THE EFFICIENCY OF THE AUSTRALIAN FOREIGN EXCHANGE MARKET

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Abstract

Testing the Efficient Market Hypothesis involves a joint hypothesis. The rationality hypothesis postulates that the realised future spot rate is the sum of the expected spot rate and a random error term. The asset pricing postulate is that the forward rate is the sum of the expected spot rate and a time-varying risk premium. Applied research has concentrated on the Speculative Efficiency Hypothesis, in which the risk premium is assumed to be zero. We use the Corbae et al (1987) methodology, which is based on the theory of cointegration and allows for a stationary, time-varying risk premium, to test a necessary condition for efficiency in the 15, 30, 60, 90 and 180 day USD/AUD forward markets. The results support nonstationarity of exchange rates and indicate a structural break. The market is inefficient pre February 1985 but efficient thereafter.

* This paper is based on my honours dissertation at the University of Western Australia (Teo, 1990). I would like to thank my supervisor Professor K.W. Clements for his guidance and advice, Drs Frank Harrigan and Sam Ouliaris for their interest and help, and Lindsay Boulton and David Waters for the data. Needless to say, any errors remaining are my own.
I. Introduction

There is now a voluminous literature testing for the efficiency of the foreign exchange market, particularly with the advent of floating exchange rates in 1973. Simply put: Is available information optimally used in the determination of exchange rates?

Early tests of the Efficient Market Hypothesis focused on the joint hypothesis of the forward rate being an unbiased predictor of the future spot rate, and agents being risk neutral. This is the Speculative Efficiency Hypothesis or SEH (Bilson, 1981). The results generally were mixed; see e.g. Frenkel (1976, 1977), Longworth (1981), Hansen and Hodrick (1980), and Hsieh (1984). Rejection of the SEH, however, is consistent with market inefficiency or the existence of a time varying risk premium. Attempts to incorporate a risk premium so as to test the General Efficiency Hypothesis (Levich, 1985) have also yielded conflicting results; see e.g. Frankel (1982), Domowitz and Hakkio (1985), Hansen and Hodrick (1983) and Hodrick and Srivastava (1984).

For Australia, Levis (1982) and Turnovsky and Ball (1983) have found weak support for the SEH. However, these studies were done at a time when there was a managed exchange rate system. Tease (1988) and Madsen (1990) report that more extensive tests of the semi strong form of the SEH (i.e. the orthogonality of other information) reveal a structural break in the Australian foreign exchange market post February 1985. They disagree, however, on which maturities indicate speculative inefficiency.

This paper extends the past Australian studies in the following ways. Firstly, we use a methodology propounded by Corbae et al (1987) to test a necessary condition for market efficiency, which encompasses any model of pricing that includes a stationary risk premium. This is particularly relevant, given that Buchanan and Felmingham (1990) have identified a time varying risk premium on the AUD. Secondly, data on forward and spot rates are sampled weekly so as to give more precision to the parameter estimates. Thirdly, a relatively larger number of maturities for the USD/AUD forward market is investigated.
The rest of the paper is structured as follows. Section II outlines the theoretical background and methodology. Section III reports the results of unit root tests on the exchange rates investigated. Section IV presents the results of cointegration tests. Concluding remarks are presented in Section V.

II. Theory and methodology

Testing the General Efficiency Hypothesis involves testing a joint hypothesis. The first half of the hypothesis is

\[ s_{t+n} = E(s_{t+n}) + \epsilon_t \]  \hspace{1cm} (1)

where \( s_{t+n} \) is the natural logarithm of the spot rate at time \( t+n \), \( \bar{s}_{t+n} \) is the corresponding random variable, \( E \) is the expectation operator at time \( t \), and \( \epsilon_t \) is a mean zero white noise error term. Lower case letters involving exchange rates denote that they are in natural logarithms. Equation (1) says that economic agents are rational and use all available information in the formation of expectations.

The second half of the hypothesis is

\[ f_{t,n} = E(s_{t+n}) + RP_t \]  \hspace{1cm} (2)

where \( f_{t,n} \) is the \( n \)-period forward rate at time \( t \), and \( RP_t \) is the risk premium at time \( t \). Equation (2) says that agents are risk averse and require a risk premium before entering into a forward contract.

Existing tests of efficiency in the forward market typically use differenced data rather than exchange rates in levels form so as to remove nonstationarity and permit the use of standard econometric techniques for statistical inference. However, omission of a "relevant" explanatory variable (e.g. the risk premium) in tests of the SEH would affect the consistency of the other coefficient estimates. Hence, tests of market efficiency should identify the risk premium.
The Corbae et al (1987) methodology (to be outlined) exploits the known nonstationarity of spot and forward rates (Meese and Singleton, 1982, and Corbae and Ouliaris, 1986), and is based on the theory of cointegration (Engle and Granger, 1987). A cointegrated system permits individual time series to be integrated of order one (I(1)), but requires a linear combination of the series to be stationary (I(0)). Furthermore, Park and Phillips (1986, 1987) demonstrate that a stationary variable can be omitted from a cointegrating regression without affecting the consistency of the coefficient estimates, nor the power of the statistical procedures for hypothesis testing.

In testing the General Efficiency Hypothesis, equations (1) and (2) are represented in regression form as:

\[ s_{t+n} = a + b f_{t,n} + c R P_t + \varepsilon_t \quad (3) \]

The corresponding null hypothesis is \( H_0: a = 0, b = 1 \) and \( c = -1 \), and where \( \varepsilon_t \) is a mean zero white noise process which is uncorrelated with any information publicly available at time \( t \).

Let \( X_t = s_{t+n} - f_{t,n} \) be the forecast error. Then, from equation (3), assuming \( a = 0, b \neq 1 \) and \( c = -1 \),

\[ X_t = -R P_t + \varepsilon_t + (b-1) f_{t,n} \]
\[ = -R P_t + u_t \quad (4) \]

where \( u_t = \varepsilon_t + (b-1) f_{t,n} \). Since \( f_{t,n} \) is typically \( I(1) \), \( u_t \) is also \( I(1) \) if \( b \neq 1 \). This is interpreted as implying that new information is not incorporated into the forward rate and suggests market inefficiency. Conversely, if \( b = 1 \), \( u_t \) is \( I(0) \). Market efficiency therefore implies that \( s_{t+n} \) and \( f_{t,n} \) are cointegrated with the cointegrating vector \( (1, -1) \). An equivalent test of market efficiency, assuming \( R P_t \) is \( I(0) \), is therefore a unit root test of the variable \( X_t \). It should be noted that although previous studies have tested for the stationarity of forecast errors, it is only with the use of the theory of cointegration that permits this to be interpreted as a necessary condition for market efficiency.
III. Testing for nonstationarity

Five maturities for the USD/AUD forward exchange rate contracts are investigated: the 15 day, 1 month, 2 month, 3 month and 6 month forward contracts, and essentially covers the period from December 1983 to February 1990. The data are sampled weekly (refer to the Appendix for further description).

As a precondition, we test the exchange rates for a unit root using the Augmented Dickey Fuller test (Said and Dickey 1984) and the $\Phi_3$ test statistic (Dickey and Fuller 1981). The ADF test accounts for temporally dependent and heterogeneously distributed errors by including lagged first differences in the fitted regression. The null hypothesis is $\alpha = 1$ in

$$y_t = \mu + \alpha y_{t-1} + v_t,$$

and where the error sequence $v_t$ satisfies the moment and mixing conditions given in Assumption 2.1 of Phillips and Perron (1988). The ADF ($\mu$) test statistic allows for a constant term in the fitted regression. The ADF ($\mu, t$) test statistic allows for a constant term and a trend in the fitted regression, and is used here as the alternative hypothesis is that of deterministic stationarity about a mean and trend term. The $\Phi_3$ test statistic tests the joint hypothesis that the series is a random walk with a drift.

We follow Perman (1989) in attempting to include a sufficient number of lags in the ADF regression so as to eliminate serial correlation, nonnormality and heteroscedasticity in the error terms when possible. The diagnostic tests are not reported (see Teo, 1990, for details). We find that nonnormality is virtually impossible to eliminate, as is heteroscedasticity in some cases. We have given precedence to the elimination of serial correlation. The lag reported is for a parsimonious representation of the ADF regression which enables serial correlation, and heteroscedasticity (when possible) to be eliminated. We also vary the number of lags to see if the results differ qualitatively.

The computed values of ADF ($\mu, t$) and $\Phi_3$ are given in Table 1. The values of ADF ($\mu, t$) indicate that the null of a unit root is not rejected at conventional levels of significance in all six exchange rates considered. The
results are insensitive to the number of lags used in the ADF regressions (not reported here). None of the values of $\Phi_3$ is statistically significant. We are therefore unable to reject the null hypothesis that each of the exchange rate series follows a random walk with drift.

Table 1
Unit Root Tests for Spot and Forward Rates
$H_0$: Nonstationarity

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number of observations</th>
<th>Lags</th>
<th>ADF ((\mu,t))</th>
<th>$\Phi_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_t$</td>
<td>319</td>
<td>10</td>
<td>-2.79</td>
<td>4.64</td>
</tr>
<tr>
<td>$f_{t,15}$</td>
<td>319</td>
<td>10</td>
<td>-2.80</td>
<td>4.64</td>
</tr>
<tr>
<td>$f_{t,30}$</td>
<td>320</td>
<td>10</td>
<td>-2.54</td>
<td>4.02</td>
</tr>
<tr>
<td>$f_{t,60}$</td>
<td>313</td>
<td>5</td>
<td>-2.07</td>
<td>3.36</td>
</tr>
<tr>
<td>$f_{t,90}$</td>
<td>312</td>
<td>10</td>
<td>-2.46</td>
<td>3.85</td>
</tr>
<tr>
<td>$f_{t,180}$</td>
<td>299</td>
<td>15</td>
<td>-2.38</td>
<td>3.62</td>
</tr>
</tbody>
</table>

Notes: The critical value of ADF (\(\mu,t\)) is -3.13 at the 10% level of significance, -3.42 at 5%, -3.68 at 2.5% and -3.98 at 1% (Source: Table 8.5.2 in Fuller, 1976, pg 373). The critical value of $\Phi_3$ at the 10% level is 5.36 (Source: Table VI in Dickey and Fuller, 1981, pg 1063).

IV. Testing a necessary condition for market efficiency

In this section, we attempt to shed some light on the debate (Tease 1988, Madsen 1990) as to which forward markets in the Australian foreign exchange market have undergone a behavioural change post February 1985. We follow Madsen in dividing the sample into two periods by omitting the period from February 1985 to July 1985 due to parameter instability within this period. Subperiod 1 essentially is from December 1983 to January 1985, while Subperiod 2 essentially is from August 1985 to February 1990.
The Corbae et al (1987) methodology is applied to the entire period, as well as the subperiods to test the null hypothesis that the forecast errors, $s_{t+n} - f_{t,n}$, are not cointegrated. We use the same approach as in Section III concerning the number of lags in the ADF regressions. Table 2 gives the values of ADF ($\mu$). For the entire sample, the forecast errors are cointegrated, which lend support to the Efficient Market Hypothesis. Aside from the 180 day forecast errors, the results for the other forecast errors are insensitive to the number of lags used (not reported here). The 180 day forecast errors, however, are not cointegrated when smaller lags are used. Since the power of the ADF test statistics increases with the number of lags used, it seems likely that the 180 day market satisfies the condition for market efficiency.

For Subperiod 1, the forecast errors are not cointegrated with the vector $(1, -1)$. The results are also insensitive to the number of lags used (not reported here). Hence, the foreign exchange market is inefficient during the period from December 1983 to February 1985. We suggest that this is possibly due to a learning period from the switch from a managed float regime to a “freely” floating exchange rate regime. Alternatively, these results could be due to the failure of economic agents to anticipate the substantial depreciation of the AUD from February 1985 to June 1985, thereby leading to substantial forecast errors.

For Subperiod 2, the null hypothesis of no cointegration is rejected at conventional levels of significance. Aside from the 180 day forecast errors, the results are insensitive to the number of lags used (again, not reported here). The 180 day forecast errors, however, are not cointegrated when a smaller number of lags are used. In general, the results of Table 2 lend support to the Efficient Market Hypothesis.
Table 2
Tests of Cointegration of $s_{t+n} - f_{t,n}$
$H_0$: No Cointegration

<table>
<thead>
<tr>
<th>Maturity of forward contracts (in days)</th>
<th>Number of observations</th>
<th>Lags</th>
<th>ADF ($\mu$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full Period</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>319</td>
<td>15</td>
<td>-5.08**</td>
</tr>
<tr>
<td>30</td>
<td>320</td>
<td>5</td>
<td>-4.43**</td>
</tr>
<tr>
<td>60</td>
<td>313</td>
<td>15</td>
<td>-4.52**</td>
</tr>
<tr>
<td>90</td>
<td>312</td>
<td>15</td>
<td>-3.31*</td>
</tr>
<tr>
<td>180</td>
<td>299</td>
<td>10</td>
<td>-3.53**</td>
</tr>
<tr>
<td><strong>Subperiod 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>57</td>
<td>5</td>
<td>-1.67</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
<td>5</td>
<td>-1.46</td>
</tr>
<tr>
<td>60</td>
<td>56</td>
<td>5</td>
<td>-0.86</td>
</tr>
<tr>
<td>90</td>
<td>60</td>
<td>5</td>
<td>-1.28</td>
</tr>
<tr>
<td>180</td>
<td>60</td>
<td>5</td>
<td>-1.76</td>
</tr>
<tr>
<td><strong>Subperiod 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>236</td>
<td>15</td>
<td>-4.26**</td>
</tr>
<tr>
<td>30</td>
<td>234</td>
<td>10</td>
<td>-3.75**</td>
</tr>
<tr>
<td>60</td>
<td>231</td>
<td>15</td>
<td>-3.93**</td>
</tr>
<tr>
<td>90</td>
<td>226</td>
<td>15</td>
<td>-3.11*</td>
</tr>
<tr>
<td>180</td>
<td>214</td>
<td>15</td>
<td>-3.52**</td>
</tr>
</tbody>
</table>

Notes: The critical value of ADF ($\mu$) is -2.57 at the 10% level of significance, -2.87 at 5%, -3.13 at 2.5% and -3.44 at 1% (Source: Table 8.5.2 in Fuller, 1976, pg 373). A * denotes significant at the 5% level; and a ** denotes significant at the 1% level.
V. Conclusion

In this paper, we investigated the efficiency of the Australian foreign exchange market since the December 1983 float. We find that the USD/AUD spot rate, 15 day, 30 day, 60 day, 90 day and 180 day USD/AUD forward rates are nonstationary. The necessary condition for market efficiency cannot be rejected for all five forward maturities for the entire sample period from December 1983 to February 1990. Further analysis, however, reveals a structural break post February 1985 --- the market is inefficient pre February 1985 but efficient thereafter.

We emphasise the importance in future studies of the Australian foreign exchange market of allowing for the structural break in February 1985 so as to avoid making misleading conclusions concerning market efficiency. We also recommend that studies of market efficiency should test for the stationarity of forecast errors for two reasons: to justify the use of traditional econometric inference techniques, and also because cointegration of the forward and future spot rates is a necessary condition for market efficiency.
Appendix

Five maturities for the USD/AUD forward exchange rate contracts are investigated: the 15 day, 1 month, 2 month, 3 month and 6 month forward markets. The 1 month forward rates are interpreted as 30 day rates, the 3 month rates as 90 day rates, and the 6 month rates as 180 day rates. The database for these three forward rates and the spot rate is obtained from the Reserve Bank of Australia and comprises daily 4 p.m. Sydney rates. The 15 day and 2 month forward rates, and the corresponding spot rates, are obtained from the daily ANZ Bank exchange rate release and refer to transactions less than $A 25,000 in value. Essentially, the data refer to the period December 1983 to February 1990.

The forward and spot rates are sampled weekly and matched with the corresponding spot rate as follows:
1) The 15 day Tuesday forward rate is matched with the Wednesday spot rate 15 days hence.
2) The 30 day Tuesday forward rate is matched with the Thursday spot rate 30 days hence.
3) The 2 month forward contracts are sampled every Thursday. The maturity dates indicate that the duration was often greater than 60 days. Hence, the forward rate is matched with the spot rate prevailing 2 days before the stated maturity date, as it takes 2 days for a spot transaction to be delivered. If the date falls on a weekend, the spot rate on the Friday of the week just ended is taken. For ease of exposition, the 2 month forward rates are referred to as 60 day rates in the text.
4) The 90 day Tuesday forward rates are matched with the Monday spot rates 90 days hence.
5) The 180 day Thursday forward rate is matched with the Tuesday spot rate 180 days hence.
Bibliography


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