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5 Exchange Rate Dynamics

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Exchange rates adjust until the existing stocks of currencies are willingly held. While this statement may be considered a tautology, economists have not reached a consensus on the mechanism by which an increase in the price of a currency reduces the demand for it. Seen in the light of the recent experience, the early versions of the elasticities and monetary approaches to exchange rate determination failed because of two considerations. First, these approaches specified that the exchange rate influenced the relative demand for money through its influence on a transmitting economic variable—the trade balance in the first instance and the price level in the second. Second, empirical observation suggested that the speed of transmission was not rapid enough to maintain equilibrium in the foreign exchange market on a day-to-day basis. Either viable models of the foreign exchange market must specify the mechanism by which the exchange rate directly influences the demand for money, or they must rely on a transmission variable which is as free to move as the exchange rate itself.

During the past decade, the most popular model of the second type has been Rudiger Dornbusch's (1976) model of exchange rate dynamics. In the Dornbusch model, the exchange rate "works" through its influence on interest rate differentials. An appreciation of sterling against the dollar in the spot market creates an anticipated depreciation in the future. In order to maintain interest rate parity, nominal interest rates must increase in the United Kingdom relative to the United States, and it is the increase in nominal interest rates which directly reduces the demand for sterling relative to dollars. This description of the Dornbusch mechanism may be reversed in order to directly assign a market-clearing role to the local interest rate. Suppose that the demand for sterling should increase for some reason. Those who attempt to build up their currency holdings will do so by attempting to

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sell assets. Since the quantity of currency is fixed, the result of this attempt will be lower bond prices and higher interest rates. However, at the existing exchange rate, the higher local interest rates will create an incipient capital inflow into the United Kingdom. Since the current account is fixed in the short run, the exchange rate must appreciate in order to clear the foreign exchange market. It will continue to appreciate until the anticipated depreciation of sterling offsets the international interest rate differential.

Although this description of the adjustment mechanism has gained wide acceptance in both academia and the financial markets, attempts to apply it empirically have not been notably successful.[1] In a recent survey of empirical models of exchange rate determination, Meese and Rogoff (1981) demonstrate that none of the simple econometric models of the exchange rate outperform a random walk specification in which the best forecast of the future spot rate is the current spot rate. In addition, Rogoff and Meese cast doubt on the efficient market underpinnings of the Dornbusch model by demonstrating that the spot rate forecast is also superior to the forecast embodied in the forward rate.

In part, the lack of success in the empirical implementation of theoretical models of the exchange rate may be due to the instability experienced during the 1970s. The oil crisis, the freezing of Iranian assets, the debt problems of the LDCs and the Eastern European countries, and the changing institutional arrangements in the international monetary system are all factors that are difficult to account for within the confines of traditional econometric analysis. It may also be the case that the foreign exchange market, as an asset market, is not amenable to standard econometric techniques. In the domestic financial literature, attempts to forecast asset prices typically are left to commercial forecasters, and the finding that the exchange rate was generated by a random walk during the first decade of floating would not be a source of dismay but an affirmation of market efficiency.

There is, however, no theoretical ground for rejecting econometric models of asset prices. The theory simply states that the most important source of a change in the price of an asset is a revision in the market's expectations of its future value. The empirical problem arises because it is extremely difficult to quantify the revisions in market expectations. Since it is to be expected that standard empirical proxies are inexact, it is also to be expected that the power of tests based upon these proxies is low.

In this paper, an attempt is made to avoid the problem of directly modeling market expectations. It is based upon the idea that the innovations in market "fundamentals," whatever they may be, can be observed from the innovations in the financial asset prices themselves. Suppose, for example,

1. See Bilson (1978), Frankel (1979), and Driskill (1981). The discussion in the December 1981 *American Economic Review* of Frankel's paper is directed toward estimation problems with this type of model.

that an economist was left in a room with a computer terminal, a copy of Dornbusch's paper, and the past history of exchange rates and interest rate differentials for two unknown currencies. Would that economist be able to infer that the data were generated by the theoretical model?

The object, then, is to make inferences about the adjustment mechanism in international financial markets through an analysis of the dynamics of international asset prices. As it stands, the paper is more an exercise in methodology and exploratory data analysis than an attempt to present definitive tests of alternative hypotheses. There are, of course, a number of other models of exchange rate dynamics which are broadly consistent with observed empirical regularities.[2] In more sophisticated applications of the approach, it should be possible to present dynamic models which distinguish between these alternatives. For the moment, however, a simple variant of the Dornbusch model will be considered as a case study to be applied to the recent history of the £/$ and DM/$ exchange rates.

5.1 A Theoretical Model of Exchange Rate Dynamics

In this section, vector autoregressions for exchange rates and interest rate differentials are derived from a discrete time, two-country version of the Dornbusch model of exchange rate dynamics. The model is described in the following five equations:

(1) $$m - p = -\alpha x$$

(2) $$x = \theta(\bar{e} - e)$$

(3) $$p = \phi Le + (1 - \phi) Lp$$

(4) $$m = Lm + u$$

(5) $$\bar{e} = L\bar{e} + u + v,$$

where m = log (net supply of sterling/net supply of dollars);
x = forward premium on the dollar;
= sterling interest rate − dollar interest rate;
e = log (exchange rate, i.e., £/$);
$\bar{e}$ = log (expected exchange rate);
α = interest rate semielasticity of the demand for money;
ϕ = velocity of price adjustment parameter;
θ = expectations parameter;
u = innovation in net relative supply of sterling;
v = innovation in expected exchange rate that is independent of the innovation in the net supply of sterling;
L = the lag operator, i.e., $Lz_t = z_{t-1}$.

2. Frenkel (1981) discusses the role of "news" in models of exchange rate determination.

Equation (1) represents the equilibrium condition in the foreign exchange market: the demand for sterling, relative to dollars, is assumed to depend positively on relative prices and negatively on the interest rate differential. All other influences on the relative demand for the two currencies are subsumed into the net relative supply term. Equation (2) is the Dornbusch version of the interest rate parity condition: the forward premium, which is assumed to be equal to the expected increase in the price of sterling, is assumed to be proportional to the difference between the expected long-run exchange rate, $\bar{e}$, and the spot rate, e. Equation (3) is a simple relative price adjustment equation in which the current level of relative prices is assumed to be a weighted average of the exchange rate and the level of relative prices in the previous period. This specification does not allow for any immediate pass-through of the exchange rate into relative prices. Apart from certain simplifications and notational changes, the first three equations are standard components of the Dornbusch model.

In equation (4), the relative supply of money is assumed to be generated by a random walk process. This assumption is implicit in the original model, and Driskill (1981) presents some evidence in favor of its empirical relevance. In equation (5), however, an important modification is introduced. In the Dornbusch model, and in the majority of other models of exchange rate dynamics, expectations of future money growth are often tied to current changes in the money supply. As Wilson (1979) and others have demonstrated, the dynamic response to an anticipated future change in the money supply within this framework is quite different from the response to a current realized innovation. In equation (5), the fact is recognized by the introduction of an additional source of disturbance to the system: an innovation in the expected future exchange rate which is unrelated to current changes in the relative net supply of money.

These v innovations may be justified on a number of grounds. Within the framework of monetary models, v innovations may represent changes in the expected future path of monetary policy which are unrelated to changes in the current money supply. Alternatively, the v innovations could represent temporary real disturbances, speculative factors, or pure noise.

One could obviously extend this approach to allow for additional sources of disturbances in the system. One obvious extension to the present model would be to introduce innovations into the real exchange rate in equation (3). Another approach would be to allow for separate disturbances in the two countries. For the moment, however, we are primarily interested in the relationship between exchange rates and interest rate differentials and, for this purpose, the simple model specified above provides a convenient starting point.

There are a number of approaches that could be taken to the estimation of the model specified in equations (1) through (5). Frankel (1979) estimates a quasi-reduced form which allows for the nominal interest rate differential to enter as an independent variable. Bilson (1978) estimated a three-equation version with exchange rates, interest rates, and prices as dependent variables, and Driskill (1981) has estimated a two-equation system explaining prices and exchange rates. More recently, Driskill and Shefferin (1981) have estimated a three-equation system accounting for prices, exchange rates, and interest rates using full-information maximum likelihood techniques. As the discussion of Frankel's paper in the December 1981 issue of the *American Economic Review* indicates, this brief survey only touches the top of an econometric iceberg. In general, history has not been kind to these econometric models. Equations which appeared to fit the data well within the sample period did not retain their forecasting ability in postsample experiments. The results reported by Meese and Rogoff (1981) suggest, in fact, that the simple random walk hypothesis, in which the best forecast of the future spot rate is its current value, outperforms most standard econometric models.

For this reason, it may be worthwhile to approach the estimation of the model from a different perspective. One of the problems with standard econometric procedures is that the models of expectations formation are very simple and unrealistic. Although it may be useful for some purposes to assume that market participants base their expectations of future money supplies on a simple autoregression of past money, any reader of the *Wall Street Journal* must realize that this type of approach is unlikely to capture accurately the expectational influences on the exchange rate. In addition, the flexible exchange rate period has probably been subject to as many important shifts in the demand for currencies as in the supply, and these demand shocks are unobservable. While the introduction of dummy variables may help to explain the past, they are of limited value for predicting the future.

In the present paper, these problems are addressed through the assumption that both the forcing series, m_t, and the gradually adjusting series, p_t, are unobservable variables. This assumption is based on the idea that current market participants are making their decisions on the basis of expectations of the future values of these fundamental series. Published estimates, or ad hoc forecasting rules, thus are likely to be very poor approximations to the true expectations. This issue, which is quite separate from that of the accuracy of the money supply series, may explain which equations relating the innovation in the exchange rate to innovations in relative money supplies have been unsuccessful.

The task, then, is to demonstrate that the exchange rate and interest rate differentials observed during the floating rate period are consistent with the model described in equations (1) through (5). Furthermore, this consistency must be demonstrated using only the past history of the two financial asset prices. For an informal view of the solution procedure, consider the simple Dornbusch model in which there are only money supply shocks. This model predicts a number of well-defined characteristics of the exchange rate and interest rate differential series: *(a)* the innovations in the two series should be negatively correlated, since an increase (depreciation) of the price of the local currency works by lowering local interest rates relative to world rates; *(b)* the anticipated changes in the two series should also be negatively correlated, since this is required by the overshooting scenario; and *(c)* the change in the anticipated change in both series should be negatively related to the current innovations. In other words, if we observe a depreciation of the exchange rate today, the anticipated appreciation for the future should increase. If the actual data demonstrated these characteristics, then it would be possible to conclude that the dynamics of the exchange rate and the interest rate differentials are consistent with the model.

The main advantage of this approach, in contrast with traditional econometric procedures, is that we are able to obtain good estimates of the innovations in relative money supply and demand from the innovations in the asset prices themselves. A second advantage of the approach is that it allows the use of higher frequency data. Although exchange rate and interest rate data are available almost continuously, most of the presumed determinants of these prices are only available on a monthly or quarterly basis. Restricting the econometric research to the two financial prices allows the use of weekly, or even daily, data.

At the present time, economists have fairly diffuse priors over the economic determinants of exchange rates. In addition to the variables stressed by monetary models, more recent theories have assigned a role to the current account, the stock of wealth, and the supply of currency-denominated debt. Given that these controversies are unlikely to be resolved soon, the model-free approach based on time series analysis may be a useful nonjudgmental tool for studying the adjustment dynamics of international financial markets.

5.2 Theoretical Autoregressions for Exchange Rates and Forward Premia

In this section, the "unobservable" variables, relative prices and the net relative supply of money, will be eliminated from the model in order to arrive at the joint process generating the exchange rate and the forward premium. This process will then be estimated using weekly data on the two time series. As a first step, solve the money market equilibrium condition for the relative price and substitute this equation into the price adjustment equation. Since the forward premium is the price that maintains the equilibrium condition in the foreign exchange market in the short run, the resulting expression is solved for this variable.

$$x = -\frac{1}{\alpha}m + \frac{\phi}{\alpha}Le + \frac{1-\phi}{\alpha}Lm + (1-\phi)Lx. \tag{6}$$

Since the money supply is assumed to follow a random walk, equation (6) is differenced and the relative money supply variable is replaced by its innovation.

$$(7) \qquad \Delta x = \frac{\phi}{\alpha} L\Delta e + (1 - \phi) Lx + w - (1 - \phi) Lw.$$

In equation (7), the relative money supply innovation, u, has been replaced by the innovation in the forward premium, w. The two innovations are related in equation (8).

$$(8) \qquad w = -\frac{1}{\alpha} u.$$

By making use of the fact that the autoregressive and the moving average structure in (7) are the same, equation (7) can be restated in the following form.

$$(9) \qquad \Delta x = \frac{(\phi/\alpha) L}{[1 - (1 - \phi)L]} \Delta e + w.$$

Equation (9) imposes a number of testable restrictions on the process generating the forward premium. First, the predictable part of the change in the premium is an exponentially declining distributed lag of the past changes in the exchange rate. Second, given the past history of the exchange rate, lagged changes in the forward premium should not have any significant predictive power over current changes. Third, only the relative money supply innovations induce changes in the current value of the premium; changes in expected future relative money supplies have no influence.

The economics behind these results is straightforward. In the Dornbusch model, the role of the forward premium is to maintain equilibrium in the foreign exchange market. The exchange rate only influences the current demand for the two currencies through its influence on the forward premium. Consequently, all of the burden of adjusting to future shocks is placed directly on the exchange rate. As far as the predictable part of the change in the premium is concerned, the results follow from the fact that there is only one variable in the system which adjusts over time. Hence the past history of the system can be represented by the past history of either of the endogenous variables.

The solution for the exchange rate begins by differencing equation (2) and introducing the process generating $\Delta\bar{e}$. This yields

$$(10) \qquad \Delta e = -\frac{1}{\theta} \Delta x + w + v.$$

If equation (9) is used to eliminate the relative money supply innovation from (10), the following final form for the exchange rate may be obtained.

$$\Delta e = -\frac{1 + \alpha\theta}{\theta}\Delta x + \frac{\phi}{[1 - (1 - \phi)L]}L\Delta e + v. \quad (11)$$

As an alternative, it would be possible to use (9) to eliminate the contemporaneous change in the forward premium from (10). Equation (11), however, has the important advantage that the θ parameter can be identified from the coefficient relating the change in the exchange rate to the change in the forward premium. Since the change in the premium is uncorrelated with the v innovation by construction, the estimates of the parameters will be unbiased.

Before proceeding to the empirical analysis, it may be useful to check the validity of the model through a simulation experiment. For the structural parameters, it is assumed that prices adjust to the real exchange rate at a rate of 1% per week, hence ϕ equals .01, and that the interest elasticity of the demand for money is $-.1$. If monthly interest rates are approximately 1% per month, the semielasticity would then be 10. Given these assumed values, the value of the expectations coefficient, θ, is defined by the rational expectations condition:

$$\theta_1, \theta_2 = \frac{-\phi\alpha \pm \sqrt{(\phi\alpha)^2 + 4\phi\alpha}}{-2\alpha}. \quad (12)$$

Choosing the positive root, and introducing the assumed values of the other parameters, we arrive at an estimate of θ of .037. These values will serve as a useful standard of comparison with the actual estimates.

The estimates of the constrained system are provided in table 5.1. The first notable fact from these results is that the parameters are generally estimated imprecisely. The exception to this rule is the price adjustment parameter, which is significantly different from zero in both cases. The results for

Table 5.1 **Estimates of the Constrained Model**

Parameter	Control	£/$	DM/$
ϕ	.01	.066	.054
		(.029)	(.027)
α	10	15.24	180.59
		(26.07)	(1488.26)
θ	.037	.140	.076
		(.536)	(3.324)
σ_v		.012	.013
σ_w		.003	.006
D-W (v)		2.150	2.011
D-W (w)		2.920	2.730

Notes: The parameters were estimated from a weekly sample of 393 observations using the spot rate and the 1-month forward premium from the Harris Bank *Weekly Review* data tape. The sample runs from January 1974 to September 1981.

the £/$ rate are, however, reasonably consistent with prior expectations. The two adjustment parameters are larger than one might expect, but the interest semielasticity of the demand for money is very close to prior expectations. The main surprise in the DM/$ results is the very large estimate of the interest rate semielasticity. Even with interest rates as low as 5% on an annual basis, this estimate suggests an interest elasticity of about .75 in the DM/$ rate.

The large estimated interest elasticity in the German case results in a pattern of exchange rate dynamics which is familiar from the discussion of near perfect currency substitution. In the currency substitution literature, a high degree of currency substitution results in greater variability in the exchange rate because the expected change in the exchange rate must be kept small. Consider, as an example, a 1% increase in the demand for either sterling or deutsche marks relative to dollars. The adjustment pattern predicted by the models is given in table 5.2.

The control solution is surely familiar to students of the Dornbusch model. In response to a 1% increase in the relative demand for money, the exchange rate appreciates immediately by 3.7% on an annual basis and the interest rate differential increases by 1.2% per annum. As prices adjust, the exchange rate depreciates and the interest rate differential declines. The results for the £/$ rate mirror this pattern: the initial overshooting is smaller, and the adjustment is more rapid, but the dynamics are certainly consistent with the underlying model.

Table 5.2 Dynamic Response to an Increase in the Relative Demand for Money

	Control		£/$		DM/$	
t	$e - e_0$	$x - x_0$	$e - e_0$	$x - x_0$	$e - e_0$	$x - x_0$
−1	0	0	0	0	0	0
0	−3.7	1.2	−1.56	.84	−1.16	.07
5	−3.2	.99	−1.36	.50	−1.14	.05
10	−2.8	.82	−1.25	.30	−1.13	.04
15	−2.5	.68	−1.17	.18	−1.12	.03
20	−2.3	.56	−1.13	.11	−1.11	.02
25	−2.1	.46	−1.11	.07	−1.10	.02
30	−1.9	.38	−1.09	.04	−1.10	.01
35	−1.8	.32	−1.08	.02	−1.09	.00
40	−1.6	.27	−1.08	.01	−1.09	.00
45	−1.5	.22	−1.07	.01	−1.09	.00

Note: The $e - e_0$ column represents the % deviation of the exchange rate from the rate that would have existed in the absence of the 1% increase in the demand for money in period 0. The $x - x_0$ column represents the deviation of the interest rate differential—expressed in annual percentage terms—from the interest rate differential that would have occurred in the absence of the 1% increase in the demand for money in period 0.

In the DM/$ rate, the characteristics of closely substitutable currencies are evident. The extent of the overshooting is small relative to the other results, and the increase in the interest rate differential is also small. Clearly these factors are interrelated. The overshooting must be small in order for the expected rate of change in the exchange rate to be small, given that the adjustment velocities are about the same as in the £/$ case.

In this section, it has been demonstrated that simple dynamic models of exchange rate determination can be formulated and estimated as vector autoregressive processes. Estimates of the Dornbusch model were not particularly precise, but the dynamic response of the exchange rate and the interest rate differential to an increase in the demand for money was broadly consistent with the predictions of the model. This fact, however, does not represent a test of the model. In the next section, the constrained model will be tested against a less constrained alternative.

5.3 Unconstrained Vector Autoregressions

A more general specification of the joint process generating the exchange rate and the forward premium is presented in equations (13) and (14):

$$[1 - A11(L)]\,\Delta e + A22(L)\,\Delta x = Cw + v \tag{13}$$

$$A21(L)\,\Delta e + [1 - A22(L)]\,\Delta x = w. \tag{14}$$

In these equations, the $A(L)$ functions are polynomials in the lag operator and C is a parameter relating the innovation in the forward premium to the exchange rate. This general model differs from the constrained model in two important respects: the distributed lags are unconstrained across equations and the lagged values of the change in the premium are introduced into both equations. In the estimation, fourth degree polynomials are used to test the alternative hypothesis.

Estimates of equations (13) and (14) are presented in table 5.3. It is obvious that the constrained model will be rejected by the sample data. In fact, the lagged values of the forward premium are important predictors of both the change in the exchange rate and the change in the forward premium. This impression is confirmed by a likelihood ratio test of the alternative models. Twice the difference between the log likelihood ratios of the constrained and unconstrained models is 182.42 in the £/$ case and 86.28 in the DM/$ case. Under the hypothesis that the constrained model is correct, this variable is distributed X^2 with 17 degrees of freedom. The probability that a X^2 variable with 17 degrees of freedom is greater than 33.4 is 1%. The estimates consequently reject the hypothesis that the constrained model is correct.

Given the simplicity of the model, the fact that it is rejected by the data should not be a cause for undue dismay. What is required is a more general

Table 5.3 **Estimates of the Unconstrained Model**

Parameter	£/$	DM/$
*A*11–1	–.011	.056
	(.049)	(.050)
*A*11–2	.128**	.135**
	(.049)	(.049)
*A*11–3	.062	–.064
	(.049)	(.050)
*A*11–4	.103**	.048
	(.050)	(.050)
*A*12–1	.698**	.555
	(.225)	(.552)
*A*12–2	.685**	–.736
	(.265)	(.595)
*A*12–3	.102	–2.344**
	(.266)	(.595)
*A*12–4	–.496**	–.346
	(.229)	(.559)
*A*21–1	.008	–.007
	(.011)	(.004)
*A*21–2	.001	.002
	(.011)	(.004)
*A*21–3	–.014	.002
	(.011)	(.005)
*A*21–4	.004	.001
	(.011)	(.005)
*A*22–1	–.669**	–.408**
	(.051)	(.051)
*A*22–2	–.451**	–.094
	(.059)	(.054)
*A*22–3	–.291**	.016
	(.060)	(.054)
*A*22–4	.012	–.006
	(.051)	(.051)
C	–.418	–.023
	(.224)	(.548)
v	.011	.012
w	.003	.001

Note: Constants were estimated but not reported.

specification of the dynamic interaction between exchange rates and interest rates that will allow for tests of dynamics which are not model specific. In the following, such tests will be developed and tested for two important concepts in the literature on exchange rate dynamics: magnification and overshooting.

Before proceeding to the tests, it may be worthwhile to describe these theories in general terms. The overshooting hypothesis, which was a theoretical feature of the Dornbusch model, refers to a situation in which the short-run change in an endogenous variable in response to an innovation is greater than the long-run change. This implies that an innovation that causes the endogenous variable to increase on impact must also create an anticipated decline in the endogenous variable during the adjustment period. Hence the anticipated change is negatively correlated to the innovation. The magnification effect, on the other hand, is generally based upon the idea that the exogenous variables which generate exchange rates are positively correlated. Hence an innovation, for example, in the money supply affects the exchange rate both directly and by increasing the future money supply. Since the expected future increase creates an anticipated depreciation of the currency, which reduces the demand for it, the depreciation of the exchange rate will be more than proportional to the increase in the money supply. During the adjustment period, the exchange rate will continue to depreciate in the absence of new disturbances. Hence, in contrast to the overshooting hypothesis, the magnification effect posits a positive correlation between the current innovation and the expected future change in the endogenous variable.

These concepts may be formally specified and tested within the framework of the model specified in equations (13) and (14). The first step in the development of the tests is to derive the univariate representations of the vector autoregressive processes. The univariate processes are defined in equations (15) and (16):

$$\text{(15)} \qquad [(1 - A\,11)\,(1 - A22) - A12A21]\,\Delta e = [C(1 - A22) - A12[\,u + (1 - A22)\,v$$

$$\text{(16)} \qquad [(1 - A11)\,(1 - A22) - A12A21]\,\Delta x = [(1 - A11) - C{*}A21]\,u - A21\,v.$$

The gain in a time series is defined as the change in the expected terminal value, conditional upon the new information at time t. If

$$A11 = a_{11-1}\,L + a_{11-2}\,L^2 + a_{11-3}\,L^3 + \ldots + a_{11-n}\,L^n,$$

then define

$$B11 = a_{11-1} + a_{11-2} + a_{11-3} + \ldots + a_{11-n}.$$

Using this definition, we have that

$$\underset{t}{E}\,e_{t+i} - \underset{t-1}{E}\,e_{t+i} = \frac{[C(1 - B22) - B12]}{[(1 - B11)\,(1 - B22) - B12B21]}\,\text{u} + \frac{(1 - B22)}{[(1 - B11)\,(1 - B22) - B12B21]}\,v$$

and

$$\underset{t}{E}\, x_{t+i} - \underset{t-1}{E}\, x_{t+i} = \frac{[(1 - B11) - C^{*}B21]}{[(1 - B11)(1 - B22) - B12B21]}\, u - \frac{B21}{[(1 - B11)(1 - B22) - B12B21]}\, v$$

as i tends to infinity. It is reasonable to define these expressions as the change in the expected permanent exchange rate in response to the innovations at time t. Based upon the information at time t, the model predicts a dynamic path for the exchange rate with some stable terminal value, at t + 1, new innovations are observed and new terminal values are calculated. The change in the expected terminal values is the change in the permanent exchange rate.

With these concepts in hand, definitions of magnification and overshooting effects are straightforward. A magnification effect, which we might also call an undershooting effect, refers to a situation in which the change in the actual exchange rate in response to the innovation at time t is less than the change in the permanent exchange rate. This implies that the actual rate must continue to move in the same direction in order to reach the terminal value.

On the other hand, a magnification effect occurs when the actual change in the exchange rate in response to the innovation exceeds the change in the permanent exchange rate. This pattern implies that the future changes in the rate must, to some extent, reverse the current change in order to reach the terminal point. These definitions are fairly general in that they do not require a specific pattern of adjustment toward the terminal value. For example, the exchange rate might increase in response to an innovation, continue to increase in the following weeks, and then decline as prices adjusted. As long as the terminal point fell below the initial change, this would be characterized as an overshooting situation.

There are two innovations in the version of the Dornbusch model described above, and they imply different patterns of exchange rate dynamics. A current money supply shock, a u innovation, implies overshooting: the exchange rate must initially increase by more than its long-run value in order to induce a market-clearing interest rate differential. On the other hand, a future shock, a v innovation, leads to undershooting. To see this, consider an anticipated future tightening of the money supply. Since the interest rate must remain fixed, all of the burden of adjustment is placed upon the exchange rate in the short run, and it must appreciate in proportion to the anticipated fall in the money supply. During the subsequent adjustment, prices will tend to fall, and interest rates will have to increase in order to maintain equilibrium in the money market. Through the forward parity condition, the increase in interest rates will lead to a further appreciation of the exchange rate.

A simple test of magnification and/or overshooting involves an examination of the long-run response to an innovation with the impact response. Table 5.4 presents a comparison of these values for the two cases under study.

The results reported in table 5.4 for the £/$ rate are broadly consistent with the theoretical model. For contemporaneous money shocks, overshooting is evident in both the exchange rate and the forward premium, and the degree of overshooting in the forward premium is certainly statistically significant. In addition, a magnification effect is evident in the response of the exchange rate to a future innovation in relative money supply: a 1% increase in per one leads to an eventual increase of 1.4%.

In the DM/$ case, the results are more mixed. While there is strong evidence of overshooting in the forward premium in response to a contemporaneous money shock, the exchange rate appears to be independent of these shocks in both the short run and the long run. While the random walk nature of the exchange rate may be due to currency substitution, this explanation is difficult to reconcile with the evidence of reasonably strong negative correlation in the forward premium. However, the results are more supportive of the model in the case of future shocks. As in the £/$ case, future shocks are associated with undershooting in the exchange rate and in the forward premium.

Table 5.4 Magnification and Overshooting Effects

Relation	£/$	DM/$
$\Delta e:u$		
Impact	−.4183	−.0225
	(.224)	(.548)
Permanent	−.0004	−.0215
	(.011)	(.006)
$\Delta e:v$		
Impact	1.000	1.000
Permanent	1.3919	1.220
	(.176)	(.138)
$\Delta x:u$		
Impact	1.0000	1.0000
Permanent	.4166	.6746
	(.039)	(.062)
$\Delta x:v$		
Impact	.0000	.0000
Permanent	−.0077	−2.3675
	(.543)	(1.416)

5.5 Conclusions

The purpose of this paper has been to outline an approach to the testing of dynamic models of exchange rate determination. This approach is based upon the idea that it is difficult to measure directly the process by which market participants revise their expectations about current and future money supplies. On the other hand, it is possible to make indirect inferences about these expectations through a time series analysis of related financial prices. In an application of the process to the Dornbusch model of exchange rate dynamics, it was shown that all of the key parameters of the model could be identified from a vector autoregression of the weekly time series of the exchange rate and the forward premium.

The restrictions placed upon the parameters of the vector autoregression by the Dornbusch model were firmly rejected by the data. Given the simplicity of the model, this rejection was probably to be expected. In the final section of the paper, a more general characterization of exchange rate overshooting and magnification effects was developed and tested against the data. In the £/$ case, the more general specification did appear to match the broad empirical regularities present in the time series process generating the two prices. In the DM/$ case, the results were more problematic.

Given the exploratory nature of the paper, it is worthwhile to close the paper with some suggestions for extending the method. In the empirical research, the parameters of the time series models were found to be quite unstable over time. Hence an important future step would be to take account of the drift in the parameters through varying parameter regression techniques. In addition, the relative variance of the two innovations was also not constant over time, and it could be the case that the parameter drift is related to this variation. Finally, there is a need to develop similar autoregressive models for other popular models of exchange rate dynamics. This step would allow for multimodel tests of exchange rate dynamics.

Comment Richard M. Levich

The papers by Hans Genberg and John Bilson are both engaged in exploratory research to understand the short-run dynamic behavior of exchange rates. The explicit motivation for both studies is the view that previous research has not adequately explained the recent trends and volatility in major exchange rates. The erratic relationship between the theory and the reality of exchange rate behavior leads Bilson to observe that "economists currently have fairly diffuse priors on the economic determinants of exchange rates." As a consequence, both Bilson and Genberg propose a new line of research—one that looks at the "tracks" of recent exchange rate behavior and asks what type of exchange rate theory (i.e., exogenous variables, their interrelationships and stochastic processes) would be consistent with this behavior.

As I suggested above, this new line of research stems from Genberg's and Bilson's frustration with the explanatory (i.e., in sample) and predictive (i.e., postsample) performance of popular exchange rate models. In capsule form, what do these two authors propose?

Genberg proposes to remain agnostic about the fundamental variables, the Z_t driving exchange rates. He also decides not to entertain complicated time series processes for his Z_t. Instead, he considers only AR(1) processes in the levels and percentage changes. With these assumptions, Genberg derives relationships between forward rate innovations *(IF)* and spot rate innovations *(IS)*. Empirical analysis of the *IF* and *IS* series can therefore be used to infer the nature of the Z_t process. Genberg concludes that: AR(1) processes on the Z_t seem sufficient to explain the time series behavior of spot and forward rate innovations; there is little evidence for exchange rate overshooting; and the foreign exchange market appears to anticipate and reflect changes in expected monetary behavior.

Bilson, on the other hand, begins with the basic Dornbusch exchange rate dynamics model. This model fosters two testable hypotheses: (1) negative contemporaneous correlation between the exchange rate and domestic interest rate series, and (2) negative autocorrelation *within* both the exchange rate and domestic interest rate series. Bilson adapts the basic model by assuming that in the current period both the money supply and domestic prices are unobservable. This leads him to adopt a vector autoregression (VAR) technique for testing his hypothesis. Bilson's empirical results offer only mixed evidence on the hypothesis.

Both Genberg and Bilson appear to be pursuing a nontraditional style of empirical analysis. Rather than specify the exchange rate as a function of certain independent variables in a tightly specified model, the authors seem to ask a more limited question: Are certain broad empirical findings (e.g., autocorrelation or cross-correlation patterns among series) consistent with the predictions of a general class of exchange rate models? If so, Genberg and Bilson will interpret these empirical regularities as evidence supporting a general model of exchange rate behavior.

I will argue that while new studies of exchange rate behavior are always welcome, we should not be surprised by the poor ability of earlier studies to explain short-run exchange rate behavior. Part of my argument is general, applicable to any asset pricing situation, and part is specific to the foreign exchange market.

In my view, the most important finding to come from the last decade of research is the realization that foreign exchange is a financial asset. Therefore, foreign exchange rates will exhibit behavior closely identified with stock and bond prices—that is, prices will adjust quickly and sometimes by a large amount in response to new information about current variables, the future values of these variables or simply the confidence with which these expectations are held. The implication of this is that over the long run, asset prices should be set in accordance with well-known asset pricing formulas, but over the short run there is considerable scope for prices to be a noisy series and at variance with observable fundamentals. (I am not suggesting here that asset markets are inefficient in the short run or that profit opportunities exist. Costly information whose implications and accuracy are highly uncertain and the psychological state of market agents are real factors in the short run.)

Existing economic theories seem to be quite capable of explaining cross-sectional variation—why there are 10,000 Argentinian pesos per dollar, 1,300 Italian lire per dollar, and only 0.5 British pounds per dollar. Existing theory is also capable of explaining the bulk of currency movements over a long time period—why the mark rose from $0.35 in 1973 to $0.50 in 1980. Existing theories fail to adequately explain short-run currency fluctuations—why the mark rose from $0.50 on Monday to $0.52 on Tuesday or Friday. Some of these currency movements can be attributed to unexpected changes in fundamental variables (i.e., "news"). But the remainder are attributable to "purely technical" factors (e.g., large corporations meeting contractual obligations on prearranged dates, large financial institutions taking short-term positions in markets with little net speculative capital), central bank intervention, and other factors that contribute to what we often label "noise" from the standpoint of a highly stylized macro model. My point here is that economists know a good deal about exchange rate determination, as evidenced by the cross-section and long-run comparisons. The analysis of short-run currency movements puts the foreign exchange market very much "under the microscope," where most of our existing theories do not have a comparative advantage for explaining observed behavior.

While the above discussion on valuation problems describes both the equity market and the foreign exchange market, I believe the problems are fundamentally more difficult in the foreign exchange market. Consider the example of a large consumer products company such as Kraft Foods, General Mills, or Proctor and Gamble. Many of the directors and officers of these firms may have been employed for 5 years, 10 years, or more. They may make and publicize 5-year plans. Both the demand side and supply side of these industries may be fairly stable, or at least predictable, in response to known demographics and spending habits. In short, it is conceivable that market analysts might come to know these firms so that their share prices and returns were fairly stable or predictable.

In contrast, the fundamental variables which effect foreign exchange rates—namely, monetary and real events—are heavily influenced by government action. The nature of governmental planning (monetary or fiscal policy) is that it is short term (generally no longer than one year), somewhat uncertain to the extent that legislative approval is required, and totally uncertain given that a new administration with completely different policies may be voted in at the next election. This setting suggests to me that the foreign exchange market is starved for information relative to the stock market. My point here is that currency analysts are not likely to know very much about the fundamental determinants of exchange rates at horizons past one or two years. Consequently, expectations concerning fundamental variables are likely to be weakly held and uncertainty acts to deter a large pool of risk capital. Both factors contribute toward short-run exchange rate volatility.

A final point that inhibits easy empirical tests in the foreign exchange market is that most models hypothesize shocks of known size and duration that occur one at a time. In practice, however, these conditions are never satisfied. An initial disturbance may occur on Monday. A disturbance with an opposite effect occurs on Wednesday. And news arrives on Friday that causes us to revise our assessment of Monday's shock. In a multiple factor, lagged adjustment model, it may be nearly impossible to isolate individual disturbances and follow their effects through to the exchange rate.

* * *

Hans Genberg's paper begins by setting up the Z_t processes and deriving the relationship between spot and forward innovations (*IS* and *IF*) that appear in expressions (12) and (16). The thrust of the empirical work, then, is to determine whether the data on *IS* and *IF* are consistent with rational expectations on the Z_t. This procedure raises two issues. First, no alternative hypothesis for the Z_t is specified. A common interpretation of many early empirical studies of floating exchange rates was that the data were so volatile that few hypotheses could be rejected. Testing one hypothesis on the Z_t versus an alternative would be the preferred procedure. Second, the procedure assumes for simplicity that there is only one Z_t. As we argued earlier, it is more likely that Z_t is a vector and that disturbances occur in one variable while the market is still adjusting to an earlier disturbance in another variable. Thus the exchange rate series probably reflects a complicated overlay of disturbances and adjustments that is both difficult to model theoretically and test for empirically.

Another assumption that might be questioned is Genberg's definition of *IS* and *IF*. Note that the definition of an innovation does not allow any role for transaction costs, risk premia, or the technical (but real) factors I discussed earlier. What concerns me here is that the empirical values for these innovations, which will be subjected to close scrutiny, are likely to be very small numbers. I suggest that it is an exaggeration to define *IS* and *IF* as reflecting only innovations in the Z_t rather than transaction costs, risk premia, or other variables.

Genberg's analysis relies on the so-called news model, wherein today's exchange rate depends on deviations between expected and realized values for the Z_t. It seems to me that this formulation is not compatible with a model that incorporates risk premia for risk-averse investors. The news model suggests that if analysts expect 10% money supply growth and 10% growth is realized, then no exchange rate change is required. But surely if analysts were worried that actual money growth might reach 20% (there must also have been some probability of money growth less than 10%), this announcement, which confirms expectations, must make risk-averse investors feel relieved. The value of domestic currency should rise on this news that removes uncertainty.

Also on the topic of news, I would argue that in an efficient market the source of news is necessarily shifting. Suppose the market sees that inflation is volatile and unpredictable. More resources should be spent to understand and forecast inflation with more precision. Once this is accomplished, inflation ceases to be a newsworthy variable. But now relative ignorance about some other variable causes it to be an important source of news driving exchange rates.

On the positive side, Genberg's paper marks an important step by analyzing the term structure of forward rate innovations. Both the magnitude and duration of disturbances are important factors for analyzing exchange rate behavior. Genberg's approach here is innovative, and it seems to be a promising avenue for gauging the persistence if not the magnitude of exchange market disturbances.

John Bilson's approach also is to analyze correlation and time series properties of exchange rates and interest rates to see if they are consistent with the Dornbusch exchange rate dynamics model. Bilson does not offer an alternative hypothesis. The null hypothesis—negative contemporaneous correlation between exchange rates and domestic interest rates, and negative autocorrelation within the exchange rate and interest rate series—are supported in only half the cases. The second hypothesis is poorly stated since the dynamics model predicts a positive shock in period 1 to be followed by a negative shock in period 2 (i.e., negative autocorrelation), but then the negative shocks continue in periods 3 on (i.e., positive autocorrelation). This null hypothesis seems especially susceptible to the problem of multiple and overlapping disturbances upsetting the autocorrelation pattern.

Bilson's analysis includes only 1-month forward contracts, so these tests are more limited than for Genberg. Bilson's regressions of correlations against volatility measures for spot and forward rates are provocative but very likely confuse short-term noise in the independent variables with real disturbances. My preference would be toward analyzing the large disturbances in the driving variables and testing for announcement effects, perhaps by a variance criterion. M. F. Melhem (NYU, Ph.D. in progress) is currently analyzing the data in this way. Melhem finds that during the period 1973–78, the $/DM and $/$C rates were roughly twice as volatile over the 1-day interval Thursday (9:00 A.M.) to Friday (9:00 A.M.) than over any other similar interval. Over this sample period, the weekly United States money supply figures were announced during the Thursday/Friday interval. Melhem also finds that these daily exchange rate changes respond significantly to the unexpected money supply component, and insignificantly to the expected money supply component. For the $/$C rates, the pattern of response is stronger for spot rates and short-term forward rates, consistent with an overshooting model.

The papers by Genberg and Bilson have embarked on exploratory research to compare short-run exchange behavior to the predictions of a general class of exchange rate model. In this comment, I have argued that current economic models are very useful to explain cross-sectional exchange rate differences and major currency swings over long time periods. Existing economic models, applied in an environment with major monetary and structural uncertainties, cannot be expected to gauge exchange rate values with a 5% or 10% tolerance limit. Since these figures are within the range of current month-to-month exchange rate changes, we cannot expect that existing exchange rate models will be useful for pinpointing exchange rate values, although they should get the rough direction of movement correct.

The general problem with both papers is that they may put the foreign exchange market "too much under the microscope" relative to the sophistication of current models. Genberg's paper, however, which looks at the term structure of innovations, seems to offer some promise for gauging the magnitude and duration of economic disturbances.

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