RISK PREMIA, MARKET EFFICIENCY AND THE EXCHANGE RATE: SOME EVIDENCE SINCE THE FLOAT

Warren J. Tease*

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ABSTRACT

The Australian dollar was floated in December 1983. Since that time the exchange rate has become more volatile and has depreciated significantly. The aim of this paper is to examine the behaviour of the foreign exchange market since the float. In particular, the paper considers whether the joint hypotheses underlying the notion of speculative efficiency - namely market efficiency and risk neutrality - hold in the post-float forward market. Under the speculative efficiency hypothesis, the forward exchange rate is a rational expectation of the future spot exchange rate. The paper examines this speculative efficiency hypothesis for forward rates of different maturities, by examining whether the forward rate provides the best available forecast of the future spot rate.

The paper endeavours to make full use of the data available by sampling more finely than the contract interval. This procedure, however, involves some econometric difficulties. In particular, the residuals from OLS estimation will be serially correlated, following a low order moving average process. Consequently, the estimated standard errors will be inconsistent. To overcome this, the relevant equations are estimated by first obtaining consistent parameter estimates by OLS and then estimating a consistent asymptotic covariance matrix.

The findings of the paper can be summarised as follows. For the post-float period as a whole, the speculative efficiency hypothesis can be rejected for the 30-day forward market but not for the 15-day and 90-day forward markets. However, some evidence of parameter instability is found. In particular, there is evidence of a structural break in several of the reported equations after February 1985; the time of the first major depreciation. For the period after February 1985, each of the markets was found to be speculatively inefficient, in the sense that other available information improves upon the forecast of the future spot rate that is provided by the forward rate.

It must be stressed that due to the joint nature of the hypothesis it is impossible to state whether the observed deviations from this definition of speculative efficiency were due to market inefficiency (i.e., agents not using available information optimally) or risk aversion (i.e., risk averse speculators may drive a risk premium or wedge between the market's expectation of the future spot rate and the current forward rate). Because of the limited sample period since the float it is difficult to conduct more sophisticated tests for the existence of particular forms of risk premia in the forward market.

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1. Introduction

There is an extensive literature testing the "efficiency" of foreign exchange markets - that is, whether available information is optimally used in the determination of exchange rates. This widespread interest in foreign exchange market efficiency can be attributed to two factors. First, information on forward and spot exchange rates provide a rich source of data which can be used to (indirectly) test whether agents form their expectations rationally. Second, deviations from the efficiency hypothesis have important policy implications. In particular, if the foreign exchange market is inefficient the authorities can, in principle, intervene successfully to prevent or burst price "bubbles" or to assist the market to move quickly to a new equilibrium. Such intervention can help to smooth fluctuations in the exchange rate.

Tests of market efficiency used in much of this literature are actually tests of the joint hypotheses that markets are efficient and (at least some) agents are risk neutral. The assumption of risk neutrality is needed to give empirical content to the familiar notion of market efficiency discussed in Fama (1976). The market efficiency hypothesis states that prices fully reflect available information. By imposing the assumption of risk neutrality, testable implications of the efficiency hypothesis can be derived.[1] These testable versions of the model will be discussed in the following section.

Many recent studies of exchange markets overseas including Hansen and Hodrick (1980), Hodrick and Srivastava (1984), Hakkio (1981), Hsieh (1982), Baillie, Lippens and McMahon (1983) and Korajczyk (1985) all find evidence of inefficiency. That is, other available information improves upon the forecast of the future spot exchange rate that is provided by the current forward rate.

For Australia, on the other hand, several studies including Levis (1982) and Turnovsky and Ball (1983) have found weak support for the speculative efficiency hypothesis. Levis found that, for the period 1974-1981, the 90-day US$/$A forward rate was an unbiased predictor of future US$/$A spot rates and that US$/$A forward premiums contained no unexploited information about future

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1. Bilson (1981) has popularised the name "speculative efficiency" for this joint hypothesis. He defines the market to be speculatively efficient if the supply of speculative funds is infinitely elastic at the forward price that equals the expected spot price. To avoid confusion I shall use this terminology.

US$/$A spot rates. Turnovsky and Ball (1983), conducting similar tests over the same sample period, found that the speculative efficiency hypothesis could not be rejected at the one per cent level of confidence but could be rejected at the five per cent level.

These two studies were conducted at a time when Australia had a managed exchange rate system. The introduction of a floating exchange rate system in December 1983 and the associated increase in exchange rate volatility[2] may have altered behaviour in the foreign exchange market. The purpose of this paper is to re-examine the speculative efficiency hypothesis for the period of floating exchange rates. This paper extends previous Australian studies in three areas. First, data on forward and spot exchange rates are sampled weekly, thus giving more precision to the parameter estimates. Secondly the paper pays more attention to tests of semi-strong form versions of the hypothesis than earlier papers. Finally, the speculative efficiency hypothesis is examined for forward rates of different maturities.

The earlier Australian studies failed to reject the speculative efficiency hypothesis on the ground that the forward rate was an unbiased predictor of future spot exchange rates. On this criterion alone, the present paper also fails to reject the speculative efficiency hypothesis. However, the more extensive tests of the semi-strong form of the speculative efficiency hypothesis (i.e., the orthogonality of other information) suggest that the forecast errors in the 30-day market are serially correlated and that there was a behavioural change in the market after the depreciation of February 1985. In particular, the null hypothesis of speculative efficiency is rejected for each market after the February 1985 depreciation. Readily available information (on earlier expectation errors and forward premiums) improves the forecast of the future spot exchange rate that is provided by the current forward rate. Since the tests involve a joint hypothesis, this rejection could be due to market inefficiency and/or time varying risk premia. Because of the limited sample size since the float it was not possible to conduct more sophisticated tests of the existence of time varying risk premia.[3]

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2. See Trevor and Donald (forthcoming).

3. For instance, Cosset (1984) uses a measure of risk premium derived in Graver, Litzenberger and Stehle (1976) which is a function of world prices and nominal world wealth, while Mark (1985) using a model of intertemporal asset pricing derives a risk premium which is a function of real consumption, amongst other things. There are very few observations on these variables since the float. Thus, further testing in this area will be limited until the data become available.

The paper is structured as follows. Section 2 outlines the joint hypothesis and examines its testable implications. Section 3 discusses some econometric issues while section 4 discusses the data and results. Section 5 offers some concluding thoughts.

2. Joint tests of risk neutrality and market efficiency

In an efficient market, agents cannot derive abnormal returns by systematically exploiting available information. In the forward market, for instance, if some agents are risk neutral and the market is informationally efficient, the forward price will equal the expected spot price. Given the assumptions of risk neutrality and market efficiency, any systematic deviation between these two prices would indicate unexploited profit opportunities in the forward market. The assumption of risk neutrality ensures this equality holds. This is because the forward price embodies both expectations of future spot prices and a risk premium reflecting the riskiness of the forward contract. Risk neutrality ensures that this risk premium is zero.

If the forward market is informationally efficient and if agents are risk neutral then the forward rate will equal the expected future spot rate (or the rational expectation of the future spot rate), thus

(1) $$E[S_{t+n}|\phi_t] = F_{t,n}$$

where $F_{t,n}$ = forward rate contracted at period t for payment at period t+n

S_{t+n} = spot rate in period t+n

ϕ_t = information set available to agents at period t

$E[.|\phi_t]$ = mathematical expectation conditional on $\phi(t)$

Forward rates and spot rates are expressed as natural logs (hence ignoring Jensen's inequality).

The conditional forecast error, ε_{t+n}, can be written as

(2) $$\varepsilon_{t+n} = S_{t+n} - F_{t,n}$$

Given market efficiency and risk neutrality, as defined in (1), the expected forecast error is

$$(3) \qquad E[\epsilon_{t+n}|\phi_t] = E[S_{t+n} - F_{t,n}|\phi_t] = 0$$

If the joint hypothesis of speculative efficiency is valid, then the expected value of the conditional forecast error is zero. If ϵ_{t+n} has a zero mean then the constant term, α_1, in equation (4) should be insignificantly different from zero

$$(4) \qquad \epsilon_{t+n} = \alpha_1 + \nu_t$$

Furthermore, ϵ_{t+n} should be uncorrelated with variables in the information set ϕ_t. Any correlation between variables in ϕ_t and ϵ_{t+n} would indicate that $F_{t,n}$ is not an optimal predictor of S_{t+n}. Thus, by positing variables that may appear in ϕ_t, several testable implications of (3) can be developed.

Although the choice of variables that may be elements of ϕ_t is partly arbitrary, it is assumed that ϕ_t contains <u>observable</u> lagged values of

- the expectation error, ϵ_{t+n},
- the spot holding period yield, $Y_{t,n} = S_t - S_{t-n}$,
- the forward premium, $P_{t,n} = F_{t,n} - S_t$.

Geweke and Feige (1979), Hansen and Hodrick (1980) and Hsieh (1982) have also chosen to use various combinations of the above variables as elements of ϕ_t. The rationale for this choice of information variables is as follows. If forward rates are rational expectations of future spot rates then the observed forecast errors should be uncorrelated with future forecast errors. Hence, lagged forecast errors should not provide additional information about future forecast errors. The spot holding period yield represents the return to pure spot exchange rate speculation (i.e., abstracting from interest received on any financial assets held over the n periods). Any information which this yield provides about future spot prices should be reflected in the forward price. Similarly, any information which the forward premium (which, given covered interest rate parity, is a proxy for interest differentials) provides about future spot prices should be reflected in the forward price.

Thus we are provided with several tests of efficiency and risk neutrality. The following regressions[4] will reveal whether ϵ_{t+n} is correlated with elements of ϕ_t

(5) $$\epsilon_{t+n} = \alpha_2 + \beta(L)\,\epsilon_t + \nu_t$$

$$L = 0, 1, \ldots, 3$$

where $$\epsilon_t = S_t - F_{t-n,n}$$

(6) $$\epsilon_{t+n} = \alpha_3 + \gamma(L)P_{t,n} + \nu_t$$

$$L = 0, 1, \ldots, 3$$

$$P_{t,n} = F_{t,n} - S_t$$

(7) $$\epsilon_{t+n} = \alpha_4 + \delta(L)\,Y_{t,n} + \nu_t$$

$$L = 0, 1, \ldots, 3$$

$$Y_{t,n} = S_t - S_{t-n}$$

Equations (4) and (5) in combination provide a test of whether the series ϵ_{t+n} is a fair game.[5] If the sequence of ϵ_{t+n} is a fair game then $\alpha_1 = 0$ and $\alpha_2 = \beta_i = 0$ for all i. Furthermore, if ϵ_{t+n} is uncorrelated with ϕ_t then the estimated coefficients in (6) and (7) should satisfy the condition $\alpha_3 = \gamma_i = 0$ and $\alpha_4 = \delta_i = 0$, for all i, respectively.

Finally, if the market is efficient and agents are risk neutral then the forward rate should be an unbiased predictor of future spot rates. A simple test of unbiasedness is given in (8)

(8) $$S_{t+n} = \alpha + \beta F_{t,n} + \nu_t$$

Unbiasedness will be satisfied if $\alpha = 0$ and $\beta = 1$.

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4. The choice of lag length is arbitrary. However, for the sake of parsimony I shall restrict the analysis to four lags. This is also in keeping with previous studies such as Hansen and Hodrick (1980).

5. The sequence ϵ_{t+n} is a fair game if $E[\epsilon_{t+n}|\phi_t] = 0$ and ϵ_{t+n} is not serially correlated. If this condition holds then the expected return to speculation will equal the actual return.

If the restrictions associated with any of these equations are not supported by the data then the joint null hypothesis of speculative efficiency can be rejected.

3. Econometric methodology

To maximise the sample size, overlapping data are used. That is, data on spot rates and 15-day, 30-day and 90-day forward rates are sampled weekly. The econometric consequences of adopting this sampling procedure can be demonstrated by the following model. Consider the forecasting equation

$$(9) \qquad E(Z_{t+n}|\phi_t) = X_t\beta$$

where X_t is a vector of elements of ϕ_t and β is a vector of parameters.

To test for rationality, (9) can be estimated as

$$(9') \qquad Z_{t+n} = X_t\beta + u_{t+n}$$

where $u_{t+n} = Z_{t+n} - E(Z_{t+n}|\phi_t)$, is the forecast error which becomes observable at period t+n.

Using data sampled more finely than the forecast interval n will result in serially correlated errors. In particular, it will be found that

$$\text{Cov}[u_{t+n}, u_{t+n-k}] \neq 0 \qquad \text{for } k=1, 2...n-1$$

and

$$\text{Cov}[u_{t+n}, u_{t+n-k}] = 0 \qquad \text{for } k \geq n$$

This result obtains because the future values $Z_{t+1}, Z_{t+2}, \ldots Z_{t+n-1}$ are unobservable at period t, the time the forecast is made. Consequently, the corresponding forecast errors $u_{t+n-k} = Z_{t+n-k} - E(Z_{t+n-k}|\phi_{t-k})$ for k=1, 2...n-1 are unobservable and are thus not elements of ϕ_t. Since u_{t+n-k} for $k \leq n-1$ are not elements of ϕ_t it is possible that they are correlated with u_{t+n}. Because of this serial correlation, OLS estimation of (9'), will yield consistent coefficient estimates, but inconsistent estimates of the standard errors.

To overcome this problem, Hansen and Hodrick (1980) estimate β by OLS and follow Hansen (1979) to estimate a consistent asymptotic covariance matrix.[6]

Hansen (1979) shows that

(10) $$\sqrt{T}(\hat{\beta}_T - \beta) \xrightarrow{d} N(0,\theta)$$

where T is the sample size

$\hat{\beta}_T$ is the OLS estimator

θ is the asymptotic covariance matrix.

Hansen and Hodrick (1980) show that a consistent estimate of θ is obtained from

(11) $$\hat{\theta}_T = T(X'X)^{-1}X'\hat{\Omega}X(X'X)^{-1}$$

where $\hat{\Omega}$ is a TxT symmetric matrix with non-zero elements being the serial covariances of the OLS residuals. The results reported in the following section will follow this procedure.

4. Data and Results

(a) Full Sample Tests

Data on US$/$A spot and forward rates were obtained from the Daily Exchange Rate release of the Commonwealth Bank of Australia.[7] Tests were conducted across a range of maturities. In particular, tests of the efficiency of the 15-day, 30-day and 90-day forward markets were conducted. The results of estimating equations (4) through (8) for each of these markets are reported in Tables 1 through 5. In equations (4) through (7) we are interested in testing

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6. GLS is inappropriate in (9') since variables typically contained in X_t are not strictly exogenous. GLS estimates of β thus do not satisfy the orthogonality condition resulting in inconsistent estimates. Hansen and Hodrick (1980 p 833) note that their procedure is not fully efficient but is computationally more tractable than alternative procedures.

7. For a more detailed description of the construction of the data see the Appendix.

the joint null hypothesis that all coefficients in each equation are zero while in equation (8) we are interested in testing the hypothesis that $\alpha = 0$ and $\beta = 1$. These joint hypotheses are tested via the $\chi^2(m)$ statistic, which has the form

$$(12) \qquad \chi^2(m) = T(\hat{\beta}_T - \beta_o)' \, \hat{\theta}_T^{-1}(\hat{\beta}_T - \beta_o)$$

This statistic has a χ^2 distribution with m degrees of freedom, where m is the number of restrictions.

The results of estimating equation (4), given in Table 1, show that the null hypothesis, that the mean of the forecast error is zero, cannot be rejected in any of the markets. Furthermore, from Table 2, there is little evidence of serial correlation in the forecast errors of the 15-day and 90-day markets. Although an individual parameter, $\hat{\beta}_2$, in the 15-day market is significantly different from zero, the χ^2 statistic indicates that the joint null hypothesis $\alpha = \beta = 0$ cannot be rejected. However, in the 30-day market there is evidence of serially correlated forecast errors; the χ^2 statistic is highly significant. The sequence of forecast errors in the 30-day market are not uncorrelated suggesting that this market is not speculatively efficient.

These two tests are weak form tests of efficiency. Semi-strong form tests of efficiency are provided by estimating equations (6) and (7). The results of these estimations are reported in Table 3 and Table 4. In each of the markets it is found that neither lags of the forward premium nor lags of the spot holding period yield are significant explanators of the forecast error. Although some individual parameter estimates are significantly different from zero, each χ^2 statistic is insignificant. Thus, the respective joint null hypotheses $\alpha = \gamma = 0$ and $\alpha = \delta = 0$ cannot be rejected.

Finally, the results in Table 5 show that the forward rate is an unbiased predictor of future spot rates in each market. That is, the joint null hypothesis $\alpha = 0$, $\beta = 1$ cannot be rejected.

These results suggest that, for the post float period as a whole, the joint hypothesis that agents are risk neutral and markets are efficient cannot be rejected in the 15-day and 90-day forward markets. However, this joint hypothesis can be rejected in the 30-day forward market where lagged forecast errors help predict the future spot rate. Because of the joint nature of these tests it is impossible to determine whether rejection in the 30-day market is due to market inefficiency or to risk aversion.

Table 1

$$c_{t+n} = \alpha + \nu_t$$

Sample Period: 13 December 1983 - 28 January 1986

Maturity	T	$\hat{\alpha}$	R^2	$\chi^2(m)$
15 day	111	-0.003 (0.004)	0.0	-
30 day	109	-0.006 (0.008)	0.0	-
90 day	102	-0.026 (0.026)	0.0	-

Standard errors are in brackets.
T is the number of observations
(*) Significantly different from zero at the five per cent level
(**) Significantly different from zero at the one per cent level

Table 2

$$c_{t+n} = \alpha + \beta(L)c_t + \nu_t$$

Sample Period: 13 December 1983 - 28 January 1986

Maturity	T	$\hat{\alpha}$	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	R^2	$\chi^2(5)$
15 day	107	-0.004 (0.004)	0.248 (0.136)	-0.261* (0.124)	0.032 (0.123)	-0.032 (0.134)	0.04	6.81
30 Day	103	-0.006 (0.009)	0.107 (0.164)	-0.318** (0.102)	0.157 (0.103)	0.185 (0.165)	0.06	26.77**
90 Day	86	-0.040 (0.031)	0.199 (0.333)	-0.001 (0.126)	-0.022 (0.109)	-0.496 (0.305)	0.15	4.20

See footnotes Table 1

Table 3

$$\varepsilon_{t+n} = \alpha + \gamma(L)\, P_{t,n} + \nu_t$$

Sample Period: 13 December 1983 - 28 January 1986

Maturity	T	$\hat{\alpha}$	$\hat{\gamma}_0$	$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$	R^2	$\chi^2(5)$
15 day	108	-0.009 (0.006)	-3.083 (6.710)	-6.168 (6.740)	1.126 (4.650)	5.053 (4.640)	0.04	3.27
30 Day	106	-0.017 (0.010)	5.615 (4.400)	6.763* (3.040)	-3.668 (2.950)	-5.862 (4.180)	0.09	7.81
90 Day	99	-0.050 (0.030)	0.017 (5.780)	-0.800** (0.200)	3.991 (2.710)	-5.987 (5.260)	0.10	3.02

See footnotes Table 1

Table 4

$$\varepsilon_{t+n} = \alpha + \delta(L)\, Y_{t,n} + \nu_t$$

Sample Period: 13 December 1983 - 28 January 1986

Maturity	T	$\hat{\alpha}$	$\hat{\delta}_0$	$\hat{\delta}_1$	$\hat{\delta}_2$	$\hat{\delta}_3$	R^2	$\chi^2(5)$
15 day	108	-0.003 (0.004)	0.272 (0.148)	-0.345* (0.155)	0.219 (0.150)	-0.098 (0.143)	0.04	6.52
30 Day	102	-0.006 (0.009)	0.141 (0.205)	-0.272 (0.167)	-0.065 (0.169)	0.377 (0.207)	0.07	6.25
90 Day	86	-0.045 (0.031)	0.181 (0.385)	-0.197 (0.244)	0.158 (0.231)	-0.542 (0.363)	0.20	4.73

See footnotes Table 1

Table 5

$$S_{t+n} = \alpha + \beta F_{t,n} + \nu_t$$

Sample Period: 13 December 1983 - 28 January 1986

Maturity	T	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\chi^2(2)$
15 day	111	-0.013 (0.009)	0.962** (0.033)	0.95	1.98
30 day	109	-0.027 (0.017)	0.914** (0.060)	0.90	2.60
90 Day	102	-0.089 (0.046)	0.733** (0.170)	0.67	3.84

See footnotes Tables 1

The major event experienced in the foreign exchange market since the float was the large depreciation of the Australian dollar which commenced in February 1985. Although this paper cannot explain whether this depreciation was a consequence of altered economic fundamentals or rational price bubbles, it can test to see if behaviour in the market has altered since its occurrence. The following sub-section constructs and implements a test of parameter instability which can be used in conjunction with the Hansen-Hodrick procedure.

(b) A Test of Parameter Stability[8]

As previously mentioned, because of the presence of serial correlation, estimation has proceeded by first obtaining consistent OLS parameter estimates and then estimating a consistent asymptotic covariance matrix. This procedure renders "traditional" tests of stability inappropriate. For instance, Cusum and Cusum of Squares tests (see Brown, Durban and Evans (1975) and Harvey (1983)) are not appropriate when there are serially correlated errors. Furthermore, the residual sum of squares produced by the OLS estimates are not appropriate for the construction of Chow tests. To overcome this a Wald test is constructed which makes use of the consistent estimates of the asymptotic covariance matrices.

Consider the linear model

(13) $$\begin{vmatrix} Z_1 \\ Z_2 \end{vmatrix} = \begin{vmatrix} X_1 & 0 \\ 0 & X_2 \end{vmatrix} \begin{vmatrix} \beta_1 \\ \beta_2 \end{vmatrix} + \begin{vmatrix} \varepsilon_1 \\ \varepsilon_2 \end{vmatrix}$$

Z_i = dependent variable in period i

X_i = vector of independent variables in period i

β_i = parameter vector in period i

ε_i = stochastic residual in period i

We are interested in testing whether the parameters are equal in both periods. The null hypothesis H_o: $\beta_1 = \beta_2$, can be expressed as

$R\beta = r = 0$

8. I am grateful to Rob Trevor for suggesting the test statistic used in this section.

where R is a (kx2k) matrix of the form

$$R = |I, -I|$$

and β is a (2kx1) vector of parameters of the form

$$\beta = \begin{vmatrix} \beta_1 \\ \beta_2 \end{vmatrix}$$

and k is the number of parameters.

From equation (10) it follows that

$$(14) \qquad \sqrt{T_1}(\hat{\beta}_1 - \beta_1) \xrightarrow{d} N(0, \theta_1)$$

and

$$(15) \qquad \sqrt{T_2}(\hat{\beta}_2 - \beta_2) \xrightarrow{d} N(0, \theta_2)$$

which can be expressed as

$$(16) \qquad \begin{vmatrix} \sqrt{T_1}(\hat{\beta}_1 - \beta_1) \\ \sqrt{T_2}(\hat{\beta}_2 - \beta_2) \end{vmatrix} \xrightarrow{d} N(0, \theta)$$

where $\theta = \begin{vmatrix} \theta_1 & 0 \\ 0 & \theta_2 \end{vmatrix}$

and θ_1 and θ_2 are the asymptotic covariance matrices for periods 1 and 2.

A test statistic, W(k), for the linear restriction Rβ=r is given by

$$(17) \qquad W(k) = (R\hat{\beta}-r)'[R\hat{V}R']^{-1} (R\hat{\beta}-r)$$

$$(18) \qquad \text{where } \hat{V} = \begin{vmatrix} \frac{\hat{\theta}_1}{T_1} & 0 \\ 0 & \frac{\hat{\theta}_2}{T_2} \end{vmatrix}$$

Substituting (18) into (17) gives

$$(19) \qquad W(k) = (R\hat{\beta}-r)'\left(\frac{\hat{\theta}_1}{T_1} + \frac{\hat{\theta}_2}{T_2}\right)^{-1} (R\hat{\beta}-r)$$

Where W(k) has a $\chi^2(k)$ distribution with k degrees of freedom

The results of these stability tests are reported in Tables 6 through 10. In each test the sample is divided into two periods, 13 December 1983 - 5 February 1985 and 12 February 1985 - 28 January 1986.[9]

The results reported in Table 6 suggest that the mean of the forecast errors are insignificantly different from zero in both periods.

Tables 7 and 9 show that for the 15-day and 30-day markets the null hypothesis of speculative efficiency cannot be rejected in either period. However, in the 90-day market this null hypothesis can be rejected in Period 1 but not Period 2. Furthermore, there is evidence of parameter instability in the equations estimated for the 90-day market. The latter appears to be the result of changes to the constant term. The last two rows of Table 11 report the results of testing the stability and significance of the constant term in both equations. In both cases the constant term is found to be unstable. The null hypothesis that $\alpha = 0$ is rejected in Period 1 but not in Period 2 in both equations.

More striking results are to be found in Tables 8 and 10. First, consider Table 10. In all markets, the parameters are found to be significantly different in each period. In particular, the results show that while the forward rate was an unbiased predictor of future spot rates in Period 1 this was not the case in the subsequent period. On the basis of these results, the speculatively efficiency hypothesis can be rejected for all three markets in Period 2.

A similar result is obtained in Table 8.[10] In the 15-day market there is evidence of instability. However, the speculative efficiency hypothesis

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9. The observation for 5 February 1985 was chosen to split the sample because it represents the start of the large depreciation. In the period from December 1983 to the end of January 1985 the $A depreciated by about 12 per cent against the US$, or approximately 0.2 per cent per week. From 5 February 1985 - 12 February the $A depreciated by about 4 per cent against the US$, while for the month of February as a whole the depreciation was around 17 per cent.

10. At first it appears that the χ^2 and t-statistics in the equations relating to the 30-day and 90-day markets are inconsistent. The χ^2 statistics, for instance, reject the joint hypothesis that all the parameters are equal to zero whereas the t-statistics suggest that, individually, each of the parameters are zero. The relatively high R^2's in these equations suggest that the equations, as a whole, explain a significant proportion of the forecast error. This is consistent with the significant χ^2 tests. It is likely, therefore, that the insignificance of individual parameters is caused by multi-collinearity.

Table 6

$$\varepsilon_{t+n} = \alpha + \nu_t$$

Period 1 13 December 1983 - 5 February 1985
Period 2 12 February 1985 - 28 January 1986

	Period 1				Period 2				
Maturity	T_1	$\hat{\alpha}$	R^2	$\chi^2(2)$	T_2	$\hat{\alpha}$	R^2	$\chi^2(2)$	W(2)
15 Day	61	-0.007 (0.005)	0.0	-	50	0.001 (0.046)	0.0	-	0.80
30 Day	61	-0.016 (0.011)	0.0	-	48	0.007 (0.010)	0.0	-	2.29
90 Day	61	-0.057 (0.031)	0.0	-	41	0.019 (0.010)	0.0	-	5.55

See footnotes Table 1

Table 7

$$\varepsilon_{t+n} = \alpha + \beta(L)\varepsilon_t + \upsilon_t$$

Period 1 13 December 1983 - 5 February 1985
Period 2 12 February 1985 - 28 January 1986

Maturity	Period 1 T_1	$\hat{\alpha}$	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	R^2	$\chi^2(5)$	Period 2 T_2	$\hat{\alpha}$	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	R^2	$\chi^2(5)$	W(5)
15 Day	57	-0.006	0.668*	-0.470	0.012	0.097	0.12	9.63	50	0.0	0.136	-0.205	0.054	-0.077	0.03	2.04	4.16
		(0.005)	(0.261)	(0.270)	(0.255)	(0.244)				(0.007)	(0.165)	(0.164)	(0.165)	(0.167)			
30 Day	55	-0.018	0.351	-0.279	-0.129	0.195	0.02	5.16	48	0.009	0.061	-0.310*	0.205	0.225	0.17	9.67	5.45
		(0.011)	(0.354)	(0.279)	(0.264)	(0.358)				(0.009)	(0.154)	(0.138)	(0.141)	(0.158)			
90 Day	45	-0.102**	0.002	-0.532*	0.154	-0.795	0.42	20.17**	41	0.015	0.110	0.115	-0.003	-0.312	0.15	4.16	17.45*
		(0.026)	(0.592)	(0.263)	(0.257)	(0.515)				(0.014)	(0.374)	(0.501)	(0.492)	(0.372)			

See footnotes Table 1

Table 8

$$\varepsilon_{t+n} = \alpha + \gamma(L)P_{t,n} + \nu_t$$

Sub-period 1   13 December 1983 - 5 February 1985
Sub-period 2   12 February 1985 - 28 January 1986

		Period 1								Period 2							
Maturity	T_1	$\hat{\alpha}$	$\hat{\gamma}_0$	$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$	R^2	$\chi^2(5)$	T_2	$\hat{\alpha}$	$\hat{\gamma}_0$	$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$	R^2	$\chi^2(5)$	W(5)
15 Day	58	-0.007	6.383	7.235	-5.560	5.142	0.16	9.65	50	-.0441*	-1.812	-9.314	-4.454	-0.799	0.19	7.39	11.90*
		(0.005)	(11.609)	(11.499)	(6.612)	(5.925)				(0.018)	(9.415)	(9.032)	(9.106)	(9.281)			
30 Day	58	-0.014	-4.207	-2.272	-1.948	-5.641	0.40	17.67**	48	-0.069**	5.500	7.470*	2.499	-3.177	0.33	14.84*	23.27**
		(0.008)	(6.321)	(2.784)	(4.811)	(5.034)				(0.023)	(5.310)	(3.303)	(3.350)	(4.996)			
90 Day	58	-0.033	9.596	2.442	1.167	0.645	0.65	31.36**	41	-0.096	-0.141	-8.318**	-0.921	2.635	0.24	110.79**	35.07**
		(0.021)	(5.349)	(3.381)	(3.714)	(3.884)				(0.076)	(3.328)	(2.708)	(2.383)	(4.034)			

See footnotes Table 1

Table 9

$$\varepsilon_{t+n} = \alpha + \delta(L)Y_{t,n} + \nu_t$$

Period 1   13 December 1983 - 5 February 1985
Period 2   12 February 1985 - 28 January 1986

Maturity	T_1	$\hat{\alpha}$	$\hat{\delta}_0$	$\hat{\delta}_1$	$\hat{\delta}_2$	$\hat{\delta}_3$	R^2	$\chi^2(5)$	T_2	$\hat{\alpha}$	$\hat{\delta}_0$	$\hat{\delta}_1$	$\hat{\delta}_2$	$\hat{\delta}_3$	R^2	$\chi^2(5)$	W(5)
	Period 1								Period 2								
15 Day	56	-0.006	0.625**	-0.391	0.162	0.071	0.11	8.84	49	0.000	0.171	-0.328	0.229	-0.147	0.04	2.68	4.26
		(0.005)	(0.261)	(0.289)	(0.256)	(0.235)				(0.007)	(0.182)	(0.203)	(0.204)	(0.184)			
30 Day	53	-0.018	0.430	-0.442	-0.054	0.322	0.04	6.40	48	-0.010	0.058	-0.148	-0.159	0.476*	0.20	7.56	6.26
		(0.011)	(0.380)	(0.327)	(0.324)	(0.390)				(0.009)	(0.195)	(0.195)	(0.202)	(0.202)			
90 Day	45	-0.101**	0.041	-0.422	0.088	-0.794	0.45	22.10**	41	0.013	0.081	0.019	0.100	-0.317	0.13	7.67	20.54*
		(0.025)	(0.484)	(0.281)	(0.240)	(0.449)				(0.011)	(0.264)	(0.289)	(0.272)	(0.253)			

See footnotes Table 1

Table 10

$$S_{t+n} = \alpha + \beta F_{t,n} + \nu_t$$

Period 1 13 December 1983 - 5 February 1985
Period 2 12 February 1985 - 28 January 1986

		Period 1					Period 2				
Maturity	T_1	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\chi^2(2)$	T_2	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\chi^2(2)$	W(2)
15 Day	61	0.008 (0.014)	1.111** (0.093)	0.83	3.29	49	-0.259** (0.052)	0.310* (0.139)	0.15	24.79**	24.75**
30 Day	61	0.008 (0.029)	1.170** (0.199)	0.70	2.94	48	-0.350** (0.076)	0.065 (0.199)	0.00	22.60**	19.33**
90 Day	61	-0.001 (0.077)	1.409** (0.519)	0.48	4.92	41	-0.436** (0.126)	-0.168 (0.323)	0.07	15.07*	8.70*

See footnotes Table 1

Table 11

Maturity	Regressions	Null Hypothesis	m=k	$\chi^2(m)$ Period 1	$\chi^2(m)$ Period 2	Null Hypothesis	W(k)
30 Day	$\epsilon_{t+n} = \alpha + \gamma(L)P_{t,n} + v_t$	$\alpha = \gamma_1 = 0$	2	4.57	22.82**	$\alpha_1 = \alpha_2$, $\gamma_{11} = \gamma_{12}$[a]	7.74*
		$\gamma_1 = 0$	1	0.53	58.84**	$\gamma_{11} = \gamma_{12}$	6.20*
		$\alpha = 0$	1	3.70	118.77**	$\alpha_1 = \alpha_2$	8.72*
90 Day	$\epsilon_{t+n} = \alpha + \gamma(L)P_{t,n} + v_t$	$\alpha = \gamma_1 = 0$	2	5.40	218.5**	$\alpha_1 = \alpha_2$, $\gamma_{11} = \gamma_{12}$	10.60*
		$\gamma_1 = 0$	1	1.26	142.3**	$\gamma_{11} = \gamma_{12}$	16.50*
		$\alpha = 0$	1	3.03	113.6**	$\alpha_1 = \alpha_2$	1.95
	$\epsilon_{t+n} = \alpha + \beta(L)\epsilon_t + v_t$	$\alpha = 0$	1	24.22**	1.49	$\alpha_1 = \alpha_2$	22.82**
	$\epsilon_{t+n} = \alpha + \delta(L)Y_{t,n} + v_t$	$\alpha = 0$	1	24.76**	2.13	$\alpha_1 = \alpha_2$	25.08**

See footnotes Table 1

a. $\gamma_{11} = \gamma_1$ in period 1 and $\gamma_{12} = \gamma_1$ in period 2 cannot be rejected in either period. In the 30-day and 90-day markets, however, the null hypothesis of speculative efficiency is rejected in both periods. Additionally, there is evidence of a structural break in these equations. Closer inspection of Table 8 reveals that, in both the 30-day and the 90-day markets, the parameter γ_1 becomes highly significant in Period 2 and in the 30-day market the constant term also becomes significant in this period. One interpretation of this result is that the first lag of the forward premium could be used to reduce the observed forecast error in the latter but not the former period. That is, the market failed to use all available information when setting the forward price in the post depreciation period. To examine this hypothesis the stability and significance of α and γ_1 are tested, both individually and, where appropriate, jointly. The relevant χ^2 and Wald tests are reported in the first six rows of Table 11.

The results in Table 11 show that both singularly and jointly the coefficients α and γ_1 in the equation relating to the 30-day market become significantly different from zero in period 2 and that they are unstable over time. For the 90-day market each restriction is rejected in the second period and the parameter γ_1 is found to be unstable. These results are consistent with the hypothesis that the first lag of the forward premium could be used to reduce the observed forecast errors in the latter but not the former period.

These results suggest that after the February 1985 depreciation there has been a significant change in some of the relationships in the forward market. Both weak form (Table 10) and semi-strong form (Table 8) tests of the speculative efficiency hypothesis are rejected for the period after February 1985 but are not rejected for the period before this time. In the 90-day market there is also evidence of speculative inefficiency in the earlier period.

5. Conclusion

The aim of this paper has been to shed some light on the behaviour of the foreign exchange market since the floating of the Australian dollar. The focus of the study has been on the speculative efficiency hypothesis. It has been found that, for the post-float period as a whole, this hypothesis could not be rejected in the 15-day and 90-day markets. However, the joint hypothesis can be rejected in the 30-day market. In particular, the forecast errors in the 30 day market were found to be serially correlated. Hence, readily available information can be used to improve the forecast of the future spot exchange rate that is provided by the current forward rate.

A major finding of the paper has been the identification of a behavioural change in the forward market after February 1985. The results, in general, suggest that the markets (particularly the 15-day and 30-day markets) were speculatively efficient before the major depreciation in February 1985 but have not been speculatively efficient since this time. The exception to this was the 90-day market. In this market there was evidence of speculative inefficiency before and after the depreciation. The finding suggests that subsequent to the depreciation started in February 1985 the market became less efficient in its use of available information and/or a risk premium developed.

DATA CONSTRUCTION APPENDIX

Data were obtained from the Commonwealth Bank's daily exchange rate release. Three maturities were tested. These were for the 15-day, 30-day and 90-day markets. Weekly observations on bid spot and forward rates were used. Careful attention was given to the construction of the lagged forecast errors, premiums and holding period yields to ensure that each was observable at the time the forward contract was being entered into.

15 Day Data

Forward rates were sampled on Tuesday's and spot rates were sampled on Wednesday's 15 days hence. This yields the forecast error

$$\epsilon_{t+15} = S_{t+15} - F_{t,15}$$

Many studies simply lag the forecast error n times, where n is the number of weeks of the contract, to test for serial correlation in the forecast errors. However, in the 15 day market this would yield an independent variable equal to

$$\epsilon_{t+1} = S_{t+1} - F_{t-14,15}$$

Clearly, S_{t+1} is unobservable at period t the time the forward contract is being entered into. To overcome this a series of observable lagged forecast errors were constructed by sampling spot rates on Tuesdays (the day forward contracts are being entered into) and forward rates on Mondays 15 days prior. This yields

$$\epsilon_t = S_t - F_{t-15,15}$$

This series was then used as the independent variable in the relevant equations.

30 Day Data

Forward rates were sampled on Wednesdays, and spot rates on Fridays 30 days hence, yielding the dependent variable

$$\epsilon_{t+30} = S_{t+30} - F_{t,30}$$

Lagging this four times would yield

$$\varepsilon_{t+2} = S_{t+2} - F_{t-28,30}$$

Once again we would have an unobservable spot rate. Thus to construct the independent variables spot rates were sampled on Wednesdays and forward rates on Mondays 30 days prior, yielding independent variables

$$\varepsilon_{t} = S_{t} - F_{t-30,30}$$

<u>90 Day Data</u>

Forward rates were sampled on Tuesdays and spot rates on Mondays 90 days hence, yielding

$$\varepsilon_{t+90} = S_{t+90} - F_{t,90}$$

Lagging this by 13 weeks times yields

$$\varepsilon_{t-1} = S_{t-1} - F_{t-91,90}$$

Clearly the spot rate is observable. Therefore this was used as the lagged forecast error in the relevant tests.

BIBLIOGRAPHY

Argy, V.E. (1986) "Foreign Exchange Market Efficiency - Theory and Evidence", Macquarie University Center for Studies in Money, Banking and Finance, No. 8602-A.

Baillie, R.T., Lippens, R.E. and P.C. McMahon (1983), "Testing Rational Expectations and Efficiency in the Foreign Exchange Market", Econometrica Vol. 51 No. 3, pp.553-563.

Bilson, J.F.O. (1981), "The Speculative Efficiency Hypothesis", Journal of Business, July, pp.435-452.

Brown, B.W. and S. Maital (1981), "What Do Economists Know? An Empirical Study of Experts' Expectations" Econometrica Vol. 49 No.2 pp.491-505.

Brown, R.L., Durbin, J. and J.M. Evans (1975), "Techniques for Testing the Constancy of Regression Relationships over Time" Journal of the Royal Statistical Society, B, 37, pp.149-192.

Cosset, J.C. (1984), "On the Presence of Risk Premiums in the Foreign Exchange Markets" Journal of Internatinal Economics Vol. 16 No. 1/2 pp.139-155.

Fama, E. (1976), Foundations of Finance, Basic Books, New York.

________ (1984), "Forward and Spot Exchange Rates", Journal of Monetary Economics, Vol. 14 No. 3, pp.319-339.

Geweke, J. and F. Feige (1979), "Some Joint Tests of Efficiency of Markets for Forward Foreign Exchange", The Review of Economics and Statistics, Vol. LXI No. 3, pp.334-342.

Graver, F., R. Litzenberger and R. Stehle, (1976), "Sharing Rules and Equilibrium in an International Capital Market Under Uncertainty" Journal of Financial Economics, 3, pp.233-256.

Hakkio, C.S. (1981), "Expectations and the Forward Exchange Rate", International Economic Review Vol. 22 No. 3 pp.663-679.

Hansen, L.P. (1979), "The Asymptotic Distribution of Least Squares Estimators with Endogenous Regressors and Dependent Residuals", Graduate School of Industrial Administration, Carnegie-Mellon University.

Hansen, L.P. and R.J. Hodrick (1980), "Forward Exchange Rates as Optimal Predictors of Future Spot Rates", Journal of Political Economy, October, pp.829-853.

Harvey, A.C. (1983) The Econometric Analysis of Time Series, Phillip Allan, Oxford.

Hodrick, R.J. and S. Srivastava (1984), "An Investigation of Risk and Return in Forward Foreign Exchange", Journal of International Money and Finance, Vol. 3 No. 1, pp.5-31.

Hsieh, D.A. (1982), "Tests of Rational Expectations and No Risk Premium in Forward Exchange Markets", National Bureau of Economic Research Working Paper No. 843.

Hsieh, D.A. and N. Kulatilaka (1982), "Rational Expectations and Risk Premia in Forward Markets: Primary Metals at the London Metals Exchange", Journal of Finance, December, pp.1199-1207.

Korajczyk, R.A. (1985) "The Pricing of Forward Contracts for Foreign Exchange" Journal of Political Economy Vol. 93 No. 2 pp 346-368.

Levich, R.M. (1979), "On the Efficiency of Markets for Foreign Exchange" in R. Dornbusch and J.A. Frenkel eds, International Economic Policy - Theory and Evidence, Baltimore, John Hopkins University Press.

Levis, M. (1982), "The Behaviour of the Australian Forward Exchange Market", Australian Journal of Management, Vol. 7 No. 1, pp.61-75.

Mark, N.C. (1985), "On Time Varying Risk Premia in the Foreign Exchange Market: An Econometric Analysis" Journal of Monetary Economics Vol. 16 No. 1 pp.3-19.

Stockman, A.C. (1978), "Risk, Information and Forward Exchange Rates" in J.A. Frenkel and H.G. Johnson eds, The Economics of Exchange Rates, Addison-Wesley, Phillipines.

Trevor, R.G. and S.G. Donald (1986), "Exchange Rate Regimes and the Volatility of Financial Prices: The Australian Case", Reserve Bank of Australia Research Discussion Paper, forthcoming.

Turnovsky, S. and K.M. Ball (1983), "Covered Interest Parity and Speculative Efficiency: Some Empirical Evidence for Australia", Economic Record, Vol. 59, pp.271-280.