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Exchange rate forecasts with the Michigan Quarterly Econometric Model of the US economy

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Gandolfo et al. [*Journal of Banking and Finance* 14 (1990) 965–992] have shown that their continuous time model of the Italian economy produces better ex post out-of-sample forecasts of the lira/$ exchange rate than either existing structural or random-walk models. When the Michigan Quarterly Econometric Model is used, it is found that ex post out-of-sample forecasts of the trade-weighted value of the US dollar produced by the model are also superior to forecasts of a random-walk model. However, ex ante forecasts in which all the exogenous as well as the endogenous variables are forecast are less accurate than those produced by the random walk. The price of imported goods in foreign currency, an exogenous variable in both the Michigan and Italian econometric models, is the key variable in the Michigan model which explains the divergence of the ex ante and ex post forecasting results.

Keywords: Exchange rate forecasts; Structural econometric models; Random walk

JEL classification: F47; C53; C32; C22

1. Introduction

Gandolfo, Padoan and Paladino (1990) (GPP) report that out-of-sample forecasts of the lira/$ exchange rate using a continuous-time model of the Italian economy outperform forecasts of a random-walk model. They offer this result as an antidote to those who would interpret the predictive failure of the single-equation models of the exchange rate examined by Meese and Rogoff (1983a, b) as a failure of economic theory. While the results obtained from the Italian model are suggestive, it is not clear to what extent they are

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specific to the Italian economy or are due to the use of an economy-wide model, a continuous-time model, the particular variables that are taken to be exogenous for purposes of the out-of-sample forecasts, or the particular sample period that was examined.

The purpose of this paper is to present the results of an attempt to replicate the GPP experiment using the Michigan Quarterly Econometric Model (MQEM) of the US economy to forecast a trade-weighted average of the value of the US dollar. A brief overview of MQEM is given in the next section and the exchange-rate equation that is used in MQEM is introduced. For purposes of comparison, a set of single-equation 'structural' models of the exchange rate of the type investigated by Meese and Rogoff (1983a, b) are also introduced. The results of the forecast exercise are discussed in section 3. Section 4 concludes the paper.

2. Structural models of the exchange rate

2.1. *The Michigan Quarterly Econometric Model*[1]

The Michigan Quarterly Econometric Model of the US economy is a forecasting and policy analysis model maintained by the Research Seminar in Quantitative Economics at the University of Michigan and is used to produce forecasts of the US economy on a regular basis. The first version of what is today called MQEM was the now-classic Klein–Goldberger model, an annual model containing 20 equations. The version of the model used for this study contains 206 equations, 99 of which are stochastic.

2.1.1. *Overview of MQEM*

The block structure of MQEM is shown in table 1. Blocks 1 (wages and prices) and 2 (productivity and employment) implicitly comprise the supply side of the model. The basic wage rate, hourly compensation in the private nonfarm sector of the economy, is determined by an expectations-augmented Phillips curve. The corresponding core price index, the nonfarm price deflator, is determined by a variable mark-up on unit labor costs, but also depends on interest rates and crude materials prices.

The aggregate demand sector of the model is represented by the equations in blocks 3, 4, and 5. This part of the model has an IS–LM interpretation which is derived in Green et al. (1991). The IS curve can be derived from the equations in blocks 3 and 4 that explain expenditures and income flows; the LM curve can be obtained from the equations of the monetary sector (block 5). As a result of adaptive expectations and partial adjustment specifications

[1]This section draws heavily on Hymans (1990) and Green et al. (1991).

Table 1
Block structure of MQEM.

	Block	Principal endogenous variables
(1)	Wages and prices	Compensation per hour Private nonfarm GNP deflator 20 GNP component deflators Three energy price deflators Index of the exchange value of the dollar Automobile and truck price indexes
(2)	Productivity and employment	Output per hour Employment rate, males 20 and over Aggregate unemployment rate

(3)	Expenditures, purchases	Unit vehicle sales
		  US cars and trucks
		  Imported cars and trucks
		Consumption
		  Autos, new
		  Autos, net used and parts
		  Trucks
		  Furniture and household equipment
		  Other durables
		  Five nondurables components
		  Services
		Business fixed investment
		  Structures
		  Equipment
		    Agriculture
		    Production
		    Autos
		    Trucks
		    Other
		Residential building
		  Housing starts
		Inventory investment
		  New autos
		  Trucks
		  Nonfarm, nonvehicle
		Imports
		  Non-petroleum
		    Autos, trucks
		Exports

(4)	Income flows	Private wages and salaries Profits Interest income Dividends Other labor income Nonfarm proprietor income Farm proprietor income Govt. unemployment benefits Taxes Capital consumption allowances Interest on government debt To foreigners
(5)	Monetary sector	M1 plus total savings deposits M2 plus short term treasury securities Three-month Treasury bill rate Budget identity Six term structure equations Monetary base Govt. demand deposits
(6)	Output composition	Services component of real GNP Manufacturing index of industrial production Index of available capacity in manufacturing Gross auto product Gross truck product

for many of the equations, the IS and LM curves are much steeper in the short run than in the long run.

2.1.2. Exchange-rate determination in MQEM

The exchange rate in MQEM is determined directly by a variable purchasing power parity (PPP) relationship. The structural equation estimated over the period 1973:2–1987:4 is

$$\begin{aligned}\Delta \ln e = {} & \underset{(0.002)}{0.0021} + \underset{(0.044)}{1.0161}\Delta \ln p_f/p + \underset{(0.042)}{0.1102}\Delta[\ln p_f/p]_{-1} \\ & + \underset{(0.007)}{0.0210}\Delta \ln r/r_f + \underset{(0.011)}{0.0320}\ln [x+k]_{-1}/[m+tr+i_f], \qquad (1)\end{aligned}$$

with $R^2=0.938$, s.e. $=0.011$, DW $=1.82$ and where

e = the trade-weighted value of the US dollar relative to G-10 countries plus Switzerland,
p_f = the implicit deflator for non-oil goods and services imported by the US denominated in foreign currencies
p = the US export price deflator,
r = three-month US Treasury bill rate,
r_f = trade weighted average of three-month foreign interest rates,
x = US exports of goods and services (current dollars),
k = net capital grants received by the US (current dollars),
m = US imports of goods and services (current dollars),
tr = personal and federal government transfers to foreigners (current dollars),
i_f = federal government interest payments to foreigners (current dollars).

If there is no differential between US and foreign interest rates and the (lagged) US current account is in balance, the last two terms in this equation are zero and the exchange rate moves to restore PPP among currencies. The presence of an interest rate differential or a current account imbalance modulates the movement of the exchange rate. In particular, if the US short-term interest rate exceeds foreign interest rates or the US has a current account surplus, there will be upward pressure on the value of the US dollar. In standard forecasting mode, MQEM takes p_f, r/r_f, tr, and k to be exogenous.

2.2. Single-equation models of the exchange rate

For purposes of comparison with MQEM, forecasts of single-equation 'structural' models of the exchange rate are also examined. The general form of these models is taken from Meese and Rogoff (1983a, b). Let e_{jt} denote the natural logarithm of the exchange rate between the US and country j in period t. Then the general form of the exchange-rate equation is

$$e_{jt}=\alpha_{j0}+\alpha_{j1}(m_t-m_{jt})+\alpha_{j2}(y_t-y_{jt})+\alpha_{j3}(rs_t-rs_{jt})$$

$$+\alpha_{j4}(rl_t-rl_{jt})+\alpha_{j5}(ca_t-ca_{jt})+\alpha_{j6}e_{jt-1}+u_{jt}, \quad (2.a)$$

$$u_{jt}=\rho_j u_{jt-1}+v_{jt}, \quad (2.b)$$

where the independent variables are defined as follows:

m = natural logarithm of the money stock,
y = natural logarithm of income,
rs = short-term interest rate,
rl = long-term interest rate,
ca = cumulated current account balance.

A variable with a t subscript designates the US value of the variable at time t and a variable with a jt subscript designates the value of the variable for country j at time t.

Three versions of this model were used in the forecasting exercise. The unrestricted equation corresponds to the model developed by Hooper and Morton (1982) and is designated as HM. With the restriction $\alpha_{j5}=0$ the equation reduces to the model investigated by Dornbusch (1976) and Frankel (1979) and is designated as DF. Finally, with the restrictions $\alpha_{j4}=\alpha_{j5}=0$, the equation reduces to the model investigated by Frenkel (1976) and Bilson (1978) and is designated as FB.

In its most general form, eq. (2) includes a lagged dependent variable e_{jt-1} and allows for serial correlation of the disturbance term u_{jt}. It turned out to be redundant from the point of view of forecast accuracy to include both lagged adjustment and serially correlated disturbances simultaneously, so three versions of each model were estimated: (a) $\alpha_{j6}=\rho_j=0$, (b) $\alpha_{j6}=0$, and (c) $\rho_j=0$. Thus variant (a) does not allow for dynamic adjustment of either type, variant (b) allows for autocorrelated disturbances, and variant (c) allows for lagged adjustment of the exchange rate.

Previous research has used variants of this equation to investigate both bilateral exchange rates and an index of bilateral exchange rates. For example, Meese and Rogoff (1983a) report results for both selected bilateral rates and an index of US exchange rates; Hooper and Morton (1982) were concerned exclusively with an average of US exchange rates. In order to obtain forecasts of the trade weighted value of the dollar relative to G-10 countries plus Switzerland which are required for comparison with MQEM, it is necessary to aggregate (2) over the countries in the index. Two different aggregation procedures were used. The first method involves aggregation of the bilateral exchange rate equation assuming that the coefficients $\alpha_{jk}=\beta_k$ and $\rho_j=\rho$ for all j, i.e., the bilateral coefficients are the same for all countries over which the equation is aggregated. If w_j denotes the (fixed) weight attached to e_{jt} in the exchange rate index e_t, then

$$e_t=\sum_j w_j e_{jt}. \tag{3}$$

The aggregate equation then becomes

$$e_t=\beta_0+\beta_1(m_t-m_{ft})+\beta_2(y_t-y_{ft})+\beta_3(rs_t-rs_{ft})+\beta_4(rl_t-rl_{ft})$$

$$+\beta_5(ca_t-ca_{ft})+\beta_6 e_{t-1}+u_{ft}, \tag{4.a}$$

$$u_{ft}=\rho u_{ft-1}+v_t, \tag{4.b}$$

where a variable with the ft subscript denotes a weighted average of the values of the variable for the countries in the index with weights equal to w_j. The coefficients in this aggregate equation are then estimated and the resulting equation is used to generate forecasts. The second procedure involves estimation of the coefficients in the bilateral equation, using these estimates to generate forecasts of the bilateral exchange rate, and then aggregating the bilateral forecasts using (3).

The first approach, aggregate and then estimate, is the method used by Hooper and Morton (1982) and Meese and Rogoff (1983a). The advantage of this approach is that only one equation is estimated with the index of exchange rates as the dependent variable. The potential disadvantages of this approach are that it assumes at least implicitly that the coefficients in the bilateral exchange rate equation are the same for all countries in the index and the sample is limited to the period for which data are available for all of the countries in the index. The potential advantage of the second approach, estimate and then aggregate, is that it allows the country coefficients to differ and each bilateral equation can be estimated using all the data available for that country.

3. Empirical results

The forecast period chosen for study is 1985:1–1990:3. As shown in fig. 1, the value of the dollar declined sharply during the first half of this forecast period and then varied about what appears to be a more normal historical value thereafter. Both one- and four-quarter ahead forecasts of the natural

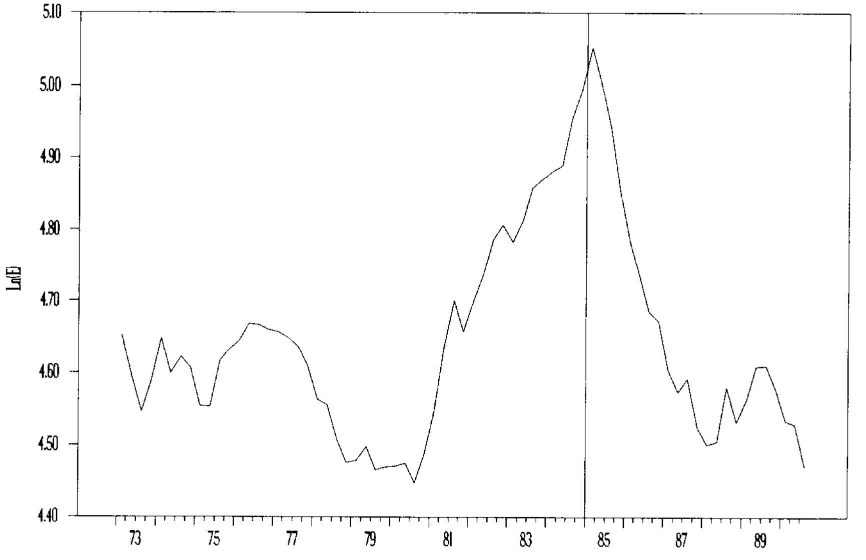

Fig. 1. Logarithm of the trade weighted value of the US dollar, 1973:1–1990:3.

logarithm of the trade weighted value of the dollar were generated. There are thus 23 one-quarter ahead forecasts and 20 four-quarter ahead forecasts.

3.1. Single-equation forecasts

The definitions of the variables used to estimate the single-equation models and the sample periods for which they were available are shown in the Data Appendix. When the aggregate eq. (4) was estimated over the period 1982:1–1990:3, the longest period for which data for all the countries in the exchange rate index were available, the results shown in table 2 were obtained. Based on the Durbin–Watson (DW) statistics, some correction for serial correlation is clearly required for the FB and DF models. And based on the standard error of the estimate (s.e.), the lagged dependent variable version of each of the three models fits the data better than either of the other two variants. For the lagged dependent variable versions of the models, the money stock differential is significant for all three models but the real income differential is not. The evidence on the interest rate differentials in the lagged adjustment models is mixed: the short-term interest rate differential is significant in the FB model, neither the short-term nor the long-term interest rate differential is individually significant in the DF model, and the long-term but not the short-term interest rate differential is significant in the HM lagged adjustment model. Finally, the capital account differential is statistically significant in the HM model.

Table 2

Parameter estimates of structural models of the aggregate US exchange rate: 1982:1–1990:3.[a]

Model	Constant	$m-m_f$	$y-y_f$	$rs-rs_f$	$rl-rl_f$	$ca-ca_f$	e_{-1}	ρ	s.e./DW
FB (a)	−5.163	−3.782	8.073	−0.022					0.103
	(−4.00)	(−7.66)	(5.26)	(−1.32)					0.472
FB (b)	−3.568	−1.022	1.071	−0.016				0.999	0.045
	(−0.59)	(−1.47)	(0.83)	(−1.41)				(13.30)	1.552
FB (c)	−1.055	−0.578	0.325	0.017			0.910		0.035
	(−2.03)	(−2.13)	(0.44)	(2.67)			(15.07)		2.055
DF (a)	−2.113	−2.634	0.764	−0.091	0.174				0.083
	(−1.65)	(−5.41)	(0.35)	(−4.22)	(4.12)				0.669
DF (b)	−2.193	−0.901	0.740	−0.030	0.033			0.998	0.045
	(−0.44)	(−1.29)	(2.72)	(−1.90)	(1.26)			(12.00)	1.831
DF (c)	−0.782	−0.582	−0.462	0.002	0.031		0.851		0.033
	(−1.44)	(−2.18)	(−0.51)	(0.20)	(1.44)		(11.81)		2.081
HM (a)	0.226	−1.744	2.964	−0.074	0.095	0.084			0.039
	(0.35)	(−7.13)	(2.85)	(−7.23)	(4.43)	(10.16)			1.829
HM (b)	0.274	−1.727	2.946	−0.073	0.093	0.084		0.051	0.040
	(0.40)	(−6.67)	(2.72)	(−6.81)	(4.21)	(9.63)		(0.23)	1.911
HM (c)	−0.330	−0.933	0.801	−0.023	0.049	0.032	0.563		0.033
	(−0.59)	(−3.03)	(0.75)	(−1.35)	(2.19)	(2.01)	(3.55)		2.081

[a] t-Statistics are shown in parentheses.

Table 3

Root mean squared errors of in-sample forecasts of the US exchange rate (ln E): 1985:1–1990:3.

	Aggregate equation: forecast horizon		Bilateral equations: forecast horizon	
Model	1 Qtr.	4 Qtr.	1 Qtr.	4 Qtr.
FB (a)	0.1113	0.1097	0.1372	0.1032
FB (b)	0.0436	0.0968	0.0443	0.1074
FB (c)	0.0364	0.0477	0.0401	0.0805
DF (a)	0.0828	0.0885	0.1115	0.0901
DF (b)	0.0407	0.0881	0.0447	0.1099
DF (c)	0.0341	0.0443	0.0398	0.0786
HM (a)	0.0355	0.0378	0.0796	0.06311
HM (b)	0.0355	0.0377	0.0390	0.0800
HM (c)	0.0312	0.0353	0.0396	0.0806
RW	0.0495	0.1431	0.0495	0.1431

When the estimated equations shown in table 2 were used to generate one- and four-quarter ahead forecasts for the period 1985:1–1990:3, the results shown in table 3 were obtained. These forecasts are not true ex ante forecasts for two reasons: the entire sample period including the forecast period is used to estimate the coefficients in the equations and the independent variables are set equal to their actual values. For models with a lagged dependent variable or autocorrelated disturbance term, one-quarter ahead forecasts used the actual value of the lagged dependent variable or lagged residual; four-quarter ahead forecasts were generated sequentially with predicted values for the lagged dependent variable or lagged residual. For purposes of comparison, the forecasts of a random-walk model, RW, are also included.

The results for the in-sample forecasts shown in table 3 indicate that the best forecasts are produced by the lagged dependent variable versions of all three model, a result that might have been anticipated on the basis of the standard errors of the regression equations reported in table 2. The aggregate equations produce slightly more accurate forecasts than the aggregated bilateral equations for the one-quarter ahead forecasts and much better four-quarter ahead forecasts. Finally, notice that the lagged dependent variable versions of these models produce forecasts that have smaller root mean squared forecast errors than the random walk model. The differences in rmse values are much larger for the four-quarter ahead forecasts than for the one-quarter ahead forecasts. The finding that the random walk is dominated by the aggregate structural equations is not that surprising since the lagged dependent variable versions of the models encompass the random-walk model as a special case and the least squares estimates of the coefficients ensure the best possible fit over a period that includes the forecast period.

A more rigorous test of the single-equation models is provided by rolling-regression forecasts in which the model is estimated using data prior to the forecast period. The results of a rolling-regression experiment are shown in table 4. The key point that emerges from these calculations is that with only a few exceptions, the random-walk forecasts are more accurate than the single-equation forecasts. It is interesting to note that the bilateral approach produces more accurate one-quarter ahead forecasts than the corresponding aggregate approach, but the improvement over the random-walk forecasts is negligible. For the four-quarter ahead forecasts, only the aggregate DF model with autocorrelated disturbances produces better forecasts than the random walk, and again the difference in accuracy is relatively small.

The conclusion from these forecasting experiments is that it is possible to construct single equation 'structural' models of the exchange rate index that generate more accurate in-sample forecasts than the random walk, but this superiority does not extend to out-of-sample forecasts.

3.2. MQEM forecasts

The root mean squared errors (rmse) of the alternative MQEM forecasts are shown in table 5. For one-quarter ahead forecasts, the simple random

Table 4

Root mean squared errors of rolling-regression forecasts of the US exchange rate (ln E): 1985:1–1990:3.[a]

	Aggregate equation: forecast horizon		Bilateral equations: forecast horizon	
Model	1 Qtr.	4 Qtr.	1 Qtr.	4 Qtr.
FB (a)	0.1273	0.1745	0.1704	0.2301
FB (b)	0.0649	0.1688	0.0512	0.1505
FB (c)	0.0488	0.2029	0.0464	0.1417
DF (a)	0.1043	0.1589	0.1499	0.2102
DF (b)	0.0670	0.1120	0.0532	0.1638
DF (c)	0.0506	0.2117	0.0471	0.1489
HM (a)	0.0688	0.1806	0.1187	0.2587
HM (b)	0.0764	0.1758	0.0504	0.1744
HM (c)	0.0589	0.2462	0.0513	0.2098
RW	0.0495	0.1431	0.0495	0.1431

[a] The rolling-regression forecasts are based on estimates of the model coefficients that use only data prior to the forecast period.

Table 5

Root mean squared errors of MQEM forecasts of the US exchange rate (ln E): 1985:1–1990:3.[a]

	Forecast horizon	
Model	1 Qtr.	4 Qtr.
Random walk	0.0495	0.1431
Random walk with drift	0.0508	0.1250
MQEM single equation	0.0097	0.0285
MQEM complete model	0.0125	0.0441
MQEM augmented model A	0.0120	0.0420
MQEM augmented model B	0.0470	0.1519
MQEM augmented model C	0.0575	0.1950

[a] The single-equation forecasts (random walk with drift and MQEM single equation) are based on rolling-regression estimates of the model coefficients using only data prior to the forecast period. For the full-model forecasts, the exchange rate equation is estimated over the period 1973:2–1987:4.

walk model has a rmse of 0.0495 or 4.95%, since it is the natural logarithm of the exchange rate that is being predicted. The rmse of the four-quarter ahead forecasts from the simple random walk model is 14.31%. As seen in the second row of entries in the table, it makes little difference in terms of forecast accuracy whether or not a constant term is included in the random walk model.

Using the MQEM exchange-rate equation as a single-equation model with all of the explanatory variables in the equation taken as exogenous results in a dramatic improvement in the accuracy of the exchange-rate forecasts. The rmse of one-quarter ahead rolling-regression forecasts falls to 0.97% compared to 4.95% for the random-walk model, and for the four-quarter ahead forecasts the rmse is 2.85% compared to 14.35% for the random-walk model. Even when the exchange-rate equation is embedded in the full model so that the exchange rate, the export deflator, the value of exports and the value of imports are forecast simultaneously with all of the other endogenous variables of the model, the exchange-rate forecasts are still much more accurate than the random-walk forecasts. The rmse of one-quarter ahead forecasts is now 1.25% and the rmse of four-quarter ahead forecasts is 4.41%; both well below the corresponding rmse values for the random-walk forecasts.[2]

The use of an economy-wide forecasting model for the US economy produces exchange-rate forecasts that are decidedly superior to those produced by a random-walk model. These full-model forecasting results for the US economy are consistent with the results obtained by Gandolfo, Padoan, and Paladino for the Italian economy using a continuous-time simultaneous equations model. This indicates that the GPP results are not specific to the Italian economy nor necessarily due to the use of a continuous-time model.

The full-model forecasts take both p_f and r/r_f as exogenous and hence given. This gives the structural model the 'benefit of the doubt' as a descriptive model, but leaves unanswered the question of how well the model would perform relative to the random-walk model in a true ex ante forecasting exercise. In an attempt to answer that question, it is necessary to augment the model to explain these two potentially critical variables, p_f and r/r_f. This is done in two steps: first an equation is added to explain r/r_f, and then an equation is added to explain p_f. The interest rate differential equation is based on the notion that foreign interest rates respond with a distributed lag to changes in the US rate. The empirical equation estimated over the period 1973:3–1990:3 is

$$\begin{aligned}\ln r/r_f = &-\underset{(0.176)}{0.1287}+\underset{(0.067)}{0.7622}\ln r-\underset{(0.082)}{0.7166}\ln r_{-1}+\underset{(0.083)}{0.5735}\ln[r/r_f]_{-1}\\ &+\underset{(0.139)}{0.7133}u_{-1},\end{aligned} \tag{5}$$

with $R^2=0.911$, s.e.$=0.062$, and DW$=1.76$. (The term u_{-1} indicates that the equation was estimated with a correction for first-order serial correlation.)

[2]The single-equation forecasts (random walk with drift and MQEM single equation) are rolling-regression forecasts in which the coefficients were estimated using data prior to the forecast period; for the full-model forecasts, the exchange rate equation is estimated over the period 1973:2–1987:4.

When this equation is added to the model, r_f becomes an endogenous variable since the domestic interest rate, r, is an endogenous variable in MQEM. The forecast results, shown as MQEM augmented model A in table 5, indicate that the root mean square forecast errors of both the one- and four-quarter ahead forecasts *fall* slightly. We therefore conclude that prior knowledge of the actual interest rate differential is not critical in forecasting the exchange rate.

An equation is also needed for p_f to complete this experiment. Using the standard Box–Jenkins modelling procedure, a univariate ARIMA(1,1,0) equation was found using data for the period 1973:2–1990:3:

$$\underset{(0.007)}{\Delta \ln p_f = 0.0112} + \underset{(0.113)}{0.4042\Delta \ln[p_f]_{-1}}, \tag{6}$$

with $R^2=0.158$, s.e. $=0.037$, DW $=2.03$. When this equation is appended to the model, the results shown as MQEM augmented model B in table 4 were obtained. These results indicate that better forecasts of p_f than those produced by a 'naive' time series model are necessary in order to obtain the result that MQEM delivers better forecasts of the exchange rate than the random-walk model.

Notice, however, that the simple time series model for $\ln p_f$ does not produce a very good fit; the standard error of the estimate is 0.037 or 3.7%. A much better fit can be obtained with a bivariate model in which the change in the logarithm of p_f responds with a distributed lag to the change in the logarithm of the domestic US price level expressed in terms of foreign currency:

$$\Delta \ln p_f = \underset{(0.034)}{0.8233\Delta \ln cpi{*}e} - \underset{(0.082)}{0.5708\Delta \ln [cpi{*}e]_{-1}} + \underset{(0.094)}{0.6224\Delta \ln [p_f]_{-1}}, \tag{7}$$

with $R^2=0.918$, s.e. $=0.012$, DW $=2.07$. However, when this equation is added to the model, the results shown as MQEM augmented model C in table 5 were obtained. Even though this simple 'pricing to market' equation for p_f fits the data rather well, when combined with the rest of the model it produces forecasts of the exchange rate which are worse than those of the random-walk model. A number of variations on this model were tried including dropping the contemporaneous value of $\Delta \ln cpi{*}e$ from the equation and entering $\Delta \ln cpi_{-1}$ and $\Delta \ln e_{-1}$ separately. All such attempts were unsuccessful in terms of obtaining a model with improved ex ante forecast accuracy.

While the results in table 5 indicate that it is possible to find a structural equation which will produce better outside-sample forecasts than the random-walk model, they do not address the question of the statistical significance of the differences in forecast accuracy. The results of three tests

Table 6

Tests against the random-walk model.[a]

Model	Forecast horizon 1 Quarter W-K	W-K*	D-M	4 Quarters W-K	W-K*	D-M
MQEM single equation	11.33	13.42	5.31	12.75	14.17	2.21
MQEM complete model	8.71	11.67	5.08	6.96	4.46	2.01
MQEM augmented model A	9.09	12.02	5.12	7.50	4.84	2.04
MQEM augmented model B	0.50	0.46	0.46	−0.81	−0.62	−0.59
MQEM augmented model C	−0.72	−0.84	−0.75	−1.56	−0.76	−0.75

[a] The MQEM single-equation forecasts are based on rolling-regression estimates of the model coefficients using only data prior to the forecast period. For the full-model forecasts, the exchange rate equation is estimated over the period 1973:2–1987:4.

of significance are shown in table 6. The test designated by W-K is the Williams–Kloot described in Williams (1959), the test designated by W-K* is the Williams–Kloot test corrected for heteroskedasticity and serial correlation, and D-M is the test statistic proposed by Diebold and Mariano (1991). Let f_1 and f_2 denote alternative forecasts of the variable y and let e_1 and e_2 denote the corresponding forecast errors. The W-K test statistic is the t-ratio for a test of the hypothesis that the coefficient of f_1-f_2 is zero in the regression of $y-(f_1+f_2)/2$ on f_1-f_2. A significant t-ratio leads to a rejection of the hypothesis that the forecast error variance is the same for the two forecasts. The W-K* statistic for the one-quarter ahead forecasts corrects the t-statistic for heteroskedasticity and the W-K* statistic for the four-quarter ahead forecasts corrects for heteroskedasticity and for third-order serial correlation using the estimator proposed by Newey and West (1987). The D-M test involves a test of the hypothesis that the mean difference $d=e_1{}^2-e_2{}^2$ is zero with an appropriate correction for serial correlation in the d series.

The results of these tests uniformly agree that for both one- and four-quarter ahead forecasts, the MQEM single equation forecasts, the MQEM complete model forecasts, and the MQEM augmented model A forecasts have significantly smaller mean squared errors than the random-walk forecasts. On the other hand, the MQEM augmented model B and model C forecasts have root mean squared errors that do not differ significantly from the random-walk forecasts.

4. Conclusion

The results of this paper indicate that standard single-equation 'structural' models of the exchange rate do not produce appreciably better out-of-sample forecasts of an index of US exchange rates than a random walk. However, the structural equation for the exchange value of the US dollar in the Michigan Quarterly Econometric Model of the US economy does produce significantly better out-of-sample forecasts than a random-walk model. Even when the exchange-rate equation is embedded in the full model so that the exchange rate, the export deflator, the value of exports and the value of imports are forecast simultaneously with all of the other endogenous variables of the model, the exchange-rate forecasts are still much more accurate than the random-walk forecasts. However, the results are extremely sensitive to the particular variables that are specified as exogenous and hence taken as given for the out-of-sample forecasts. In particular, one of the key variables is the price of US imports denominated in foreign currencies. With this variable taken as exogenous, as it is in the experiments reported by Gandolfo, Padoan, and Paladino for the Italian economy, the MQEM out-of-sample forecasts are strikingly more accurate than those produced by the random-walk model. But if the import price must be predicted in advance, as would be necessary in a true ex ante forecast, the decided edge in forecast accuracy of MQEM disappears.

The results of this paper illustrate a general and well-known problem in the use of conditional (ex post) forecasts to compare and evaluate different models. And that is that one model may produce much better forecasts than another, not because it is a better forecasting model, but because the information set on which its forecasts are based is much more informative. This potential difficulty is especially acute in the comparison and evaluation of economy-wide models which often contain a large number of exogenous variables. It is important to standardize the information set on which forecasts from alternative models are based in order to draw inferences about model reliability from a comparison of ex post forecasts.

Data appendix

The data used to estimate the aggregate and bilateral exchange rate equations were obtained from various sources including the Division of International Finance of the Board of Governors of the Federal Reserve System, the Federal Reserve Bank of St. Louis, and the Research Seminar in Quantitative Economics at the University of Michigan. Real GNP was used to measure income, narrowly defined money (M1) was used to measure the money supply, a three-month Treasury bill rate or interbank interest rate was used for the short-term interest rate, and bellwether bond yields were used to measure the long-term interest rate.

The aggregate exchange rate is a trade-weighted average of the ten bilateral exchange rates with the weights shown in the following table. The sample periods for which the data for each of the G-10 countries plus Switzerland were available are also shown in the table.

Country	Weight	Sample period
Belgium	6.4	75:1–90:3
Canada	9.1	71:1–90:3
France	13.1	73:1–90:3
Germany	20.8	73:1–90:3
Italy	9.0	75:1–90:3
Japan	13.6	77:2–90:3
Netherlands	8.3	75:1–90:3
Sweden	4.2	82:1–90:3
Switzerland	3.6	74:1–91:3
United Kingdom	11.9	73:3–90:3

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