CAN ECONOMISTS FORECAST EXCHANGE RATES?

IF SO, IS IT PROFITABLE?

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ABSTRACT

Critics claim that traditional economic models explain a near zero proportion of exchange rate variation, and cannot outperform a random walk in post-sample forecasting. Perceived deficiencies include undue reliance on single equation methods and inadequate modelling of expectations. In addressing these issues, this paper develops a simultaneous rational expectations model of the US dollar/Deutschemark market, using information from both spot and futures markets.

Post-sample, this model significantly outperforms forecasts by rival predictors such as a random walk and a lagged futures rate. This latter comparison suggests that the market is not semi-strong form efficient. A trading routine based on the model produced significant returns after allowance is made for the Treasury Bill rate and the variability of returns.

JEL Codes: G13, G14, F13.

Key Words: simultaneous model; exchange rates; rational expectations; trading routine.

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I Introduction

Critics such as Isard (1987) and Meese (1990) have emphasized the poor performance, in recent decades, of traditional economic models of exchange rate determination. These models are unable to outperform a naïve random walk model in post-sample forecasting, a deficiency which has been attributed to undue reliance on single equation methods, inadequate modeling of expectations and insufficient attention to capital flows (Isard, 1987, pp 3, 15, 16; Meese, 1990, p 117). **This paper addresses these issues by developing a simultaneous rational expectations model of the US dollar/Deutschemark market, using information from both spot and futures markets.** The paper has its foundations in the theoretical model of Peston and Yamey (1960), and in the empirical exchange rate models of Goss and Avsar (1996, 2000). In particular, it extends the work of Goss and Avsar (1996, 2000) by endogenising the risk premium, by testing for non-linearities, and by employing the model for simulated trading purposes.

In recent research on the informational efficiency of the foreign exchange market, the likelihood of rejection of the efficient markets hypothesis (EMH) generally, has varied directly with the width of the information set. For example, while Frenkel (1981), Bilson (1981), Baillie, Lippens and McMahon (1983) and Baillie, Bailey and McMahon (1984) did not reject the unbiasedness hypothesis, for a range of major currencies against the US dollar, with single equation estimation, Bilson (1981) and Baillie *et al* (1984) did reject that hypothesis with SURE estimation.

Hansen and Hodrick (1980) rejected the semi-strong EMH for the Deutschemark, Canadian dollar and Swiss franc against the US dollar, where the public information set was defined as prior forecast errors for own and other major currencies. Geweke and Feige (1979), using a methodology similar to that of Hansen and Hodrick (1980), did not reject the EMH for the USD/DM, USD/GBP, USD/SF and USD/FF considered separately, but did reject that hypothesis for the group of currencies with SURE estimation. Goss and Avsar (1996, 2000), using the model prediction approach (see below) rejected the semi-strong EMH for the AUD/USD and USD/DM markets (see also surveys by Hodrick (1987, pp 54-56, 140-50); Baillie and McMahon (1989, pp 162-79), Taylor (1995, pp 13-21) and Stein and Paladino (1998, pp 1685-99)).

In Section II of this paper the model specification is discussed, while Section III discusses data, tests for stationarity and cointegration, and estimation methods. Results are discussed in Section IV while Section V presents some conclusions.

II Model Specification

This model contains behavioural relationships for short hedgers, long hedgers, net short speculators, and agents with unhedged spot market commitments. Consider first the position of **short hedgers**, such as US exporters to Germany or German investors exporting capital to US. These agents are long in spot Deutschemarks, and are hedging the risk of a fall in the spot rate (both spot and futures exchange rates are quoted as US dollars per Deutschemark). The first question is whether short hedgers should be represented as fully hedged or as covering only a fraction of their spot market commitments. The former is the carrying charge hypothesis of Working, (1953a, 1962), while the second corresponds to his selective hedging hypothesis. Preliminary estimation favoured the latter hypothesis, and the futures market positions of short hedgers, therefore are represented as a direct function of the current futures rate and a negative function of the expected futures rate. These positions are assumed also to vary directly with US exports to Germany, employed here as a proxy for the spot market commitments of these agents. The specification of the short hedging relationship is

$$H_t = \theta_1 + \theta_2 P_t + \theta_3 P^*_{t+1} + \theta_4 X_t + e_{1t} \tag{1}$$

where H = futures market positions of short hedgers;

P = current futures rate;

P^*_{t+1} = rational expectation of the futures rate at time (t+1), formed at time t;

X = US exports to Germany;

t = time in months;

e = error term;

and θ_1 = constant; $\theta_2, \theta_4 > 0; \theta_3 < 0$.

Consider next the position of **long hedgers**, such as US importers from Germany, or US investors who plan to acquire German assets. These agents have a commitment to purchase spot Deutschemarks in the future, and are hedging the risk of a rise in the spot rate. Preliminary estimation suggested that these agents should be represented as fully hedged, which is consistent with the 'operational hedging' hypothesis of Working (1953b, 1962). The market commitments of long hedgers, therefore, are assumed to vary negatively with the current contango (or forward premium) (futures rate minus spot rate) and positively with the expected contango, and US Gross Domestic Product, which is employed here as a proxy for the spot market commitments of long hedgers (a measure which also is supported by preliminary estimation). The specification of this function is

$$L_t = \theta_5 + \theta_6(P_t - A_t) + \theta_7(P^*_{t+1} - A^*_{t+1}) + \theta_8 GDP_t + e_{2t} \qquad (2)$$

where L = market commitments of long hedgers;

A = current spot rate;

A_{t+1}^* = rational expectation of the spot rate at time (t+1), formed at time t;

GDP = US Gross Domestic Product;

and $\theta_6 < 0; \theta_7, \theta_8 > 0$.

Short speculators in Deutschemark currency futures expect the futures rate to fall, while **long speculators** in futures expect this rate to rise. In this paper, speculative activity is represented by a relationship for **net short speculators**, whose market positions are assumed to vary directly with the current futures rate and negatively with the expected futures rate. Traditionally, market commitments of speculators have been assumed to vary negatively with a risk premium (Kaldor, 1960; Brennan, 1958), although Stein (1986, pp 48-52) has argued, in his hedging pressure theory, that the effect of an increase in the risk premium, on the futures exchange rate, and by implication on agents' market positions, may be positive or negative. The specification of this equation is

$$NSS_t = \theta_9 + \theta_{10} P_t + \theta_{11} P^*_{t+1} + \theta_{12} r_t + e_{3t} \quad (3)$$

where NSS = market positions of net short speculators in futures;

r = marginal risk premium;

and $\theta_{10} > 0; \theta_{11} < 0, \theta_{12} \gtrless 0$.

The risk premium is endogenised as an M-GARCH variable, following Engle, Lilien and Robins (1987) (see below). This treatment is consistent with the view of Stein (1991, p 39) that the risk premium should be related to objectively measurable quantities rather than treated as a residual. Some agents have current long, **unhedged spot market commitments** in Deutschemarks, either because they are importing German goods to US, or because they are acquiring German assets. Since these positions are unhedged, they are equivalent to long speculation in spot, and can be expected to vary negatively with the current spot rate and US-German interest differential, and positively with the expected spot rate, so the equation is specified as

$$U_t = \theta_{13} + \theta_{14} A_t + \theta_{15} A^*_{t+1} + \theta_{16} ID_t + e_{4t} \quad (4)$$

where U_t = unhedged spot market commitments in Deutschemarks;

ID = US-German nominal interest differential;

and $\theta_{14}, \theta_{16} < 0; \theta_{15} > 0$.

Preliminary estimation suggests that there should be no risk premium in (4). Identity (5) defines U, which is unobservable, as all long spot market commitments minus long hedging, while (6) is a market clearing identity:

$$U_t \equiv (M_t + AKO_t) - L_t \tag{5}$$

$$NSS_t \equiv L_t - H_t \tag{6}$$

where M = US imports from Germany;

AKO = US capital outflow to Germany.

There are seven endogenous variables (P, A, H, L, NSS, U, r) and five exogenous variables (X, M, GDP, ID, AKO).

Conventional identification conditions are not applicable to simultaneous linear rational expectations models with forward expectations, first because expectations of endogenous variables are replaced by functions of observed variables, and second because the reduced form parameters are highly non-linear functions of the structural parameters (see Pesaran, 1987, pp 120, 157-60). While rank conditions for global identification cannot be derived, local identification is possible, and this model satisfies the practical order condition derived by Pesaran (1987, p 160).[1]

III Data, Stationarity and Estimation

Data

The data employed in the estimation of this model are defined, and a summary of data sources is provided in Appendix 1. There are two points to be emphasized:

first the market commitments of the various groups of traders are measured by open positions provided by the Commodity Futures Trading Commission (CFTC), which are point of time data. The CFTC provides data on Large Hedgers ('Commercials'), Large Speculators ('Non-commercials') and Small ('Non-reporting') Traders. Data on Non-reporting traders are not divided, into hedging and speculation, but in this paper these data have been disaggregated in the same ratio as the open positions of large (reporting) traders[2]. Second, these market commitments, which are provided at end of month only, are synchronized with spot and futures exchange rates, which are daily rates on the last trading day of each month[3].

Stationarity

The question is whether these variables are stationary. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, both of which test the null of non-stationarity, were executed. The ADF tests suggest that the variables P, A, H, X, M, ID are I(1). The low power of the ADF tests, however, is well known (Evans and Savin, 1981), and the PP tests, reported in Table 1, which generally have greater power (see Banerjee *et al* 1993, p 113), suggest that only the spot and futures exchange rates and the interest differential are I(1), and that all other variables are I(0). The PP tests, therefore, are taken as definitive.

The question is then whether the spot exchange rate and the interest differential in equation (4), are cointegrated (cointegration between P and P* in (1) and (3), and between A and A* in (4), can be presumed). Table 2 reports the Johansen maximum Eigenvalue test, which tests the hypothesis that the number of cointegrating relationships m is at most equal to q (where $q<n$, the number of I(1) variables in the equation) against the specific alternative $m \leq q+1$. It will be seen that this test suggests there is one cointegrating relationship between A and ID.

Estimation

This model, in linear form, was estimated first by limited information methods, and these estimates were employed as initial values in full information estimation. The latter estimates, while potentially more efficient, are less robust to specification errors than those obtained by limited information procedures (Pesaran, 1987, pp 162-63, 189, 195-96). Tests were executed also for the presence of non-linearities in the model.

It is reasonable to expect non-linearities in futures market relationships because of the asymmetries present; these include first that futures contracts are traded on margin while spot market trading typically requires payment for the full value of the asset; second, delivery, if possible under a futures contract, is possible only at seller's option; third hedgers in futures have spot market commitments, while speculators do not; and fourth, speculation on the spot premium is asymmetric with that on the forward premium.

Limited information estimates were obtained as follows. First, an instrument was obtained for an unobservable rational expectation of an endogenous variable, such as P^*_{t+1}, as an OLS fitted value on a set of public information, which is defined as all pre-determined variables in the model. That is

$$P^*_{t+1} = E\left(P_{t+1}\middle|\phi_t\right) \qquad (7)$$

$$P_{t+1} = E\left(P_{t+1}\middle|\phi_t\right) + \eta_t \qquad (8)$$

where ϕ_t = set of public information at time *t*.

$E(\eta_t = 0)$, and $E(\eta_t\eta_{t-1}) = 0$

This procedure follows McCallum (1979), and was employed by Goss and Avsar (1996, 2000). Second, with expectational variables and a serially uncorrelated error term, consistent parameter estimates can be obtained by instrumental variables (IV) (McCallum, 1979). This method was employed[4] for equation (4). If, however, a correction for first order autocorrelation is made, consistent estimates can be obtained, not by GLS, but by non-linear least squares, applied to fitted values for all variables in the AR transformed equation. (Flood and Garber, 1980; Cumby *et al* 1983).

Lagrange Multiplier tests indicated the presence of ARCH effects in equations (1), (2) and (3). Using the Akaike Information Criterion and the Schwartz Bayesian Information Criterion to assist in the choice of model, and general to specific modelling to determine lag length (see Maddala and Kim, 1998, pp 19, 78), the conditional variance of equation (1) was represented as an EGARCH (1,0) process, that of equation (2) as an EGARCH (3.2) while the conditional variance of (3) was represented as an EGARCH (1,1) (see Nelson, 1991). For example, an EGARCH (1,1) process can be written

$$\ln h_t = \alpha_0 + \alpha_1 \left| \frac{e_{t-1}}{\sqrt{h_{t-1}}} \right| + \beta_1 \ln h_{t-1} + \gamma_1 \frac{e_{t-1}}{\sqrt{h_{t-1}}} \qquad (9)$$

where e_t = error term in a structural equation, and $h_t = V(e_t | e_{t-1})$

and α_0, α_1 ,β, γ are coefficients to be estimated. The last term on the right side of (9) captures any asymmetry between innovations and volatility. The M-GARCH terms in equations (1), (2) and (3) are significant, and in all three cases the mean and variance equations were estimated by maximum likelihood (ML).

Ramsey's RESET test for model mis-specification was executed to ascertain whether non-linear terms (essentially squares and cubes of price and expected price variables) should be added to the equations (Ramsey, 1969). This test addresses the null that additional variables do not result in any significant increase in R^2, although it does not suggest the alternative model. Appendix 2 provides F statistics, together with probability values to test the null hypothesis that the coefficients of the squares and cubes of price terms are all zero, in equations (1) to (4). It can be seen that this test, which is applicable only to equations estimated by least squares, suggests the possible presence of non-linearities in equations (2) and (3) but not in equations (1) or (4).

Accordingly, squares and cubes of the forward premium were added to equation (2), and of the futures exchange rate to equation (3). The conditional variance was modelled as an EGARCH (1,1) process in each case, using the model selection procedures described above, and equations (2) and (3), and their variance equations, were estimated by ML. The resulting coefficient estimates, however (not reported here for reasons of space but available from the authors), generally exhibited lack of significance and signs contrary to restrictions. These versions of the model, therefore, were not pursued, and **the final version of the model is the linear form discussed above.** The estimations described above were performed using the software *EViews* version 3.0.

IV Results

Estimates of the coefficients for equations (1) to (4), and the relevant variance equations, for the intra-sample period 1983(02) to 1989(12) (83 observations), are presented in Table 3. Three features are noteworthy. First, the significance of the estimates of $\theta_3, \theta_7, \theta_{11}, \theta_{15}$ indicates support for the Rational Expectations Hypothesis (REH), although it should be noted that this significance test is evidently less powerful than a comparison of post-sample forecasts of the spot rate as a test of the REH (see below). The former test is unable to discriminate between a Rational Expectations Equilibrium, and a situation where agents are still learning the true model. Second, US exports to Germany and US GDP are evidently satisfactory proxies for the spot market commitments of short and long hedgers respectively. Third, the estimates of the coefficients of the M-GARCH terms ($\psi_1, \psi_2, \theta_{12}$) require interpretation. In equation (1) the positive estimate of ψ_1 implies that short hedgers increase their hedge cover in the face of increased volatility, while in equation (2) the negative estimate of ψ_2 is taken to mean that long hedgers reduce their spot market commitments and, in line with this reduction, reduce their hedge positions, in response to increased volatility. In equation (3) the negative estimate of θ_{12} suggests that speculators reduce their positions in the presence of increased volatility, and is consistent with the treatment of the risk premium in the classic papers of Kaldor (1960) and Brennan (1958).

The diagnostic tests on the residuals of equations (1) to (4), reported in Table 4, indicate that there is no remaining serial correlation, and that the residuals are stationary and normally distributed.

An evaluation of the intra-sample simulation of spot and futures exchange rates, according to the criteria of correlation coefficient, Theil's inequality coefficient (1C) and per cent root mean square error (%RMSE), is presented in Table 5. According to the last criterion, the model simulates exchange rates better than it does other variables (not reported here), and simulates the spot rate better than it does the futures rate.

Post-Sample Results

Forecasts

Table 6 provides an evaluation of post-sample simulation of spot and futures exchange rates, two months ahead, for the post-sample forecast period (1990(02) to 1992(11) (34 observations). Again concentrating on the per cent RMSE criterion, it can be seen that the forecast of the spot rate has improved slightly, compared with the intra-sample simulation, while the forecast of the futures rate has deteriorated slightly. Table 7 compares the post-sample forecast of the spot rate by the model (AS, same as A in Table 6) with two alternative forecasts. One rival forecast is that of a naïve random walk (ANAIVE), in which the current spot rate is taken to be a forecast of the spot rate two months ahead. The other alternative forecast of the spot rate is that implicit in a futures rate lagged two months from maturity (P_{t-2}). According to the per cent RMSE criterion, the spot rate forecast provided by the model clearly outperforms that of the random walk, which is the better of the two alternatives, and this difference is significant according to the test described in Granger and Newbold (1986, pp 278-79).

Comparison of the spot rate forecast provided by the model with that implicit in a lagged futures rate affords a test of the semi-strong EMH (Leuthold and Hartmann, 1979; Leuthold and Garcia, 1992). If the model outperforms the futures rate, the former evidently contains information not impounded in the futures rate, and this would constitute evidence against the EMH. In contrast, if the lagged futures rate outperforms the model, this is no proof of market efficiency, but may reflect a mis-specified model.

In this case, the model provides a post-sample forecast of the spot rate which is significantly better than that of the lagged futures rate, according to the criterion employed. Rausser and Carter (1983), however, argue that such an outcome is a necessary, but not a sufficient condition for the demonstration of market inefficiency. According to Rausser and Carter (1983), to constitute a sufficient condition for rejection of the EMH, a trading program based on the model must be capable of producing risk adjusted profits.

Simulated Trading

To illuminate further the question of informational efficiency in this market, the model developed above was employed for simulated trading purposes. The following **trading strategy** was employed:

(a) if AS>P, this was interpreted as a signal that spot and futures rates would rise, and a **long** position was taken in the relevant futures contract (as defined in endnote 2).

(b) if AS<P, this was interpreted as a signal that spot and futures rates would fall, and a **short** position was taken in the relevant futures contract.

(c) if AS=P, this was interpreted as a signal that spot and futures rates would remain constant, and no position was taken.

Although information is incomplete, there seems to be agreement in the literature that speculators' positions in futures markets typically are held for periods of less than one month, and frequently are held for a few days or less. For example, Working (1977, pp 182, 184) found that 72 per cent of speculators' trading in wheat futures at Chicago Board of Trade for a sample period in 1947 was intra-day, while only 35 per cent of hedgers' trading was intra-day. He found also that

23.2 per cent of speculators' positions in wheat were scalping (held for a few minutes only), while in corn futures 10.9 per cent of speculators' positions were scalping. Rutledge (1978/1986), in studying the effect of speculation on prices for a range of US commodities and two major exchange rates (including the USD/DM rate) set a lag of five days as a sufficient period to discern the possible impact upon prices. Taylor (1992, p 21), who studied the results of simulated trading in the USD/Yen market, calculated returns as the difference between opening and closing prices on the same day. In contrast, Leuthold and Garcia (1992, p 66), who developed simultaneous monthly models for US livestock futures markets, held simulated trading positions for one month or longer.

In this paper an attempt is made to **take account of this diversity of views by holding simulated trading positions for seven days and for one month**. These positions were determined, as outlined above, **in conjunction with forecasts of the spot rate**, generated by the model, **one month ahead**. That is simulated trading positions were taken in the futures contract as defined in endnote 2, and held for seven days in one trading strategy, and for one month in the other strategy. Annualised per cent rates of return were calculated for each simulated trading position, and risk was taken into account as follows:

(a) Credit risk was taken into account by subtracting the 30 day US Treasury Bill rate in per cent p a from the annualised returns to obtain Net Annualised Return;

(b) Risk of loss due to unfavourable variation of exchange rates was taken into account by relating the Mean Net Annualised Return (MNAR) to the standard deviation of the sample Net Annualised Returns.

The outcomes of these simulated trades are summarized in Table 8. It can be seen that more than 70 per cent of the total trades were short, although less than half of the short trades were profitable, while most of the long trades were profitable. While both seven day and one month holding periods managed to produce positive MNARs, **the returns from the one month trades were not significantly different from zero, when the variation of these returns is taken into account[5]. The seven day trades, by comparison, produced many large positive Net Annualised Returns, which not only dominated the losses but also resulted in a MNAR which is statistically different from zero[6]**.

These results may be construed as evidence against the EMH. Nevertheless, the present authors are reluctant to reject the EMH on the basis of this evidence, because only one post-sample trading period has been employed in this paper, and it would be desirable to demonstrate that significant gains could be generated by similar programs over **repeated** trading periods, before rejecting the EMH.

VI Conclusions

Critics have claimed that traditional economic models of exchange rate determination have performed poorly in post-sample forecasting, and suffer from the deficiencies *inter alia* of undue reliance on single equation methods, and inadequate modelling of expectations. This paper, in addressing these issues, develops a simultaneous, rational expectations model of the USD/DM market, and uses information from both spot and futures markets. This model contains functional relationships for short hedgers, long hedgers, net short speculators in futures, and unhedged spot market positions, and is closed with a market clearing identity.

Phillips-Perron tests for stationarity suggest that only spot and futures exchange rates and the nominal interest differential are I(1), and that all other variables are stationary. Johansen cointegration tests suggest that the spot rate and the interest differential, which appear in the unhedged spot positions equation, are cointegrated.

Although this paper cites four major examples of asymmetries in futures markets, nevertheless tests for the presence of non-linearities in the empirical version of this model indicated that non-linear terms were not helpful in the quest for an improved explanation of exchange rate determination. Accordingly, the model was estimated in linear form, first by limited information methods, and these estimates were used as initial values for full information estimation. The FIML estimates, however, were distinctly inferior to those obtained for the individual equations, reflecting perhaps our imperfect understanding of agent inter-temporal behaviour in a risky world of spot and derivatives markets for currencies. The conditional variance in each of the hedging and speculative futures relationships was represented as an EGARCH (p, q) process, while the residuals of the unhedged spot commitments equation did not exhibit any serial correlation or heteroscedasticity.

In post-sample forecasts of the spot rate, this model significantly outperforms conventional benchmarks such as a naïve random walk and a lagged futures rate. A simulated trading program based on forecasts by this model, produced significant net annualised returns after the Treasury Bill rate and the variability of the returns were taken into account. While this last outcome may constitute evidence against the efficient markets hypothesis, it is unlikely to be a basis for clear rejection: that would require repeated demonstrations of similar outcomes over several time periods. Moreover, whether the allowance made for risk is appropriate, in calculating net returns from these simulated trading routines, is a matter for subjective evaluation.

Table 1

Unit Root Tests: Phillips-Perron

Variable	Calculated Test Statistic	5% Critical Value	Order of Integration
H	– 5.0240	– 2.8963	I(0)
L	– 9.7394	– 3.4639	I(0)
NSS	– 4.6961	– 2.8967	I(0)
U	– 9.1823	– 3.4639	I(0)
P-A	– 7.5169	– 2.8963	I(0)
P	– 1.9586	– 3.4639	I(1)
A	– 1.9919	– 3.4639	I(1)
X	– 3.4400	– 2.8963	I(0)
M	– 4.7838	– 2.8963	I(0)
AKO	– 4.5712	– 2.8963	I(0)
GKI	– 2.9695	– 2.8963	I(0)
ID	– 2.0039	– 2.8963	I(1)
GDP	– 4.4872	– 3.4652	I(0)

Table 2

Johansen Maximum Eigenvalue Test

Equation: I(1) Variables	Test Statistic	5% Critical Value	No. of Cointegrating Vectors: *m*
(4)	28.557	25.32	$m = 0$
A_t, ID_t	9.005	12.25	$m \leq 1$

Table 3

Coefficient Estimates: Equations (1) to (4)

Equation	Coefficient	Variable	Estimate	Asymptotic *t* Value
(1)	θ_1	Constant	-28759.86	-3.342
	θ_2	P_t	248817.5	3.906
	θ_3	P^*_{t+1}	− 191015.8	− 2.885
	θ_4	X_t	7.842	3.099
	Ψ_1	$\sqrt{h_{1t}}$	1.569	3.577
Variance	α_0	Constant	18.800	54.865
(1)	α_1	$\left\lvert \frac{e_{1t-1}}{\sqrt{h_{1t-1}}} \right\rvert$	-0.197	-0.763
	γ_1	$\frac{e_{1t-1}}{\sqrt{h_{1t-1}}}$	0.703	3.742
(2)	θ_5	Constant	− 5271.403	− 0.307
	θ_6	$(P_t - A_t)$	− 466528.9	− 3.969
	θ_7	$\left(P^*_{t+1} - A^*_{t+1}\right)$	635512.1	3.149
	θ_8	GDP_t	185.671	12.914
	Ψ_2	$\sqrt{h_{2t}}$	-4.444	-2.181

Table 3 (Continued)

Equation	Coefficient	Variable	Estimate	Asymptotic *t* Value
Variance	α_2	Constant	30.587	6.749
(2)	α_3	$\left\lvert \frac{e_{2t-1}}{\sqrt{h_{2t-1}}} \right\rvert$	0.103	1.149
	α_4	$\left\lvert \frac{e_{2t-2}}{\sqrt{h_{2t-2}}} \right\rvert$	- 0.115	- 0.878
	α_5	$\left\lvert \frac{e_{2t-3}}{\sqrt{h_{2t-3}}} \right\rvert$	- 0.340	- 1.730
	β_1	$\ln h_{2t-1}$	- 0.420	- 2.593
	β_2	$\ln h_{2t-2}$	- 0.273	- 1.318
	γ_2	$\frac{e_{2t-1}}{\sqrt{h_{2t-1}}}$	- 0.041	- 0.902
	γ_3	$\frac{e_{2t-2}}{\sqrt{h_{2t-2}}}$	0.014	0.247
	γ_4	$\frac{e_{2t-3}}{\sqrt{h_{2t-3}}}$	- 0.085	- 1.070
(3)	θ_9	Constant	- 14417.93	0.988
	θ_{10}	P_t	167611.0	2.538
	θ_{11}	P_{t+1}^*	– 221183.8	– 3.169
	θ_{12}	$r_t (= \sqrt{h_{3t}})$	– 1.959	– 1.655

Equation	Coefficient	Variable	Estimate	Asymptotic *t* Value
Variance	α_6	Constant	8.589	2.032
(3)	α_7	$\left\| \frac{e_{3t-1}}{\sqrt{h_{3t-1}}} \right\|$	0.134	0.973
	β_3	$\ln h_{3t-1}$	0.528	2.244
	γ_5	$\frac{e_{3t-1}}{\sqrt{h_{3t-1}}}$	- 0.470	- 1.966
(4)	θ_{13}	Constant	- 548.547	- 4.783
	θ_{14}	A_t	− 1109.290	− 1.630
	θ_{15}	A^*_{t+1}	1414.860	2.030
	θ_{16}	ID_t	− 78.023	− 2.284

Table 4

Diagnostic Tests on Residuals

Test \ Equation	1	2	3	4
Lying-Box Q				
Calculated χ^2_{24}	13.702	25.984	19.242	19.873
Critical $\chi^2_{24}(0.05)$	36.415	36.415	36.415	36.415
Phillips-Perron				
Calculated	- 7.646	- 7.998	- 7.774	- 8.154
5% Critical Value	- 2.897	- 2.897	- 2.897	- 2.897
Jarque-Bera				
Calculated	0.632	2.749	0.271	0.367
p-value	0.729	0.253	0.873	0.832

Table 5

Intra-Sample Simulation of Exchange Rates

Variable	Correlation Coefficient	Theil's IC	% RMSE
A	0.9958	0.0092	1.832
P	0.9864	0.0171	3.789

Table 6

Post-Sample Simulation of Exchange Rates

Variable	Correlation Coefficient	Theil's IC	% RMSE
A	0.9704	0.0078	1.521
P	0.8734	0.0194	4.005

Table 7

Post-Sample Forecasts of Spot Exchange Rate

Forecast Model	Correlation Coefficient	Theil's IC	% RMSE
AS	0.9704	0.0078	1.521
ANAIVE	0.6115	0.0262	5.414
P_{t-2}	0.5912	0.0279	5.748

TABLE 8
SIMULATED TRADING: SUMMARY OF RESULTS

	7 Day Position	1 Month Position
Trades: Total Number	35	35
Short Positions: Number Number Profitable	25 10	25 11
Long Positions: Number Number Profitable	10 7	10 8
Mean Return: % p a Standard Deviation **Test Statistic**	93.262 235.478 2.309	16.185 58.546 1.612

Appendix 1

Summary of Data Sources

Variable	Definition	Source
A	Daily observations, last trading day of month, interbank rate in USD/DM.	*Statistical Supplement to Monthly Reports of Deutschebundesbank*, Series 5, 1983-92.
P	Daily observations, last trading day of month in USD/DM, for a future on average two months from delivery (see n 2).	International Monetary Market (IMM) 1983-89, *Asian Wall Street Journal*, 1990-92.
H, L, NSS	End of month open positions in number of contracts each 125,000 DM	CFTC *Commitments of Traders*, 1983-92
U	End of month, spot commitments in number of contracts.	Identity (5).
ID	US nominal interest rate, day to day money less German nominal interest rate, day to day loans.	OECD *Main Economic Indicators*, 1983-92, Tables R2/07, R2/01.
X	Monthly observations, mill DM.	Deutschebundesbank, *Stat Suppl Series 4*, 1983-92
M	Monthly observations, mill DM, converted to contracts.	Above.
AKO	Monthly observations, mill DM, unofficial direct and portfolio capital movements, converted to contracts.	Above.
GKI	German capital inflow to US, monthly observations, mill DM, unofficial direct and portfolio investment (this variable is in the information set and was used in preliminary estimation).	Above.
GDP	US Gross Domestic Product, mill US dollars, quarterly, interpolated to months observations with program TRANSF (Wymer 1977).	*Survey of Current Business.*

Appendix 2

Ramsey Reset Test for Specification Error

Equation/ Dependent Variable	Calculated F Statistic	Probability Value
1 (H)	1.1663	0.3171
2 (L)	3.5156	0.0347
3 (NSS)	2.6740	0.0734
4 (U)	0.1635	0.8493

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ENDNOTES

1 This condition is that the number of predetermined variables in the model should be at least equal to the total number of endogenous, predetermined and expectational variables in the equation under consideration minus one (Pesaran 1987, p 160).

2 It has been suggested that for some commodities and for some time periods, the open positions of Non-reporting Traders should be treated as all speculative (see Peck, 1982). There is, however, no information available to support such a view for this market.

3 The Deutschemark (DM) contract at the Chicago Mercantile Exchange IMM calls for delivery of 125,000 DM in the months of March, June, September and December. A continuous series of futures prices is constructed by choosing a futures contract which is on average two months from maturity; when the month is December, January, February the future is March; when the month is March, April, May, the future is June; when the month is June, July, August the future is September; when the month is September, October, November, the future is December.

4 The instruments employed in the estimation of equation (4) are as follows:

$U_{t-1}, A_{t-1}, ID_t, P_{t-1}, GDP_t, X_t, H_{t-1}, L_{t-1}, NSS_{t-1}, M_t, AKO_t, \sqrt{h_{1t-1}}, \sqrt{h_{2t-1}}, \sqrt{h_{3t-1}}$.

5 No allowance has been made for transactions costs in the estimation of these returns. Transactions costs in futures markets comprise the commission and

liquidity costs of trading, and typically are smaller than in most other asset markets.

For example, Taylor (1992, p 106), in estimating returns to trading USD/Yen futures on the CME, made an allowance of 0.2 per cent of the dollar price of the futures contracts traded (based on retail commission costs of USD80 per contract and liquidity costs of USD25 per contract round turn). Deduction of costs of this magnitude is unlikely to have a significant impact on the returns estimated in this paper.

6 A buy and hold strategy in USD/DM futures, by comparison, produced a Mean Net Annualised Return (MNAR) of 4.637% (standard deviation of 43.024%) for 35 trades held for 1 month, and a MNAR of 65.388% (standard deviation of 136.730%) if held for 7 days. Only the second of these results is statistically different from zero, and in both cases the MNAR values are less than those produced, for comparable holding periods, by trading strategies based on the model.