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The Economics of Exchange Rates

By MARK P. TAYLOR
University of Liverpool
and
Centre for Economic Policy Research, London

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I. *Introduction*

This paper reviews the literature on exchange rate economics over the last two decades, with particular reference to recent developments. Exchange rate economics has been one of the most active—if challenging—areas of economic research over the last twenty years, and the amount of ground covered here is correspondingly vast. Thus, we can only hope to give a selective survey of the terrain and of its major promontories. In particular, we discuss the evidence on foreign exchange market efficiency (Section II), the theory and evidence relating to the determination of exchange rates (Sections III and IV respectively), recent work on the effectiveness of foreign exchange intervention (Section V), and the recent literature on exchange rate behavior within target zones (Section VI). The emerging literature on foreign exchange market microstructure is also briefly discussed (Section VII). In the concluding section of the paper we attempt to draw

out some broad themes in the research program, and speculate on the likely or desirable course of future research in this area.[1]

II. *Speculative Efficiency*

In an efficient speculative market, prices should fully reflect information available to market participants and it should be impossible for a trader to earn excess returns to speculation. Academic interest in foreign exchange market efficiency can be traced to arguments concerning the information content of financial market prices and the implications for social efficiency. In its simplest form, the efficient markets hypothesis can be reduced to a joint hypothesis that foreign exchange market participants are, in an aggregate sense a) endowed with rational expectation and b) risk-neutral. The hypothesis can be modified to adjust for risk, so that it then becomes a joint hypothesis of a model of equilibrium returns (which may admit risk premia) and rational expectations.

If the risk-neutral efficient markets hypothesis holds, then the expected foreign exchange gain from holding one currency rather than another (the expected exchange rate change) must be just offset by the opportunity cost of holding funds in this currency rather than the other (the interest rate differential). This is the cornerstone parity condition for testing foreign exchange market efficiency—the uncovered interest rate parity condition:

$$\Delta_k s^e_{t+k} = i_t - i^*_t \qquad (1)$$

where s_t denotes the logarithm of the spot exchange rate (domestic price of foreign currency) at time t, i_t, and i^*_t are the nominal interest rates available on similar domestic and foreign securities respectively (with k periods to maturity), $\Delta_k s_{t+k} \equiv s_{t+k} - s_t$, and superscript e denotes the market's expectation based on information at time t.

1. *Testing Foreign Exchange Market Efficiency*

Early efficiency studies tested for the randomness of exchange rate changes (e.g., William Poole 1967). However, only if the nominal interest rate differential is identically equal to a constant, and expectations are rational, does (1) imply a random walk in the exchange rate (with drift if the constant is non-zero). Generally, the random walk model is inconsistent with the uncovered interest rate parity condition. Robert Cumby and Obstfeld's (1981) analysis is a logical extension of this literature because they test for—and reject—the randomness of deviations from uncovered interest rate parity. Notwithstanding this, however, it remains true that time series for the major nominal exchange rates over the recent float are extremely hard to distinguish empirically from random walks (Michael Mussa 1984).

Another method of testing market efficiency is to test for the profitability of filter rules. A simple j-percent filter rule involves buying a currency whenever it rises j percent above its most recent trough and selling the currency whenever it falls j 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. A number of studies do indicate the profitability of simple filter rules (Dooley and Jeffrey Shafer 1983; Levich and Lee Thomas 1993), although it is usually not

[1] This paper can be viewed as an extension and update of earlier surveys, notably Richard Levich (1985) and MacDonald and Taylor (1992). All of the topics discussed are dealt with more fully in Taylor (forthcoming).

clear that the optimal filter rule size could have been chosen ex ante, and there are often also important elements of riskiness in that substantial subperiod losses are often generated. Further, indirect evidence on the profitability of trading rules is provided by Charles Engel and James Hamilton (1990), who show that the dollar, from the early 1970s to the late 1980s, was susceptible to "long swings" (largely uninterrupted trends), which are susceptible to mechanical ("trend-following") trading rules.

More often, researchers have tested for efficiency by regression-based analysis of spot and forward exchange rates. The forward rate is the rate agreed upon now for an exchange of currencies at some agreed future point in time. The forward premium at a certain maturity is the percentage difference between the current forward rate of that maturity and the current spot rate.[2] Assuming covered interest parity (see equation (7) discussed below), the interest rate differential should be just equal to the forward premium. Under rational expectations, the expected change in the exchange rate should differ from the actual change only by a rational expectations forecast error. Hence, the uncovered interest rate parity condition (1) can be tested by estimating a regression equation of the form

$$\Delta_k s_{t+k} = \alpha + \beta(f_t^{(k)} - s_t) + \eta_{t+k} \qquad (2)$$

where $f_t^{(k)}$ is the logarithm of the forward rate for maturity k periods ahead and η_{t+k} is a disturbance term.[3] If agents are risk-neutral and have rational expectations, we should expect the slope parameter, β, to be equal to one and the disturbance term η_{t+k}—the rational expectations forecast error under the null hypothesis—to be uncorrelated with information available at time t.[4] Empirical studies of (2), for a large variety of currencies and time periods, for the recent floating experience, generally report results which are unfavorable to the efficient markets hypothesis under risk neutrality (e.g., Eugene Fama 1984). Indeed it is stylized fact that estimates of β, using exchange rates against the dollar, are generally closer to minus unity than plus unity (Froot and Richard Thaler 1990). A number of authors have interpreted the stylized fact of a negative coefficient in this regression—the so-called "forward discount bias"—as evidence that the forward premium mispredicts the direction of the subsequent change in the spot rate, although such statements may be misleading because they ignore the constant term in the regression (Hodrick 1992). What the negativity of the estimated slope coefficient does imply, however, is that the more the foreign currency is at a premium in the forward market at a certain term k, the less the home currency—usually the dollar—is predicted to depreciate over the k peri-

[2] Some authors term this the forward discount rather than the forward premium. The choice is essentially arbitrary, because a premium is just a negative discount.

[3] Regression relationships involving exchange rates are normally expressed in logarithms in order to circumvent the so-called "Siegel paradox" (Jeremy Siegel 1972): because of Jensen's inequality, one cannot have, simultaneously, an unbiased expectation of, say the mark-dollar exchange rate (marks per dollar) and of the dollar-mark exchange rate (dollars per mark) because $1/E(S) \neq E(1/S)$. Although the problem seems to be avoided if exchange rates are expressed in logarithms because $E(-s) = -E(s)$, agents must still form expectations of final payoffs S and $1/S$, so that it is not clear that taking logarithms does avoid the problem. Engel (1984), using an argument based on real as opposed to nominal returns to speculation, derives an efficiency condition which is independent of the choice of numéraire currency. J. Huston McCulloch (1975), using 1920s data, demonstrates the operational importance of the Siegel paradox to be slight.

[4] This follows from the formal property of rational expectations forecast errors that $E[\eta_{t+k}|\Omega_t] = 0$, where $E[\,|\Omega_t]$ denotes the mathematical expectation conditioned on the information set available at time t, Ω_t.

ods to maturity.[5] This may imply an expected appreciation of the home currency, but the constant terms are relatively large and often it does not.

Early regression-based tests of foreign exchange market efficiency regressed the logarithm of the spot rate onto the lagged logarithm of the forward rate (e.g., Frenkel 1976), and usually found an estimated slope coefficient close to unity. It was subsequently realized, however, that standard regression analysis (or at least standard inferential statistical theory) was invalid with such a relationship, because of the nonstationarity of the series. Moreover, it should be noted that the two relationships (2) and

$$s_{t+k} = \alpha + \beta f_t^{(k)} + \eta'_{t+k} \qquad (3)$$

are identical only under the null hypothesis $\beta = 1$. In particular, suppose (2) holds with $\beta \neq 1$. Then (2) may be reparameterized as

$$s_{t+k} = \alpha + \beta f_t^{(k)} + [(1-\beta)s_t + \eta_{t+k}], \qquad (4)$$

so that the error term in (3), η'_{t+k}, is seen to be $[(1-\beta)s_t + \eta_{t+k}]$. Now, if s_t is nonstationary, then its sample variance will be very high. But the ordinary least squares estimator works by minimizing the residual variance in a regression relationship. Thus, ordinary least squares applied to (3) will tend to drive the estimated value of β toward unity, regardless of the true value of β.

As noted above, a stylized fact concerning major exchange rates over the recent float is that they are not only nonstationary but are extremely hard to distinguish from simple random walks. If the exchange rate did literally follow a random walk, then the estimated value of β in (2) should be close to zero, regardless of whether the market is efficient. Moreover, because the best predictor of future values of the spot rate is, under the assumption of a random walk, just the current spot rate, then the simple efficiency hypothesis combined with the random walk hypothesis would imply $f_t^{(k)} = s^e_{t+k} = s_t$, so that the regressor in (2) should be close to zero, in which case β would be unidentified. In practice, the observed variation in $(f_t^{(k)}) - s_t)$ would almost certainly be non-zero, even under these assumptioms, if only because of measurement errors.

Thus, regressions of the form (2) or (3) as tests of simple efficiency are seriously confounded by the near-random-walk behavior of spot exchange rates. Given these problems, perhaps a better way of testing the simple efficiency hypothesis is to test the orthogonality of the forward rate forecast error (the error made in forecasting the future spot rate using the current forward rate[6]) with respect to a given information set by imposing the restriction $\beta = 1$ in (2) and testing the null hypothesis that $\Psi = 0$ in regressions of the form:

$$s_{t+k} - f_t^{(k)} = \Psi I_t + \eta_{t+k} \qquad (5)$$

where I_t is a vector of variables selected from the information set available at time t. Orthogonality tests of this kind, using lagged forecast errors of the exchange rate in question in I_t, generally have rejected the simple, risk-neutral efficient markets hypothesis; even stronger rejections are usually obtained when additional information is included in I_t (Lars Hansen and Hodrick 1980).

A discernible trend in the efficiency literature since the 1970s has been to-

[5] Equivalently, via the covered interest arbitrage condition, these findings indicate that the more U.S. interest rates exceed foreign interest rates, the more the dollar tends on average to appreciate over the holding period, not to depreciate so as to offset on average the interest differential in favor of the home currency.

[6] This term, $(s_{t+k} - f_t^{(k)})$, alternatively may be thought of as the return to forward speculation. Some authors term it the "excess return" because no allowance is made for risk.

ward increasing econometric sophistication. Thus, early tests of efficiency, which involved simple tests for a random walk in the spot rate, were supplanted by basic linear regression analyses of uncovered interest parity, which were in turn supplanted by application of the use of sophisticated rational expectations estimators which allowed the use of data sampled more finely than the term of the forward contract involved (Hansen and Hodrick 1980).[7] By and large, this increasing sophistication has generated increasingly strong evidence against the simple, no-risk-premium speculative efficiency hypothesis.

2. *Rethinking Efficiency I: Risk Premia*[8]

The rejection of the simple, risk-neutral efficient markets hypothesis may be due to the risk-aversion of market participants or to a departure from the pure rational expectations hypothesis, or both. If foreign exchange market participants are risk-averse, the uncovered interest parity condition (1) may be distorted by a risk premium, ρ_t say, because agents demand a higher rate of return than the interest differential in return for the risk of holding foreign currency. Thus, arbitrage will ensure that the interest rate cost of holding foreign currency (i.e., the interest rate differential) is just equal to the expected gain from holding foreign currency (the expected rate of depreciation of the domestic currency) plus a risk premium:[9]

$$i_t - i_t^* = \Delta_k s_{t+k}^e + \rho_t. \tag{6}$$

If the risk premium is time-varying and correlated with the forward premium or the interest rate differential, this would confound efficiency tests of the kind outlined above (Fama 1984). This reasoning has led to a search for stable empirical models of the risk premium on the assumption of rational expectations. Because of the theoretical relationship between risk and the second moments of asset price distributions, researchers have often tested for a risk premium as a function of the variance of forecast errors or of exchange rate movements (Frankel 1982b; Ian Domowitz and Hakkio 1985; Alberto Giovannini and Philipe Jorion 1989). In common with other empirical risk premium models, such as latent variables formulations (Hansen and Hodrick 1983), such models have generally met with mixed and somewhat limited success, and have not been found to be robust when applied to different data sets and sample periods. As noted by Lewis (forthcoming), for credible degrees of risk aversion, empirical risk premium models have so far been unable to explain to any significant degree the variation in the excess return from forward market speculation.

3. *Rethinking Efficiency II: Expectations*

An alternative explanation of the rejection of the simple efficient markets hy-

[7] An additional, econometrically sophisticated method of testing the simple efficient markets hypothesis—which also generally has led to rejections of the hypothesis—has involved testing the nonlinear cross-equation restrictions which the hypothesis imposes on a vector autoregression (VAR) in spot and forward rates. This was originally suggested in the context of foreign exchange rates by Craig Hakkio (1981) although, as the subsequent cointegration literature revealed, a VAR in first differences alone is not appropriate for spot and forward rates.

[8] See Karen Lewis (forthcoming) for a recent survey of the literature on the foreign exchange risk premium and departures from the rational expectations paradigm. Frankel (1988) surveys the empirical work on risk premia.

[9] Our use of the term "premium" rather than "discount" is again arbitrary and follows standard usage in the literature; risk premia can, however, be negative. Note also that (6) is an arbitrage condition rather than a behavioral relationship. In particular, (6) could just as well be written with ρ_t on the left-hand-side, in which case it would have to redefined as -1 times its present implicit definition, $\rho_t \equiv i_t - i_t^* - \Delta_k s_{t+k}^e$.

pothesis is that there is a failure, in some sense, of the expectations component of the joint hypothesis. Examples in this group are: the "peso problem" originally suggested by Rogoff (1979); rational bubbles; learning about regime shifts (Lewis 1989); or inefficient information processing, as suggested, for example, by John Bilson (1981). The peso problem 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 if agents' expectations are rational, and thus may generate apparent evidence of non-zero excess returns from forward speculation. In common with peso problems, the presence of rational bubbles may also show up as non-zero excess returns even when agents are risk-neutral. Similarly, when agents are learning about their environment they may be unable fully to exploit arbitrage opportunities which are apparent in the data ex post. A problem with admitting peso problems, bubbles or learning into the class of explanations of the forward discount bias is that, as noted above, a very large number of econometric studies—encompassing an even larger range of exchange rates and sample periods—have found that the direction of bias is the same, i.e., that the estimated uncovered interest rate parity slope parameter, β in (2), is generally negative and closer to minus unity than plus unity. For example, Lewis (1989), in a study of the relationship of the early 1980s dollar appreciation with learning about the U.S. money supply process, notes a persistence in the forward rate errors which, in itself, is prima facie evidence against the learning explanation: agents cannot forever be learning about a once-for-all regime shift. Similarly, the peso problem is essentially a small-sample phenomenon; it cannot explain the *overall* stylized fact that estimates of β are negative.

4. *Rethinking Efficiency III: Survey Data Studies*

A problem with much of the empirical work on the possible rationalizations of the rejection of the simple, risk-neutral efficient markets hypothesis, is that in testing one leg of the joint hypothesis, researchers typically have assumed that the other leg is true. For instance, the search for a stable empirical risk premium model generally has been conditioned on the assumption of rational expectations. Thus, some researchers have employed survey data on exchange rate expectations to conduct tests of each component of the joint hypothesis (Froot and Frankel 1989; see Shinji Takagi 1991 for a survey of survey data studies). In general, the overall conclusion that emerges from survey data studies appears to be that *both* risk aversion *and* departures from rational expectations are responsible for rejection of the simple efficient markets hypothesis.[10,11]

5. *Other Parity Conditions*

Although uncovered interest rate parity is the basic parity condition for as-

[10] In an influential study, Froot and Frankel (1989) did not reject the hypothesis that the bias is due entirely to systematic expectational errors. In particular, they found a slope coefficient insignificantly different from one in the regression of the market survey forecast onto the forward premium. Hodrick (1992) notes, however, that the R^2 in this regression is far from perfect, as it should be if the forward premium is the market's expected rate of depreciation and risk factors are insignificant.

[11] McCallum (1994) suggests that the negativity of the estimated uncovered interest rate parity slope coefficient is consistent with a simultaneity induced by the existence of a government reaction function in which the interest rate differential is set in order to avoid large current exchange rate movements as well as to smooth interest rate movements. This is a special case of the general point made by Fama (1984) that negativity of estimated β requires negative covariation between the risk premium and the expected rate of depreciation.

sessing the efficiency of the foreign exchange market, two other arbitrage conditions which receive considerable attention in the literature are covered interest rate parity and purchasing power parity.[12]

(a) *Covered interest rate parity.* If there are no barriers to arbitrage across international financial markets, then arbitrage should ensure that the interest differential on similar assets, adjusted for covering in the forward foreign exchange market the movement of currencies at the maturity of the underlying assets, be continuously equal to zero, so that covered interest rate parity should hold:[13]

$$(i_t - i_t^*) - (f_t^{(k)} - s_t) = 0. \tag{7}$$

Frenkel and Levich (1975, 1977) test for departures from (7) for a number of major exchange rates during the 1970s, allowing for transactions costs, and find very few departures when Euro-deposit rates are used, but significantly more (some 20%) when Treasury bill discounts are used. Further evidence supportive of covered interest rate parity for several major exchange rates during the recent float is provided by Kevin Clinton (1988). Taylor (1987, 1989) uses very high quality, high frequency, contemporaneously sampled data for spot and forward exchange rates and Euro-deposit rates, and finds, inter alia, that there are few profitable violations of covered interest rate parity, even in periods of market uncertainty and turbulence.[14]

(b) *Purchasing power parity.*[15] Absolute purchasing power parity implies that the exchange rate is equal to the ratio of the two relevant national price levels. Relative purchasing power parity posits that changes in the exchange rate are equal to changes in relative national prices. Thus, in estimates of equations of the form

$$s_t = \alpha + \beta p_t + \beta^* p_t^* + u_t, \tag{8}$$

a test of the restrictions $\beta = 1$, $\beta^* = -1$ would be interpreted as a test of absolute purchasing power parity, while a test of the same restrictions applied to the equation with the variables in first differences would be interpreted as a test of relative purchasing power parity. The real exchange rate, in logarithmic form

$$\pi_t \equiv s_t - p_t + p_t^*, \tag{9}$$

[12] Tests of these two parity conditions have different implications from tests for uncovered interest parity. Covered interest parity, for example, should hold independently of agents' attitudes toward risk and their method of forming expectations, so that tests of this parity condition are really tests of barriers to arbitrage. While purchasing power parity can be given an efficient markets interpretation, its major importance lies in the link between economic fundamentals (the determinants of price movements) and exchange rate movements. Nevertheless, these parity conditions recur in theoretical and empirical exchange rate work: covered interest parity was used above to derive equation (2) from equation (1), for example, and both parity conditions have been used regularly in work on exchange rate determination, as we shall see below. Thus, a brief discussion of the empirical evidence relating to these parity conditions is warranted in the present context.

[13] It is clearly important in this connection to consider home and foreign assets which are comparable in terms of maturity, and also in terms of other characteristics such as default and political risk; most often, researchers have used offshore, Euro-currency interest rates. A typical barrier to arbitrage would be capital controls; deviations from covered interest parity using domestic security interest rates (or the spread between offshore and onshore rates) have often been used as an indirect indicator of the presence and effectiveness of these (Dooley and Isard 1980).

[14] Another test of covered interest rate parity—where the forward premium is regressed onto the interest differential—has also been strongly supportive of this parity condition (e.g., Branson 1969). Regression-based tests of covered interest rate parity should, however, be interpreted with caution: while a researcher may be unable to reject the hypothesis that the intercept and slope coefficients are respectively zero and unity, the fitted residuals may themselves represent substantial arbitrage opportunities.

[15] See Froot and Rogoff (forthcoming) for a comprehensive survey of the literature on purchasing power parity and long-run real exchange rates.

can be interpreted as a measure of the deviation from absolute purchasing power parity. Purchasing power parity (PPP) has variously been viewed as a theory of exchange rate determination, as a short- or long-run equilibrium condition, and as an efficient arbitrage condition in either goods or asset markets (Officer 1976; Frenkel 1976, 1978; Rudiger Dornbusch 1987a). The professional consensus on the validity of purchasing power parity has shifted radically over the past two decades or so. Prior to the recent float, the consensus appeared to support the existence of a fairly stable real exchange rate (e.g., Milton Friedman and Anna Schwartz 1963; Henry Gaillot 1970). As we discuss below, however, the prevailing orthodoxy of the early 1970s, largely associated with the monetary approach to the exchange rate, assumed the much stronger proposition of continuous purchasing power parity (e.g., Frenkel 1976; and the studies in Frenkel and Harry Johnson 1978). In the mid to late 1970s, in the light of the very high variability of real exchange rates (the "collapse" of PPP; Frenkel 1981a) this extreme position was largely abandoned. Subsequently, studies published mostly in the 1980s, which could not reject the hypothesis of random walk behavior in real exchange rates (Michael Adler and Bruce Lehmann 1983), reduced further the confidence in purchasing power parity and led to the rather widespread belief that PPP was of little use empirically and that real exchange rate movements were highly persistent (Dornbusch 1988). More recently, researchers have tested for cointegration between the nominal exchange rate and relative prices—interpreted as testing for long-run purchasing power parity—by testing for mean reversion or stationarity in the real exchange rate or in the residual of an equation such as (8). Earlier cointegration studies generally reported a failure of significant mean reversion of the exchange rate toward purchasing power parity for the recent floating experience (Taylor 1988; Nelson Mark 1990), but were supportive of reversion toward purchasing power parity for the interwar float (Taylor and Patrick McMahon 1988), for the 1950s U.S.-Canadian float (Robert McNown and Wallace 1989), and for the exchange rates of high-inflation countries (Taufiq Choudhry, McNown, and Wallace 1991). Very recent applied work on long-run purchasing power parity among the major industrialized economies has, however, been more favorable toward the long-run purchasing power parity hypothesis for the recent float (e.g., Yin-Wong Cheung and Kon Lai 1993 and MacDonald 1993, who relax the constraints $\beta = -\beta^* = 1$ in (8)). A number of authors have argued that the data period for the recent float alone may simply be too short to provide any reasonable degree of test power in the normal statistical tests for stationarity of the real exchange rate (Frankel 1990), and researchers have sought to remedy this by various means. Niso Abuaf and Jorion (1990) increase the power of their tests by using longer time series and by utilizing systems estimation methods and are able to reject the unit root (random walk) hypothesis for the real exchange rate. Francis Diebold, Steven Husted, and Mark Rush (1991) apply fractional integration techniques to nineteenth century data and find evidence of long-run purchasing power parity. James Lothian and Taylor (forthcoming) utilize sterling-dollar and sterling-franc exchange rate data spanning the two centuries ending in 1990, and find strong evidence in favor of mean reversion in the real exchange rate. Robert Flood and Taylor (forthcoming) find strong support for mean reversion toward long-run purchasing power parity using panel data

on 21 industrialized countries over the floating rate period and regressing five-, ten-, and twenty-year average exchange rate movements on average inflation differentials against the U.S.

III. *Models of Exchange Rate Determination*

Prior to the 1970s, the dominant international macro model was, broadly speaking, an open Keynesian model which had been developed in its essentials by James Meade (1951). The model was further developed in a series of papers by Robert Mundell (e.g., Mundell 1963) and J. Marcus Fleming (1962), and came to be known as the Mundell-Fleming model. Although the integration of asset markets and capital mobility into open-economy macroeconomics was an important contribution of the Mundell-Fleming model, its treatment of asset market equilibrium is, however, inadequate in that the stock-flow implications of interest rate differential changes are not worked out.[16] The distinguishing feature of exchange rate models developed during the 1970s is that they are based on considerations of stock equilibrium in international financial markets.

1. *The Monetary Model I: Flexible Prices*

The monetary approach to the exchange rate, which emerged as the dominant exchange rate model at the start of the recent float in the early 1970s,[17] starts from the definition of the exchange rate as the relative price of two monies and attempts to model that relative price in terms of the relative supply of and demand for those monies. The demand for money, m, is assumed to depend on real income, y, the price level, p, and the level of the nominal interest rate, i (foreign variables are denoted by an asterisk). With all variables except interest rates expressed in logarithms, monetary equilibria in the domestic and foreign country respectively are given by

$$m_t = p_t + \kappa y_t - \theta i_t \tag{10}$$

$$m_t^* = p_t^* + \kappa^* y_t^* - \theta^* i_t^*. \tag{11}$$

An important assumption in the flexible price monetary model is continuous purchasing power parity. Setting $\beta = -\beta^* = 1$ and normalizing the price indices so that $\alpha = 0$ in (8), the purchasing power parity condition is:

$$s_t = p_t - p_t^*. \tag{12}$$

The domestic money supply determines the domestic price level and hence the exchange rate is determined by relative money supplies. Solving (10), (11), and (12) for the exchange rate gives

$$s_t = m_t - m_t^* - \kappa y_t + \kappa^* y_t + \theta i_t - \theta^* i_t^*. \tag{13}$$

Equation (13) is the fundamental flexible-price monetary equation. From (13), we can see that an increase in the domestic money supply, relative to the foreign money stock, will lead to a rise in s_t—i.e., a depreciation of the domestic currency in terms of the foreign currency. A rise in domestic real income, other things equal, creates an excess demand for the domestic money stock. In an attempt to increase their real money balances, domestic residents reduce expenditure and prices fall until money market equilibrium is achieved. Via purchasing power parity, falling domestic prices (with foreign prices constant) imply an appreciation of the domestic cur-

[16] In his verbal exposition of his capital account theory, Meade had, in fact, worked through the stock equilibrium implications of a movement in international interest rate differentials, but did not faithfully represent this feature in the mathematical appendix to his volume. Mundell and Fleming followed Meade's mathematical representation and thus abstracted from considerations of stock equilibrium.

[17] See, for example, the studies collected together in Frenkel and Johnson (1978).

rency in terms of the foreign currency. Similarly, a depreciation follows from an increase in the domestic interest rate as this reduces the domestic demand for money.[18]

In practice, researchers often simplify the model by imposing $\kappa = \kappa^{\circ}$ and $\theta = \theta^{\circ}$ in (13). By invoking the uncovered interest parity condition we can then substitute Δs^{e}_{t+1} for $(i_t - i^{*}_t)$ in the resulting equation to get

$$s_t = m_t - m^{*}_t - \kappa(y_t - y^{*}_t) + \theta \Delta s^{e}_{t+1}. \quad (14)$$

The rational expectations solution to (14) is

$$s_t = (1+\theta)^{-1} \sum_{i=0}^{\infty} \left(\frac{\theta}{1+\theta} \right)^{i} E[(m - m^{*})_{t+i} - \kappa(y - y^{*})_{t+i} | \Omega_t], \quad (15)$$

where $E[\cdot|\Omega_t]$ denotes the mathematical expectation conditioned on the information set available at time t, Ω_t. It is well known from the rational expectations literature, however, that equation (15) is only one solution to (14) from a potentially infinite set. If we denote the exchange rate given by (15) by $\hat{s}_t$ then (14) has multiple rational expectations solutions of the form

$$s_t = \hat{s}_t + \zeta_t \quad (16)$$

where the rational bubble term ζ_t satisfies

$$E[\zeta_{t+1} | \Omega_t] = \theta^{-1}(1+\theta)\zeta_t \quad (17)$$

Rational bubbles represent significant departures from the fundamentals of the model which would not be detected in a specification such as (13). Thus, testing for the presence of bubbles can be interpreted as an important specification test of the model (Richard Meese 1986).

Open economy macroeconomics is essentially about six aggregate markets: goods, labor, money, foreign exchange, domestic bonds (i.e., non-money assets) and foreign bonds. But the flexible-price monetary model concentrates directly on equilibrium conditions in only one of these markets—the money market. This is implicitly achieved in the following fashion. By assuming perfect substitutability of domestic and foreign assets, the domestic and foreign bond markets essentially become a single market. Assuming that the exchange rate adjusts freely to equilibrate supply and demand in the foreign exchange market and also assuming equilibrium in the goods market (through perfectly flexible prices) and in the labor market (through flexible wages) then implies equilibrium in three of the five remaining markets. By Walras' law (the principle that equilibrium in n-1 markets of an n-market system implies equilibrium in the n-th market), the equilibrium of the full system is then determined by equilibrium conditions for the money market. The flexible-price monetary model is thus, implicitly, a market-clearing general equilibrium model in which continuous purchasing power parity among national price levels is assumed.

The very high volatility of real exchange rates during the 1970s float, conspicuously refuting the assumption of continuous purchasing power parity, led to the development of two further classes of models: sticky-price monetary models and equilibrium models.

2. *The Monetary Model II: Sticky Prices and Overshooting*

Sticky-price monetary models, originally due to Dornbusch (1976), allow short-term overshooting of the nominal and real exchange rates above their long-

[18] Because the domestic interest rate is endogenous in the flexible-price monetary model, however, it is, in fact, not completely logical to consider increases in i which are independent of movements in i° or domestic or foreign monies or incomes.

run equilibrium levels. This results as the "jump variables" in the system—exchange rates and interest rates—compensate for stickiness in other variables—notably goods prices. Consider the effects of a cut in the nominal domestic money supply. Because goods prices are sticky in the short run, this implies an initial fall in the real money supply and a consequent rise in interest rates in order to clear the money market. The rise in domestic interest rates then leads to a capital inflow and an appreciation of the nominal exchange rate (a rise in the value of domestic currency in terms of foreign currency). Investors are aware that they are forcing the value of the domestic currency up artificially and that they may therefore suffer a foreign exchange loss when the proceeds of their investment are used to repay liabilities in foreign currency. However, so long as the *expected* foreign exchange loss (expected rate of depreciation) is less than the *known* capital market gain (the interest differential), risk-neutral investors will continue to borrow abroad in order to buy domestic assets. A short-run equilibrium is achieved when the expected rate of depreciation is just equal to the interest differential (uncovered interest rate parity holds). Because the expected rate of depreciation must then be non-zero for a non-zero interest differential, the exchange rate must have overshot its long-run equilibrium (purchasing power parity) 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 to long-run purchasing power parity.[19]

[19] Frankel (1979) argues that the sticky-price monetary model should allow a role for secular differences between inflation rates. In his real interest differential variant of the sticky-price monetary model the long-term interest rate differential is included as a proxy for the long-term inflation rate differential. Willem Buiter and Miller (1981) also develop a variant of the Dornbusch model with steady-state ("core") inflation, and use it to analyze, inter alia, the dynamic effects of natural resource discoveries on output and exchange rates.

The essential characteristics of the sticky-price monetary model can be seen in a three-equation structural model in continuous time, holding foreign variables and domestic income constant (these are simplifying rather than necessary assumptions):

$$\dot{s} = i - i^* \tag{18}$$

$$m = p + \kappa\bar{y} - \theta i \tag{19}$$

$$\dot{p} = \gamma[\alpha + \mu(s - p) - \psi i - \bar{y}]. \tag{20}$$

Equation (18) is the uncovered interest parity condition expressed in continuous time and utilizing certainty equivalence because of the linearity of the model. Equation (19) is a domestic money-market equilibrium condition and equation (20) is a Phillips curve relationship, relating domestic price movements to excess aggregate demand, where aggregate demand has an autonomous component, a component depending upon international competitiveness, and a component which is interest-rate sensitive. If we use a bar to denote a variable in long-run (noninflationary) equilibrium, we can reduce this system to a two-equation differential equation system:[20]

$$\begin{bmatrix} \dot{s} \\ \dot{p} \end{bmatrix} = \begin{bmatrix} 0 & 1/\theta \\ \gamma\mu & -\gamma(\mu + \psi/\theta) \end{bmatrix} \begin{bmatrix} s - \bar{s} \\ p - \bar{p} \end{bmatrix}. \tag{21}$$

The coefficient matrix in (21) has a negative determinant and so the system has a unique convergent saddle path. The qualitative solution to (21) is shown

[20] Note that the level of the money stock is exogenous to the model, assumed under the control of the authorities. Thus, for any given level of the money stock, the perfect foresight equilibrium involves assuming $\bar{m} = m$.

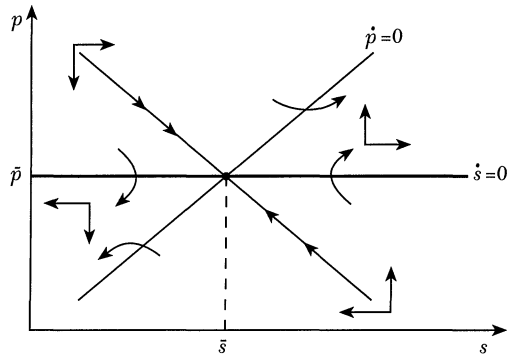

Figure 1. The Qualitative Solution to the Sticky-Price Monetary Model

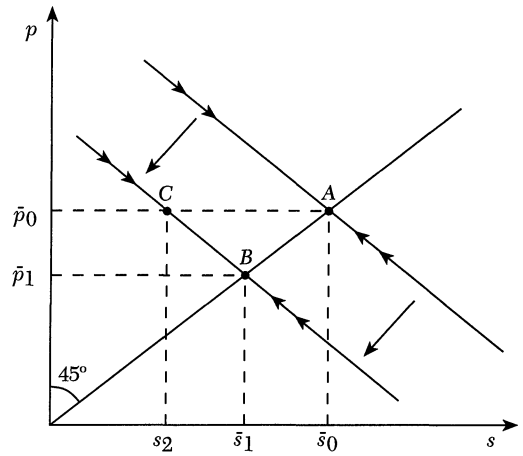

Figure 2. Overshooting Following a Monetary Contraction

in Figure 1, where the saddle path slopes down from left to right in (s,p)-space.

Now consider again the effects of a cut in the money supply. In the long run, the price level will be lower, at $\bar{p}_1$ instead of the initial level $\bar{p}_0$ in Figure 2, because of the neutrality of money in this model. Because long-run purchasing power parity holds in the model, and holding foreign prices constant, the long-run exchange rate will appreciate proportionately (i.e., s will be lower), moving from $\bar{s}_0$ to $\bar{s}_1$ along the 45° ray. The stable saddle path, which originally went through point A must now go through the new long run equilibrium B. Because prices take time to adjust, however, the economy cannot jump directly from A to B. Instead, prices initially remain fixed and the exchange rate jumps to s_2 in order to get on to the new saddle path. Prices then adjust slowly and the economy moves along the saddle path from C to the new long run equilibrium B. The net effect of the money supply cut is a long-run appreciation of $\bar{s}_0 - \bar{s}_1$, with an initial overshoot of $s_2 - \bar{s}_1$.

3. *Equilibrium Models and Liquidity Models*

Equilibrium exchange rate models of the type developed originally by Alan Stockman (1980) and Robert Lucas (1982) analyze the general equilibrium of a two-country model by maximizing the expected present value of a representative agent's utility, subject to budget constraints and cash-in-advance constraints (by convention, agents are required to hold local currency, the accepted medium of exchange, with which to purchase goods).[21] In an important sense, equilibrium models are an extension or generalization of the flexible-price monetary model to allow for multiple traded goods and real shocks across countries. A simple equilibrium model can be sketched as follows. Consider a two country, two good world in which prices are flexible and markets are in equilibrium, as in the flexible-price monetary model, but in which, in contrast to the monetary model, agents distinguish between domestic and foreign goods in terms of well-defined preferences. Further, for simplicity, assume that all agents, domestic or foreign, have identical homothetic preferences.[22]

[21] See Stockman (1987) for a more extensive, largely nontechnical exposition. This literature is an offshoot of the real business cycle literature.

[22] For nonhomothetic preferences, many disturbances create transfer-problem-like conditions with unpredictable terms-of-trade effects.

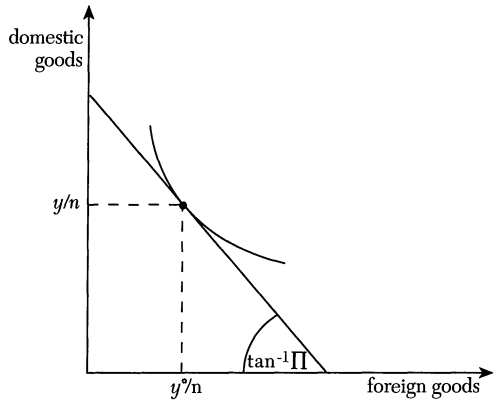

Figure 3. Determination of the Real Exchange Rate in the Equilibrium Model

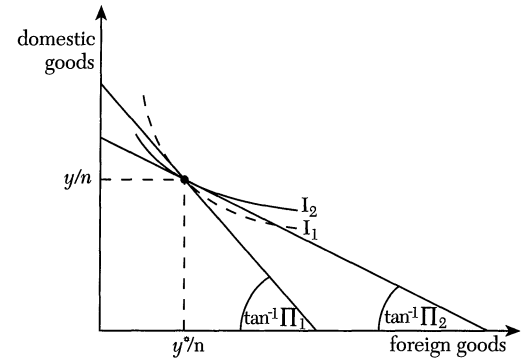

Figure 4. The Effect on the Real Exchange Rate of a Preference Shift Toward Foreign Goods

Then, given domestic and foreign output of y and y^* respectively, the equilibrium relative price of foreign output, Π say, must be the slope of a representative agent's indifference curve at the point $(y^*/n, y/n)$ in foreign-domestic output per capita space (where $n/2$ is the number of individuals in each economy), as in Figure 3. But, the relative price of foreign output is the real exchange rate which is defined in logarithmic form (π) by (9). Now interpret expressions (10) and (11) as linearizations of expressions derived from maximizing the representative agent's utility function subject to a cash-in-advance constraint, assuming that government policy (and other influences on the constancy of parameters) remain constant. Combining (21) with (10) and (11) and letting, for ease of exposition, $\kappa = \kappa^\circ$ and $\theta = \theta^\circ = 0$, we have

$$s_t = m_t - m_t^* - \kappa(y_t - y_t^*) + \pi_t. \qquad (22)$$

Equation (22) is, in this very simple formulation, the key equation determining the nominal exchange rate in the equilibrium model, and illustrates the fact that the equilibrium model can be viewed as a generalization of the monetary model.[23] Indeed, relative monetary expansion leads to a depreciation of the domestic currency (one-for-one in this simple formulation) as in the simple monetary model. However, some of the implications of the equilibrium model are either qualitatively or quantitatively different from those of the flexible-price monetary model or else incapable of analysis within a purely monetary framework. As an example of the latter, consider an exogenous shift in preferences away from foreign goods toward domestic goods, represented as a flattening of indifference curves as in Figure 4 (from I_1 to I_2). With per capita outputs fixed, this implies a fall in the relative price of foreign output (or conversely a rise in the relative price of domestic output)—Π falls (from Π_1 to Π_2 in Figure 4).[24] Assuming unchanged monetary policies, this movement in the real exchange rate will, however, be brought about entirely (and swiftly) by a movement in the nominal exchange rate without any movement in national price levels. Thus, demand

[23] Because of the strict cash-in-advance constraint, the assumed preferences, and the fixed output levels, intertemporal considerations are absent from this very simple formulation.

[24] Note that upper case pi denotes the real exchange rate, lower case pi the logarithm of the real exchange rate.

shifts are capable of explaining the observed volatility of nominal exchange rates in excess of volatility in relative prices in equilibrium models. The fall in s, in this case matching the fall in π, will be observed as a decline in domestic competitiveness. It would be a mistake, however, to infer that this rise in the relative price of domestic goods was caused by the appreciation of the domestic currency: both are the result of the underlying demand shift.

In this simple equilibrium model, an increase in domestic productivity (output per capita) has two analytically separate effects. The first effect—the "relative price effect"—involves a reduction in the relative price of domestic output and so an increase in π which, through (22), will tend to raise s (depreciate the domestic currency). The second effect—the "money demand effect"—will tend to appreciate the domestic currency (i.e., depress s) as the transactions demand for money rises, exactly as in the monetary model. Whether the exchange rate rises or falls depends upon the relative size of these effects which, in turn, depends upon the degree of substitutability between domestic and foreign goods—the higher the degree of substitutability, the smaller the relative price effect. Thus, supply disturbances will generate volatility of nominal exchange rates in excess of the volatility of relative prices only if the degree of substitutability between domestic and foreign goods is relatively small (Obstfeld and Stockman 1985).[25]

[25] In the simple equilibrium model we have sketched here, we have implicitly made a host of simplifying assumptions. Chief among these is the assumption that individuals in either economy hold exactly the same fractions of their wealth in any firm, domestic or foreign. If this assumption is violated, then supply and demand shifts will alter the relative distribution of wealth between domestic and foreign residents as, for example, one country becomes relatively more productive. This, in turn, will affect the equilibrium level of the exchange rate (Stockman 1987).

In the very recent literature on liquidity models of the exchange rate, some authors have extended the equilibrium model framework by incorporating an extra cash-in-advance constraint on agents. In these models, agents are required to hold cash not only with which to purchase goods but also with which to purchase assets (as originally suggested in a closed-economy context by Lucas, 1990). In the two-country model of Vittorio Grilli and Roubini (1992), for instance, the money supply and bond issue of each country are linked through the government budget constraint, and agents must decide on how much domestic and foreign currency to hold in order to purchase domestic and foreign goods and assets. Once this decision is made, subsequent shocks to the bond and money supplies will affect nominal interest rates (in order to clear bond markets) and also, because the expected rate of monetary *growth* (as opposed to the *level* of the money supply) and hence expected inflation is unaffected, will affect real interest rates. This in turn affects the nominal and real exchange rates. It is interesting to contrast liquidity models with the sticky-price monetary model, because the latter assumes sticky goods prices and instantaneous portfolio adjustment, while liquidity models essentially assume slow portfolio adjustment and perfectly flexible goods prices. Many of the implications of the two types of models are similar, and they are, for example, observationally equivalent with respect to the impact of monetary shocks: A positive shock to the money supply generates a decline in real and nominal interest rates in both models, the domestic currency appreciates against the foreign currency in both real and nominal terms, and output rises (in response to lower real interest rates) until prices and portfolios are again in equilibrium.

4. *The Portfolio Balance Model*

The key distinguishing feature of the portfolio balance model is the assumed imperfect substitutability between domestic and foreign assets.[26] We do not have space here to set out a fully specified portfolio balance model, but we can give a flavor of this class of models by setting out a very basic model and tracing through a simple example. Consider a simple model in which the net financial wealth of the private sector (W) is divided into three components: money (M), domestically issued bonds (B) and foreign bonds denominated in foreign currency and held by domestic residents (B^*). B can be thought of as government debt held by the domestic private sector; B^* is the level of net claims on foreigners held by the private sector. Because, under a free float, a current account surplus on the balance of payments must be exactly matched by a capital account deficit (i.e., capital outflow and hence an increase in net foreign indebtedness to the domestic economy), the current account must give the rate of accumulation of B^* over time. With foreign and domestic interest rates given by i and i^* as before, we can write down our definition of wealth and simple domestic demand functions for its components as follows:[27]

$$W \equiv M + B + SB^* \tag{23}$$

$$M = M(i, i^* + \hat{S}^e)W \qquad M_1 < 0, M_2 < 0 \tag{24}$$

$$B = B(i, i^* + \hat{S}^e)W \qquad B_1 > 0, B_2 < 0 \tag{25}$$

$$SB^* = B^*(i, i^* + \hat{S}^e)W \qquad B_1^* < 0, B_2^* > 0 \tag{26}$$

$$\dot{B}^* = T(S/P) + i^*B^* \qquad T_1 > 0 \tag{27}$$

where $\hat{S}^e$ denotes the expected rate of depreciation of the domestic currency. Relation (23) is an identity defining wealth and (24), (25), and (26) are standard asset demand functions.[28] Equation (27) gives the rate of change of B^*, the capital account, as equal to the current account which is in turn equal to the sum of the trade balance, $T(.)$, and net debt service receipts, i^*B^*. The trade balance depends positively on the level of the real exchange rate (a devaluation improves the trade balance). For simplicity, assume static expectations, i.e., $\hat{S}^e = 0$. Now consider an open market purchase of domestic bonds by the authorities, paid for by printing money. In order to induce agents to hold more money and fewer bonds, the domestic interest rate falls (the price of domestic bonds rises) and, as agents attempt to compensate for the reduction in their portfolios of domestic interest-bearing assets by buying foreign bonds, the exchange rate will depreciate, driving up the domestic currency value of foreign bonds. The net *impact* effect is a lower domestic interest rate and a depreciated currency, say from S_0 to S_1 (AC) in Figure 5. Suppose that the economy was initially in equilibrium with a trade balance of zero and net foreign assets of zero (and hence a current account of zero). This is depicted in Figure 5 at the point corresponding to time t_0. Figure 5 is drawn so that the initial (t_0) values of the price level and the exchange rate are normalized to unity. Assuming that the

[26] A comprehensive treatment of the portfolio balance model is given in Branson and Dale Henderson (1985).

[27] X_k denotes the partial derivative of $X(.)$ with respect to the k-th argument, for X=M, B, B^*, and T. The shift to upper case letters here indicates that variables are in levels rather than logarithms. As throughout, interest rates are in percentage terms.

[28] Note 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; this allows them to be written in nominal terms (assuming homogeneity in prices and real wealth, prices cancel out). Note, however, that goods prices are indeterminate in this model. In what follows we assume long-run neutrality.

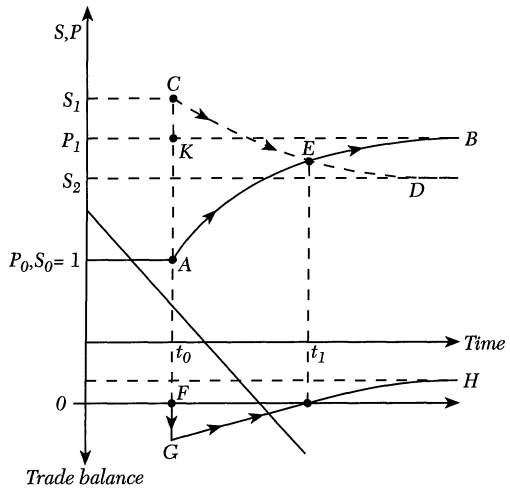

Figure 5. The Dynamics of an Open-Market Purchase of Domestic Bonds in the Portfolio Balance Model

Marshall-Lerner condition holds, the improvement in competitiveness will improve the trade balance from zero to a positive amount (FG) (ignoring any "J-curve" effects). This means that the current account goes into surplus and domestic residents begin to acquire net foreign assets; equation (27). Residents will then attempt to sell some of their foreign assets in order to rebalance their portfolios, and the exchange rate will begin to appreciate—in the diagram from point C along CD. This erosion of competitiveness will lead to a deterioration of the trade balance along GH. Meanwhile, the increase in the money supply will have begun to increase prices along the path AB toward the new long run equilibrium price level P_1; this adds to the deterioration of competitiveness and hence the trade balance. At point E (time t_1), the exchange rate and the price level are equal in value and hence their ratio is unity—the same as the initial ratio at time t_0. Because we have implicitly held foreign prices constant, this means that the real exchange rate is back to its original level and so the trade balance must also be back to its original level, i.e., zero. This is no longer enough to restore long-run equilibrium, however. Domestic residents have now acquired a positive level of net foreign assets and will be receiving a stream of interest income i^*B^* from abroad. Thus, they are still acquiring foreign assets—equation (27)—and so the exchange rate is still appreciating as agents attempt to rebalance their portfolios and sell these foreign assets. In order for the current account balance to be zero, the trade balance must actually go into deficit. This requires a further appreciation of the exchange rate to its long run equilibrium level S_2, by which time the price level has reached its long run equilibrium level P_1 and the current account just balances ($-T(S_2/P_1) = i^*B^*$) so that there is no further net accumulation of foreign assets. The overall effect of the open market purchase on the exchange rate is a long-run depreciation from S_0 to S_2, with an initial overshoot of $S_1 - S_2$.[29]

IV. *The Empirical Evidence on Exchange Rate Models*

1. *Testing the Monetary Class of Models*

In an influential paper, Frenkel (1976) finds evidence strongly supportive of the flexible-price monetary model for the German mark-U.S. dollar exchange rate during the German hyperinflation of the

[29] Our exposition of the portfolio balance model assumes that exchange rate expectations are static, so that the expected rate of depreciation is zero. In fact, most of the properties of the model remain intact when rational expectations are introduced, except that impact effects become much more pronounced and a key distinction must now be drawn between anticipated disturbances (the effect of which will already be discounted into the current exchange rate level) and unanticipated disturbances (which require an initial jump in the exchange rate and then a slow adjustment to the new equilibrium). A more completely specified model would also allow for interaction between production, consumption, saving, and the level of wealth. See Branson and Henderson (1985).

1920s. The subsequent accumulation of data during the 1970s allowed estimation of the model for the major exchange rates during the recent float, and these early studies were also broadly supportive of the flexible-price monetary model (e.g., Bilson 1978; Dornbusch 1979). Beyond the late 1970s, however, the flexible-price monetary model (or its real interest differential variant) ceases to provide a good explanation of variations in exchange rate data: the estimated equations break down, providing poor fits, exhibiting incorrectly signed coefficients and failing general equation diagnostics (Frankel 1993b). In particular, estimates of equations for the dollar-mark rate often produce coefficients which imply that increases in Germany's money supply during this period caused its currency to appreciate.[30] Some authors sought to explain this breakdown as due to econometric misspecification, while others argued that large current account deficits or surpluses during the period generated important wealth effects which are not adequately captured in the simple monetary model (e.g., Frankel 1982a, 1993b).

The evidence for the sticky-price monetary model is also weak when the data period is extended beyond the late 1970s. For example, while Robert Driskell (1981), reports single-equation estimation results largely favorable to the sticky-price monetary model for the Swiss franc-U.S. dollar, 1973–77, David Backus (1984) finds little support using U.S.-Canadian data for the period 1971–80. Another implication of the sticky-price monetary model is proportional variation between the real exchange rate and the real interest rate differential. This follows from the basic assumptions of the overshooting model: slowly adjusting prices and uncovered interest rate parity, and can be derived by subtracting relative inflation from either side of equation (1). A number of studies have failed to find strong evidence of this relationship, notably Meese and Rogoff (1988) who could not find cointegration between real exchange rates and real interest rate differentials. (See also Edison and Dianne Pauls 1993.) Recent work suggests, however, that this may be due to omitted variables which are determinants of the equilibrium real exchange rate or the risk premium (e.g., Adrian Throop 1993). Marianne Baxter (1994) uses band-spectral regression techniques and finds that that there may be a significant positive correlation between real interest rate differentials and real exchange rate changes at "business-cycle" (six to thirty-two quarters) and "trend" (more than thirty-two quarters) frequencies.

More recently, MacDonald and Taylor (1993, forthcoming) apply multivariate cointegration analysis and dynamic modeling techniques to a number of exchange rates and find some evidence to support the monetary model as a long-run equilibrium toward which the exchange rate converges, while allowing for complicated short-run dynamics. Because all of the monetary models collapse to an equilibrium condition of the form (13) in the long run, these tests have no power to discriminate between the alternative varieties. The usefulness of the cointegration approach suggested by these studies should, moreover, be taken as at most tentative: their robustness across different data periods and exchange rates has yet to be demonstrated.

Robert Flood and Andrew Rose (1993), observing the increased volatility of exchange rates under floating as opposed to fixed exchange rate regimes, argue that any tentatively adequate exchange rate model should have funda-

[30] Frankel (1982a) called this the "mystery of the multiplying marks."

mentals which are also much more volatile during floating rate regimes. In fact, these authors find little shift in the volatility of economic fundamentals suggested by flexible-price or sticky-price monetary models across different nominal exchange rate regimes for a number of OECD exchange rates. Similar evidence is reported by Baxter and Stockman (1989), who examine the time-series behavior of a number of key macro-economic aggregates for 49 countries over the postwar period. Although they detect evidence of increased real exchange rate variability under flexible exchange rates than under pegged nominal exchange rate systems, Baxter and Stockman find no systematic differences in the behavior of the macroeconomic aggregates under alternative exchange rate arrangements. Again, this suggests that there are speculative forces at work in the foreign exchange market which are not reflected in the usual menu of macroeconomic fundamentals.[31]

2. *Testing the Portfolio Balance Model*

Much less empirical work has been carried out on the portfolio balance approach to the exchange rate than on the monetary class of models, presumably because of the problems which researchers have encountered in mapping theoretical portfolio balance models into real-world financial data. This clearly raises important methodological issues such as what non-money assets to include in the empirical model as well as important practical issues such as whether the data is actually available, especially on a bilateral basis. Log-linear versions of reduced-form portfolio balance exchange rate equations, using cumulated current accounts for the stock of foreign assets, have, however, been estimated for many of the major exchange rates for the 1970s float, with poor results: estimated coefficients are often insignificant and there is a persistent problem of residual autocorrelation (e.g., Branson, Hannu Halttunen, and Paul Masson 1977).[32]

The imperfect substitutability of domestic and foreign assets which is assumed in the portfolio balance model is equivalent to assuming that there is a risk premium separating expected depreciation and the domestic-foreign interest differential, and in the portfolio balance model this risk premium will be a function of relative domestic and foreign debt outstanding. An alternative, indirect method of testing the portfolio balance model, therefore, is to test for empirical relationships of this kind. Investigations of this kind have usually reported statistically insignificant relationships (Frankel 1982b; Rogoff 1984). In a recent study of the effectiveness of exchange rate intervention for dollar-mark and dollar-Swiss franc during the 1980s, Kathryn Dominguez and Frankel (1993b) measure the risk premium using survey data and show that the resulting measure can in fact be explained by an empirical model which is consistent with the port-

[31] A number of studies have noted that, under the recent float, nominal exchange rates have shown much greater variability than important macroeconomic fundamentals such as price levels and real incomes—see e.g., Dornbusch and Frankel (1988), Frankel and Froot (1990a), Richard Marston (1989).

[32] Dooley and Isard (1982) estimate the portfolio-balance model under rational expectations for the dollar-mark exchange rate. While their estimated model provides predictions which are superior to the forward rate as a spot-rate predictor, the coefficient of correlation between observed and predicted changes in the exchange rate is only 0.4. The authors conclude that beating the forward rate is evidence in favor of the existence of risk premia, while the poor goodness of fit suggests that their simplifications of the portfolio balance model may be too severe, or perhaps that there are substantial unexpected shifts in the underlying macroeconomic variables.

folio balance model with the additional assumption of mean-variance optimization on the part of investors. In some ways, the relative success of the Dominguez and Frankel (1993b) study is consistent with the recent empirical literature on foreign exchange market efficiency, discussed in Section II, which suggests the existence of significant foreign exchange risk premia and non-rational expectations.

3. *Testing Equilibrium and Liquidity Models*

In order to specify and solve an equilibrium model it is necessary to make a set of assumptions, such as uniform preferences or a specific utility function, which no one would seriously expect to hold exactly in the real world, even though the qualitative predictions of the model may be valid. Thus, these models are not amenable to direct econometric testing. Rather, researchers have sought to test the broad rather than specific implications of this class of models for exchange rate behavior.

Stylized facts or characteristics of the recent float include the high volatility of real exchange rates, the very high correlation of changes in real and nominal exchange rates and the absence of strongly mean-reverting properties in either series. As we discussed above, equilibrium models are capable of explaining the variability of nominal exchange rates in excess of relative price variability (and hence the variability of real exchange rates), but so is the sticky-price monetary model. Some authors have argued, however, that the difficulty researchers have experienced in rejecting the hypothesis of non-stationarity in the real exchange rate is evidence against the sticky-price model and in favor of equilibrium models. Explaining the persistence in both real and nominal exchange rates over the recent float within the framework of the sticky-price model, it is argued, involves assuming either implausibly sluggish price adjustment or else that movements in nominal exchange rates are due largely to permanent real disturbances (Stockman 1987). Equilibrium models, on the other hand, are not contradicted by persistence in real and nominal exchange rate movements. In the simple equilibrium model sketched above, for example, permanent shocks to technology could affect the slope of the "budget line" in Figure 3 and so permanently affect the equilibrium real exchange rate. Moreover, as we demonstrated with the aid of Figure 4, a permanent shift in preferences could lead, in this model, to a permanent shift in nominal and real exchange rates with domestic price levels unchanged—illustrating how equilibrium models are consistent with persistent, correlated movements in real and nominal exchange rates. There are two basic responses to this line of argument. First, as Frankel (1990) argues forcibly, noncontradiction is not the same as confirmation: simply being consistent with the facts is not enough to demonstrate the empirical validity of a theory. Secondly, as discussed above, there is now emerging evidence that real exchange rates may, in fact, be mean reverting.[33]

One testable implication of the simplest equilibrium models is the neutrality of the exchange rate with respect to the exchange rate regime: because the real exchange rate is determined by real variables such as tastes and technology, its behavior ought to be independent of whether the nominal exchange rate is

[33] Note, however, that mean reversion in the real exchange rate is not inconsistent with the broad class of equilibrium models, because it is possible that real shocks themselves are mean reverting, e.g., because of technology transfer.

pegged or allowed to float freely. Although the major real exchange rates have been demonstrably more volatile during the recent floating-rate period, this may be due to the greater variability of underlying real shocks during this period. Stockman's (1983) study of 38 countries over a variety of time periods (including, for example, countries whose currencies remained pegged to the dollar after 1973) does conclude, however, that real exchange rates are significantly more volatile under floating nominal rate regimes; see also Mussa (1986) and Baxter and Stockman (1989). This evidence does indeed, constitute a rejection of the simplest equilibrium models, although it is possible that the evidence is to some extent confounded by the endogeneity of the choice of exchange rate regime—i.e., countries experiencing greater real disturbances are more likely to choose flexible exchange rate systems. Moreover, Stockman (1983) also shows that the assumptions necessary for regime-neutrality are in fact quite restrictive in a fully specified equilibrium model, and include Ricardian equivalence, no wealth-distribution effects of nominal price changes, no real effects of inflation, no real effects of changes in the level of the money supply, complete asset markets, completely flexible prices, and identical sets of government policies under different exchange-rate systems. Because it is unlikely that all of these conditions will be met in practice, Stockman argues that only the simplest class of equilibrium models should be rejected, and that equilibrium models should be developed which relax some or all of these assumptions. In a more recent paper, Stockman (1988) notes that countries with fixed exchange rates are more likely to introduce controls on trade or capital flows in order to control losses of international reserves. Thus, a disturbance that would tend to raise the relative price of foreign goods (e.g., a preference shift toward foreign goods) will raise the probability that the domestic country will, at some future point, impose capital or trade restrictions that will raise the future relative world price of domestic goods. With intertemporal substitution, this induces a higher world demand for domestic goods now, serving to offset partly the direct effect of the disturbance, which was to raise the relative price of the foreign good, and hence to reduce the resulting movement in the real exchange rate. Thus, countries with pegged exchange rates will experience lower volatility in the real exchange rate than countries with flexible exchange rates.

Empirical studies of the implications of liquidity models include Martin Eichenbaum and Charles Evans (1993) (for the U.S.) and Grilli and Roubini (1993) (for the other G-7 countries). These researchers provide evidence that unanticipated monetary contractions lead to increases in the level of domestic interest rates and an appreciation of the domestic currency in both real and nominal terms, which is inconsistent with most equilibrium models in which nominal shocks should not affect real variables, but is consistent with liquidity models with asset-market cash-in-advance constraints.[34] As discussed in Section III.3, however, sticky-price monetary models and liquidity models are observationally equivalent in this respect.

Overall, although the empirical evidence rejects the very simplest equilibrium models, it is not possible at this stage to draw any firm conclusions concerning the empirical validity of the whole class of equilibrium or liquidity models.

[34] These papers are examples of "news" studies discussed more generally in the next subsection.

4. *News Effects and Exchange Rate Movements*[35]

There is a strand of the literature which has sought to test the relevance of economic fundamentals for exchange rate movements through an examination of the effect of "news" about fundamentals on unexpected exchange rate movements. If the market is efficient, the unexpected exchange rate change, $(s_{t+k} - s^e_{t+k})$, can only be due to news arriving between the time the expectation was formed and time $t + k$. Thus, if these news effects could be measured, they should be significantly correlated with the unexpected change. Empirical implementation of this approach involves choosing a vector of variables, z_t say, which are thought to affect the exchange rate, getting a measure of agents' expectation of z_{t+k} based on information at time t, z^e_{t+k}, and measuring news about fundamentals as $(z_{t+k} - z^e_{t+k})$. A regression of $(s_{t+k} - s^e_{t+k})$ onto the news term should then yield a significant estimated coefficient. Typically, researchers have used the interest rate differential or have used exchange rate theory to choose z_t, and have used either time-series methods (Frenkel 1981b) or survey data (Dornbusch 1980) to form z^e_{t+k}. The expected value of s_{t+k} has most often been taken as equal to the forward rate at time t (thus implicitly assuming a zero risk premium). An advantage of the news approach is that it allows one to test the influence of the underlying fundamentals without having to specify a precise functional form for the exchange rate equation. Using this approach and a variety of choices of elements of z_t, a number of researchers have reported significant news effects, thus indicating the importance of fundamentals in explaining exchange rate movements (e.g., Dornbusch 1980; Sebastian Edwards 1982). Some researchers have found, however, that the full effects of news on the exchange rate are often observed with a lag (e.g., Eichenbaum and Evans 1993).[36]

5. *The Out-of-Sample Forecasting Performance of Exchange Rate Models*

Another way of examining the empirical content of exchange rate theories is to examine their *out-of-sample* forecasting performance. In a landmark paper, Meese and Rogoff (1983a) compare the out-of-sample forecasts produced by various exchange rate models with forecasts produced by a random walk model, by the forward exchange rate, by a univariate regression of the spot rate, and by a vector autoregression. They use rolling regressions to generate a succession of out-of-sample forecasts for each model and for various time horizons. The conclusion which emerges from this study is that, on a comparison of root mean square errors (RMSEs), none of the asset-market exchange rate models outperforms the simple random walk, even though actual future values of the right-hand-side variables are allowed in the dynamic forecasts (thereby giving the models a very large informational advantage).[37] Further work by the same authors (Meese and Rogoff 1983b) sug-

[35] See Frankel and Rose (1994) for a recent more comprehensive survey of work on "news" and foreign exchange markets.

[36] Frankel and Rose (1994) point out that slow adjustment of the exchange rate to monetary surprises in a sticky-price monetary model might explain the negative correlation of forward rate forecast errors and forward premia, discussed in Section II.

[37] Meese and Rogoff compare random-walk forecasts with those produced by the flexible-price monetary model, Frankel's (1979) real interest rate differential variant of the monetary model, and a synthesis of the monetary and portfolio balance models suggested by Peter Hooper and John Morton (1982).

gested that the estimated models may have been affected by simultaneity bias. Imposing coefficient constraints taken from the empirical literature on money demand, Meese and Rogoff find that although the coefficient-constrained asset reduced forms still fail to outperform the random walk model for most horizons up to a year, combinations of parameter constraints can be found such that the models do outperform the random walk model for horizons beyond twelve months. Even at these longer horizons, however, the models are unstable in the sense that the minimum RMSE models have different coefficient values at different horizons.

Although beating the random walk still remains the standard metric by which to judge empirical exchange rate models, researchers have found that one key to improving forecast performance based on economic fundamentals lies in the introduction of equation dynamics. This has been done in various ways: by using dynamic forecasting equations for the forcing variables in the forward-looking, rational expectations version of the flexible-price monetary model, by incorporating dynamic partial adjustment terms into the estimating equation, by using time-varying parameter estimation techniques, and—most recently—by using dynamic error correction forms.[38] A particularly interesting example of the latter is Mark's (1993) study of long-horizon predictability. Mark estimates equations of the form:

$$\Delta_k s_{t+k} = \alpha + \beta(z_t - s_t) + \nu_{t+k} \qquad (28)$$

where z_t is the exchange rate fundamental suggested by the monetary class of models, $z_t \equiv [(m_t - m_t^*) - \kappa(y_t - y_t^*)]$, and ν_{t+k} is a disturbance term.[39] In a series of forecasting tests over very long horizons for a number of quarterly dollar exchange rates, Mark finds that (28) is a good predictor of the nominal exchange rate, particularly at the four-year horizon. Moreover, both the goodness of in-sample fit and the estimated value of β_k rise as the horizon k rises. Mark interprets this as evidence that, while quarter-to-quarter exchange rate movements may be noisy, systematic movements related to the fundamentals become apparent in long-horizon changes.

V. *Official Intervention*

Official intervention in foreign exchange markets occurs when the authorities buy or sell foreign exchange, normally against their own currency and in order to affect the exchange rate. Sterilized intervention occurs when the authorities—simultaneously or with a very short lag—take action to offset or "sterilize" the effects of the resulting change in official foreign asset holdings on the domestic monetary base. The exchange rate effects of intervention—in particular sterilized intervention—have been an issue of some debate in the literature. At the outset of the current float, in the early 1970s, a "clean" rather than a "dirty" or managed float was favored. Then, in the late 1970s, the U.S. was frequently criticized for its reluctance to intervene in support of the dollar. By the early 1980s, however, the prevailing consensus among economists, policy makers, and foreign exchange market practitioners appeared to be that intervention, particularly sterilized intervention, could have at most very small

[38] E.g., Throop (1993), MacDonald and Taylor (1993, forthcoming). Kees Koedijk and Peter Schotman (1990) estimate an error-correction *real* exchange rate equation and show that this is superior, in-sample, to a random-walk model.

[39] Mark chooses a priori values of λ of 1.0 and 0.3. Equation (28) can in fact be derived from the Dornbusch (1976) model, and Mark (1993) shows that β tends in that case to unity as the horizon, k, gets longer.

and transitory effects on the exchange rate. This view was enshrined in the conclusions of the Jurgensen Report (1983), commissioned by the 1982 G-7 Economic Summit of Heads of Government at Versailles. After the meeting of the G-5 economic leaders at the Plaza Hotel in New York in September 1985, however, official views on the usefulness of intervention appeared to switch again. Since that time, intervention in the markets for the major exchange rates has been regular and, at times, heavy.[40]

1. *The Channels of Influence*

Sterilized intervention may influence the exchange rate through either of two channels: by changing the relative supplies of assets, and by signaling policy intentions. Its effects through the first channel can be analyzed within the framework of the portfolio balance model of exchange rate determination which was outlined above. Suppose, for example, that the authorities purchase foreign exchange and carry out an open market sale of domestic bonds in order to sterilize the effect of the rise in official reserves on the money supply. If domestic and foreign bonds are perfect substitutes in private agents' portfolios (so that the portfolio balance model essentially collapses to a monetary model), and assuming that agents' portfolios were initially in stock equilibrium, then they will sell foreign bonds one for one with the increase in domestic bonds. Thus, the private sector will sell the same amount of foreign currency that the authorities bought, and there will be no net effect on the level of the exchange rate.[41] If domestic and foreign bonds are less than perfectly substitutable, however, private sales of foreign bonds will be less than the increase in the stock of bonds privately held, and so the intervention will have a net effect on the level of the exchange rate.

The second channel of influence—the signaling or expectations channel (Mussa 1981)—allows for the intervention to affect exchange rates by providing the market with relevant information that was previously not known or incorporated into the current exchange rate. This presumes that the authorities have superior information to other market participants and that they are willing to reveal this information through their actions in the foreign exchange market. Even in a simple flexible-price monetary model, sterilized intervention could affect the exchange rate through the signaling channel by altering agents' exchange rate expectations about future movements in relative money or income, which then feeds back into the current exchange rate; see equation (15).

2. *The Empirical Evidence on the Effectiveness of Intervention*[42]

Empirical work on the effectiveness of intervention via the portfolio balance channel has generally taken one of the following forms. First, researchers have directly estimated structural asset demand equations of portfolio balance models (Obstfeld 1983; Lewis 1988). Secondly, researchers have estimated *inverted* asset demand equations where the ex post difference in the rate of return between domestic and foreign assets is regressed onto a range of variables: under the joint null hypothesis of perfect substitutability and rational expectations, the estimated regression coefficients should be insignificantly differ-

[40] Dominguez and Frankel (1993a) provide an up to date account of the history of official intervention over the recent float.

[41] See Kenen (1982) for a thorough analysis of the long- and short-run effects of intervention in the framework of the portfolio balance model.

[42] Recent surveys of the empirical literature on foreign exchange market intervention include Edison (1993) and Lewis (forthcoming).

ent from zero (Rogoff 1984; Deborah Danker et al. 1987). A third approach involves estimating asset demand equations derived in a specific optimization framework, such as mean-variance analysis (Frankel 1982b). Much of this literature has found difficulty in rejecting the hypothesis that the exchange rate effects of intervention through the portfolio balance channel are very small and at best very short lived. A recent treatment by Obstfeld (1990), for example, argues that sterilized intervention in itself has not played an important role in promoting exchange rate realignment since the 1985 Plaza Accord, but rather that realignments have occurred as the result of appropriate macro-policy coordination. This conventional wisdom has been challenged in several recent papers. Dominguez and Frankel (1993b), for instance, using survey data on dollar-mark and dollar-Swiss franc exchange rate expectations to construct measures of the risk premium as the deviation from uncovered interest rate parity $[(i_t - i_t^*) - \Delta s^e_{t+k}]$ (see equation (6)) find that intervention variables have significant explanatory power for the risk premium, in addition to terms in the second moments of exchange rate changes.

Tests of the influence of sterilized intervention through the signaling channel involve testing for the significance of intervention variables in equations relating to exchange rate expectations. Studies of the signaling effect have generally produced very mixed results (Owen Humpage 1989; Dominguez 1986). In a recent study, Dominguez and Frankel (1993c), again using survey data on dollar-mark exchange rate expectations, find that official announcements of exchange rate policy and reported intervention significantly affect exchange rate expectations and that, overall, the effectiveness of intervention, in terms of significantly affecting both weekly and daily exchange rate changes, is very much enhanced if it is publicly announced.

Although Dominguez and Frankel (1993b, 1993c) offer no explanation as to why their results concerning the effectiveness of intervention, through either channel, stand in contrast to much of the earlier literature, Edison (1993) points out that the more obvious distinguishing factors include the use of survey data rather than reliance on an assumption of rational expectations, the use of a bilateral rather than a multi-currency model, and concentration on data for the 1980s.

Each of the Dominguez and Frankel studies cited above employs daily intervention data obtained from the U.S. and German authorities. Pietro Catte, Giampaolo Galli, and Salvatore Rebecchini (1992) additionally employ daily data on intervention by the Japanese authorities and carry out a statistical analysis of coordinated G-3 intervention over the 1985–1991 period. Of seventeen episodes of coordinated intervention identified over this period, the authors claim that all were successful in the sense of reversing the trend in the dollar and, in the case of the Plaza episode (late 1985), making it resume its fall. Out of ten major turning points in the dollar-mark exchange rate over the period, the authors identify nine of these as coinciding exactly with periods of concerted intervention. Note that Catte et al. make no attempt to disentangle sterilized from unsterilized intervention; neither do they attempt to disentangle the portfolio balance and signalling effects. In interpreting their results, however, Catte et al. do seem to favor the signaling channel explanation. Given the magnitude of uncertainty about the link between exchange rates and fundamentals, they suggest that the signals provided by intervention may help coordinate agents' expectations, inducing them to converge on a particular model of the economy

and pick a value of the exchange rate that is similar to that targeted by the authorities.

Overall, therefore, the evidence on the effectiveness of official intervention is unclear, although some recent studies do suggest a significant link.

VI. *Exchange Rates and Target Zones*

A "target zone" is a range within which the authorities are committed to keeping the nominal exchange rate. The Exchange Rate Mechanism of the European Monetary System is an example of a *multilateral* target zone, the theory of which has not yet been fully worked out. The best examples of unilateral target zones, to which much of existing target zone theory applies, are those pursued by the three Nordic countries outside of the ERM: Finland, Norway, and Sweden. Following an original paper by Paul Krugman, circulated since 1987 and published in 1991 (Krugman 1991), a substantial literature on this topic has appeared with remarkable speed.[43]

1. *The Basic Target Zone Model*

Consider a flexible-price monetary model of the exchange rate expressed in continuous time:

$$s = m + v + \theta E[ds \mid \Omega(t)]/dt. \qquad (29)$$

Equation (29) is the continuous-time analogue of equation (14) under the assumption of rational expectations, where v lumps together all of the right-hand-side fundamentals in (14) beside domestic money and the expected exchange rate change.[44] The money supply is assumed to be a policy variable under the control of the authorities. The shift variable, v, is assumed to follow a Brownian motion, which is the continuous-time analogue of a random walk. Under a *free float*, the authorities are assumed not to alter m to offset movements in v, so that, from (29), s itself follows a Brownian motion process and the expected change in the exchange rate is zero, $E[ds|\Omega(t)]/dt=0$. Thus, in a plot of the exchange rate against the fundamentals, $m + v$, s would lie on a 45° ray (the "free-float" line FF in Figure 6). Under a *fixed exchange rate* regime, the authorities would alter m in order to offset movements in v and the expected exchange rate change would again be zero but a plot of s against $m + v$ would be concentrated at a single point. In the *basic target zone model,* the authorities stand ready to intervene at the upper ($s_{\max}$) and lower ($s_{\min}$) edges of the band, where they will alter the level of the fundamentals (i.e., change the level of m) just enough to keep the exchange rate within the band.[45] Technically, the solution to the basic target zone model implies that the relationship between the exchange rate and the fundamentals is

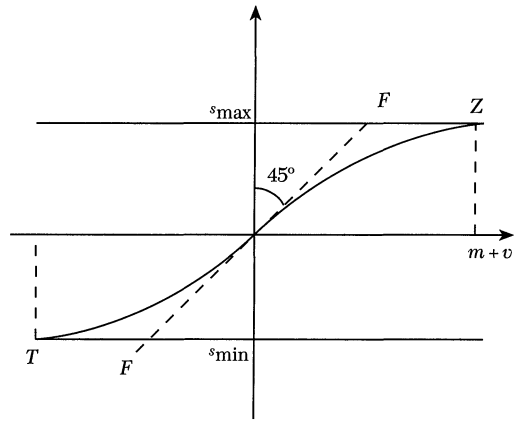

Figure 6. The Basic Target Zone Model

[43] Svensson (1992) provides a comprehensive survey of the target zone literature. A useful source reference is Krugman and Miller (1992).

[44] $\Omega(t)$ again denotes the information set available at time t; the shift in notation to $\Omega(t)$ from Ω_t reflects the shift to continuous time.

[45] Clearly, intervention is assumed to be unsterilized because it affects the exchange rate through changes in the money supply.

described by a nonlinear, *S*-shaped curve pasted smoothly onto the upper and lower edges of the target zone (*TZ* in Figure 6). This characteristic *S*-shape is the graphical representation of the two main features of the Krugman model: the "honeymoon effect" and the "smooth-pasting conditions."

The honeymoon effect entails that, in a plot of s against $m + v$ under a fully credible target zone arrangement, s will lie on a curve which is less steep than the 45° line (if $m + v$ is on the horizontal axis). Intuitively, if s is near the top of the band (above the central parity) the probability is higher that the exchange rate will touch the edge of the band and trigger intervention by the authorities. Thus, the probability that the exchange rate will fall is higher than the probability that it will rise. Thus, market agents will bid the exchange rate below the level it would be at if there were no probability of intervention—i.e., s must lie below the 45° "free float line." By a symmetric argument, when s is nearer to the lower edge of the band, it must be above the free float line. The honeymoon effect thus implies that a credible target zone is stabilizing in the sense that the range of variation in the exchange rate will be smaller, for any given range of variation in the fundamentals, than under a free float.

The smooth-pasting conditions are boundary conditions for the solution of the basic target zone model which entail that in $(m + v, s)$-space, the permissible exchange rate path must "paste" smoothly onto the upper and lower edges of the band. This result is again quite intuitive: If the exchange rate were simply to bump into the edge of the band at an angle, traders would be offered a one-way bet, because they know that the authorities would intervene to bring the rate back into the band. Because traders would start taking positions *in anticipation* of the one-way bet before it occurred, this will tend to work against the influence of the fundamentals as the band is approached—e.g., a currency depreciating because of weak fundamentals will be bought near the edge of the band in anticipation of official support. Thus, the exchange rate becomes increasingly less responsive to movements in the fundamentals as the edges of the band are approached and, in the limit, the slope of *TZ*, which measures the responsiveness of the exchange rate to the fundamentals, tends to zero.[46]

The formal solution to the basic (symmetric) target zone model is an *S*-shaped function of the form

$$s = m + v + A[e^{\alpha(m+v)} - e^{-\alpha(m+v)}] \qquad (30)$$

where $\alpha = (2/\theta\sigma^2)^{1/2}$, σ is the variance of the innovation in the fundamentals, and A is uniquely determined by the smooth-pasting conditions.[47]

2. *Testing the Basic Target Zone Model*

The basic target zone model has been tested empirically on data from the European Monetary System, the Nordic countries, the Bretton Woods system, and the Gold Standard. Invariably, these tests have rejected the basic model (see, for example, R. Flood et al. 1991). For example, plots of the exchange rate against the fundamentals (variously defined), as well as more sophisticated tests, do not reveal anything resembling the predicted *S*-shape (Meese and Rose 1990).

3. *Modifications to the Basic Target Zone Model*

Given the empirical rejection of the basic target zone model, a number of authors have sought to rehabilitate the

[46] An alternative derivation of the smooth-pasting result is given by R. Flood and Garber (1991).

[47] This solution assumes symmetry of the target zone and zero drift in the fundamentals.

model by modifying its underlying assumptions to allow for imperfect credibility of the arrangement, intramarginal intervention, sticky prices, and so on. For example, incorporating intramarginal intervention substantially reduces the impact of the smooth-pasting conditions. This is because, as s approaches the edges of the band, the authorities are already known to be intervening. The perceived probability of hitting the edge of the band is therefore lower than under marginal intervention. The probability of a riskless arbitrage opportunity occurring will therefore be lower and the slope of the curve relating the exchange rate to the fundamentals will be closer to a straight line, with smooth pasting occurring only when the exchange rate is very close to the band. Thus, the presence of intramarginal intervention may explain why researchers have found little evidence of nonlinearities or the characteristic *S*-shaped curve (Hans Lindberg and Paul Söderlind 1992).

In assuming an underlying flexible-price monetary exchange rate model, the target zone literature may also have been unduly naive, because the empirical evidence on the monetary models, albeit under regimes closer to a free float than a target zone, is so overwhelmingly negative. The implicit assumption of market efficiency in the target zone model, in spite of mounting evidence to the contrary, has also been criticized. Krugman and Miller (1993), for example, argue that policy makers have in the past been willing to enter into target zone arrangements precisely because of their skepticism with respect to the efficiency of foreign exchange markets and the rationality of foreign exchange market participants. If the motivation behind target zones is in fact largely due to the fear of irrational runs on a currency, then it is ironic that the standard target zone model rules this out by assumption.

VII. *Market Microstructure*

As seen from the news literature, studies of long-term exchange rate movements, and studies of economies experiencing pathologically large movements in the fundamentals such as a hyperinflation, macroeconomic fundamentals are important influences on exchange rates. Nevertheless, the empirical literature as a whole demonstrates that there are often large and persistent movements in exchange rates which are apparently unexplained by the macro fundamentals. One motivation for the emerging literature on market microstructure has been the desire to understand the mechanisms generating these deviations from the fundamentals. In this literature, researchers focus on the behavior of market agents and market characteristics rather than on the influence of macro fundamentals.[48]

One way in which a speculative movement away from the level consistent with the macro fundamentals could begin, for example, is if some agents have destabilizing expectations—e.g., if a five percent rise leads them to expect a ten percent rise, which causes them to buy the appreciating currency, causing it to rise faster in a self-fulfilling fashion. "Bandwagon" effects of this kind have been examined by Frankel and Froot (1987), Helen Allen and Taylor (1990), Takatoshi Ito (1993), and others, using survey data on expectations, and this work tentatively suggests that expectations may

[48] A comprehensive survey on the literature on the theory and evidence relating to foreign exchange market microstructure would warrent a full-length paper in itself, and we have space here only to flag some of the salient issues and to provide a starting point for further reading. Mark Flood (1991) provides a good, nontechnical survey of market microstructure theory applied to the foreign exchange market. The volume edited by Frankel, Galli, and Giovannini (forthcoming) contains a selection of recent scholarship in this area.

be more destabilizing over shorter horizons.

Another suggested explanation of anomalous exchange rate movements is the widespread influence of foreign exchange analysts who do not base their predictions on economic theory—the fundamentals—but on the identification of supposedly recurring patterns in graphs of exchange rate movements—i.e., "technical" or "chart" analysts (Charles Goodhart 1988; Frankel and Froot 1990a, 1990b; Allen and Taylor 1990). Questionnaire surveys conducted by the Group of Thirty (1985) and Taylor and Allen (1992) reveal that extremely high proportions of traders employ technical or chartist analysis, especially when forecasting over shorter horizons. Goodhart (1988) presents a discussion of how exchange rate misalignments might occur by considering the possibility that the rate is determined by the balance of chartist and fundamentalist predictions.[49] A similar approach is developed more formally by Frankel and Froot (1990a), who explain the sharp rise in the demand for the U.S. dollar over the 1981–85 period as a shift in the weight of market opinion away from fundamentalists and toward chartists. Bilson (1990) emphasizes that technical traders employing "overbought or oversold" indicators ("oscillators"), will tend to impart nonlinearity into exchange rate movements because small exchange rate changes which do not trigger the oscillator will tend to be positively correlated because of the effect of trend-following trading programs, while larger exchange rate movements, which trigger an oscillator, indicating that a currency has been "oversold" or "overbought," will be negatively correlated. Bilson (1990) estimates simple nonlinear exchange rate equations which are consistent with this pattern of serial correlation and which are moderately successful in capturing exchange rate changes.[50]

In some respects, however, the questions posed by microstructural analyses are often quite different from those applicable to macroeconomic studies. Thus, researchers have begun to analyze microstructural topics such as the determinants of the bid-ask spread (e.g., Hendrik Bessembinder 1994) and the volume of trade in foreign exchange markets, and why, for example, volume is very much higher on a gross basis (among foreign exchange dealers and brokers) than on a net basis (involving nonfinancial companies).[51] Frankel and Froot (1990b), for example, show that the volume of trade and market volatility is related to the heterogeneity of exchange rate expectations, as reflected in dispersion in survey expectations.[52]

It should be noted, moreover, that the very notion of a dispersion of expectations across market participants runs counter to more traditional analyses of exchange rates which assume rational expectations and hence homogeneous expectations across market participants. Although it might be argued that the

[49] Analyzing the accuracy of a number of individual technical analysts' one-week and four-week ahead forecasts of three major exchange rates, Allen and Taylor (1990) find that some chartists were able to outperform a range of alternative forecasting procedures. Earlier studies by Levich (1980) and Stephen Goodman (1979) found that, in terms of profitability, chartist foreign exchange forecast services' forecasts outperformed the forward rate in qualitative tests, while the forward rate outperformed fundamentals based services.,

[50] David Hsieh (1988) also detects evidence of nonlinearities in exchange rate movements. See also Paul De Grauwe, Hans Dewachter, and Mark Embrechts (1993).

[51] Frankel and Froot (1990b), for example, suggest that over 95 percent of market transactions in major exchange rates are typically between foreign exchange market dealers or brokers, while Richard Lyons (1993) suggests that over 80 percent is between market makers alone.

[52] Ito (1990) and MacDonald (1992) also report evidence of heterogeneity of expectations, using disaggregated survey data.

rational expactations equilibrium may be policed by only a few well informed traders, homogeneity of expectations is a working assumption in most traditional studies. In contrast, many microstructural studies often place the heterogeneity of expectations at center stage: the determination of the equilibrium exchange rate becomes endogenous to the whole process of information transmission and price discovery (Hal Varian 1989).

Other studies in the emerging market microstructure literature have looked at the way information is processed and transmitted through the market, and the relationship of information processing to market volatility and volume. Lyons (1993), for example, reports evidence that volume affects the bid-ask spread through the information signalled by market volume as well as the desire of market makers to control their inventory of currencies. Tim Bollerslev and Michael Melvin (1994) also provide empirical support for a model in which the bid-ask spread is determined by underlying uncertainty concerning exchange rate movements. In related work on market volatility, several authors have documented regularities in market volatility (Hsieh 1988; Goodhart and Marcello Giugale 1988), and the contagion of exchange rate volatility across foreign exchange markets (the so-called "meteor shower"), which may be interpreted as evidence of information processing (Robert Engle, Ito, and Wen-Ling Lin 1990).

VIII. *Conclusion*

In this final section we identify some of the broad trends in the literature during the 1980s and early 1990s, and speculate as to the likely future directions of the research program.[53] We remarked in Section II on the trend toward increasing econometric sophistication in tests of foreign exchange market efficiency. This observation also holds more generally of empirical work on exchange rates. Thus, applied researchers on exchange rates have begun to apply recently developed, sophisticated time series techniques. Attention has also tended to shift from examination of macroeconomic models of exchange rates toward work related to the foreign exchange market as a financial market per se (e.g., risk premium models, models of deviations from speculative efficiency such as peso problems and learning models, microstructural analyses). The two areas of the literature which have conspicuously bucked this trend are the work on target zones and that on equilibrium exchange rate models. The former of these, at least in its initial incarnation, has met with spectacular empirical failure. Advocates of the latter have tended to eschew formal econometric analysis as a means of judging its relevance, preferring to adduce support by appeal to their consistency with broad stylized facts of exchange rate and macrovariable behavior.

The emerging finding that the data provide support for some of the long-run relationships suggested by economic theory suggests that progress might be made by concentrating on the long-run determinants of exchange rates. But it seems that further attempts to provide explanations of short-term exchange rate movements based *solely* on macroeconomic fundamentals may not prove successful[54] —and this perhaps accounts for

[53] The reader is cautioned that the speculations in this concluding section are, by necessity, subjective. They are, however, by no means esoteric.

[54] Not only has the search for macroeconomic fundamentals been extensive, but the results of Baxter and Stockman (1989), R. Flood and Rose (1993), and others, as noted above, suggest that the usual set of macroeconomic fundamentals is unlikely to be capable of explaining exchange rate

the shift toward more purely financial models of exchange rate movements and heightened interest in market microstructure. The macroeconomic fundamentals are clearly important in setting the parameters within which the exchange rate moves in the short term, but they do not appear to tell the whole story. It is in this context that the emerging literature on foreign exchange market microstructure seems especially promising. In the light of our discussion of the recent literature on foreign exchange market intervention, further work on the microeconomics of the interaction of the central bank and market traders may also be warranted.[55]

But economics has an important normative as well as positive element, and it is clear that in terms of assessing the appropriateness of exchange rate behavior and policy, the macro fundamentals are of supreme importance. Viewed from this perspective, the macroeconomic fundamentals thus provide an indispensable framework for policy debate and analysis.

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