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by

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Introduction

This study compares structural and time series models of exchange rate determination on the basis of their out-of-sample forecasting and explanatory power. We find that a random walk model would have outperformed all the other models as a predictor of the logarithm of major-country exchange rates during the 1970's.[1/]

The narrower implications of our results concern the apparent instability of the underlying macroeconomic structure. Previous studies, which assume a constant structure and test models on the basis of in-sample fit, may not be valid. The parameters may be changing over time, either due to changes in economic policy rules (the Lucas critique), oil supply shocks, technological changes and transfers, or due to more nebulous factors such as political events. The broader implications of the results concern the failure of the structural models to predict or even explain exchange rate behavior out-of-sample. A poor predictive performance could be rationalized by arguing that the explanatory variables (money, income, interest rates, current accounts ...) are difficult to predict, and thus the exchange rate is difficult to predict. However, even when uncertainty about the explanatory variables is purged by using ex-post realized values of these variables, the structural models still fail to fit the data out-of-sample as well as the random walk model. Furthermore, we generate some structural model forecasts by imposing theoretical coefficient

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constraints and using realized explanatory variables. These limited experiments only reinforce the conclusion that existing empirical structural models cannot predict or even <u>explain</u> movements in exchange rates over the 1970's.

In our experiment, each competing model is used to generate forecasts at one to twelve month horizons for the dollar/pound, dollar/mark, dollar/yen and trade-weighted dollar exchange rates.[2/] The parameters of each model are estimated on the basis of the most up-to-date information available at the time of a given forecast. This is accomplished by using rolling regressions to re-estimate the parameters of each model every forecast period.

As representative structural models we choose the monetary model, the Dornbusch-Frankel model and the Hooper-Morton model. This last model extends the Dornbusch-Frankel model to include the effects of the current account. These models have been successful by measures of in-sample fit. They explain poorly out of sample, and fail to outperform the random walk model.

A wide variety of univariate techniques also lose to the random walk model, as does a vector autoregression composed of exchange rates, relative short-term interest rates, relative inflation rates, and the current account.

Even optimally formed linear combinations of forecasts cannot outperform the forecasts of the random walk model. The forward rate does not predict any better than the random walk model either. But the interpretation of its relative performance is somewhat tangential to the main issue here, which is: how good are existing empirical models of exchange rate determination?[3/]

A description of the competing models and the techniques used to estimate them is presented in the first section of the paper. The second section discusses our methodology for comparing models on the basis of out-of-sample fit, and the third section contains the main results. A fourth section looks at linear combinations of the forecasts of the different models.

There are three appendices. One describes the data, and another gives a more comprehensive listing of the empirical results. The third appendix reports tests of the exogeneity specification of the Dornbusch-Frankel model.

I. A Description of the Models

Here we discuss the specification and statistical estimation of the various competing models.

A. The Structural Models

While many models of exchange rate determination have been advanced, the "asset" models have enjoyed the greatest popularity in the recent empirical literature. We include three of the asset models in our study: the monetary (Bilson-Frenkel-Mussa) model, the Dornbusch-Frankel model, and the Hooper-Morton model.[4/] The Dornbusch-Frankel model has the same long-run properties as the monetary model, but allows for slow price adjustment and consequent short-run deviations from purchasing power parity. The Hooper-Morton model extends the Dornbusch-Frankel model to allow for changes in the long-run real exchange rate. These real exchange rate changes are assumed to be correlated with unanticipated shocks to the current account.[5/]

The specification of the three models we use are subsumed in the general specification given in equation (1):

$$e = a_0 + a_1(m - \overset{*}{m}) + a_2(y - \overset{*}{y}) + a_3(r_s - \overset{*}{r}_s) + a_4(\pi - \overset{*}{\pi}) + a_5CA + a_6\overset{*}{CA} + \mu \qquad (1)$$

where e is the logarithm of the exchange rate (in dollars/foreign currency units), $m-\overset{*}{m}$ is the logarithm of the ratio of the U.S. money supply to the foreign money supply, $y-\overset{*}{y}$ is the logarithm of the ratio of U.S. to foreign real output, $r_s - \overset{*}{r}_s$ is the short term interest differential and $\pi - \overset{*}{\pi}$ is the long-term inflation differential. CA and $\overset{*}{CA}$ represent the cumulated U.S. and foreign current accounts, and μ is a disturbance term.

All of the models hypothesize first degree homogeneity in relative money supplies, or $a_1 = 1$. The Bilson-Frenkel-Mussa monetary model, which assumes flexible prices, and purchasing power parity, imposes the additional constraints $a_4 = a_5 = a_6 = 0$. The Dornbusch-Frankel model imposes the constraint $a_5 = a_6 = 0$. None of the coefficients in equation (1) is constrained to be zero in the Hooper-Morton model.[6/]

The approach generally used to compare these types of models involves estimating a model of the general form, and then testing hypotheses on the coefficients.[7/] When overall performance is measured by in-sample fit, regressions based on equation (1) do reasonably well.

One drawback to this approach is that it is difficult to deal with the statistical problems encountered in obtaining consistent estimates of the coefficients in equation (1). Variables such as relative money supplies and relative outputs are treated as exogenous variables in the underlying theoretical models, but may be more realistically thought of as endogenous variables. Other variables, such as the short-term interest differential, are endogenous even in the underlying theoretical models. Yet they are still treated as legitimate regressors in ordinary least squares regressions of equation (1).[8/]

Evidence on the exogeneity specification of the monetary model is presented in Glaessner (1979) and Caves and Feige (1980). In an appendix, we test the exogeneity specification of the Frankel (1979) model, using bilateral data. This specification is rejected for German/U.S. and Japanese/U.S., but not the U.K./U.S. data sets.

In an effort to deal with the possible endogeneity of the right-hand side variables, we estimated the parameters of the structural models using both ordinary least squares and instrumental variables techniques.[9/]

If one of the structural models summarized by equation (1) is true, and if its parameter estimates can be consistently estimated with instrumental variables techniques, then our use of actual realized values of the explanatory variables should help the predictive performance of instrumental variables techniques vis à vis ordinary least squares. However, ordinary least squares parameter estimates always yielded the best structural model forecasts in our experiments.[10/]

While most of the forecasts generated in this study are based on models with freely estimated coefficients, we also tried forecasting the monetary model by imposing priors. The same logic given above for why consistent instrumental variables techniques should predict well applies here. When the coefficient constraints are correct, forecasts based on realized values of the explanatory variables should perform quite well, even when the explanatory variables themselves are difficult to predict.

We based our priors for the monetary model on those presented in Bilson (1978). Bilson, who performs a type of Bayesian estimation of the dollar/DM rate, presents the following 95 percent confidence intervals around his priors on the coefficients of equation (1):

$$
\begin{aligned}
0.9 &\leqq a_1 \leqq 1.1 \\
-0.5 &\geqq a_2 \geqq -1.5 \\
0 &\geqq a_3 \geqq -0.03
\end{aligned}
\tag{2}
$$

(He implicitly sets $a_4 = a_5 = a_6 = 0$.)

When imposing these priors, we still needed to use rolling regressions to estimate and update our out-of-sample forecasts of the seasonals and the constant term. (We also tried setting all the seasonal parameters at zero).

The forecasts based on the monetary model with constrained coefficients did not predict as well as forecasts based on the monetary model with freely estimated coefficients.[11/]

It is considerably more difficult to obtain priors on the other structural models, since the parameters in equation (1) can involve the speed of adjustment coefficient in the goods market. Following Frankel (1979), we did try constraining $a_1 = 1$. However, this constraint did not improve the forecasting performance of his model.

Since we obtain better forecasts by using ordinary least squares than by using either instrumental variables or by imposing priors on the coefficients, we only report the ordinary least squares results for the structural models.

B. Univariate and Multivariate Time Series Models

Several univariate time series models are used in our experiments. All are estimated for the logarithm of the exchange rate.

The first model is a long autoregression (AR) with the order a function of sample size.[12/] Other AR processes are estimated using the Schwarz (1978) and Akaike (1974) criteria for selection of lag length.[13/] Another univariate technique involves direct application of the Wiener-Kolmogorov prediction formula in the frequency domain. (See Sargent (1980)). Finally, a weighted least squares method is used to estimate the parameters of a long autoregression. This procedure uses geometric weights to place greater emphasis on current observations.[14/]

The random walk model, which uses the current spot rate as a predictor of all future spot rates, is also a univariate model. While the basic random walk model obviously requires no estimation, we did try estimating a random walk model with a drift parameter. The drift parameter was estimated as the mean monthly (logarithmic) exchange rate change, calculated on the basis of the sample available at the time of a given forecast.

While differences among these univariate models are of interest, we only discuss the results for the long AR model (with order a function of sample size) and for the random walk model. The performance of the long A.R. model is characteristic of the best of the univariate models with estimated coefficients, while the random walk model performs just as well as the random walk model with drift.[15/]

An unconstrained vector autoregression (VAR) serves as our representative multivariate time series model. The VAR includes current and lagged values of four variables: the logarithm of the exchange rate, the short-term interest differential, the CPI inflation differential and the U.S. current account. The same number of lags of all the variables appear in each of of the exchange rate is given by:

$$e_t = a_1 e_{t-1} + a_2 e_{t-2} \cdots + a\, e_{t-n} + b_1 (r - \overset{*}{r})_{t-1} + \cdots + b_n (r - \overset{*}{r})_{t-n}$$

$$+ C_1 (\pi - \overset{*}{\pi})_{t-1} + \cdots C_n (\pi - \overset{*}{\pi})_{t-n} + d_1 CA_{t-1} + \cdots d_n CA_{t-n} + v_t \tag{2}$$

where v_t is an error term which is serially uncorrelated, but may be contemporaneously correlated with the error terms in the equations for the other variables. Any contemporaneous relationships between the variables are captured here through the covariance matrix of these disturbance terms. The maximum lag length, n, is chosen using a multivariate order selection criterion.[16/]

The four variables in the VAR represent a subset of the variables in the general specification of the structural models, equation (1). Given the limited sample period, there is a tradeoff between including more variables and more lags.

C. Selecting the Data

The data are chosen to conform to the theoretical assumptions underlying the specification of the structural models. A subset of these data is used to estimate the time series models.

All of the raw data used in this study are seasonally unadjusted. This allows us to estimate the seasonal and structural parameters on a consistent basis.[17/] The use of seasonally adjusted data, especially data smoothed with a two-sided filter such as Census X11, can seriously distort the parameter estimates.[18/] Another reason for avoiding seasonally adjusted data is that we wanted to be careful to base all our forecasts on information available at the time of the forecast. Forecasts based on seasonally adjusted data, adjusted over the extended sample period, implicitly make use of information which would not have been available.

The dollar/mark, dollar/pound and dollar/yen spot exchange rate data are monthly point-sample data. We use an average of daily rates for the trade-weighted dollar, partly becasue that data is more readily available and partly to be consistent with other work on the trade-weighted dollar. (See Hooper and Morton (1980)).

For the purposes of this study, point sample data have a decided advantage over monthly average data. Suppose an exchange rate follows a random walk on a mid-day to mid-day basis. Then a series consisting of monthly averages of the mid-day quotes will exhibit positive serial correlation.[19/]

Bilateral forward rates of one, three, six and twelve month maturities, are drawn from the same day of the month as the spot rates. Point-sample short-term and long-term interest rate data also match the spot rate data.

We use treasury bill rates and interbank rates for short-term interest rates. Using these interest rates makes sense when estimating models based on money demand equations. However, Euromarket rates would be more likely to conform to another assumption underlying most of the structural models: perfect asset substitutibility.

Following Frankel (1979), relative long-term interest rates were used as one proxy for relative long-run expected inflation rates. The data are described further in Appendix II.

II. The Methodology for Comparing Models Out-of-Sample

All of the competing models are estimated over a monthly data series which extends back to March 1973, the beginning of the floating rate period. Out-of-sample forecasts are generated for the period December 1976 through November 1980, and for the subperiod December 1978 through November 1980. The choice of the four year forecast period is predicated on our desire to have sufficient degrees of freedom available for initial parameter estimates for all the models, especially the vector autoregression (VAR). We analyze the recent two year sub-period in part because of the major change in U.S. intervention strategy beginning November 1978, and in part to see whether the relative performances of the competing models are different over the recent sub-period than over the entire forecast period.

Each model is initially estimated (for each exchange rate) using data up through the first forecasting period, November 1976. Forecasts are generated at horizons of one, three, six, and twelve months.[20/] Then the data for December 1976 are added to the sample, and the parameters of each model, including the seasonal adjustment parameters, are re-estimated using rolling regressions. New forecasts are generated at one, three, six and twelve month horizons. Then another month of data is added, and so on.

Of course, the structural models require forecasts of their explanatory variables in order to generate forecasts of the exchange rate. In order to give these models the benefit of the doubt, we use actual realized values of their respective explanatory variables. This procedure directly addresses one possible defense of these models: structural exchange rate models have explanatory power, but predict badly because their exogenous (explanatory) variables themselves are difficult to predict.[21/]

All of the models are estimated for the logarithm of the exchange rate, and we compare models on the basis of their ability to predict the logarithm rather than the level of the exchange rate. By comparing predictors on the basis of their ability to predict the logarithm of the exchange rate, we avoid any problems arising from Jensen's inequality.[22/] Because of Jensen's inequality, the best predictor of the level of dollar/mark rate might not be the best predictor of the level of the mark/dollar rate.

Out-of-sample forecast accuracy is measured by three statistics: mean bias, mean absolute bias, and root mean square error.[23/] Because we are looking at the logarithm of the exchange rate, these statistics are unit free and are comparable across currencies.

The methodology used here for comparing models out-of-sample is drawn from the macro literature. (See for example Nelson (1972), Christ (1975), Fair (1980) or Litterman (1979)). Although out-of-sample prediction comparisons have considerable intuitive appeal, presently available techniques are not based on formal hypothesis testing.

We are able to construct a formal test at one month forecast horizons, under the assumption that the models yield unbiased forecasts.[24/] However, at longer forecast horizons, even optimal unbiased forecast errors follow a moving average process. The moving average process is of the order of the forecast horizon minus one.[25/]

III. The Results

Tables I, II, and III broadly characterize the results of our study.

Table I presents average rankings for the seven models. These rankings are a simple average of the models' individual rankings for each statistic (mean bias, mean absolute bias, and root mean square error) for each exchange rate (dollar/mark, dollar/pound, dollar/yen, and the trade weighted dollar) at each forecast horizon (one, three, six, and twelve months).

The random walk model, which uses the current spot rate as a predictor of all future spot rates, outperforms all of the structural and time series models. It ranks first over the entire four year forecasting period, December 1976 through November 1980, and over the recent two year sub-period, December 1978 through November 1980.

Table II breaks down these rankings by forecast horizon. The random walk model ranks ahead of the times series and structural models at all forecast horizons.

At one month horizons, we can formally compare the prediction error variance of an individual estimated model with the prediction error variance of the random walk model. The formal test of equality of variances is only valid under the assumption that both predictors are unbiased. Given this assumption, we find that the random walk model always has the lower one step ahead prediction error variance. In fact, we can reject the null hypothesis of equality of variances at the 10% significance level in almost every case. The only exception is that the long AR model is not significantly worse than the random walk model over the recent two year forecast period for all three bilateral rates, and it is also not significantly worse for the dollar/pound rate over the full four year forecast period.

Table I: Average out-of-sample forecast rankings*
aggregated across exchange rates, horizons and statistics**

Model	Forecast Period (a) December 1976–November 1980	Forecast Period (b) December 1978–November 1980
Random Walk	1.6	1.5
Vector AR	3.0	2.9
Univariate AR	3.0	3.8
Forward Rate	3.3	3.0
Hooper-Morton	4.6	5.4
Dornbusch-Frankel	5.2	4.8
Monetary	6.6	5.9

*In Tables I-III, average rankings do not add to 28 because we did not have forward rate data for the trade-weighted dollar at 1, 3 and 6 month horizons. See Appendix I.

**Exchange rates: dollar/mark, dollar/pound, dollar/yen and the trade-weighted dollar
Forecast horizons: 1 month, 3 months, 6 months, 12 months
Statistics: mean bias, mean absolute bias, root mean square error

Table II: Average out-of-sample forecast rankings at different horizons*

Model	Horizons: one month (a)	one month (b)	three months (a)	three months (b)	six months (a)	six months (b)	twelve months (a)	twelve months (b)
Random Walk	1.4	1.1	1.3	1.2	1.7	1.5	2.1	2.2
Vector AR	3.3	3.5	3.2	2.7	2.8	2.5	2.6	2.8
Univariate AR	1.8	2.1	2.5	3.6	3.5	4.3	4.2	5.3
Forward Rate	3.7	3.4	3.3	2.9	3.2	3.1	3.0	2.5
Hooper-Morton	4.6	5.5	4.5	5.8	4.4	5.0	5.0	5.1
Dornbusch-Frankel	5.6	5.4	5.4	4.9	4.8	4.5	4.9	4.5
Monetary	6.8	6.2	6.8	5.9	6.6	6.0	6.2	5.6

*Rankings are aggregated across exchange rates and statistics

(a) Rankings for the four year forecasting period December 1976 through November 1980
(b) Rankings for the two year forecasting period December 1976 through November 1980

Table III: Average out-of-sample forecast rankings for the individual exchange rates

Exchange Rate

Model	dollar/mark (a)	dollar/mark (b)	dollar/pound (a)	dollar/pound (b)	dollar/yen (a)	dollar/yen (b)	trade-weighted dollar (a)	trade-weighted dollar (b)
Random Walk	1.7	1.4	1.7	1.5	1.7	1.5	1.5	1.8
Vector AR	3.7	3.3	2.4	2.6	3.6	1.9	2.3	3.6
Univariate AR	2.5	3.8	2.1	1.9	4.6	5.2	2.8	4.4
Forward Rate	2.2	1.7	3.8	4.0	4.1	3.6	2.3	1.3
Hooper-Morton	5.2	6.1	5.4	5.0	3.5	6.2	4.5	4.2
Dornbusch-Frankel	5.8	4.8	5.6	6.0	4.5	5.5	4.8	3.0
Monetary	7.0	6.9	7.0	7.0	6.1	4.2	6.2	5.6

*Rankings are aggregated across statistics and horizons

(a) Rankings for the four year forecasting period December 1976 through November 1980
(b) Rankings for the two year forecasting period December 1976 through November 1980

Table III gives the average rankings for the individual exchange rates. The random walk model again ranks ahead of both the time series models and the structural models.

At the risk of distracting from the issue of how well existing empirical models explain the exchange rate, we have included the forward rate in these tables. Given the assumptions of market efficiency and rational expectations, the relative performance of the forward rate may be interpreted as evidence on the existence of a risk premium. For example, the forward rate could predict worse than the random walk model when there is a time-varying risk premium, even if the risk premium is zero on average.[26/]

The spot rate does not always outperform the forward rate. In particular, the forward rate ranks ahead of the spot rate as a predictor of the dollar/mark exchange rate at the longest forecast horizon.

Appendix I contains more detailed results, including the individual statistics at each horizon for each exchange rate. One feature of these results especially worth noting is the way root mean square error rises with the length of the forecast horizon. Under the assumption that the (logarithm of the) exchange rate follows a random walk, we would expect the RMSE of the random walk model to rise with the square root of the forecast horizon. For a damped process, the RMSE of the true model and of the random walk model would rise more slowly, converging (not necessarily monotonically) to a finite limit at long forecast horizons. The RMSE statistics given in Appendix I for the random walk model do very roughly rise with the square root of forecast horizon.

The dominance of the random walk model limits the usefulness of a comparison among the models with estimated coefficients. The relatively strong performance of the long autoregressive (AR) model is due to the low mean bias of its forecasts. It is worth emphasizing that even though exchange rates probably do not follow a random walk exactly, there is no reason that a long A.R. with freely estimated coefficients should predict better than the random walk model. The random walk model may impose a coefficient restriction which is approximately correct. It is well known that imposing such constraints tends to improve forecast accuracy. See Sims (1980) or Litterman (1979) for further discussion.

The relative superiority of the random walk model over the structural models is less pronounced at longer forecasting horizons. Perhaps the structural models benefit more at longer forecasting horizons from our technique of generating their forecasts using actual realized values of their right-hand side (exogenous) variables. The vector autoregression moves up in the rankings at long forecast horizons as well, even though it uses no out-of-sample information to form its forecasts.[27] The VAR forecasts all four of its own variables.

While the random walk model may be as good a predictor as any of major exchange rates, it does not predict well. The root mean square error statistics listed in Appendix I reflect approximate percentage standard deviations, since they apply to the logarithm of the exchange rate. At one month forecasting horizons, the RMSE for the bilateral rates range from 2.3% for the dollar/pound rate to 3.7% for the dollar/yen rate. At twelve months, the root-mean square errors range from 10.2% for dollar/pound rate to 19.1% for the dollar/yen rate. (These are based on the full four year forecasting period.)

While such volatility need not imply structural instability, it certainly cautions against those in-sample testing techniques which ignore the problem entirely. It is clear that conventional in-sample tests which purport to capture the structure of the serial correlation of the exchange rate do not deal adequately with the instability of this structure over time.

IV. Optimal Linear Combinations of Forecasts

Theoretically, optimal linear combinations of two or more unbiased predictors should perform at least as well as any one alone. Even a bad predictor can sometimes be profitably combined with a good predictor; the forecasting gain depends on their covariation.

Here we consider whether it is possible, by estimating weights for the forecasts of the different models (including the random walk model), to produce a forecaster which beats the random walk model. Following Granger and Newbold (1977), we estimate a regression of the form:

$$e_t = a_1 f^1_{t-1} + a_2 f^2_{t-1} + \dots + a_{n-1} f^{n-1}_{t-1}$$

$$+ (1 - a_1 - a_2 - \dots - a_{n-1}) f^n_{t-1} + v_t \qquad (3)$$

where f^j_{t-1} is the one month ahead forecast of the logarithm of the exchange rate, formed using model j based on t-1 information. e_t is the logarithm of the actual exchange rate at time t.

The weights, while constrained to sum to one, do not all have to be positive. We estimate the weights in equation (3) using ordinary least squares. This procedure is valid only for one month ahead forecasts. At longer forecast horizons, the models' forecast errors, will follow a moving average process. Since estimation of a linear combination like equation (3) is more complicated in this case, we choose to focus entirely on one step ahead predictors.

The weights in equation (3) are estimated on the basis of information available at time t-1 only, and are re-estimated each period using rolling regressions. The weighted average forecaster does not generate a forecast for the first n-1 months of the forecasting period, because it requires observations to fit the weights.

We considered linear combinations of the six time series and structural models taken together and also taken two at time. We included the random walk model but excluded the forward rate as here we are not primarily concerned with market efficiency and risk premium issues.

The estimated linear combination of all the forecasts never improves upon the random walk model for any of the three statistical measures of forecast accuracy we use. Estimated linear combinations of the different forecasts taken two at time do sometimes slightly outperform the random walk model. However, no two models combine to outperform the random walk model for more than one exchange rate. Combinations which work slightly better over the two year forecast period do worse over the four year period, and vice versa.[28/]

Conclusions

Three major bilateral exchange rates (the dollar/mark, dollar/pound and dollar/yen) and the trade-weighted dollar are all well-approximated by the random walk model. The representative structural models do not perform well out-of-sample; they predict poorly even when uncertainty about future values of the explanatory variables is removed.

Why are the out-of-sample results presented here so different from the more optimistic in-sample results presented in other studies? Simultaneous equations bias is a possible answer, but this was accounted for by imposing theoretical coefficient constraints, using instrumental variables techniques, and by estimating a vector autoregression. The failure of regressors to satisfy stationarity assumptions implicit in in-sample hypothesis testing is another possibility. If, for example, an explanatory variable follows a nonstationary process, then conventional hypothesis tests may no longer be appropriate. Still another possibility is the presence of nonlinearities in the underlying structural models; we made no attempt to account for this potential problem.

But the most likely explanation for the different picture painted by out-of-sample tests is structural instability. While reasons for the instability are difficult to identify, one possibility is changes in economic policy rules. We are not sure that this was more important than other factors causing structural instability during the seventies: e.g., the two oil shocks, technological changes and transfers, and changes in global trade patterns. But whatever the source, this instability cannot be ignored, and in-sample tests which assume constant parameter values may be an inadequate method of testing exchange rate theories on 1970's data.

The result that the reprensentative structural models do not explain the data out-of-sample is striking. It is quite possible that these models, which focus primarily on financial market phenomena, do not adequately address the sources of real exchange rate instability which characterized the seventies.

Appendix I

The following tables contain the detailed results of our study. There is a separate table for every exchange rate at each forecast horizon. There are also separate tables for the results over the full four year forecasting horizon, December 1976 through November 1978, and the two year subperiod, December 1978 through November 1980. Every table lists mean bias, mean absolute bias and root mean square error statistics for all of the seven competing prediction models. The top row of every table lists average rankings. These rankings are averages of the rankings for each of the three individual statistics.

Table XXXVI includes the statistics for the random walk model with drift.

TABLE IV

$/DM — 1 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.0	2.3	6.0	5.0	7.0	4.0	2.7
MEAN ERROR	-0.0000	0.0085	-0.1342	-0.1212	-0.1774	-0.0441	0.0096
MEAN ABSOLUTE ERROR	0.0286	0.0356	0.1421	0.1271	0.1774	0.0570	0.0378
RMSE	0.0398	0.0467	0.1585	0.1416	0.1858	0.0708	0.0464

TABLE V

$/DM — 3 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.7	1.3	6.0	5.0	7.0	3.3	3.7
MEAN ERROR	-0.0000	0.0098	-0.1544	-0.1337	-0.1899	-0.0363	0.0354
MEAN ABSOLUTE ERROR	0.0430	0.0401	0.1604	0.1394	0.1899	0.0598	0.0632
RMSE	0.0559	0.0493	0.1788	0.1530	0.1990	0.0705	0.0777

TABLE VI

$/DM — 6 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.0	2.0	6.0	5.0	7.0	3.0	4.0
MEAN ERROR	-0.0081	0.0199	-0.1763	-0.1398	-0.1960	-0.0366	0.0764
MEAN ABSOLUTE ERROR	0.0370	0.0442	0.1764	0.1444	0.1980	0.0725	0.0856
RMSE	0.0459	0.0538	0.1986	0.1589	0.2047	0.0822	0.0954

TABLE VII

$/DM — 12 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	2.0	1.0	6.3	4.0	6.7	3.0	5.0
MEAN ERROR	-0.0304	0.0168	-0.2109	-0.1480	-0.2247	-0.0905	0.1526
MEAN ABSOLUTE ERROR	0.0592	0.0341	0.2109	0.1480	0.2247	0.1056	0.1544
RMSE	0.0633	0.0449	0.2327	0.1682	0.2320	0.1195	0.1758

TABLE VIII

$/DM 1 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.3	3.0	5.0	6.0	7.0	4.0	1.7
MEAN ERROR	-0.0048	-0.0102	-0.0932	-0.1084	-0.1446	-0.0448	-0.0014
MEAN ABSOLUTE ERROR	0.0239	0.0359	0.0992	0.1113	0.1446	0.0518	0.0309
RMSE	0.0327	0.0460	0.1227	0.1231	0.1560	0.0643	0.0387

TABLE IX

$/DM 3 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.3	2.3	5.0	6.0	7.0	4.0	2.3
MEAN ERROR	-0.0161	-0.0188	-0.1060	-0.1256	-0.1592	-0.0482	-0.0044
MEAN ABSOLUTE ERROR	0.0400	0.0436	0.1116	0.1283	0.1592	0.0623	0.0621
RMSE	0.0511	0.0544	0.1384	0.1385	0.1699	0.0746	0.0733

TABLE X

$/DM 6 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.7	2.0	5.3	5.7	7.0	3.3	3.0
MEAN ERROR	-0.0376	-0.0274	-0.1327	-0.1484	-0.1768	-0.0602	-0.0072
MEAN ABSOLUTE ERROR	0.0514	0.0564	0.1332	0.1504	0.1768	0.0783	0.0966
RMSE	0.0627	0.0656	0.1604	0.1566	0.1835	0.0915	0.1119

TABLE XI

$/DM 12 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	2.3	1.3	5.3	5.7	7.0	3.3	3.0
MEAN ERROR	-0.0854	-0.0623	-0.1856	-0.1928	-0.2165	-0.1188	-0.0011
MEAN ABSOLUTE ERROR	0.0957	0.0801	0.1856	0.1928	0.2185	0.1241	0.1746
RMSE	0.1061	0.0982	0.2033	0.2032	0.2232	0.1364	0.1974

TABLE XII

$/YEN — 1 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.0	4.0	5.7	6.7	5.7	3.0	2.0
MEAN ERROR	0.0039	0.0158	0.0393	0.0255	-0.0217	-0.0149	-0.0074
MEAN ABSOLUTE ERROR	0.0308	0.0560	0.0831	0.0880	0.0867	0.0467	0.0346
RMSE	0.0372	0.0698	0.1140	0.1200	0.1151	0.0602	0.0434

TABLE XIII

$/YEN — 3 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.3	3.3	7.0	5.7	4.3	1.7	4.7
MEAN ERROR	0.0092	0.0345	0.0634	0.0403	-0.0275	0.0001	-0.0435
MEAN ABSOLUTE ERROR	0.0538	0.0889	0.1139	0.1085	0.1073	0.0613	0.1068
RMSE	0.0683	0.0988	0.1581	0.1501	0.1475	0.0722	0.1270

TABLE XIV

$/YEN — 6 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.7	3.3	6.0	4.7	4.0	1.3	7.0
MEAN ERROR	0.0196	0.0626	0.1275	0.0908	-0.0338	0.0281	-0.1620
MEAN ABSOLUTE ERROR	0.0978	0.1227	0.1540	0.1299	0.1332	0.0879	0.2279
RMSE	0.1067	0.1361	0.2194	0.1799	0.1635	0.1006	0.2570

TABLE XV

$/YEN — 12 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	2.0	3.7	6.0	5.0	2.7	1.7	7.0
MEAN ERROR	0.0655	0.1358	0.2846	0.2319	-0.0299	0.0745	-0.4492
MEAN ABSOLUTE ERROR	0.1178	0.1373	0.2846	0.2319	0.1424	0.0950	0.5464
RMSE	0.1421	0.1883	0.3046	0.2493	0.1557	0.1316	0.6091

TABLE XVI

$/YEN 1 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.3	4.0	4.3	5.7	7.0	4.0	1.7
MEAN ERROR	-0.0066	-0.0179	-0.0082	-0.0234	-0.0717	-0.0350	-0.0051
MEAN ABSOLUTE ERROR	0.0283	0.0571	0.0713	0.0801	0.1042	0.0512	0.0352
RMSE	0.0371	0.0711	0.1025	0.1066	0.1282	0.0668	0.0447

TABLE XVII

$/YEN 3 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.3	4.0	3.3	5.3	7.0	3.3	3.7
MEAN ERROR	-0.0211	-0.0229	-0.0031	-0.0271	-0.0864	-0.0419	-0.0224
MEAN ABSOLUTE ERROR	0.0579	0.0918	0.0895	0.0983	0.1245	0.0725	0.0902
RMSE	0.0722	0.1022	0.1314	0.1294	0.1532	0.0902	0.1125

TABLE XVIII

$/YEN 6 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	2.0	3.7	2.7	3.3	6.3	3.3	6.7
MEAN ERROR	-0.0386	-0.0296	0.0083	-0.0255	-0.1047	-0.0501	-0.0560
MEAN ABSOLUTE ERROR	0.1094	0.1352	0.1161	0.1230	0.1490	0.1188	0.1839
RMSE	0.1207	0.1470	0.1700	0.1548	0.1744	0.1339	0.2287

TABLE XIX

$/YEN 12 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	2.0	4.7	3.7	3.7	4.0	3.7	6.3
MEAN ERROR	-0.0605	-0.0351	0.0338	-0.0174	-0.1289	-0.0712	-0.0625
MEAN ABSOLUTE ERROR	0.1663	0.1858	0.1816	0.1915	0.1767	0.1744	0.4311
RMSE	0.1908	0.2229	0.2156	0.2119	0.2019	0.2115	0.5326

TABLE XX

$/¥ 1 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.3	4.0	5.0	6.0	7.0	3.0	1.7
MEAN ERROR	-0.0084	-0.0260	-0.1007	-0.1237	-0.2183	-0.0187	-0.0080
MEAN ABSOLUTE ERROR	0.0198	0.0352	0.1041	0.1238	0.2183	0.0311	0.0249
RMSE	0.0255	0.0432	0.1191	0.1367	0.2210	0.0397	0.0306

TABLE XXI

$/¥ 3 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.0	4.0	5.0	6.0	7.0	2.7	2.3
MEAN ERROR	-0.0261	-0.0466	-0.1217	-0.1363	-0.2394	-0.0360	-0.0315
MEAN ABSOLUTE ERROR	0.0370	0.0490	0.1217	0.1363	0.2394	0.0421	0.0431
RMSE	0.0442	0.0567	0.1370	0.1482	0.2424	0.0532	0.0490

TABLE XXII

$/¥ 6 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.7	4.0	5.0	6.0	7.0	3.0	1.3
MEAN ERROR	-0.0551	-0.0798	-0.1495	-0.1578	-0.2661	-0.0602	-0.0495
MEAN ABSOLUTE ERROR	0.0551	0.0816	0.1495	0.1578	0.2661	0.0635	0.0521
RMSE	0.0624	0.0897	0.1608	0.1702	0.2692	0.0735	0.0671

TABLE XXIII

$/¥ 12 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	2.0	4.0	5.0	6.0	7.0	1.7	2.3
MEAN ERROR	-0.0950	-0.1169	-0.1906	-0.2024	-0.3078	-0.0943	-0.0942
MEAN ABSOLUTE ERROR	0.0950	0.1169	0.1906	0.2024	0.3078	0.0943	0.0967
RMSE	0.0987	0.1255	0.2000	0.2104	0.3122	0.0989	0.1079

TABLE XXIV

$/£ 1 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.7	4.0	5.0	6.0	7.0	2.3	2.0
MEAN ERROR	-0.0071	-0.0250	-0.0842	-0.0855	-0.1359	0.0026	-0.0048
MEAN ABSOLUTE ERROR	0.0179	0.0368	0.0943	0.1095	0.1581	0.0342	0.0203
RMSE	0.0232	0.0442	0.1120	0.1240	0.1761	0.0424	0.0260

TABLE XXV

$/£ 3 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.7	3.7	5.3	5.7	7.0	2.7	2.0
MEAN ERROR	-0.0226	-0.0448	-0.1123	-0.1026	-0.1549	-0.0115	-0.0192
MEAN ABSOLUTE ERROR	0.0350	0.0499	0.1200	0.1292	0.1800	0.0485	0.0406
RMSE	0.0434	0.0579	0.1383	0.1427	0.1962	0.0592	0.0520

TABLE XXVI

$/£ 6 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.7	4.0	5.3	5.7	7.0	2.7	1.7
MEAN ERROR	-0.0464	-0.0777	-0.1458	-0.1328	-0.1847	-0.0353	-0.0287
MEAN ABSOLUTE ERROR	0.0476	0.0788	0.1491	0.1530	0.2039	0.0632	0.0556
RMSE	0.0581	0.0869	0.1659	0.1671	0.2199	0.0747	0.0729

TABLE XXVII

$/£ 12 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.7	3.7	6.0	5.0	7.0	2.0	2.7
MEAN ERROR	-0.0961	-0.1347	-0.2177	-0.2041	-0.2509	-0.0848	-0.0510
MEAN ABSOLUTE ERROR	0.0961	0.1347	0.2177	0.2057	0.2518	0.1016	0.1223
RMSE	0.1016	[illegible]	0.2271	0.2212	0.2687	0.1083	0.1532

TABLE XXVIII

W.A.$ 1 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.0	N.A.	5.3	3.7	5.0	4.0	2.0
MEAN ERROR	-0.0002	-	0.0132	0.0096	0.0291	0.0321	0.0039
MEAN ABSOLUTE ERROR	0.0141	-	0.0449	0.0384	0.0426	0.0339	0.0190
RMSE	0.0185	-	0.0545	0.0475	0.0494	0.0430	0.0250

TABLE XXIX

W.A.$ 3 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.0	N.A	5.0	2.8	5.3	3.0	3.8
MEAN ERROR	0.0020	-	0.0126	0.0084	0.0343	0.0331	0.0153
MEAN ABSOLUTE ERROR	0.0247	-	0.0484	0.0405	0.0482	0.0376	0.0407
RMSE	0.0316	-	0.0581	0.0499	0.0546	0.0463	0.0498

TABLE XXX

W.A.$ 6 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.7	N.A.	3.3	2.3	6.0	2.7	5.0
MEAN ERROR	0.0084	-	0.0071	0.0027	0.0424	0.0206	0.0365
MEAN ABSOLUTE ERROR	0.0224	-	0.0459	0.0383	0.0543	0.0321	0.0481
RMSE	0.0266	-	0.0561	0.0478	0.0616	0.0422	0.0595

TABLE XXXI

W.A.$ 12 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1978.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	2.7	1.3	3.2	3.0	6.0	4.8	7.0
MEAN ERROR	0.0140	-0.0107	-0.0070	-0.0126	0.0623	0.0402	0.1011
MEAN ABSOLUTE ERROR	0.0220	0.0171	0.0421	0.0387	0.0724	0.0444	0.1011
RMSE	0.0245	0.0237	0.0523	0.0483	0.0835	0.0522	0.1148

TABLE XXXII

W.A.$ 1 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.3	N.A.	4.3	4.7	6.0	3.0	1.7
MEAN ERROR	0.0035	-	0.0298	0.0325	0.0449	0.0199	0.0027
MEAN ABSOLUTE ERROR	0.0134	-	0.0459	0.0469	0.0517	0.0333	0.0171
RMSE	0.0175	-	0.0541	0.0541	0.0579	0.0409	0.0234

TABLE XXXIII

W.A.$ 3 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.0	N.A.	4.3	4.7	6.0	3.0	2.0
MEAN ERROR	0.0125	-	0.0398	0.0423	0.0564	0.0196	0.0128
MEAN ABSOLUTE ERROR	0.0243	-	0.0569	0.0576	0.0631	0.0474	0.0335
RMSE	0.0321	-	0.0658	0.0657	0.0695	0.6571	0.0428

TABLE XXXIV

W.A.$ 6 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	1.3	N.A.	4.5	4.5	6.0	2.0	2.7
MEAN ERROR	0.0279	-	0.0545	0.0557	0.0732	0.0181	0.0333
MEAN ABSOLUTE ERROR	0.0359	-	0.0717	0.0714	0.0784	0.0500	0.0502
RMSE	0.0434	-	0.0818	0.0819	0.0860	0.0608	0.0597

TABLE XXXV

W.A.$ 12 MONTH AHEAD OUT-OF-SAMPLE PREDICTION ERRORS: 1976.12-1980.11

MODEL:	RANDOM WALK	FORWARD RATE	HOOPER-MORTON	DORNBUSCH-FRANKEL	MONETARY	VECTOR AR	UNIVARIATE AR
AVERAGE RANK OVER ALL STATISTICS	2.3	2.3	5.0	5.3	7.0	1.3	4.7
MEAN ERROR	0.0591	0.0557	0.0863	0.0859	0.1135	0.0582	0.0902
MEAN ABSOLUTE ERROR	0.0629	0.0669	0.1036	0.1040	0.1170	0.0609	0.0949
RMSE	0.0760	0.0856	0.1179	0.1203	0.1285	0.0746	0.1073

Table XXXVI: Random Walk with Drift Model

	$/DM		$/yen		$/£		trade-weighted $	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
<u>Model</u>/<u>Statistic</u>/<u>Horizon</u>								
<u>ONE MONTH</u>								
Mean Bias	-.015	-.007	-.087	-.062	.003	.001	.070	.054
Mean Absolute Bias	.028	.029	.087	.062	.017	.019	.070	.054
RMSE	.036	.041	.098	.072	.022	.024	.074	.058
<u>THREE MONTHS</u>								
Mean Bias	-.027	-.007	-.103	-.057	-.013	-.016	.080	.057
Mean Absolute Bias	.045	.043	.108	.067	.031	.032	.081	.058
RMSE	.057	.057	.128	.087	.039	.039	.088	.066
<u>SIX MONTHS</u>								
Mean Bias	-.049	-.016	-.122	-.057	-.036	-.043	.097	.064
Mean Absolute Bias	.059	.038	.143	.067	.040	.044	.097	.065
RMSE	.071	.048	.173	.087	.051	.054	.105	.069
<u>TWELVE MONTHS</u>								
Mean Bias	-.097	-.038	-.147	-.004	-.086	-.085	.131	.072
Mean Absolute Bias	.106	.064	.188	.109	.086	.085	.131	.072
RMSE	.117	.068	.242	.124	.092	.089	.143	.075

(a) Forecasting period December 1976 through November 1980
(b) Forecasting period December 1978 through November 1980

Appendix II**/

The raw data used in this paper are all seasonally unadjusted. Whenever possible, daily data are drawn from identical observation dates across series. In the bilaterial data sets for Germany and the United Kingdom, the spot and forward exchange rates, short-term interest rate, and long-term bond rate are always drawn from the same date. Because a daily bond rate series is not readily available for Japan, only the exchange and interest rate dates correspond in this data set. All other bilateral series as well as all of the series used in the trade-weighted data set, are monthly data. All data are taken from publicly available sources.

The Bilateral Data Sets

The bilateral data sets draw exchange rate data from identical sources, as follows:

One, Six, and Twelve-Month Forward Exchange Rates

Data Source: Data Resources, Inc. data base.

Series: One, six, and twelve-month forward bid rates in U.S. dollars per local currency unit.

Description: Daily data based on 10:00 a.m. opening New York market rates.

Three-Month Forward and Spot Exchange Rates

Data Source: Federal Reserve Board data base.

Series: Three-month forward and spot bid rates in U.S. dollars per local currency unit.

Description: Daily data based on 12:00 noon New York market rates.

Sources of the other bilateral data series are discussed below by country.

Germany

Bond Yields

Data Source: Deutsche Bundesbank, Statistical Supplement to the Monthly Reports of the Deutsche Bundesbank, Series 2, Securities Statistics, Table 7b.

**/ Written with Julie Withers

Series: Yields in percent per annum on fully taxed outstanding bonds of the Federal Republic of Germany.

Description: Monthly data. Data are calculated as averages of four bank-week return dates including the end-of-month yield of the preceding month.

Consumer Prices

Data Source: Deutsche Bundesbank, Monthly Report of the Deutsche Bundesbank, Table VIII-7.

Series: Total cost of living index for all households.

Description: Monthly index with 1976=100.

Industrial Production

Data Source: O.E.C.D., Main Economic Indicators.

Series: Total industrial production.

Description: Monthly index with 1975=100.

Interest Rates (Three-Month)

Data Source: Frankfurter Allegemeine Zeitung.

Series: "Geldmarket Vierteljahresgeld" in percent per annum.

Description: Daily data.

Money Supply (M1)

Data Source: O.E.C.D., Main Economic Indicators.

Series: M1 money supply in billions of DM.

Description: Monthly data. Data refer to the last banking day of the month.

Adjustment: A break in the series, caused by the introduction of a new method of computation, occurs in December, 1973. The 1973 statistics are adjusted using the ratio of the new to the old statistic for December, 1973.

Trade Balance

Data Source: O.E.C.D., Main Economic Indicators.

Series: Trade balance (f.o.b. - c.i.f.) in billions of DM.

Description: Monthly data.

Japan

Bond Yields

Data Source: Bank of Japan, Economic Statistics Monthly, Table 71(2).

Series: Yields in percent per annum on listed government bonds (Tokyo Stock Exchange).

Description: Monthly data. Data refer to the last banking day of the month.

Consumer Prices

Data Source: Bank of Japan, Economic Statistics Monthly, Table 119(1).

Series: General consumer price index for all Japan.

Description: Monthly index with 1975=100.

Industrial Production

Data Source: O.E.C.D., Main Economic Indicators.

Series: Total industrial production.

Description: Monthly index with 1975=100.

Interest Rates (Three-Month)

Data Source: Federal Reserve Board data base.

Series: "Over two-month ends" bill discount rate (Tokyo Stock Exchange) in percent per annum.

Description: Daily data based on Reuters quotes.

Money supply (M1)

Data Source: O.E.C.D., Main Economic Indicators.

Series: M1 money supply in billions of yen.

Description: Monthly data. Data refer to the last banking day of the month.

Trade Balance

Data Source: O.E.C.D., Main Economic Indicators.

Series: Trade balance (f.o.b. - c.i.f.) in billions of yen.

Description: Monthly data.

United Kingdom

Bond Yields

Data Source: Financial Times

Series: "British funds, Undated, War loans 3½%" in percent per annum.

Description: Daily data.

Consumer Prices

Data Source: Department of Employment, Employment Gazette, Table 6.4.

Series: General index of retail prices, all items.

Description: Monthly index with 1974=100.

Industrial Production

Data Source: O.E.C.D., Main Economic Indicators.

Series: Three-month local authority deposits (London money rates) in percent per annum.

Description: Daily data.

Interest Rates (Three-Month)

Data Source: Financial Times.

Series: Three-month local authority deposits (London money rates) in percent per annum.

Description: Daily data.

Money Supply (M1)

Data Source: O.E.C.D., Main Economic Indicators.

Series: M1 money supply in millions of pounds.

Description: Monthly data. Data refer to the third Wednesday of the month (second in December).

Trade Balance

Data Source: O.E.C.D., Main Economic Indicators.

Series: Trade balance (f.o.b. - c.i.f.) in millions of pounds.

Description: Monthly data.

United States

With the exception of the trade balance statistics, all data are taken from the Federal Reserve Board data base. Many of these series are published in the Federal Reserve Bulletin, and all are available to the public.

Trade Balance

Data Through 1978:

Data Source: Department of Commerce, Highlights of U.S. Export and Import Trade, Exports Table E-1; Imports Table I-1.

Series: Domestic and foreign exports, excluding Department of Defense shipments, in millions of $ on a F.A.S. value basis; General imports in millions of $ on a Customs Valuation basis changing to a F.A.S. basis in 1974.

Description: Monthly data.

Adjustment: 1973 statistics are adjusted to a F.A.S. value basis using the 1974 average ratio of Customs Valuation to F.A.S. value.

1979-1980 Data:

Data Source: Department of Commerce, Summary of U.S. Export and Import Merchandise Trade, December 1980 (advance statistics for Highlights of U.S. Export and Import Trade), Exports Table 3; Imports Table 5.

Series: Total domestic exports, excluding Department of Defense grant-aid, in millions of $ on a F.A.S. value basis; General imports in millions of $ on a F.A.S. value basis.

Description: Monthly data.

THE TRADE-WEIGHTED DATA SET

The weights utilized to determine the trade-weighted statistics are as follows:

Foreign Currency	Multilateral Weight
German mark	.208
Japanese yen	.136
French franc	.131
United Kingdom pound ..	.119
Canadian dollar	.091
Italian lira	.090
Netherlands guilder ...	.083
Belgian franc	.064
Swedish Krona	.042
Swiss franc	.036
Sum	1.000

These weights represent each country's share of the total trade (measured by the sum of imports plus exports) of all ten countries in the period 1972 through 1976. For further discussion of trade-weight determination consult Peter Hooper and John Morton, "Summary Measures of the Dollar's Foreign Exchange Value" in the Federal Reserve Bulletin, October 1978.

The trade-weighted data set draws from the bilateral data sets for statistics for Germany, Japan, the United Kingdom, and the United States. The data sources for the other countries are discussed below by series.

Bond yields

France:	Morgan Guarantee Trust Company, World Financial Markets.
All others:	O.E.C.D., Main Economic Indicators.

Consumer Prices

Belgium:	Banque Nationale de Belgique, Bulletin.
Canada:	Statistics Canada, The Consumer Price Index.
France:	Institut National de la Statistique et des Études Économiques, Bulletin Mensuel de Statistique.
Italy:	Istituto Centrale di Statistica, Bolletino Mensile di Statistica.
Netherlands:	Central Bureau Voor de Statistiek, Maandschirift.
Sweden:	Statistiska Centralbyrån, Allmän Månadsstatistik.
Switzerland:	Banque Nationale Suisse, Bulletin Mensuel.

Industrial Production

All:	O.E.C.D., Main Economic Indicators.

Money Supply (M1)

Belgium:	Banque Nationale de Belgique, Bulletin.
Netherlands:	Central Bureau Voor de Statistiek, Maandschrift.
All others:	O.E.C.D., Main Economic Indicators.

Appendix III

In this appendix we test the joint exogeneity specification of the Frankel (1979) exchange rate model. In this model the logarithm of relative money supplies $\tilde{m}(t)$, the logarithm of relative national incomes $\tilde{y}(t)$, and the long term interest differential $\tilde{i}(t)$ are assumed to be exogenous with respect to the logarithm of the exchange rate s(t) and the short term interest differential $\tilde{r}(t)$. All variables are described in more detail in Appendix II.[28/]

As is well known, the failure of s(t) and $\tilde{r}(t)$ to Granger cause $\tilde{m}(t)$, $\tilde{y}(t)$, and $\tilde{i}(t)$ is a necessary but not a sufficient condition for the above exogeneity assumptions to hold, since we cannot test simultaneous causality. Thus, failure to reject the exogeneity specification is not decisive.

The statistical methodology for this test is provided by Geweke (1978). Sampling experiments reported in Geweke, Meese, and Dent (1981) suggest that a "Granger type test" will provide accurate type I errors when the null hypothesis is true and accurate type II errors when it is not true. In a Granger test of the null hypothesis that s(t) and $\tilde{r}(t)$ do not Granger cause $\tilde{m}(t)$, $\tilde{y}(t)$, and $\tilde{i}(t)$, the regression equations have the following form:

$$\tilde{m}(t) = \sum_{j=1}^{M} \alpha_1(j)\tilde{m}(t-j) + \sum_{j=1}^{M} \beta_1(j)\tilde{y}(t-j) + \sum_{j=1}^{M} \gamma_1(j)\tilde{i}(t-j)$$

$$+ \sum_{j=1}^{N} \theta_1(j)s(t-j) + \sum_{j=1}^{N} \Phi_1(j)\tilde{r}(t-j) + \varepsilon_1(t) \tag{1}$$

There are two additional regression equations with $\tilde{y}(t)$ and $\tilde{i}(t)$ as regressands, and the same set of RHS variables. The usual assumptions of the multivariate regression model apply to the (3x1) vector of disturbances $\underline{\varepsilon}(t)' = (\varepsilon_1(t), \varepsilon_2(t), \varepsilon_3(t))$.

For the reasons discussed in Geweke (1978), p. 178, we choose the lag on the hypothesized exogenous variables M to be 8 and the lag on the endogenous variables N to be 2. We report the likelihood ratio statistics for the test that $\theta_i(j)$ and $\Phi_i(j)$ are jointly zero, j=1, ..., N and i=1,2,3. Following Sims (1980), we correct the test statistic for degrees of freedom to avoid a bias in favor of rejection of the null hypothesis that s(t) and $\tilde{r}(t)$ fail to Granger cause $\tilde{m}(t)$, $\tilde{y}(t)$ and $\tilde{i}(t)$. All data were seasonally adjusted by the method described in Sims (1974a). There are 87 observations on the dependent variable. Results are organized by country in following table.

The individual equation F statistics are tests of the hypothesis that $\theta_i(j) = 0$ and $\emptyset_i(j) = 0$, j = 1, ... N, in equation i. As tests of only part of the overall exogeneity specification, these statistics should be regarded as only descriptive.

Based on the χ^2 statistics for the overall test, there is strong evidence that the joint exogeneity specification of the Frankel model is inappropriate for the dollar/mark and dollar/yen exchange rates.

Table A

Tests of the Exogeneity Specification of the Frankel (1979) Model

statistic \ currency		$/DM	$/£	$/Yen
Overall test of the exogeneity specification, χ^2 (12)		27.92**	13.74	22.59*
Individual Equations F(4,58)	m(t)	3.4722*	2.127	1.998
	y(t)	0.682	.9642	2.717*
	i(t)	4.155**	.5286	3.206*

* denotes significance at 5% level

** denotes significance at 1% level

Footnotes

1/ Cornell (1977), Mussa (1979) and Frenkel (1981) have noted that exchange rate changes are largely unpredictable. Mussa (p.10) states that; "The natural logarithm of the spot exchange rate follows approximately a random walk." The present study systematically confirms this "stylized fact." Another point Mussa makes and the results of this study support, is that the limited serial correlation found in the exchange rates by in-sample tests is likely to be unstable over time.

2/ The trade-weighted dollar is a weighted average of U.S. dollar exchange rates with the Group of Ten countries plus Switzerland. (See Appendix II).

3/ The relative performance of the forward rate bears on issues such as market efficiency and the existence of an exchange rate risk premium.

4/ See Bilson (1978), (1979), Frenkel (1976), Mussa (1976), Dornbusch (1976), Frankel (1979), and Hooper and Morton (1980).

5/ Hooper and Morton assume that changes in the level of the current account are unanticipated.

6/ Frankel (1980) presents a similar empirical model, where the cumulated current accounts of both countries enter because of wealth terms in the money demand equation. Branson, Halttunen and Masson (1979) also include the cumulated current accounts in empirical exchange rate equations. Their justification derives from the assumption of imperfect asset substitutability.

7/ See for example, Frankel (1979), (1980), or Hooper and Morton (1980).

8/ Similiar observations have been made by Hodrick (1979). Driskill and Sheffrin (1981) estimate and test the Frankel (1979) model imposing rational expectations. When they assume simple exogenous processes for relative incomes and money supplies and account for the endogeneity of the short term interest differential, they find little support for the Frankel (1979) model. Frankel (1981) has updated and re-estimated his model taking into consideration the criticisms of Hodrick (1979), Driskill and Sheffrin (1981), and Haynes and Stone (1980). The latter authors argue against a specification of equation (1) where variables enter in relative (domestic to foreign) terms rather than separately. Despite the new work on the Dornbusch-Frankel model, we feel that the underlying exogeneity assumptions continue to be suspect. In addition, when we experiment with a version of equation (1) which allows for separate coefficients on domestic and foreign money supplies and real outputs there is no gain in predictive accuracy over the versions of equation (1) we report below.

9/ For instrumental variables estimation we employ the lag one values of a subset of RHS variables in (1) as instruments. This may be inadequate since the presence of autocorrelation in the disturbance is a reasonable possibility. While it is still possible to estimate a simultaneous equation model in the presence of autocorrelated errors, the maintained hypothesis must include (1) a known form of the serial correlation, and (2) the correct endogenous/exogenous variable dichotomy. Since neither of these conditions are likely to be known a priori, we include in our study a vector autoregression of exchange rates, relative interest rates, relative price levels, and the U.S. trade balance. In such a model, no variables are assumed to be exogenous a priori.

10/ Other authors have noted similiar results for models estimated by both OLS and instrumental variables techniques. It has been found that OLS is more robust against specification errors than many instrumental variables techniques (Maddala (1977) p. 231), and that predictions from models estimated by OLS compare favorably with those from models estimated with simultaneous equations methods.

11/ When the coefficients of the monetary model are constrained to the midpoint of the ranges given in (2), root mean square errors of forecasts increase by more than tenfold.

12/ The order of the autoregression is N/log N, where N is the sample size. (rounded down to the nearest integer) A deterministic rule such as this has been employed in spectral estimation (Hannan (1970), Chapter 5), and has been applied to distributed lag models by Sims (1974b). The advantage of this procedure is that it ensures consistent parameter estimates when the lag length is finite, but unknown.

13/ The Schwarz (1978) criterion provides a consistent estimate of lag length, while the Akaike criterion was designed to minimize mean square prediction errors of the dependent variable. The relative merits of these procedures are discussed in Amemiya (1980) and Geweke and Meese (1981).

14/ We used a geometric sequence with weight .95. This was an arbitrary choice.

15/ Cornell (1977) suggests that exchange rates may be characterized as diffusion processes with drift. However, the random walk model with drift model does not forecast as well as the straight random walk with drift the case of the dollar/pound exchange rate. There, however, the improvement is marginal. For the sake of completeness, we have included the statistics for the random walk with drift model in Appendix I.

16/ This procedure is described in Parzen (1975). Lag length n is chosen to minimize the quantity

$$\mathrm{trace}[4/T \sum_{j=1}^{n} \hat{V}_j^{-1} - \hat{V}_n^{-1}], \; n = 1, \ldots M,$$

where T is sample size, M is the maximal lag considered, and $\hat{V}_j$ is an estimate of the contemporaneous covariance matrix of disturbances for the model with j lags. In our study, the VAR lag lengths selected for the dollar/mark, dollar/pound, dollar/yen and trade-weighted dollar are 6, 1, 2 and 6 respectively.

17/ We experimented with two different seasonal adjustment procedures. One method uses seasonal dummy variables. The other uses Sims' (1974a) method which explicitly allows the seasonal parameterization to expand with sample size. As the results of our experiment are robust to the choice between these two techniques, we only report the results for the more conventional dummy variables procedure.

18/ This is especially true when not all the variables are seasonally adjusted by the same method. See Sims (1974a,b) for a further discussion.

19/ This observation has been made by Working (1960). The serial correlation arises whether or not the monthly averages overlap. Despite this consideration, the results of section IV indicate that the random walk model is still a good predictor of the monthly average trade-weighted dollar.

20/ These forecast horizons are chosen to correspond to the available forward rate data.

21/ "It is likely that the bulk of observed changes in exchange rates will be related to 'unanticipated' changes in the basic determinants of the exchange rate", Mussa (1979, p. 45). An 'unanticipated' change in a variable is the part that is unpredictable on the basis of pasy history. Thus our use of realized explanatory variables removes a major source of uncertainty from the structural model predictors.

22/ Siegel (1972) notes that because $1/x$ is a convex function of the random variable x, $E(1/x)$ is not in general equal to $1/E(x)$. McCulloch (1975) suggests that this problem is not important empirically, given the historical variance of the exchange rate. Both analyses are based on an erroneous Taylor expansion which yields $E(1/x) - 1/E(x) * \mathrm{Var}(x)/E(x)^3$. This expression may be misleading because the Taylor expansion used to derive it is local, whereas the expectations integral is global. While the above expression is precisely correct when x follows a lognormal distribution, it can be way off when the distribution of x is skewed. Consider the discrete probability density function: $P(x=1) = .99$, $P(x=.01) = .01$. Then $E(1/x) - 1/E(x) = 1.99 - 1.01 = .98$. However $\frac{\mathrm{Var}(x)}{E(x)^3} \simeq .01$. The order of magnitude of the Jensen's inequality term is more likely to be large in data sets where an outside chance of a major intervention is incorporated into expectations.

23/ Let $k = 1, 3, 6, 12$ denote the forecast step, N_k the total number of forecasts in the projection period for which the actual value $A(t)$ is known, $F(t)$ denote the forecast value, and let forecasting begin in period $(t+1)$. Define

$$\text{Mean error} = \sum_{s=0}^{N_k-1} (F(t + s + k) - A(t + s + k))/N_k$$

$$\text{Mean absolute error} = \sum_{s=0}^{N_k-1} \left| F(t + s + k) - A(t + s + k) \right|/N_k$$

$$\text{Root mean square error} = \left(\sum_{s=0}^{N_k-1} (F(t + s + k) - A(t + s + k))^2/N_k \right)^{\frac{1}{2}}$$

24/ Consider two forecast errors $e^1(t)$ and $e^2(t)$ from models (1) and (2). Consider the pair of random variables $r(t) = (e^1(t) + e^2(t))$ and $s(t) = (e^1(t) - e^2(t))$. The covariance of $r(t)$ and $s(t)$ is the difference $\mathrm{var}(e^1(t)) - \mathrm{var}(e^2(t))$ given the assumption of unbiased forecasts. The forecast errors have equal variance if and only if $r(t)$ and $s(t)$ are uncorrelated. This test of zero correlation can be based on the sample correlation coefficient of $r(t)$ and $s(t)$, see Granger and Newbold (1977, p. 281) for further detail.

25/ The moving average process arises in the same manner as the one discussed in Hansen and Hodrick (1980a).

26/ A number of recent authors including Bilson (1980), Cumby and Obstfeld (1980), Geweke and Feige (1979), Hakkio (1980), Hansen and Hodrick (1980a, b), Meese and Singleton (1980), and Tryon (1979) have found evidence of the divergence of forward rates from expected future spot rates over the recent floating rate period. Bilson (1980), however, is the only author who uses an out-of-sample testing methodology. Although his model is not included in the results reported in Tables I-III, it too failed to outperform the random walk model at one month horizons.

27/ Litterman (1979), in an extensive study of VAR models, finds similar results. There, VAR procedures improve relative to structural or univariate time series models as the forecast horizon increases.

28/ Even if one combination of two forecasters had consistently and significantly beaten the random walk model, the results would not be decisive. We would still need an on ex-ante basis for choosing which two forecasters to combine.

29/ Frankel (1979), uses the long-term interest differential as one exogenous proxy for the long-run inflation differential. He also treats the short-term interest differential as an exogenous variable. We base our specification on the rational expectations version of his model, where the short-term interest differential is unambiguously an endogenous variable.

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