Bank of England

Discussion Papers

No 29

Expectations, risk and uncertainty in the foreign exchange market: some results based on survey data

by

M P Taylor

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The object of this series is to give a wider circulation to research work being undertaken in the Bank and to invite comment upon it; and any comments should be sent to the author at the address given below.

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ABSTRACT

Previous tests of the efficiency of the foreign exchange market are tests of a joint null hypothesis: that agents are both risk-neutral and endowed with rational expectations. By utilising survey data it is possible to break down the joint hypothesis and test for rational expectations and risk neutrality individually. This paper does this for expectations of the dollar-sterling and effective sterling exchange rates, for the period November 1979 to July 1985. Overall, the results strongly suggest that it is the presence of risk-averse behaviour rather than non-rational expectations that is to blame for the unconditional bias in the forward rate as a spot rate predictor. Using a measure of the risk premium as the expected return to open forward speculation, we also examine two empirical models of the risk premium and the relationship between risk and uncertainty.

1 Introduction

There is now substantial empirical evidence that the forward foreign exchange rate fails to act as an optimal predictor of the future spot exchange rate (Hansen and Hodrick 1980, Hakkio 1981, Baillie, Lippens and McMahon 1983, amongst others). All previously published work in this area is, however, a test of a joint null hypothesis - ie that market participants are both risk-neutral and endowed with rational expectations. Thus, economists have been reluctant to jettison the rational expectations assumption (in fact have tended to absorb it into their maintained hypothesis) and have gone off in search of the risk premium (Frankel 1982, Domowitz and Hakkio 1985, Taylor 1987, amongst others).

However, by utilising survey data on exchange rate expectations it is possible to apportion the blame for the non-optimality of the forward rate as a spot rate predictor between failure of the risk neutrality assumption, and failure of the rational expectations assumption, as explained below.

This paper utilises survey data on investment managers' expectations of the dollar-sterling and sterling effective exchange rates for one year ahead in order to attempt to shed some light on this question. Although our results using survey data for expectations of the dollar-sterling rate are slightly equivocal because of the possibility of an instance of the 'peso problem' (as discussed below), our results in general suggest that it is in fact the assumption of risk neutrality which is primarily responsible for the failure of the forward rate to act as an optimal spot rate predictor.

The remainder of the paper is set out as follows. The next section outlines a strategy for allocating the blame for bias in the forward premium between non-rational expectations and risk aversion, if an expectations series is available whilst section 3 gives a description of the data. Section 4 reports our main empirical results. In section 5 we examine two recently advanced empirical models of the forward exchange risk premium (Domowitz and Hakkio 1985 and Taylor 1987) using our measure of the risk premium. We also examine the relationship between risk and a simple measure of uncertainty in this section. A final section concludes.

2 Apportioning the Blame

One definition of the forward exchange risk premium is that it is the expected return to open forward speculation, since in the absence of risk considerations, agents would drive the forward exchange rate into equality

with the expected future spot rate. Denoting the spot exchange rate (foreign price of domestic currency) as s_t, and the forward exchange rate for maturity n periods ahead as f_t, then the risk premium, p_t, is defined:

$$p_t \equiv (s^e_{t+n} - f_t)/s_t \qquad (1)$$

where superscript e denotes agents' subjective expectation formed at time t. Equivalently:

$$p_t \equiv (s^e_{t+n} - s_t)/s_t - (f_t - s_t)/s_t \qquad (2)$$

- the risk premium is that part of the expected rate of appreciation not discounted in the forward premium. Note that (1) and (2) do not explicitly invoke the assumption of rational expectations - they are true by definition, regardless of whether expectations are formed in a rational or in a non-rational (eg adaptive) manner. In general, the realised value of the rate of appreciation will differ from the expected value by a forecasting error, u_{t+n} say:

$$(s_{t+n} - s_t)/s_t = (s^e_{t+n} - s_t)/s_t + u_{t+n} \qquad (3)$$

If rationality is assumed, then agents' subjective expectations are identical to the true mathematical expectations conditional on available information:

$$(s^e_{t+n} - s_t)/s_t = E\{(s_{t+n} - s_t)/s_t | \Omega_t\} \qquad (4)$$

where Ω_t represents agents' information set at time t, ie:

$$E(u_{t+n} | \Omega_t) = 0 \qquad (5)$$

- rational expectations forecasting errors are orthogonal to the information set available at the time the expectation was formed, and in particular are non-systematic.

Now consider the regression model

$$(s_{t+n} - s_t)/s_t = \alpha + \beta (f_t - s_t)/s_t + u_{t+n} \qquad (6)$$

The joint null hypothesis of rational expectations and risk neutrality can be tested via restrictions on the regression parameters in (6):

H_0: $(\alpha, \beta) = (0, 1)$

Allowing for a time-variant, but non-zero, risk premium would entail testing

H_0: $\beta = 1$

In general, regression based tests of this kind have rejected the rational expectations-risk neutrality hypothesis (see eg Fama 1984, Taylor 1987). How can we apportion responsibility for this rejection between the two components of the joint null hypothesis?

Note that the regression coefficient β in (6) is

$$\beta = \frac{\text{Cov}\{s_{t+n} - s_t)/s_t,\ (f_t - s_t)/s_t\}}{\text{Var}\{(f_t - s_t)/s_t\}}$$

Using (2), (3) and (4), it is straightforward to show, after some manipulation, that

$$\beta = 1 - \beta_{RE} - \beta_{RN} \qquad (7)$$

where

$$\beta_{RE} = - \frac{\text{Cov}\ \{u_{t+n}, (f_t - S_t)/S_t\}}{\text{Var}\ \{(f_t - S_t)/S_t\}} \qquad (8)$$

and

$$\beta_{RN} = 1 - \frac{\text{Cov}\ \{(s^e_{t+n} - s_t)/s_t,\ (f_t - s_t)/s_t\}}{\text{Var}\ \{(f_t - s_t)/s_t\}} \qquad (9)$$

Under rational expectations, the forecast errors are orthogonal to information at time t (relation (5)). Since the forward premium at time t is an element of the information set available at that point in time, β_{RE} as defined in (8) will be identically equal to zero under the assumption of rational expectations.

Regardless of how expectations are formed, under risk neutrality, the expected rate of appreciation will be equal to the forward premium (set $p_t = 0$ in (2)), and so β_{RN} as defined in (9) will be identically equal to zero.

If measurements of agents' point expectations are available, then the forecast errors and the expected rate of appreciation are observable, so that the sample analogues of (8) and (9) can be constructed and tested for statistical significance. This should shed some light on the observed failure of the forward rate to optimally predict the future spot rate.

3 The Data

On the first working day of each month since January 1981, a firm of British management consultants, Godwins, has asked the chief investment manager from each of just over fifty leading investment houses in the City of London, to predict the change in the effective sterling rate and the dollar-sterling exchange rate for one year ahead. Since the survey results are published in three-category response form (percentage of respondents expecting 'up', 'down' or 'same'), we used the well-known subjective probability method of Carlson and Parkin (1975) and Knobl (1974) to derive a series corresponding to aggregate point expectations. This involves assuming that at each observation point, each respondent has a subjective probability distribution concerning the outcome of the variable in question; and secondly that the means of the individual probability distributions are themselves normally distributed - this is sometimes termed the 'expectations distribution'. It is the series of means of the expectations distribution that is taken as the aggregate expectations series.[1] It is usually estimated as:

$$(s_t^e - s_t)/s_t = \rho \frac{F^{-1}(EF_t) + F^{-1}(1 - ER_t)}{F^{-1}(EF_t) - F^{-1}(1 - ER_t)}$$

where EF_t and ER_t are the proportions of respondents at time t expecting the variable in question to fall or rise over the given period respectively; $F(.)$ is the standard normal cumulant (so that eg $F^{-1}(EF_t)$ is the abscissa of the cumulant corresponding to the proportion EF_t). The scaling factor ρ is the 'just noticeable difference' - ie only changes greater than $\pm\rho$ per cent are deemed significant by agents. Knobl (1974) simply assumes a value of ρ of 2 (for inflation expectations), while Carlson and Parkin (1975) choose ρ so that the mean expected change over the whole sample period is equal to the mean actual change - although this method has been attacked (for example by Foster

and Gregory (1977)) for biasing rationality tests towards non-rejection. Batchelor (1982) chooses ρ to minimise the sum of squared prediction errors. In the work reported below, we use a value of ρ of 2.5, since there is no evidence to suggest an overall superior method of choosing ρ. This implies, for example, that if the current dollar-sterling rate is \$1.50, then future exchange rates between approximately \$1.46 and \$1.54 are treated as representing an insignificant rate of appreciation. However, other methods, including choosing ρ anywhere between 5.0 and 0.5 (in steps of 0.5) did not yield results in any way qualitatively different from those reported below.[2]

Since data were available up to July 1986, we were able to construct expectations series for one year ahead for the period January 1981 to July 1985, and all empirical results reported below apply to this data period (truncated as necessary because of lags).

In two recent papers, Frankel and Froot (1985) and Froot and Frankel (1986) have also utilised survey data on exchange rate expectations to examine questions of rationality and risk neutrality. The data utilised in this paper is different from that used by Frankel and Froot in a number of important ways. The data utilised by Frankel and Froot corresponds to surveys conducted by the Economist Financial Report Group, Money Market Services (MMS) and Amex Bank Review (Amex). The Amex surveys were conducted by mail over a period of up to a month, making the exact dating of the average expectations and its associated information set problematic. Moreover, in both the Amex and MMS surveys, it is not clear that the same set of respondents was used over time. Goodhart (1987) suggests that, since open forward speculation is apparently quite thin and exchange rate speculation heavily biased towards very short term positions, currency traders may in fact devote relatively little effort to forming expectations of the future spot rate (and indeed may use the forward rate as a rule of thumb). Thus, surveys which focus on currency traders, such as the Economist or MMS surveys, may in fact not be directly applicable in the present context.

The data used in the present study overcomes many of these difficulties. The same set of institutions were surveyed on the first working day of each month over the period. Moreover, since the typical survey respondent would be a manager of several very large medium to long term investment portfolios, he or she presumably must have devoted some considerable time and effort to forming expectations of future exchange rates, since such considerations must form a very basic input into any international portfolio allocation decision.

Naturally, any series which purports to be a measure of agents' expectations will be more or less subject to measurement error. However, all of the statistical procedures applied below are robust to random measurement error.

4 Empirical Results

Table 1 lists results of projecting the rate of depreciation onto the lagged forward premium, for sterling-dollar and the sterling effective exchange rate, for the period January 1981 - July 1985. In both cases, the results are qualitatively similar to those reported in Fama 1984 and Taylor 1987 - the slope coefficient is negative and significantly different from unity.[3]

Table 2 reports summary statistics for the constructed risk premia and the expected and actual rates of depreciation. For both dollar-sterling and the effective sterling rate, there is evidence of a statistically significant risk premium. Moreover, these results support Fama's (1984) conjecture that the variance of the risk premium should be greater than the variance of the expected rate of appreciation in order to account for the negative slope coefficient result as reported in Table 1, subject to a maintained hypothesis of rational expectations. Note that the fact that the expected rate of appreciation is in both cases strongly significantly different from zero implies that agents clearly did not believe the exchange rates in question to be governed by random walk behaviour (in which case the expected appreciation would be zero).

Table 3 reports results of the division of blame for $\hat{\beta} \neq 1$ in Table 1 between a failure of rational expectations and a failure of risk neutrality. The results are slightly equivocal. For dollar-sterling, although $\hat{\beta}$ is significantly different from unity, neither $\hat{\beta}_{RE}$ nor $\hat{\beta}_{RN}$ are individually significantly different from zero. This implies that although there is evidence of either risk-averse or non-rational behaviour (or both), neither of these modes of behaviour appears <u>entirely</u> to blame. However, it might be argued that the behaviour of the dollar-sterling rate during this period may be characterised by highly unusual circumstances - including perhaps rational bubbles (Evans 1986). A related issue which may confound our empirical results is the 'peso problem' (Rogoff 1979, Krasker 1980) - agents may have expected significant central bank intervention to depreciate the dollar, over a large part of the data period, which in large part did not materialise until September 1985 (the G5 'Plaza Accord'). This may have the effect of imparting significant serial correlation into the (non-overlapping) forecast errors.

For these reasons, the results for the sterling effective rate are, perhaps, slightly more reliable - although the dollar carries a high weight in the effective rate, the 'peso problem' will to some extent be counterbalanced by the other currencies in the basket. These unequivocally lay the blame for the non-optimality of the forward rate as a spot rate predictor at the door of the risk premium - $\hat{\beta}_{RE}$ is insignificantly different from zero, whilst $\hat{\beta}_{RN}$ is highly significant. This strongly suggests the presence of important risk-averse behaviour in the foreign exchange markets over this period.

5 Explaining the Risk Premium

A number of empirical models have recently been advanced to try and explain the behaviour of the forward exchange risk premium. This section aims to try and evaluate the performance of two of these models in statistically explaining our measure of the risk premium.

5.1 ARCH-in-Mean

Domowitz and Hakkio (1985) have suggested an empirical model of foreign exchange risk in which the risk premium is assumed to depend on the conditional variance of the forecast errors, which in turn are assumed to follow a low order autoregressive conditional heteroscedasticity (ARCH) process, as introduced by Engle (1982). In essence, this model suggests that the squared risk premium should be a function of lagged, squared forecast errors. Table 4 contains results of estimating a model of this kind using our risk premia measures (with the coefficients constrained to be non-negative, in order to avoid negative conditional variances). As can be seen, this (albeit rather crude) form of the ARCH-in-mean model fails to significantly explain variation in the risk premium, and the hypothesis that the coefficients on the lagged, squared forecast errors are jointly zero cannot be rejected; which is in fact broadly consistent with the results reported in Domowitz and Hakkio 1985.

5.2 Asset Yield Volatility

Taylor (1987) suggests that the exchange risk premium may be related to summary measures of asset yield volatility. Intuitively, increased relative volatility of sterling asset prices makes open forward positions in sterling relatively less attractive - thereby depressing the forward rate (dollars per pound) or, equivalently, raising the risk premium. A converse argument applies to increased relative volatility in foreign asset prices. Thus, regressing the risk premium onto measures of domestic and foreign asset yield

volatility should yield significantly positive and negative coefficients respectively. Because of problems in constructing a 'basket' volatility measure, this model was tested only for the dollar-sterling risk premium (and therefore the results must be qualified because of the potential 'peso problem', as discussed above). Table 5 reports results of regressing the dollar-sterling risk premium measure onto twelve-month moving standard deviations of UK and US stock market indices. These results are in fact quite encouraging - the slope coefficients are of the expected signs and are significantly different from zero. Moreover, the values of the Durbin-Watson and Ljung-Box statistics indicate that the volatility measures explain most of the systematic time variation in the risk premium - the low R^2 may be entirely due to random measurement error in the constructed expectations series.

5.3 Risk and Uncertainty

Following Knight (1921), economists have for many years made a distinction between risk and uncertainty. 'Uncertainty' is often thought of as applying to the case where agents find it impossible to assign prior probabilities to eventual outcomes (and will therefore be hard to insure); whilst 'risk' is generally applied to the case where agents can assign prior probabilities to outcomes.

We have generated expectations series for the rate of depreciation of the exchange rate as the series of means of the distribution of expectations across survey respondents (ie as the means of the expectations distribution). However, the standard deviation of the expectations distribution must give a measure of how unsure agents collectively are as to the most likely outcome at a point in time. Thus, the standard deviation of the expectations distribution might be taken as measuring uncertainty in some sense.[4] Table 6 reports results of regressing the risk premium measures onto the series of standard deviations of the expectations distributions. Clearly, there is a strong positive correlation between the risk premium series and the uncertainty measures - as agents become collectively more uncertain, the risk premium on sterling rises.

6 Conclusion

Previous tests of the forward rate as a spot rate predictor have generally tested a joint null hypothesis: expectations are rational and agents are risk-neutral (equivalently, foreign exchange risk is completely diversifiable). By utilising survey data on exchange rate expectations it is, however, possible to test the components of this joint null individually.

Although our results using survey expectations data on the one-year-ahead dollar-sterling exchange rate are equivocal, taken together with our results for the sterling effective rate we are led to the conclusion that it is probably risk aversion rather than non-rational expectations which are to blame for the observed non-optimality of the forward rate as a spot rate predictor. Defining the risk premium as the expected return to open forward speculation (difference between the expected rate of depreciation and the forward premium), we also used our measure to examine two recently advanced empirical models of the risk premium. Some support was found for Taylor's (1987) asset yield volatility model, while the ARCH-in-mean model of Domowitz and Hakkio (1985) was not found to explain the behaviour of the risk premium significantly. In addition, we also found a strong statistical relationship between the risk premium and a simple measure of market uncertainty.

Although it might be argued that our measure of exchange rate expectations may suffer from substantial measurement error (see eg Lahiri 1981), it should be noted that all of our statistical test procedures are in fact robust to the presence of random measurement errors (Hansen 1982). In any event, as an attempt to explain the unconditional bias in the forward rate as a spot rate predictor in terms of the presence of risk-aversion rather than non-rational expectations, it is hoped that the present analysis contributes something to the foreign exchange market efficiency debate.

NOTES

1 The idea that the distribution of means is normal can be given some motivation by appeal to the Central Limit Theorem, and there appears to be some evidence that expert forecasts are distributed in this way (Carlson 1975). At a practical level, assuming different expectations distributions may make little difference - as evidenced by Agenor (1982) who compares assumptions of normal, log-normal and Cauchy distributions.

2 Choosing ρ so that the mean expectation error in zero is clearly inappropriate when, as we suggest below, there is a possibility of the 'peso problem' - if agents consistently expected an event to occur (eg government intervention in the foreign exchange market), but which did not for most of the sample period, the true mean expectational error will clearly be non-zero.

3 All results reported in the remainder of the paper use the whole sample period, January 1981 to July 1985, truncated as necessary because of lags. Data on spot and forward rates were taken from the Financial Times (month ends). An effective sterling forward rate was constructed using forward rates for the eight most important currencies in the sterling effective rate, with the IMF MERM weights normalised to unity. Where necessary, a correction for serial correlation in the overlapping forecast errors was made using the method outlined in Hansen 1982 which does not impose constancy of the conditional autocovariances (Hansen's Case (v)). A nominal test size of five per cent is generally used in the following discussion.

4 The standard deviation of the expectations distribution is estimated as $-2\rho/\{F^{-1}(EF_t) - F^{-1}(1 - ER_t)\}$ (same notation as section 3 above).

TABLE 1

Tests of unbiasedness in the forward rate as a spot rate predictor[1]

$$(s_{t+12} - s_t)/s_t = \alpha + \beta\,(f_t - s_t)/s_t + u_{t+n}$$

Exchange Rate	$\hat{\alpha}$	$\hat{\beta}$	R^2
Dollar-sterling	-2.58	-4.63	0.26
	(5.86)	(1.92)	
Sterling effective	-1.45	-1.01	0.05
	(2.17)	(0.48)	

1 Period of estimation is January 1981-July 1985, by OLS with a method of moments adjustment to the covariance matrix (Hansen 1982). R^2 is the coefficient of determination, figures in parentheses denote estimated standard errors.

TABLE 2

Summary statistics for risk premia and expected and actual appreciation[2]

Exchange Rate	Risk Premium		Expected Appreciation		Actual Appreciation	
	Mean	Variance	Mean	Variance	Mean	Variance
Dollar-sterling	5.62 (2.89)	67.42	-6.41 (1.09)	64.98	-6.11 (2.00)	219.2
Sterling effective	4.61 (0.31)	5.45	-1.55 (0.20)	2.27	-4.55 (0.85)	39.47

2 Standard errors of means (in parentheses) are estimated by generalised method of moments (Hansen 1982), where appropriate.

TABLE 3

Apportioning the blame for non-optimality of the forward rate as a spot rate predictor[3]

$$\beta = 1 - \beta_{RE} - \beta_{RN}$$

Exchange Rate	$\hat{\beta}$	t: $\beta = 1$	$\hat{\beta}_{RE}$	t: $\beta_{RE}=0$	$\hat{\beta}_{RN}$	t: $\beta_{RN}=0$
Dollar-sterling	-4.63 (1.92)	-2.93	4.68 (2.63)	1.78	0.95 (0.67)	1.41
Sterling effective	-1.01 (0.60)	-3.35	0.60 (0.55)	1.09	1.41 (0.15)	9.67

3 Note that $\hat{\beta} = 1 - \hat{\beta}_{RE} - \hat{\beta}_{RN}$. $\hat{\beta}_{RE}$ was estimated from a regression of the forecast errors onto the forward premium (see equation (8)), using generalised method of moments. β_{RN} was estimated from a regression of the expected rate of appreciation onto the forward premium (see equation (9)). Figures in parentheses are estimated standard errors. Figures in the second, fourth and sixth columns are t-statistics for the indicated null hypothesis.

TABLE 4

Testing the ARCH-in-mean model of the risk premium[4]

$$p_t^2 = \alpha_0^2 + \sum_{i=1}^{4} \alpha_i^2 u_{t-i}^2 + \varepsilon_t$$

Exchange Rate	$\hat{\alpha}_0$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\hat{\alpha}_4$	F(4, 46)
Dollar sterling	11.680	0.001	0.148	0.077	0.327	0.50
	(4.73)	(50.62)	(0.66)	(1.28)	(0.29)	(0.74)
Sterling-effective	10.61	0.316	0.058	0.011	0.285	0.81
	(3.17)	(38.71)	(0.81)	(4.36)	(6.17)	( )

4 Estimated by non-linear least squares. Figures in parentheses below coefficient estimates are estimated standard errors. F(4, 46) is an F-statistic for the null hypothesis that $\alpha_i = 0$, i = 1, 2, 3, 4, figures below the F-values are marginal significance levels.

TABLE 5

Testing the asset yield volatility model of the risk premium[5]

$$P_t = \beta_0 + \beta_1 \sigma_t^d + \beta_2 \sigma_t^f + \epsilon_t$$

Exchange Rate	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	R^2	DW	Q(21)
Dollar-Sterling	17.810	0.015	-0.052	0.25	1.99	10.12
	(3.12)	(0.007)	(0.017)			

5 σ_t^d and σ_t^f are the twelve-month moving standard deviations in the UK FTA All Share and US Standard and Poor's composite stock market indices respectively. See Taylor 1987 for exact definitions and data sources. R^2 is the coefficient of determination, DW is the Durbin-Watson statistic, Q is the Ljung-Box statistic for 21 autocorrelations, estimated standard errors are in parentheses.

TABLE 6

Risk and uncertainty in foreign exchange[6]

$$P_t = \delta_0 + \delta_1 \sigma_t + \varepsilon_t$$

Exchange Rate	$\hat{\delta}_0$	$\hat{\delta}_1$	R^2	DW
Dollar-sterling	-4.172	1.476	0.80	0.50
	(0.85)	(0.102)		
Sterling effective	-4.061	1.246	0.05	0.32
	(0.84)	(0.108)		

6 R^2 is the coefficient of determination, DW is the Durbin-Watson statistic, figures in parentheses are estimated standard errors.

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