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Foreign Exchange Market Efficiency in Australia and Japan: An Empirical Testing*

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This paper examines whether the market efficiency hypothesis holds in the Australian and Japanese foreign exchange markets. The empirical results suggest that there are no speculative profit opportunities in the spot-forward currency markets in individual or cross-currency markets. Thus, the analysis indicates that there is significant evidence of market efficiency both in the Australian and Japanese foreign exchange markets.

I. Introduction

The foreign exchange market is the most active and unpredictable financial market in the world. Future risk and expectations of profitability change the relevant economic variables (such as price, rate of interest, etc.) and in turn change the exchange market. However, an efficient market has important policy implications in order to ensure efficient resource allocation. The widespread importance of market efficiency to the planners, policy makers, businessmen, investors and academics has induced numerous empirical studies of international financial markets. Tests of asset market efficiency, focusing on domestic equity and bond markets began in the 1950s and gained increasing popularity and significance during the 1960s.

However, with the establishment of floating exchange rates in the early 1970s and the introduction of new econometrics technique, cointegration in the 80s, the investigation of foreign exchange market efficiency attracted significant attention. Some early studies relied too heavily on stock market

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techniques and therefore did not test appropriate hypotheses concerning exchange market efficiency (Branson et al. 1977, Huang 1981, Longworth 1981 and others). Different researchers have worked with different methodologies, exchange markets, and time periods which produced different results; some have found evidence in favour of efficiency and some against it. Therefore, whether foreign exchange markets are efficient or not, it still remains a contentious issue.

With the longstanding economic relations between Australia and Japan economies bear significant importance in international trade and financial market. The objective of this paper is, therefore, to examine the exchange market efficiency both in individual as well as across the currency markets of these two industrialized economies. A brief discussion of the efficient market hypothesis followed this introductory section. Data and methodology are presented in the next section which is followed by the discussion of empirical results. A summary of the findings and conclusions are provided in the final section.

II. The Efficient Market Hypothesis

A foreign exchange market is said to be efficient if the exchange rate fully reflects all relevant and available information (Fama, 1970). When this condition is satisfied, no one can earn unusual profits by exploiting freely available information. If the agents are risk neutral and the market is informationally efficient, then the current forward exchange rate is an unbiased predictor of the future spot rate. Given the assumptions of risk neutrality and market efficiency, any systematic deviation between the expected future spot rate and the forward rate would indicate unexploited profit opportunities in the forward market.

However, recent research shows that Fama's concept of market efficiency is difficult to test in empirical works, since market efficiency is based on some stringent assumptions, such as traders and investors possess homogeneous expectations, no transaction costs to avail new information, etc. Grossman and Stiglitz (1976, 1980) have introduced an explicit cost for information, and demonstrated that the traditional market efficiency is incompatible with competitive equilibrium in the presence of information costs. In what follows, prices in competitive markets do not perfectly reflect all available information. Therefore they introduced a wider concept of market efficiency by incorporating informational efficiency. Accordingly, foreign exchange market efficiency can be written as follows:

$$E(S_t/\phi_{t-1}) - F_{t,t-1} = u_t, \tag{1}$$

where : $F_{t,t-1}$ = forward rate contracted at period t-1 for payment at period t, S_t = sport rate in period t, ϕ_{t-1} = information set available to agents up to and including time period(t-1), $E(S_t/\phi_{t-1})$ = mathematical expectation of S_t conditional on ϕ_{t-1}, u_t = the statistical error with zero mean, constant variance and no serial correlation. Further, u_t should be uncorrelated with variables in the information set ϕ_{t-1}. Any correlation between variables in ϕ_{t-1} and u_t would indicate that $F_{t,t-1}$ is not an unbiased predictor of S_t.

The efficient market hypothesis is a joint test of the efficient use of information and zero risk premium. The latter assumes that market participants are risk neutral, an assumption that is neither theoretically sound, nor empirically plausible. For example, if the risk averse investors (traders) demand future contracts to hedge their returns, a risk premium would be created that biases futures prices away from expected spot prices. Danthine (1978) also demonstrated that intertemporal optimization by risk-averse investors implies that risk premium created by their hedging demand, even when markets are efficient.[1]

There are four methods in the literature which are generally used to test foreign exchange market efficiency. The first approach concerns measuring the influence of the current forward exchange rate (F_t) on the future spot rate (S_{t+1}) (Rose, 1984).[2]

1. Recent research on asset market equilibrium model also suggested that risk premia exists but these were not adequately supported by empirical research (see Boxter et al 1985).

2. Here, S_{t+1} is spot rate at time t+1 and F_t is the forward rate established at time t for period t+1.

$$S_{t+1} = a + bF_t + u_{t+1}.$$

In this specification, for the market to be efficient, the constant term must be 0 and the slope coefficient must be 1 and u_{t+1} is a white noise process in the absence of any risk premiums. If the value of b is different from unity, it would indicate inefficiency, since in that case $(S_{t+1} - F_t)$, the forward forecast error is correlated with F_t. The inherent problem in testing equation (2) is potential non-stationarity, which raises doubt about the consistency of the standard error of the residuals. Frenkel (1976, 1979), Baillie et al. (1983) and others applied this approach in their studies.

The nonstationarity problem of the above approach has been taken care of in the second approach by respecifying equation (2) as

$$\underbrace{S_{t+1} - S_t}_{\text{rate of depreciation}} = a + b\underbrace{[F_t - S_t]}_{\text{forward premium}} + u_{t+1}. \qquad (3)$$

In this case also, for the market to be efficient, the constant term must be zero and the slope coefficient must be unity. However, the advantage of equation (3) over equation (2) is that variables entering equation (3) *a priori*, are both stationary I(0) and consequently, it would not lead to any difficulties in hypothesis testing as in equation (2). However, variables like exchange rates are more likely to be a random walk process. In that case, the left-hand side of equation (3) is stationary because $(S_{t+1} - S_t)$ is a white noise process. But there is no guarantee that the variable on the right-hand side, $(F_t - S_t)$, is stationary. The point is that $(F_t - S_t)$ can be decomposed into $(F_t - F_{t-1})$ + $(F_{t-1} - S_t)$. While the first component is stationary, the second will have the same property only if the market efficiency hypothesis holds (Maddala 1992: 600). Again this specification produces weak results; since the hypothesis that the constant is 0 and slope coefficient is 1 cannot be rejected but simultaneously the hypothesis that the constant is 0 and the slope is -1 also cannot be rejected.[3]

The third approach to test market efficiency is to run the first difference of S_{t+1} on the first difference of F_t as in equation (4).

$$S_{t+1} - S_t = \alpha + \beta(F_t - F_{t-1}) + \varepsilon_t. \quad (4)$$

In this specification also, the hypothesis to be tested is α equals 0 and β equals 1. This model suffers, as argued by Gregory and McCurdy (1984), from an omitted variable bias. This model gives inconsistent parameter estimates because the correct model to be used, if the two variables are cointegrated, is the error correction model,

$$S_{t+1} - S_t = \alpha + \beta(F_t - F_{t-1}) + \gamma(F_{t-1} - S_t) + \varepsilon_t, \quad (5)$$

Where α and β have usual meaning and γ is unknown parameter. In this case, the null hypothesis of no risk premium and rational expectations $\alpha=0$, $\beta=1$ and $\gamma=0$ could be used for testing market efficiency. So the last term ($F_{t-1} - S_t$) is omitted if the regression is run in first differences. In practice, there are some discrepancies between the results produced by the levels' equations and differences' equations. Non-stationarity may be the cause of these discrepancies (Meese 1989).

The other methodology in exchange rate modelling is the 'news' approach. The basic assumption underlying the 'news' approach is that exchange rates react only to innovations of the explanatory variables because all anticipated movements have already been embodied in the current spot rate. In other words, the 'news' approach has a clear interpretation as a test for exchange market efficiency. The 'news' innovations can be estimated by using either the second approach or the third approach discussed above.

Another alternative method that economists have been using in recent times to test market efficiency is the recently developed Engle-Granger technique, cointegration. The cointegration technique is used to detect stable long-run relationships around which there are

3. The null hypothesis for a market to be efficient is a = 0 and b = 1, but if the empirical results show a = 0 and b = -1, still one cannot reject the null hypothesis but market is unlikely to be efficient.

various possible short-run fluctuations. In a foreign exchange market, although the spot and forward exchange rates both often behave as random walks, one would expect these two variables to move together over the long-run. Therefore, a linear combination of the two variables should be stationary implying that they are cointegrated. Hence, market efficiency implies that even if the spot and forward exchange rates are nonstationary, they never drift far apart so they will be cointegrated. However, two spots or two forward rates from two different markets should not be cointegrated to satisfy the market efficiency hypothesis.[4]

From the Engle-Granger demonstration, if two variables X_t and Y_t are cointegrated, then they can be written in an error correction model (ECM),

$$\triangle Y_t = \alpha[Y_{t-1} - dX_{t-1}] + \beta_0 \triangle X_t + \sum \beta_k \triangle X_{t-k} + \sum \gamma_k \triangle Y_{t-k} + e_t \qquad (6)$$

where e_t is an iid residual and or all of the β_k, γ_k in the summation terms may be zero.

The implication for market efficiency is obvious from the ECM. If X_t and Y_t are prices of two different assets (say X_t, Japanese spot rate and Y_t, Australian spot rate), efficiency clearly requires the absence of a cointegration relationship. Otherwise, the ECM would imply that current prices are at least partly predictable using the last period's deviation from the long run cointegration relationship, indicating the presence of unexploited profit opportunities for speculators across the two markets.

It may be argued that if the currency markets are efficient, spot exchange rates should embody all relevant information, and it should not be possible to forecast one spot exchange rate as a function of another. That is spot exchange rates across currencies should not be cointegrated. This implies that the Australian spot rate and the Japanese spot rate cannot be cointegrated. If they are cointegrated, then they can follow an

4. Market participants (trader's and investors) in two different countries possess different expectations, face different transactions costs; therefore, evaluate new information not in an identical manner. Moreover, policy regimes are different in two different economics. Therefore, there are no reasons fro two spots and two forward rates in two different markets to be cointegrated.

error correction model such as (6). But (6) implies that part of the change in the spot rate is predictable; hence the market will be inefficient. Because there remains divergence between the two rates and therefore, one can earn excessive profits by using readily available information. Likewise, for a market to be efficient, two forward rates from two different markets also cannot be cointegrated.

On the other hand, for the markets to be efficient the spot and forward rates either in the Australian exchange market or in the Japanese exchange market should have cointegration relations. Then it will be possible to predict one on the basis of the other. If they are not cointegrated, their difference will be non-stationary. Then the current forward rate cannot be an unbiased estimator of the future spot rate, because there are opportunities to improve the future spot rate by using available information. For example, let $S_{t+1} = F_t + \mu_t$, where $\mu_t = \mu_{t-1} + \varepsilon_t$,(where μ_t is information set and ε_t is white noise) Then by substitution, we see that $S_{t+1} = F_t + \mu_{t-1} + \varepsilon_t$, so that the forward rate does not incorporate all available information, and therefore, the market is inefficient.

However, cointegration is a necessary but not sufficient condition for market efficiency. The reasons are as follows: first, the cointegrating vector is required to be equal to 1; otherwise, the forward rate is not an unbiased predictor of the future spot rate; second, market efficiency requires the error term in equation (3) to be white noise, while cointegration requires the error term to be stationary. Modifying the error term in the above example, say $\mu_t = \lambda \mu_{t-1} + e_t$ with $-1 < \lambda < 1$, gives $S_{t+1} = F_t + \lambda \mu_{t-1} + e_t$, so that the forward rate does not summarise all available information. Hakkio and Rush (1989) demonstrated these clearly in their studies. Besides these technical arguments, if two countries either explicitly fix the exchange rates or implicitly link their economic policies while processing similar production technologies then their currencies will not be different assets and therefore, spot and forward rates from these two countries will be cointegrated even if markets are efficient. Therefore, applying the cointegration technique one may get fragile evidence of market efficiency (for details see, Sephton and Larsen 1991).

As discussed above, exchange market efficiency requires a joint hypothesis test. Under the joint assumption, a foreign exchange market is efficient if the forward exchange rate is an unbiased predictor of the future spot rate. Baillie et al. (1983) rejected this joint hypothesis for the six currencies they considered. Hansen and Hodrick (1983) found evidence to reject this hypothesis during the 1920s and 1970s. Hsieh (1984) claimed that these results provided the strongest rejection of the hypothesis ever seen. Burt et al. (1977), Levich (1978), Bilson (1981), Hakkio (1981), Hodrick and Srivastava (1984), Frankel and Froot (1987) all found evidence of market inefficiency for the exchange market they considered. However, Cornell (1977), Levich (1979), Meese and Singleton (1980) and Frankel (1982) were not able to reject the efficiency hypothesis. Tease (1988) got interesting results in the Australian exchange market. His findings suggest that markets (using 15 and 30 day forward) were efficient before the major depreciation of the Australian dollar in 1985 and inefficient since then. Again using 90 day forward he found market inefficiency both before and after depreciation.

The research on this subject broadened after the recent development of the econometric technique, cointegration. At least a dozen studies so far have utilized this technique. However, the pioneering work was done by Hakkio and Rush in 1987 (published later in 1989). They used monthly data from British and German exchange markets over the period from July 1975 to October 1986 and found evidence of market efficiency, as neither the spot nor the forward exchange rates were cointegrated across countries. They also examined the spot and forward exchange rates of each country and found evidence that they were cointegrated, i.e., the spot British pound exchange rate was cointegrated with the forward British pound exchange rates (similarly for the Deutschmark). These are consistent with market efficiency. Following the work of Hakkio and Rush, Brian (1988) studied with daily data of the Irish foreign exchange market in 1987. She used a total of 100 observations. Her results showed that there was no evidence of cointegration in the individual asset prices, neither for the individual spot-forward system, thus providing mixed evidence on market efficiency. This is to some extent contrary to the work of Leddin (1988) which found evidence of the efficiency of the sterling market.

Baillie and Bollerslev (1989) examined the daily exchange rates

Engle-Granger two step procedures and the Johansen technique of cointegration. The conclusion which emerged from their study was that markets were not efficient. MacDonald and Taylor (1989) investigated ten currencies over the period between January 1973 and December 1985 for testing the joint behaviour of spot exchange rates and found no strong evidence of cointegration of any pair of exchange rates they examined.

Following MacDonald and Taylor, Coleman (1990) tested the same hypothesis using the log levels of daily spot rates for 18 foreign currencies. They applied tests to these currencies both pair-wise and to a higher order system (as for example, G7 and Switzerland) and found little evidence of a cointegrated relationship. Such results are also consistent with the market efficiency hypothesis.

A later study on this line was conducted by Copeland (1991). He used 5 spot exchange rates against US dollars to examine whether or not the foreign exchange markets were cross-sectionally efficient. His tests provided the expected results that the cointegration condition for an efficient market is satisfied. However, applying the Johansen test for cointegration for three currencies against the US dollar exchange rate, Sephton and Larsen (1991) got inconsistent results concerning market efficiency. On the other hand Booth and Mustafa (1991) found a cointegrated relationship between the Turkish official spot exchange rate and the black market exchange rate against the German Mark and US dollars. Such results indicated the efficiencies between these two markets.

Liu and Maddala (1992a, 1992b) made two studies along this line for four currencies against US dollars. They used survey data over the time frame of October 1984 to May 1989 and found no evidence of market efficiency both for weekly and monthly data. The most recent theoretical study was done by Dwyer and Wallace (1992). Their studies suggest that there is no equivalence between market efficiency and cointegration. They conclude that. "Unbiasedness of the forward rate as a predictor of the spot rate implies cointegration, but this has no necessary connection with market efficiency without further assumptions" (Dwyer and Wallace 1992: 325).

III. Data and the Analysis

The data used for the tests came from the Reuter data base in the Australian National University. Weekly data from Japanese and Australian foreign exchange markets against the US dollars were taken for analysis. The time period covered is from the 4th week of March, 1985 to the 4th week of June, 1994. Forward rates are one month contracts and both spot and forward rates were taken at the weekly closing rates. In each case, the data were converted into natural logs to avoid the well-known difficulty expounded by Jensen's inequality in the context of bilateral exchange rates.

The Engle-Granger cointegration technique was employed to the data in order to test market efficiency. To illustrate, let us consider two series X_t and Y_t both of which are I(d) (both are stationary after differencing d times). Linear combinations of X_t and Y_t will, in general, also be I(d). However, it is possible that there exists a vector (α, β) such that the combinations :

$$Y_t = \alpha + \beta X_t + u_t \tag{7}$$

or $u_t = Y_t - \alpha - \beta X_t$ is I(d-b) with $b > 0$, if (α, β) exist.

Then u_t be interpreted as an equilibrium error and X_t and Y_t are said to be cointegrated of order (d, b), or CI(d, b). Hence if d = b = 1 the existence of (α, β) implies that the equilibrium error is I(0) and the above combination is a stationary process. As X_t and Y_t are cointegrated, they can be written as an error correction equation as in equation (6). Equation (3) was applied to study the spot forward relation within the country and across countries; one country's current spot and forward rates were regressed on the other country's spot and forward rates.

Several tests were made to examine the concerned cointegration relation. At the outset, the Box-Pierce Q^*-statistic and autocorrelation function were used to test the stationarity of each spot and forward rate in each market. In each case, the Q^*-statistic was a long way above it's critical value (Table 1). For example, in the case of Japanese spot and forward rates, at the critical 1 percent level with 30 lags, the calculated Q^* works out to be 116.90 and 112.20 respectively. These values are enormously lags than the critical value of 53.67. Again for the same critical value and same lags, Q^*-statistics for the Australian spot and forward rates are 252.90 and 232.20 respectively. In each case the autocorrelation coefficients were significantly different from zero on the standard rule-of-thumb test for up to 30 lags (see the Appendix). These show that both spot and forward rates in each country are non-stationary. For example, the autocorrelation coefficient of the Japanese spot rate is 0.30348 at 20 lags and that of the Australian spot rate is 0.54455. However, after first differencing and applying Q^*-statistics, the results show that spot and forward rates in each market are stationary (Table 1).

Next, the commonly used Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests were applied to examine unit root properties of the spot and forward exchange rates. The results show that the hypotheses of a unit root for either the spot or the forward rates for any currency (Table 1) may not be rejected. Therefore, the results reveal that the spot and forward rates of each currency are not only non-stationary but also they are away from the random walk process.

Next seven tests of cointegration as suggested by Engle and Granger (1987) were applied. Hakkio and Rush (1989) also applied these seven tests in their studies. One of them is the general Durbin-Watson statistic from cointegration regression. The Durbin-Watson statistic is given by

$$DW = \frac{[\widehat{\mu}_t - \widehat{\mu}_{t-1}]}{\Sigma[\widehat{\mu}_t]^2} \tag{8}$$

where $\widehat{\mu}_t$ is the estimated residual from the cointegration regression. If $\widehat{\mu}_t$ is a random walk, the expected value of $[\widehat{\mu}_t - \widehat{\mu}_{t-1}]$ is zero, so the DW statistic is close to zero implying no cointegration. The test statistic of the CRDW is ζ_1.

The second and third tests involve unit root tests of residuals. These are well-known Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests. The DF test involves the estimation of regression of the first difference of residuals from the cointegration regression on its first lag that is

$$\triangle \ \widehat{\mu}_t = -\rho \ \widehat{\mu}_{t-1} + \eta_t. \tag{9}$$

The test involves the significance of the estimated $\hat{\rho}$: if $\hat{\rho}$ is positive and significantly different from zero, then the $\widehat{\mu}_t$ residuals from the equilibrium equation are stationary, so the hypothesis of cointegration is accepted. Dickey and Fuller derived the distribution for the estimator ρ that hold when ρ=1, and generated statistics such as simple t-test and F-test of unit root hypothesis. The test statistic is ζ_2. The ADF is similar but more lag values of $\widehat{\mu}_t$ need to be added to make sure that the residuals from the DF regression are serially uncorrelated.

The fourth test is the restricted vector autoregression (RVAR) which uses the fact that cointegrated variables can follow an error correction form. The test requires estimating the following two equations:

$$\triangle X_t = c_1 + b_1 \ \widehat{\mu}_{t-1} + \eta_t \tag{10}$$
$$\triangle Y_t = c_2 + b_2 \ \widehat{\mu}_{t-1} + \delta \triangle X_t + Z_t$$

The test statistic involves examining the joint significance of b_1 and b_2 (equals the sum of the squared t-statistics i.e. $\zeta_4 = (t^2_{b1} + t^2_{b2}))$. If b_1 and b_2 are significantly different from zero, X_t and Y_t satisfy an error correction model and are thereby cointegrated. The augmented RVAR or ARVAR is the fifth test which is similar to the RVAR, except that additional lags of $\triangle X_t$ and $\triangle Y_t$ are included in the regressions. The test statistic is the same as ζ_4.

The sixth test is the unrestricted VAR or UVAR which involves estimating two regressions of X_t and Y_t on their levels provided that they satisfy a VAR,

$$\triangle X_t = \alpha_1 + \beta_1 Y_{t-1} + \beta_2 X_{t-1} + \eta_t$$
$$\triangle Y_t = \alpha_2 + \beta_3 Y_{t-1} + \beta_4 X_{t-1} + \delta \triangle X_t + \eta_t \tag{11}$$

The test involves examining the joint significance of the β_s. If they are significantly different from zero, $\triangle X_t$ and $\triangle Y_t$ depend upon their levels and so may follow an error correction equation. The test statistic is $\zeta_6 = 2(F_1 + F_2)$ where F_1 is the F-statistic for testing β_1 and β_2 and F_2 is the F-statistic for testing β_3 and β_4. Finally, the augmented UVAR-test which is similar to the above, except for the additional lags of $\triangle X_t$ and $\triangle Y_t$ in the regressions were applied. The test statistic is the same as ζ_6.

There is no *a priori* reason to determine the direction of causality between the spot rates and forward rates. Therefore, analyses were done first by regressing spot rates on forward rates and then forward rates on spot rates. All the above seven tests were applied to examine whether the spot rates and the forward rates from Japanese and Australian foreign exchange markets were cointegrated. The results of all tests and theirs corresponding 5 percent critical values are given in Table 2.

Table 2 shows that two spots and forward rates from two different markets (Japan and Australia) are not cointegrated. That means none can forecast one spot (forward) rate as a function of the other spot (forward) rate. Therefore, the lack of cointegration between cross country spot and forward rates, leads us to believe that the two markets are efficient. The following conditions need to be satisfied in order to have spot-forward market efficiency in the same currency market (Hakkio and Rush, 1989).

(i) S_{t+1} and F_t must be cointegrated.
(ii) The cointegrating factor (d) must be 1
(iii) The forward forecast error ($S_{t+1} - F_t$) must be a white noise.

Using Granger's (1978) argument Hakkio and Rush (1989) suggest that if S_{t+1} and F_t are cointegrated, they can be written as ECM (ignoring lag value) as

$$S_{t+1} - S_t = a(S_t - dF_{t-1}) + b(F_t - F_{t-1}) + e_t. \quad (12)$$

where e_t is a white noise process.

Equation (12) provides the basis for the test of market efficiency : only when -a = b = d = 1, then the forward rate will be an unbiased predictor of the future rate with $S_{t+1}=F_t+e_t$. If lagged terms are included in the ECM, in addition to the requirement that -a = b = d = 1, market efficiency requires that the coefficients on lags must be zero. Following these requirements, the above 7-tests were applied to test the market efficiency of individual currency market and the results are presented in Table 3.

Table 3 reveals that we cannot accept the hypothesis of no cointegration. That means spot and forward rates in either market are cointegrated implying that one can be predicted on the basis of the other. These results are consistent with the efficient market hypothesis. As the cointegrated relationship between spot and forward rates both in Japanese and Australian exchange markets have been established, the error correction equations for the two countries were estimated to test the validity of the other two conditions of market efficiency as suggested by Hakkio and Rush (1989). The error correction equations were estimated using 4 lags to zero lags (since one month forward weekly data were used, one would expect that there might be monthly cycles). Testing for significance sequentially shows that one period lags of $\triangle S_t$ and $\triangle F_t$ are significant in the Japanese market and two period lags are significant in the Australian exchange market. The two equations are given in Table 4. Before estimating the error correction equation, the LM test was used to examine statistical adequacy, i.e., whether there is serial correlation or heteroscedasticity in spot and forward rate series. The calculated LM statistics were 2.65 and 2.10 for Japan and Australia respectively which indicate support to accept the null hypothesis of no serial correlation. On the other hand, there is evidence to support the hypothesis of homoscedasticity, i.e., the LM statistics were 2.13 and 2.40 for the two markets respectively which are below their critical value at the 5% level.

Further, the stability of the error correction equations in both markets was examined by using the F-statistics. Dividing the sample period into two separate sub-periods in the Japanese market, two separate regressions were run. Taking the unrestricted residual sum of squares (RUSS) from these two regressions and restricted residuals sum of squares (RSS) from the pooled regression, the F-test was done. The value of the calculated F works out to be 1.72 which is less than its 1% critical value of 2.60 with 3 and 477 degrees of freedom. Hence the hypothesis of stability may not be rejected. Similar results hold for the Australian market too.

All these tests reveal that the estimated equations are acceptable. From Table 4, it may be seen that R^2 is very high and at the same time calculated LM does not exceed its critical value at 5% level of significance which implies the goodness of fit of the models. The results indicate that the hypothesis of $-a = b = 1$ may not be rejected, and that the coefficients on lags are zero for the Japanese as well as for the Australian markets. The F-test was used to examine this hypothesis. The calculated and the 5% critical values are given in Table 4 which indicate support to this hypothesis. Acceptance of this hypothesis of $-a = b = 1$ and lags = 0 implies that there are no possible opportunities of speculative profits by exploiting available information. This result is consistent with the efficient market hypothesis.

Ⅳ. Conclusions

The possibility of earning unusual profits in the Japanese and the Australian foreign exchange markets by exploiting readily available information in the spot and forward exchange rates across currencies has been ruled out on the basis of an apparent lack of cointegration. On the other hand, the predictability of future spot rates on the basis of forward rates is accepted by having a cointegrating relationship between the two rates in each individual currency market. All these results are consistent with the market efficiency hypothesis. However, cointegration is only a necessary but not a sufficient condition for market efficiency. Applying the error correction model, the joint hypothesis of no risk premium combined with efficient use of information for both Japanese and Australian exchange markets could not be rejected for the sample period. This result is also consistent with market efficiency, and therefore, it may reasonably be concluded that there are no possible speculation opportunities in both exchange markets.

Table 1 Stationarity Tests of Spot and Forward Exchange Rates

	Currencies				
	Australia		Japan		Critical value
	Spot	Forward	Spot	Forwd	
$Q_1^*(30)$	252.90	232.20	116.90	112.20	53.67
$Q_2^*(30)$	18.02	25.43	8.97	10.39	53.67
DF	2.70	2.76	0.79	0.87	3.37
ADF(12)	2.44	2.49	1.41	1.01	3.17

Note: Figures in the parentheses are the number of lags.

Table 2 Test for Cointegration of Japanese and Australian Exchange Rates

Spot rates

Tests	Japanese rates on Australian rates Total 480 observations	Australian rates on Japanese rates Total 480 observations	Critical value
1. CRDW(ζ_1)	0.08	0.08	0.39
2. DF(ζ_2)	2.61	2.40	3.37
3. ADF(ζ_3)[5]	2.87	2.65	3.17
4. RVAR(ζ_4)	10.46	10.72	13.60
5. ARVAR(ζ_5)	10.29	3.73	11.80
6. UVAR(ζ_6)	11.88	17.24	18.60
7. AUAR(ζ_7)	14.68	15.06	17.90
	Cointegration regression $LS_t^J = 5.21 - 1.22\ LS_t^A$ $R^2 = .96$	Cointegration regression $LS_t^A = 2.81 - .52\ LS_t^J$ $R^2 = .96$	

Forward rates

Tests	Japanese rates on Australian's rates Total 480 observations	Australian's rates on Japanese rates Total 480 observations	Critical value
1. CRDW(ζ_1)	0.07	0.08	0.39
2. DF(ζ_2)	2.17	2.27	3.37
3. ADF(ζ_3)[5]	2.61	2.67	3.17
4. RVAR(ζ_4)	11.35	10.45	13.60
5. ARVAR(ζ_5)	11.26	3.87	11.80
6. UVAR(ζ_6)	11.14	16.70	18.60
7. AUAR(ζ_7)	16.26	12.73	17.90
	Cointegration regression $LS_t^J = 5.22 - 1.20\ LS_t^A$ $R^2 = 0.91$	Cointegration regression $LS_t^A = 2.76 - .50\ LS_t^J$ $R^2 = 0.91$	

Note : L stands for log, S for spot rates and F for forward rates and number in the brackets denotes lags.

Table 3 Test for Cointegration of Spot and Forward Rates

Japanese market

Tests	Spot rates on forward rates Total 480 observations	Forward rates on spot rates Total 480 observations	Critical value
1. CRDW(ζ_1)	1.59	1.57	0.39
2. DF(ζ_2)	10.50	10.46	3.37
3. ADF(ζ_3)[5]	3.42	3.62	3.17
4. RVAR(ζ_4)	45.43	74.16	13.60
5. ARVAR(ζ_5)	70.17	17.15	11.80
6. UVAR(ζ_6)	40.95	95.87	18.60
7. AUAR(ζ_7)	48.20	93.10	17.90

Cointegration regression
LS^J_{t+1} = 0.05 - .998 LF^J_t
R^2 = .89

Cointegration regression
LF^J_t = 0.081 - 983 LS^J_{t+1}
R^2 = .89

Australian market

Tests	Spot rates on forward rates Total 169 observations	Forward rates on spot rates Total 169 observations	Critical value
1. CRDW(ζ_1)	1.50	1.50	0.39
2. DF(ζ_2)	9.98	9.99	3.37
3. ADF(ζ_3)[5]	4.98	4.94	3.17
4. RVAR(ζ_4)	47.15	60.59	13.60
5. ARVAR(ζ_5)	27.69	12.13	11.80
6. UVAR(ζ_6)	25.07	38.42	18.60
7. AUAR(ζ_7)	65.65	42.82	17.90

Cointegration regression
LS^A_{t+1} = -0.06 + 1.01 LF^A_t
R^2 = 0.97

Cointegration regression
LF^A_t = 0.01 + .96 LS^A_{t+1}
R^2 = 0.97

Note : Same as table 2.

Table 4 Error Correction Equations for Japanese and Australian Markets

Japan

$$LS^J_{t+1} - LS^J_t = \underset{(0.001)}{-.006} - \underset{(0.951)}{0.988}\,(LS^J_t - LF^J_{t-1}) + \underset{(0.301)}{0.50}(LS^J_t - LS^J_{t-1})$$

$$+ \underset{(0.283)}{0.49}(LF^J_t - LF^J_{t-1})$$

$R^2 = .89$ LM(serial correlation) = 2.10 and LM(heteroscedasticity) = 2.13

Australia

$$LS^A_{t+1} - LS^A_t = \underset{(.024)}{0.012} + \underset{(0.942)}{0.953}(LS^A_t - LF^A_{t-1}) + \underset{(0.59)}{0.66}(LS^A_t - LS^A_{t-1})$$

$$+\underset{(0.259)}{0.385}(LS^A_{t-1} - LS^A_{t-2}) + \underset{(0.062)}{1.22}(LF^A_t - LF^A_{t-1}) - \underset{(0.452)}{0.33}(LF^A_{t-3} - LF^A_{t-4})$$

$R^2 = .92$ LM(serial correlation) = 2.10 and LM (heteroscedasticity) = 2.40

F-test of $-\hat{a} = \hat{b} = 1.0$ and lags = 0

		5% critical value
Japan	1.02	2.60
Australia	1.87	2.21

Note: Values in the brackets are standard errors.

Table 5 Sample Autocorrelation Coefficients

	Currencies			
	Japan		Australia	
Order of lags	Spot	Forward	Spot	Forward
1	.96207	.95987	.97611	.97776
2	.91623	.91636	.94879	.95062
3	.87019	.87065	.92074	.92338
4	.82414	.82571	.89471	.89414
5	.78193	.78331	.86512	.86379
6	.74387	.74312	.83443	.83263
7	.70627	.70353	.80495	.80070
8	.66777	.66375	.77533	.76723
9	.62736	.62524	.74377	.73808
10	.58890	.58281	.71880	.71153
11	.54723	.53946	.69194	.68432
12	.50779	.49812	.66412	.65852
13	.47135	.46134	.63552	.63334
14	.43935	.43027	.61267	.61031
15	.41250	.40010	.59274	.59141
16	.38682	.37113	.57644	.57628
17	.35846	.34315	.56244	.56563
18	.33287	.31498	.55417	.55776
19	.31393	.29398	.54798	.55165
20	.30238	.27922	.54455	.54291
21	.29041	.27024	.53639	.53412
22	.27977	.26255	.52741	.52622
23	.27112	.25424	.51839	.51652
24	.26435	.24801	.51094	.50703
25	.25960	.24205	.50384	.49980
26	.25551	.23950	.49530	.48852
27	.24872	.22543	.48412	.47725
28	.24135	.21793	.46515	.45312
29	.23940	.20654	.43762	.42740
30	.22541	.19875	.41540	.38875

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