for a more detailed survey).

A problem with each of these rationalizations is that in order to test for a failure in one leg of the efficient markets hypothesis, the researcher 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 were 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. 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, 1990), MacDonald and Torrance (1988b, 1990), and Taylor (1989a) all used the median of various exchange rate surveys. The broad conclusion emerging 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) and MacDonald and Taylor (forthcoming)). Furthermore, Ito (1990) demonstrated, using a highly disaggregated survey data base, that exchange rate expectations appear to be highly heterogeneous.[16]

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 efficient markets hypothesis (that is, assuming risk neutrality) thus seems to have been decisively rejected for the foreign exchange market. This result is commonly explained either

[15] For extensive surveys of this issue see Hodrick (1987) and MacDonald and Taylor (forthcoming).

[16] Froot and Ito (1988) tested the "consistency" of the median response of survey data by 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 demonstrated that the survey forecasts are inconsistent.

in terms of a time-varying risk premium or 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 it. Furthermore, a number of researchers have argued that the use of a time-varying risk premium is a vacuous device whose only function is to provide a tautological safe house for the theory (Mankiw and Summers (1984)).[17]

Perhaps, 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 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.[18] Combining this view with a fresh approach to the underlying fundamentals (for example, Dooley, Isard, and Taylor (1991)) is an approach that we believe offers much potential for future research on exchange rate economics.

IV. "News" and Exchange Rates

One important implication of the rational expectations hypothesis is that unanticipated events or news drive asset prices like the exchange rate. For example, although the strict efficient markets hypothesis 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 that 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(that is, η_{t+k} in equation (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

[17] Frankel and Froot (1990) present the most complete and formal statement of this view.

[18] Both Hakkio (1984) and MacDonald (1988) reported 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.

efficient markets hypothesis predicts that s_{t+k} should be very close to f_t, but if a researcher is examining an equation such as (23) during 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_t include all variables relevant for the process of exchange rate determination; our equation for the determination of the exchange rate is thus

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

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 $s_t^e = E(s_t \mid I_{t-1}), z_t^e = E(z_t \mid I_{t-1})$. Thus, subtracting equation (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 that a researcher faces 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_t 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 three methods to generate expected values: regression analysis, time-series analysis, and survey data.

Frenkel (1981) used time-series methods (univariate autoregressions) to generate news on nominal interest rate differentials, which he then used to explain the forward rate forecast error for the U.S. dollar-pound sterling, U.S. dollar-franc, and U.S. dollar-deutsche mark exchange rates over the period June 1973 through June 1979. Although he found that all of the estimated news coefficients had signs in accordance with the monetary model of the exchange rate, this coefficient was statistically significant only for the U.S. dollar-pound sterling.

Edwards (1982) and MacDonald (1983) provided similar mixed support for the flexible-price news approach, using a seemingly unrelated regressions estimation technique. MacDonald (1983) extended this analysis to the interwar period. Copeland (1984) incorporated oil price surprises into his news analysis of the pound sterling-U.S. dollar exchange rate. Bomhoff and Korteweg (1983), using a multistate Kalman filter technique to generate news on relative money, output, and oil prices, tested the news approach for six exchange rates over the period 1973–79. Again, their results provided some support for the approach. Branson (1984) tested 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. His results were broadly in accordance with the predictions of the portfolio balance model. In contrast to the above researchers, Dornbusch (1980) generated 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 (forthcoming) for a discussion).

V. 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 empirical evidence on their validity (a comprehensive account is given in MacDonald and Taylor (1990, forthcoming); 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:

$$(i - i^*)_t - (f - s)_t = 0. \tag{29}$$

In any computation of CIP, it is clearly important to consider home and foreign assets that are comparable in terms of maturity, as well as other characteristics such as default and political risk (Aliber (1973), Dooley and Isard (1980), and 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) demonstrated that for a selection of currencies, about 80 percent of apparent profit opportunities lay within the neutral band when treasury bills were used, and almost 100 percent when Eurorates were 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) demonstrated that deviations from CIP should be no greater than the minimum transactions costs in one of three markets: the two underlying deposit markets (for example, Euromarks and Eurodollars), and the foreign exchange swap market (that is, the market in which a currency can be simultaneously bought spot and sold forward against another currency). Based on an analysis of data for five major currencies against the U.S. dollar, which he took from midmorning quotes on the Reuter Money Rates Service for the six-month period from November 1985 to May 1986, Clinton found that the neutral band should be within ±0.06 percent a year from parity and that although the hypothesis of zero profitable deviations from parity could 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" (p. 369).

In questioning the quality of the data used by Frenkel and Levich (1975, 1977), various researchers have arrived at different conclusions. For example, using higher quality data, McCormick (1979) found that most of the deviations from CIP (70–80 percent) lay *outside* the neutral band for U.K.-U.S. Treasury bills. Taylor (1987b, 1989b), however, went further than McCormick, arguing that in order to provide a true test of CIP it is important that data on the appropriate exchange and interest rates be recorded at the same instant at which a dealer could have dealt. Using high-quality, high-frequency, contemporaneously sampled data for spot and forward dollar-pound sterling and dollar-mark exchange rates and corresponding Eurodeposit interest rates for a number of maturities, Taylor found, among other things, that there were few profitable violations of CIP, even in periods of market uncertainty and turbulence. One interesting finding of Taylor's work was a maturity effect—the frequency, size, and persistence of arbitrage opportunities appeared to be an increasing function of the length of maturity of underlying financial instruments. A rationale is offered for this in terms of banks' prudential credit limits. This finding received further support in Taylor and Fraser (1991), in which high-frequency, contemporaneous data sampled around a series of news releases (such as trade figures) were employed to test CIP.

A second method for testing the validity of CIP is the use of regression analysis. Thus, if CIP holds, and in the absence of transactions 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 nonautocorrelated error. Equation (30) has been tested by researchers for a variety of currencies and time periods (see, for example, Branson (1969), Marston (1976), Cosander and Laing (1981), and Fratianni and Wakeman (1982)). Broadly speaking, CIP is supported; although there were significant deviations of α from zero (reflecting perhaps nonzero transactions costs), the estimates of β differed insignificantly from unity in the majority of cases. As noted by Taylor (1987b, 1989b), however, it is not clear what regression-based analyses of CIP are actually testing. For example, it may be that the hypothesis that $\alpha = 0$ and $\beta = 1$ in equation (30) cannot be rejected, but that the fitted residuals themselves represent substantial arbitrage opportunities. Put another way, such a test may strongly suggest that CIP held *on average* over a period, when in fact it did not hold at *any instant* 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. 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 Eurodeposit 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 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 CIP, UIP 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, among others, Hacche and Townend (1981), Cumby and Obstfeld (1981), Davidson (1985), Loopesko (1984), and Taylor (1987a); in all instances, UIP was 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, demonstrated, using survey expectations data, that rejection was most likely caused by both risk and expectations factors. Interestingly, several papers that attempted to model deviations from UIP in terms of a risk premium have been largely unsuccessful (see, among others, Dooley and Isard (1982), Frankel (1982b, 1983, 1985b), and Rogoff (1984)).

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

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

Thus, given the stated assumptions, real interest rates must be equalized across countries, and the scope for the policymaker 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 United States against other OECD countries (see, for example, Mishkin (1984a, 1984b), Friedman and Schwartz (1982), 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 equations (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:

$$\Delta p_{t+1} - \Delta p^*_{t-1} = \underset{(0.01)}{0.028} + \underset{(0.23)}{0.503}(r - r^*)_t \qquad (38)$$

United States-Germany; January 1976–September 1981,

where standard errors are in parentheses, the price terms are consumer price indices, and the interest rates are Eurodeposit interest rates. For this equation, and for others reported by Cumby and Obstfeld, the null hypothesis of ex ante real interest rate parity is easily rejected.

Tests of PPP have often involved estimates of the following equations:

$$s_t = \alpha + \beta p_t - \beta^* p_t^* + \varphi_t \qquad (39)$$

$$\Delta s_t = \beta \Delta p_t - \beta^* \Delta p_t^* + \varphi_t. \qquad (40)$$

Thus, a test of equation (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—while a test of equation (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. Frenkel (1978, 1981) provided estimates of equations (39) and (40) for the interwar floating experience and for the recent floating experience, respectively. Frenkel's interwar estimates were highly supportive of PPP; his results for a variety of currencies for the recent floating experience were not (PPP in both its absolute and relative forms was resoundingly rejected by the data). In further tests of PPP for the interwar and recent floating experience, Krugman (1978) reported estimates of (39) and (40) that were largely unfavorable to PPP (he used a longer sample period for the interwar period than Frenkel (1978)). Krugman's results pointed to large and persistent deviations of exchange rates from PPP, especially in countries with an unstable monetary policy.

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

$$i_t - i_t^* = \Delta p^{e*}_{t+k} - \Delta p^e_{t+1} + \Delta s^e_{t+1}, \qquad (41)$$

and by assuming the expected values in equation (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 that may lead to a change in the real exchange rate in the short run, 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 so far does in fact favor the efficient markets view of PPP (see, for example, Roll (1979), Darby (1980), Frenkel (1981), Adler and Lehmann (1983), Mishkin (1984b), and MacDonald (1985a, 1985b)). However, some research has led to rejection of the hypothesis (see, for example, Cumby and Obstfeld (1984), Frankel (1985b), and Frankel and Froot (1986)).

Further evidence in favor of the efficient market PPP may be gleaned from studies that use cointegration analysis (Engle and Granger (1987)) to test for mean reversion in the real exchange rate or in the residual of an equation (equation (39)). Such studies (see, for example, Taylor (1988c)) report a failure of significant mean reversion of the exchange rate toward 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, were able to reject the unit-root (random walk) hypothesis. A similar finding for the recent float is reported by MacDonald (forthcoming). 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) and Taylor (1991b)).

Other tests of PPP are more descriptive in their nature. Thus, a number of researchers (for example, Dornbusch and Krugman (1976), 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 (1990). All of these studies reported strong rejections of the PPP hypothesis.

Of the international parity conditions covered in this section, covered interest parity receives fairly strong support from the data, especially when it is implemented with Eurodeposit interest rates and data that properly reflect the trading opportunities open to arbitrage. A less sanguine conclusion, however, emerges from the 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 that rely on UIP in their derivation. A major challenge facing researchers is to determine whether this failure is due to a violation of risk neutrality or a failure of rational expectations. Studies that 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 that 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 that have been used to test for the existence of PPP supports 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 toward PPP is at present mixed. Taylor and McMahon (1988) produced evidence strongly suggesting 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 in 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 exchange rate models discussed previously are not unequivocally validated by the data. Future modeling should therefore be aware of this inconsistency and, at the very least, should 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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