Exchange Rates, Innovations and Forecasting

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In this paper an *ex-post* forecasting experiment is performed on the basis of a version of the 'news' model of exchange rate determination. For several exchange rates the 'news' formulation of monetary exchange rate models leads to relatively accurate *ex-post* exchange rate forecasts at a number of forecasting horizons. For a majority of the exchange rates studied, however, the results do not compare favorably with those obtained from the naive random walk forecasting rule. Thus, the findings in this article provide mixed evidence with regard to a suggestion in the literature that the finding by Meese and Rogoff that structural models do not even outperform the random walk in an *ex-post* forecasting experiment, may be due to the fact that these models were not properly tested in a 'news' framework.

The forecasting performance of structural exchange rate models has recently received considerable attention. Meese and Rogoff (1983a, b) have studied the forecasting performance of several important structural exchange rate models. While in-sample studies of these models usually show quite satisfactory fits, Meese and Rogoff's out-of-sample results, based on instrumental variables estimates, were not very encouraging: the structural models failed to improve upon the simple random walk forecasting rule, even though the models' forecasts were based on actual, realized values of future explanatory variables (*i.e.*, they performed an *ex-post* forecasting experiment). Finn (1986) shows that full-information maximum-likelihood estimation of a version of the monetary model leads to a somewhat improved forecasting performance relative to the random walk in the case of the dollar/sterling exchange rate. Only at the six-month forecasting horizon, however, does her model outperform the random walk. Somanath (1986) demonstrates that, in the case of the dollar/mark exchange rate, a lagged adjustment consideration can contribute to a better forecasting performance. Wolff (1987) applied varying-parameter estimation techniques to improve the models' predictive performance. He finds that allowing estimated parameters to vary over time enhances the models' forecasting performance for the dollar/pound, dollar/mark and dollar/yen exchange rates. Contrary to Meese and Rogoff's results, *ex-post* forecasts for the dollar/mark rate compare favorably with those obtained from the naive random

walk forecasting rule. His overall results, however, may be interpreted as a confirmation of Meese and Rogoff's dim assessment of the models, since the performance of the models remains quite unimpressive, despite the fact that parameters are allowed to vary over time.

In recent years the distinction between *anticipated* and *unanticipated* movements in the exchange rate and its driving variables has been emphasized in the literature. (See, *e.g.*, Frenkel and Mussa, 1980; Frenkel, 1981; and Mussa, 1984.) The essence of this line of thinking is embodied in the 'asset market theory' of the exchange rate that is presented in Frenkel and Mussa (1980). The framework that was developed by Frenkel and Mussa views the exchange rate as a highly sensitive asset price which is immediately affected by an influx of new information. This approach is generally taken to imply that empirical research on the determinants of exchange rates should relate innovations in exchange rates to innovations in a relevant vector of explanatory variables. The idea was first implemented empirically by Frenkel (1981). Isard (1983) and Saidi (1983) have argued that the finding that the structural models do not even outperform the random walk in an *ex-post* forecasting experiment may be due to the fact that the structural models have not been properly tested in a 'news' or innovations framework. In this paper we will address this claim. We will derive a version of the 'news' model which will form the basis for a forecasting experiment. The model's *ex-post* forecasts will be studied and compared with the random walk forecasting rule. Unlike the models in Finn (1986), Wolff (1987) and most of the models in Somanath (1986), the model studied in this article is not a member of the class of models that was studied by Meese and Rogoff (1983a, b).

The paper is organized as follows. In Section I we present a derivation of the 'news' model. In Section II various ways of measuring innovations in the exchange rate and its driving variables are discussed. Then, in Sections III and IV, the forecasting results are presented. Section V offers some concluding comments.

I. A Derivation of the 'News' Model

Consider the following simple model of exchange rate determination:

$$\langle 1 \rangle \qquad s(t) = \beta' z(t) + a E[s(t+1) - s(t)|t]$$

$$\langle 2 \rangle \qquad H(L)z(t) = F[L]v(t).$$

Equation $\langle 1 \rangle$ is due to Frenkel and Mussa (1980) and states that the logarithm of the equilibrium spot exchange rate, $s(t)$, is determined not only by a set of current market fundamentals, but also by the expected rate of change of the exchange rate, $E[s(t+1) - s(t)|t]$, which motivates domestic and foreign residents to move into or out of foreign exchange depending on whether the relative price of foreign exchange is expected to rise or fall. The vector β is a vector of parameters, a $(a > 0)$ is a scalar parameter and $E[.|t]$ denotes an expected value conditional on information available at time t. Equation $\langle 1 \rangle$ represents a general relationship which can be derived from a variety of models of exchange rate determination that generally differ in their interpretations of the elements of the vector $z(t)$. In equation $\langle 2 \rangle$ it is assumed that $z(t)$ follows a general vector ARMA time series process. $H[L]$ and $F[L]$ are square matrices, assumed to be of full rank, whose elements are finite polynomials in the lag operator L. The vector $z(t)$ is assumed to be m-

dimensional and thus $F[L]$ and $H[L]$ are $m \times m$ matrices. Further, we assume that the $m \times 1$ vector of innovations $v(t)$ has a zero mean, an identity covariance matrix and no serial correlation, that is,

$$\langle 3 \rangle \qquad\qquad E[v(t)] = 0,$$

$$\langle 4 \rangle \qquad\qquad E[v(t)v'(r)] = \delta_{rt}I,$$

where I is an $m \times m$ unit matrix and δ_{rt} is the Kronecker delta. Since we assume initially that the process is stationary and invertible (stationarity will be relaxed below), all roots of $\|H[L]\| = 0$ and, $\|F[L]\| = 0$ lie outside the unit circle ($\|.\|$ indicates the determinant of a matrix). Since $H[L]$ is assumed to have full rank, $\langle 2 \rangle$ can be solved for $z(t)$:

$$\langle 5 \rangle \qquad\qquad z(t) = (H^*[L]/\|H[L]\|)F[L]v(t),$$

where $H^*[L]$ is the adjoint matrix (the transpose of the matrix of cofactors) associated with $H[L]$. Equation $\langle 5 \rangle$ expresses $z(t)$ as an infinite, invertible vector moving average process. For simplicity of notation, we define

$$\langle 6 \rangle \qquad\qquad B[L] \equiv (H^*[L]/\|H[L]\|)F[L].$$

The matrix $B[L]$ can be written as

$$\langle 7 \rangle \qquad\qquad B[L] = B_0 + B_1 L + B_2 L^2 + B_3 L^3 + \cdots$$

If we assume that expectations in equation $\langle 1 \rangle$ are formed rationally, in the sense that they are consistent with the validity of $\langle 1 \rangle$ in all future periods, then forward iteration of $\langle 1 \rangle$, application of an appropriate boundary condition and the use of a convergence argument for a matrix-valued geometric series together imply the following relationship (for a detailed derivation see Wolff, 1986, pp. 373–375):

$$\langle 8 \rangle \qquad\qquad D''[s(t)] = [1/(1+a)]\beta'Cv(t+1).$$

Here $D''[.]$ is the unexpected change operator, $D''[s(t)] \equiv s(t+1) - E[s(t+1)|t]$, and the matrix C is defined as

$$\langle 9 \rangle \qquad\qquad C \equiv \lim_{n \to \infty} \sum_{j=0}^{n} [a/(1+a)]^j B_j.$$

Under the assumption of a stationary and invertible vector ARMA process in equation $\langle 2 \rangle$, the infinite series on the right-hand side of $\langle 9 \rangle$ always converges to a finite matrix. Convergence is also obtained for all non-stationary processes that satisfy

$$\langle 10 \rangle \qquad\qquad \lim_{n \to \infty} \sum_{j=0}^{n} [a/(1+a)]^j |b_j^{kl}| < \infty$$

for all k, l, where b_j^{kl}, is the k,lth element of the matrix B_j and $|.|$ denotes an absolute value. Equation $\langle 8 \rangle$ is a linear relationship between the innovation in the spot exchange rate between t and $t+1$ and innovations in the elements of the z-vector in the corresponding period. Given appropriate measures of innovations in the exchange rate and its driving variables, the validity of $\langle 8 \rangle$ can be examined empirically. It should be noted that estimated coefficients in regression equations that are in innovations form do not have the same interpretations as those estimated from standard structural models. That is, when estimating an equation based on

$\langle 8 \rangle$ one does not recover the parameter vector β, but a complicated vector of coefficients that involves the elements of the vector β, the elements of the matrix C and the scalar a. Equation $\langle 8 \rangle$ forms the basis for the forecasting experiments that are performed in this paper.

Since innovations are inherently unobservable, any empirical study on the basis of $\langle 8 \rangle$ involves a joint examination of the model *and* the method that is used to construct innovations. We will therefore discuss the construction of innovations at some length in the next section.

II. Constructing Empirical Measures of Innovations

In this section we will take a vector-autoregressive (VAR) approach to the construction of innovations in the vector of forcing variables, z. For reasons that will become apparent below, a different approach is taken to construct innovations in the spot exchange rate. Initially we study the same set of exchange rates as Meese and Rogoff (1983a, b) and Wolff (1987): the US dollar–German mark, US dollar–Japanese yen and US dollar–British pound spot exchange rates. Cross rates are then considered in Section IV. The monthly dataset covers the period from March 1973, the beginning of the floating exchange rate period, through April 1984. The data are drawn from IMF and OECD publications and are described in detail in the Data Appendix.

The z-vectors that we employ in the VARs are closely related to the monetary models of Bilson (1978), Dornbusch (1976a), Frankel (1979), Frenkel (1976) and Clements and Frenkel (1980):

$$\langle 11 \rangle \qquad z' = [m - m^*, y - y^*, i - i^*, \pi - \pi^*, q]$$

where

$$\langle 12 \rangle \qquad q = \ln[P_t/P_n)/(P_t^*/P_n^*)].$$

Here m and m^* are the logs of the domestic and foreign money supplies, respectively; y and y^* are the logs of domestic and foreign real income levels; i and i^* domestic and foreign nominal interest rates; π and π^* are domestic and foreign long-run expected inflation rates; P_t and P_t^* are domestic and foreign price levels of internationally tradable goods and P_n and P_n^* are domestic and foreign price levels of nontradable goods.[1] The variables $m - m^*$, $y - y^*$, $i - i^*$ and $\pi - \pi^*$ are those that enter the monetary models presented in Frankel (1979) and Frenkel (1976). The variable q is an indicator variable for the equilibrium real exchange rate that is based on Balassa's (1964) approach to relative prices in a world with internationally traded and nontraded goods. (For an up-to-date description of real exchange rate movements in the period at hand, see Lothian, 1986.) This approach was subsequently introduced into modern exchange rate models by Dornbusch (1976b) and implemented empirically (in-sample) by Clements and Frenkel (1980) in a study of the dollar–pound exchange rate in the 1920s. The approach assumes the existence of two categories of goods: those that are internationally traded and those that are not. The general price level in a country is assumed to be a linear homogeneous Cobb–Douglas function of the prices of traded and nontraded goods. Given these assumptions, q, as defined in equation $\langle 12 \rangle$, is a relevant variable that enters into the equations of the monetary models. For exact derivations, see Clements and Frenkel (1980) and Wolff (1985). In Wolff (1987) it is

shown that inclusion of q in the monetary models increases the models' forecasting accuracy in the case of the dollar/yen exchange rate. Because we will engage in *ex-post* forecasting experiments, we explicitly do not include the exchange rate itself in the VAR systems. If the exchange rate itself would be included, current innovations in the zs would be calculated on the basis of future spot exchange rates, which are not assumed to be known in the current period.

Given the specification in equation $\langle 11 \rangle$, we have to choose the lag length p for each VAR model. Given the size of our samples, we will restrict our attention to VAR systems of orders up to twelve. As the results of the forecasting experiments are potentially sensitive to this choice of p, we employ three different lag length selection criteria: (i) Akaike's (1974) information criterion (AIC), (ii) Parzen's (1975) CAT criterion and (iii) likelihood ratio tests.[2] All three criteria have large sample justifications. Their relative performance in finite samples remains largely unexplored.

The VAR models are estimated using data over the period from March 1973 through April 1984. A constant and eleven seasonal dummy variables are included in the estimated equations. We have experimented with two methods to reduce the systems to stationarity: first-differencing and including a time trend in the VARs. (As the results are very similar, we only report the prediction results for the latter case in the next section.) Our three lag length selection criteria unanimously prescribe employing the full twelfth-order systems. Because a VAR system of order twelve seems rather large, the results of experimentation with smaller systems are also reported below.

A separate method is needed to construct innovations in the (log of the) spot exchange rate at time t, $s(t)$. That is, we have to find an accurate empirical proxy for the market's expectations $E[s(t+n)|t]$ concerning future spot rates at various horizons n, on the basis of information available at time t, in order to generate the innovations $s(t+n) - E[s(t+n)|t]$. An obvious choice for $E[s(t+n)|t]$ would be the forward exchange rate at time t for currency to be delivered at time $t+n$, $f(t, t+n)$. Genberg (1984) studies exchange rate innovations that are calculated along these lines. For a number of reasons, however, we will use the current spot rate as a proxy for $E[s(t+n)|t]$ when constructing exchange rate innovations. These reasons are the following:

1. In a number of studies (*e.g.*, Hansen and Hodrick, 1980; and Hsieh, 1984) forecast errors resulting from the use of the forward exchange rate as a predictor of the future spot rate have been shown to be correlated with variables that are assumed to be in traders' information sets at the time when the forward rates were quoted, such as past values of spot and forward rates. This finding indicates that forward rates are not optimal predictors of future spot rates.
2. The results in Meese and Rogoff (1983a) and Wolff (1987) show that current spot rates have been more accurate predictors of future spot rates than current forward rates.
3. For the longer forecasting horizons that we study forward rates do not exist. They could be constructed from the covered interest arbitrage relationship, but such a procedure would introduce unnecessary measurement error.

Using the current spot rate to proxy for the market's conditional expectation of the future spot rate amounts to assuming that changes in the spot rate are almost entirely unpredictable. This assumption is in accord with the empirical evidence

over the recent floating exchange rate period (see Frenkel, 1981; Meese and Rogoff, 1983a; Mussa, 1979, 1984; and Wolff, 1985, 1987). Mussa (1984) argues: '... changes in spot prices are largely unanticipated and correspond fairly closely to changes in the market's expectation of future spot prices.'

In this section we have described the construction of innovations in the variables that we will use in the forecasting experiment that is performed in Section III. In that section we will also investigate how robust the prediction results are with respect to different ways of calculating innovations in the z-vectors.

III. The *Ex-post* Prediction Results

In this section we report the prediction results on the basis of the 'news' model. The statistical forecasting equation that we use is based on equation $\langle 8 \rangle$ and the methods for constructing innovations that were described in Section II:

$$\langle 13 \rangle \qquad\qquad s(t) = s(t-1) + \varepsilon'(t)\gamma + \eta(t)$$

where $s(t)$ is the log of the spot exchange rate; $\varepsilon(t)$ is the vector of innovations in the z-variables that results from the estimated VAR models; γ is a vector of parameters to be estimated; and $\eta(t)$ is a disturbance term. Note that $\langle 13 \rangle$ is the empirical counterpart of $\langle 8 \rangle$: the innovation in the spot exchange rate, $s(t) - s(t-1)$, is a linear function of innovations in the driving variables (the elements of the vector ε). Initially, forecasts will be generated using ordinary least squares (OLS) estimation. A variety of other techniques are also implemented below.

After innovations have been calculated on the basis of the entire sample, we estimate equation $\langle 13 \rangle$ over the period March 1974 through November 1977 (45 observations). (The first twelve observations are lost because the VARs were estimated conditional on these observations.) Forecasts are generated at horizons of 1, 3, 6, 12, and 24 months. Then December 1977 data are added to the sample, the parameters are updated and new forecasts are generated. This recursive process continues until forecasts are generated using April 1984 data (the end of our sample period). For computational efficiency these rolling regressions are calculated using the Kalman filter algorithm. This procedure provides us with time series of spot rate forecasts at various prediction horizons.

Forecasting accuracy is measured by four summary statistics that are based on standard symmetric loss functions: the mean error (ME), the mean absolute error (MAE), the root mean square error (RMSE) and the U-statistic. The ME, MAE and RMSE are defined as follows:

$$ME = \sum_{j=0}^{N-1} [A(t+j+k) - F(t+j+k)]/N,$$

$$MAE = \sum_{j=0}^{N-1} |A(t+j+k) - F(t+j+k)|/N,$$

$$RMSE = \left[\sum_{j=0}^{N-1} [A(t+j+k) - F(t+j+k)]^2/N \right]^{0.5},$$

where $k = 1, 3, 6, 12, 24$ denotes the forecast step; N the total number of forecasts in the projection for which the actual value of the exchange rate, $A(t)$, is known; and $F(t)$ the forecast value. Theil's U-statistic is the ratio of the RMSE to the RMSE of

TABLE 1. Summary statistics on the forecasting performance of the 'news' model. November 1977 to April 1984.

Horizon (months)	ME	MAE	RMSE	U-statistic	No. observations
$/mark					
1	−0.55	2.77	3.63	1.02	77
3	−1.72	4.97	6.04	1.04	75
6	−3.95	7.23	9.13	1.12	72
12	−9.02	12.11	15.33	1.26	66
24	−22.18	25.78	29.33	1.47	54
$/yen					
1	−0.20	2.91	3.73	0.97	77
3	−0.66	4.87	6.51	0.96	75
6	−1.43	8.17	9.92	0.97	72
12	−4.86	10.63	13.08	1.07	66
24	−13.74	14.21	16.68	1.68	54
$/pound					
1	−0.10	2.55	3.27	0.99	77
3	−0.36	4.57	5.63	0.99	75
6	−0.83	6.60	8.27	0.98	72
12	−1.97	11.92	13.47	0.97	66
24	−6.05	23.63	25.41	1.06	54

Note: Innovations in explanatory variables are constructed on the basis of 12th-order VAR systems. In the estimation of the forecasting equations intercepts have been included.

the naive random walk forecast. Because we are lookint at the logarithm of the exchange rate, the ME, MAE and RMSE are unit-free (they are approximately in percentage terms) and comparable across currencies. The values of the summary statistics are presented in Table 1. It is interesting to study the U-statistics that are reported in Table 1. U-statistics are easily interpreted: if $U < 1$ the model performs better than the simple random walk forecasting rule and if $U > 1$ the random walk outperforms the model. The U-statistics are smaller than one in a number of cases for the dollar/yen and dollar/pound exchange rates, indicating that the 'news' model outperforms the random walk in those cases.

Intuition might suggest that if structural models work better than a random walk model, they should work better at the longer forecasting horizons. There are two reasons to expect this. First, economic fundamentals will be more important, and noise variables less important, in the long run. Second, the importance of knowing the true values of the explanatory variables should be greater in the long run than in the short run. The results in Table 1, however, indicate that the performance of the model is on average weaker, relative to the random walk, as the forecasting horizon is extended. Such a result is not uncommon in the literature: Meese and Rogoff (1983a) and Wolff (1987) report a number of cases where similar results are obtained for various currencies.

One potential explanation of our finding that the performance of the 'news' model relative to the random walk forecasting rule is on average weaker as we

forecast farther into the future goes along the following lines. If there is an extended swing in an exchange rate and the 'news' model missed out on a stream of 'news' that is responsible for the swing (*e.g.*, because a relevant explanatory variable was omitted), then model forecasts for longer horizons (which are generated using the chain rule of forecasting) will be relatively poor. For these longer horizons systematic forecast errors are compounded through the chain rule of forecasting and, as a result, long-term model forecasts may give a poorer showing relative to the random walk forecasting rule than short-term forecasts. The fact that the mean errors reported in Table 1 are consistently negative and often not much smaller in absolute value than the mean absolute errors, suggests that this is not an unlikely scenario: our version of the 'news' model seems to have missed out, on average, on 'news' that led to appreciation of the dollar.

When attempting to explain this result, it is useful to keep in mind that the statistics for the longer horizons have to be interpreted with caution, not only because the number of observations decreases as the horizon is extended, but also because the overlapping nature of the forecasts reduces the amount of independent information that is effectively present in the sample (relative to a nonoverlapping sample with an equal number of observations).

Since all three exchange rates that we study in this section involve the US dollar, it is likely that the covariance matrix of errors terms [the ηs in equation $\langle 13 \rangle$] across currencies is not diagonal. In Table 2 we present an estimate of this covariance matrix over the period March 1974 to April 1984. The table shows that off-diagonal elements are indeed of non-negligible size.

Thus, we employed Zellner's (1962) seemingly unrelated regression method (SURM) in an attempt to obtain more efficient estimates of the parameter values. The forecasting experiment was repeated using updated SURM parameter estimates on a period-by-period basis. The forecasts on the basis of SURM or iterated SURM, however, turned out not to lead to any improvement in the model's performance and are not presented. Along the lines of Wolff (1987) we have also experimented with estimation methods that allow for random walk

TABLE 2. An estimate of the covariance matrix of error terms across currencies from regression equations of the form $s(t) = \text{constant} + s(t-1)$
$$+ \varepsilon'(t)\gamma + \eta(t).$$
March 1974 to April 1984.[a]

	$/mark	$/yen	$/pound
$/mark	0.997[b]		
$/yen	0.454	0.927	
$/pound	0.477	0.328	0.817

Notes:
[a] This estimate was obtained from an iterated SURM procedure. SURM was iterated until the log determinant of the estimated covariance matrix changed by less than 0.001.
[b] All entries are scaled by 10^3.

parameter variation. In the context of the 'news' model, however, the introduction of parameter variation does not lead to an improved forecasting performance.

The empirical results in Table 1 are potentially sensitive to the method used for isolating innovations in the z-vector. In Wolff (1985), we have considered a range of alternative methods to calculate innovations:[3]

1. Shorter lag lengths for the VAR systems were tried and the forecasting experiment was repeated on the basis of innovations that were thus calculated.
2. Bayesian prior distributions of the class proposed by Litterman (1980) have been implemented in the estimation of the VARs. Litterman suggests that in the context of regressions with a large number of parameters and a high degree of collinearity, such as a VAR, suitable restrictions on the parameters may lead to substantial reduction in the sample variance of parameter estimates. We have implemented a large number of variants of Litterman's class of prior distributions in order to calculate innovations for the forecasting experiment.
3. It is quite possible that the estimated VAR systems suffer from parameter instability, as the result of changes in the underlying international economic structure. In an attempt to cope with this potential problem, we have estimated rolling-regression variants of the VARs and versions in which the parameters are allowed to vary over time. (Only generic vector random walk parameter variation was allowed for.)
4. We have tried to broaden the set of useful 'news' variables. Since much of the real appreciation of the US dollar towards the end of the sample period was not predicted by the models, it would appear useful to pay particular attention to variables that may capture 'news' concerning the strength of the US economy. We have experimented with the Index of Leading Indicators (as constructed by the US Department of Commerce) and with Standard & Poor's index of stock prices (500 common stocks) as additional elements of the vector z.

None of the variants described above, however, led to forecasting results that were better than those presented in Table 1 (or even very different). Thus, the results are robust in the sense that different innovations constructs within the vector autoregressive approach do not lead to very different *ex-post* forecasting results. It should be noted, however, that there are in principle many other ways to construct measures of 'news'.

IV. Cross-Rate Results

In the previous section we studied forecasting results from the 'news' model for three important exchange rates involving the US dollar. In order to explore to what extent the results presented there are representative, it is interesting to consider cross exchange rates, too. In Table 3 forecasting results are presented for the pound/mark, pound/yen and mark/yen exchange rates. The results in Table 3 correspond to those in Table 1: exactly the same estimation and prediction procedures were implemented. The cross-rate results, of course, are not independent from the earlier results, but they do contain additional information. Interestingly, all U-statistics reported in Table 3 are greater than one. The 'news' model is outperformed by the random walk forecasting rule for all three cross rates. Also, as in the previous section, the performance of the 'news' model, relative to the random walk is weaker as the forecasting horizon is extended.

TABLE 3. Summary statistics on the forecasting performance of the 'news' model for cross exchange rates. November 1977 to April 1984.

Horizon (months)	ME	MAE	RMSE	U-statistic	No. observations
Pound/mark					
1	−0.43	2.53	3.31	1.07	77
3	−1.26	4.93	6.09	1.13	75
6	−2.98	6.93	8.86	1.20	72
12	−6.92	11.09	13.53	1.40	66
24	−15.36	20.20	24.49	1.74	54
Pound/yen					
1	−0.04	3.03	3.96	1.02	77
3	−0.12	6.17	7.56	1.05	75
6	−0.43	10.30	12.37	1.07	72
12	−2.70	16.09	19.61	1.15	66
24	−7.27	22.09	27.96	1.27	54
Mark/yen					
1	0.49	2.84	3.67	1.01	77
3	1.48	5.59	6.85	1.03	75
6	3.21	9.36	11.74	1.07	72
12	5.39	14.03	18.58	1.10	66
24	11.79	19.87	23.81	1.29	54

Note: Innovations in explanatory variables are constructed on the basis of 12th-order VAR systems. In the estimation of the forecasting equations intercepts have been included.

Drawing together the findings in Tables 1 and 3, we have to conclude that the results are mixed. For some exchange rates the 'news' model improves upon the random walk model for a majority of forecasting horizons (although only by a small margin). For four out of the six exchange rates studied, however, the random walk forecasting rule dominates.

A general caveat is in order. The forecasting results that are obtained from estimation of the 'news' model depend critically on the validity of empirical measures of 'news' that are employed. In this respect it is important that all relevant innovations are appropriately dated. One problem with datasets such as the one that we use is that information that is subsequently available to the econometrician may not have been contemporaneously observable to economic agents. Announcement effects and the like, on the other hand, could lead to situations in which variables in our dataset that are dated at time t were actually in agents' information sets at time $t-1$ or $t-2$. Another problem is indicated by Frenkel (1984). He suggests that different frequencies of data collection for different time series may have systematic effects on the time series characteristics of the innovations series. Although it is not obvious how to tackle them in a systematic way, these problems clearly deserve more attention in future work.

V. Conclusions

In this article we performed an *ex-post* forecasting experiment on the basis of the 'news' model of exchange rate determination. For several exchange rates the 'news' formulation of monetary exchange rate models leads to relatively accurate *ex-post* exchange rate forecasts at a number of forecasting horizons. For a majority of the exchange rates studied, however, the results do not compare favorably with those obtained from the naive random walk forecasting rule.

Thus, the findings in this article provide mixed evidence with regard to Isard's (1983) and Saidi's (1983) suggestion that the Meese and Rogoff (1983a, b) conclusion that structural models of exchange rate determination do not outperform the random walk in an *ex-post* forecasting experiment, may be due to the fact that the models were not properly tested in a 'news' framework.

Appendix

Data Source

Exchange Rates

Spot exchange rates are taken from the *International Financial Statistics* (IFS) (line *ae*), published by the International Monetary Fund.

Money Supplies

Seasonally unadjusted M1 figures are used for all countries. United States: *Main Economic Indicators* (MEI), published by the Organisation for Economic Cooperation and Development. Germany, Japan and United Kingdom: *IFS* (line 34).

Real Income Levels

For all countries seasonally unadjusted figures for industrial production were taken from the *MEI*.

Interest Rates

United Kingdom and United States: treasury bill rates as reported in the *MEI*. Germany and Japan: call money rates, *IFS* (line 60b).

Price Levels and Inflation Rates

Traded and nontraded goods prices are proxied by wholesale price indices (WPIs) and consumer price indices (CPIs), respectively. Wholesale price indices generally pertain to baskets of goods that contain large shares of traded goods relative to baskets of consumer goods, which contain large shares of nontraded consumer services.

Consumer price indices: *IFS* (line 64).
Wholesale price indices: *IFS* (line 63).
Expected long-run inflation rates are proxied by CPI inflation rates over the preceeding twelve-month period.

Index of Leading Indicators (US)

A composite index of 12 leading indicators is taken from the 1984 Handbook of Cyclical Indicators (series 910), US Department of Commerce.

Stock Price Index (US)

Index of stock prices (Standard and Poor's 500 common stocks) as reported in the 1984 Handbook of Cyclical Indicators (series 19), US Department of Commerce.

Notes

1. Natural logarithms of variables are used because we will study the models' ability to predict the *log* of the spot exchange rate. By comparing predictors on the basis of their ability to predict the logarithm of the spot exchange rate, we circumvent any problems arising from Jensen's inequality. Because of Jensen's inequality the best predictor of the level of the spot exchange rate expressed as unit of currency *i* per unit of currency *j* is not generally the best predictor of the level of the spot exchange rate expressed as units of currency *j* per unit of currency *i*.
2. Parzen's CAT criterion for a *k*-variate $AR(p)$ process prescribes minimization (by choice of *p*) of the function

$$CAT(p) = \text{trace}\left(\left[k/N \sum_{j=1}^{p} (\hat{\Omega}^j)^{-1}\right] - (\hat{\Omega}^p)^{-1}\right)$$

where

$$\hat{\Omega}^j = (N/N - kj)\Omega^j,$$

N is the number of observations and Ω^j is the conditional maximum likelihood estimate of the covariance matrix of innovations vector $v(t)$, based on a fitted $AR(j)$ model.
3. We have not experimented with instrumental variables estimation techniques. While it is clearly desirable to use these methods in order to mitigate potential simultaneous equations bias, it appears very difficult, even at the conceptual level, to identify valid instruments in the case of an equation formulated in innovations form.

References

AKAIKE, HIROTUGU, 'A New Look at Statistical Model Identification,' *IEEE Transactions on Automatic Control*, March 1974, **AC-19**: 716–723.

BALASSA, BELA, 'The Purchasing Power Parity Doctrine: A Reappraisal,' *Journal of Political Economy*, December 1964, **72**: 584–596.

BILSON, JOHN F.O., 'The Monetary Approach to the Exchange Rate,' *International Monetary Fund Staff Papers*, March 1978, **25**: 48–75.

CLEMENTS, KENNETH W., AND JACOB A. FRENKEL, 'Exchange Rates, Money and Relative Prices: The Dollar–Pound in the 1920's,' *Journal of International Economics*, May 1980, **10**: 249–262.

DORNBUSCH, RUDIGER, 'Expectations and Exchange Rate Dynamics,' *Journal of Political Economy*, December 1976, **84**: 1161–1176 (1976a).

DORNBUSCH, RUDIGER, 'The Theory of Flexible Exchange Rate Regimes and Macroeconomic Policy,' in Jacob A. Frenkel and Harry G. Johnson, eds, *The Economics of Exchange Rates*, pp. 27–46, Reading: Addison-Wesley, 1976 (1976b).

FINN, MARY G., 'Forecasting the Exchange Rate: A Monetary or Random Walk Phenomenon?,' *Journal of International Money and Finance*, June 1986, **5**: 181–193.

FRANKEL, JEFFREY A., 'On the Mark: A Theory of Floating Exchange Rates Based on Real Interest Differentials,' *American Economic Review*, September 1979, **69**: 610–622.

FRENKEL, JACOB A., 'A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence,' *Scandinavian Journal of Economics*, May 1976, **78**: 200–224.

FRENKEL, JACOB A., 'Flexible Exchange Rates, Prices and the Role of "News": Lessons from the 1970's,' *Journal of Political Economy*, August 1981, **89**: 665–705.

FRENKEL, JACOB A., 'Comment', in John F.O. Bilson and Richard C. Marston, eds, *Exchange Rate Theory and Practice*, Chicago: University of Chicago Press, 1984, 58–62.

FRENKEL, JACOB A., AND MICHAEL L. MUSSA, 'The Efficiency of Foreign Exchange Markets and Measures of Turbulence,' *American Economic Review*, May 1980, **70**: 374–381.

GENBERG, HANS, 'Properties of Innovations in Spot and Forward Exchange Rates and the Role of Money Supply Processes,' in John F.O. Bilson and Richard C. Marston, eds, *Exchange Rates in Theory and Practice*, Chicago: University of Chicago Press, 1984, 153–174.

HANSEN, LARS P., AND ROBERT J. HODRICK, 'Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis,' *Journal of Political Economy*, August 1980, **88**: 829, 853.

HSIEH, DAVID A., 'Tests of Rational Expectations and no Risk Premium in Forward Exchange Markets,' *Journal of International Economics*, August 1984, **17**: 173–184.

INTERNATIONAL MONETARY FUND, *International Financial Statistics*, Various Issues, Washington: International Monetary Fund.

ISARD, PETER, 'What's Wrong with Empirical Exchange Rate Models: Some Critical Issues and New Directions,' International Finance Discussion Papers No. 226, Washington, DC: Federal Reserve Board, 1983.

LITTERMAN, ROBERT, 'A Bayesian Procedure for Forecasting with Vector Autoregressions,' Working Paper, Department of Economics, MIT, 1980.

LOTHIAN, JAMES R., 'Real Dollar Exchange Rates under the Bretton Woods and Floating Exchange-Rate Regimes,' *Journal of International Money and Finance*, December 1986, **5**: 429–448.

LUCAS, ROBERT E., JR., 'Econometric Policy Evaluation: A Critique,' *Carnegie–Rochester Conference Series on Public Policy*, 1976, **1**: 19–46.

MEESE, RICHARD A., AND KENNETH ROGOFF, 'Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?,' *Journal of International Economics*, February 1983, **14**: 3–24 (1983a).

MEESE, RICHARD A., AND KENNETH ROGOFF, 'The Out-of-Sample Failure of Exchange Rate Models: Sampling Error or Misspecification?,' in Jacob A. Frenkel, ed., *Exchange Rates and International Macroeconomics*, Chicago: University of Chicago Press, 1983, 67–105 (1983b).

MUSSA, MICHAEL L., 'Empirical Regularities in the Behavior of Exchange Rates and Theories of the Foreign Exchange Market,' *Carnegie–Rochester Conference Series on Public Policy*, 1979, **11**: 9–57.

MUSSA, MICHAEL L., 'The Theory of Exchange Rate Determination,' in John F.O. Bilson and Richard C. Marston, eds, *Exchange Rate Theory and Practice*, Chicago: University of Chicago Press, 1984, 13–58.

PARZEN, EMMANUEL, 'Multiple Time Series: Determining the Order of Approximating Autoregressive Schemes,' Technical Report No. 23, Statistical Science Division, SUNY at Buffalo, 1975.

SAIDI, NASSER, 'Comment,' in Jacob A. Frenkel, ed., *Exchange Rates and International Macroeconomics*, Chicago Press, 1983, 105–109.

SOMANATH, V.S., 'Efficient Exchange Rate Forecasts: Lagged Models Better than the Random Walk,' *Journal of International Money and Finance*, June 1986, **5**: 195–220.

WOLFF, CHRISTIAN C.P., 'Exchange Rate Models, Parameter Variation and Innovations: A Study on the Forecasting Performance of Empirical Models of Exchange Rate Determination,' Doctoral Dissertation, University of Chicago, 1985.

WOLFF, CHRISTIAN C.P., 'Exchange Rate Models and Innovations: A Derivation,' *Economics Letters*, April 1986, **20**: 373–376.

WOLFF, CHRISTIAN C.P., 'Time-Varying Parameters and the Out-of-Sample Forecasting Performance of Structural Exchange Rate Models,' *Journal of Business and Economic Statistics*, January 1987, **5**: 87–97.

ZELLNER, ARNOLD, 'An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests of Aggregation Bias,' *Journal of the American Statistical Association*, June 1962, **57**: 348–368.