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Abstract

Covered Interest Parity (CIP) holds in the 90 and 180 forward market for the AUD/USD spot exchange rate provided FM-LAD procedures are applied to daily data for the period 12/2/85 to 12/29/00. CIP fails if corrected OLS and FM-OLS procedures are applied. However UIP and FME fail in both markets on early data: 12/2/85 to 12/31/91, but hold in the 90 day market in a later sub-period: 1/3/92 to 12/29/00 FM. UIP and FME are modified (M) to accommodate a potential risk premium and domestic policy effects. The MUIP model suggests the presence of a risk premium when the cash rate is included in the MUIP in the 90 day market only and domestic policy intervention is influential in the 90 day market in these circumstances.

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Parity, Efficiency, Forward Market, Premium Cash Rate

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1. Introduction

The research outcomes presented in this paper involve a detailed examination of two interest parity conditions and forward market efficiency (FME) using daily data for the Australian and US economies over the period 12/2/1985 to 12/29/2000. Both covered (CIP) and uncovered interest parity (UIP) plus FME are tested in the 90 and 180 forward markets for the Australian/USD dollar exchange rate.

The motivation for an analysis of this kind is to be found in the significance of these three conditions for the efficiency of forward and spot markets for the AUD and consequently as a reliable guide to international investors and for the orderly conduct of Australia's monetary policy. In selecting this troika of market efficiency conditions, the emphasis is placed on the behaviour of the USD/AUD exchange rate in the very short run when it is only capital movements, which explain exchange rate movements. The two parity conditions are the cornerstones on which forward market efficiency is founded. CIP asserts that the forward premium on foreign exchange must equal the difference between domestic and foreign interest rates on securities of the same term to maturity provided domestic and foreign bonds are both free of default risk. A second requirement for FME is that speculative trading should bring the forward premium (discount) into equality with expected depreciation (appreciation) of the domestic currency. This constitutes the CIP condition.

Tests of these hypotheses have a practical significance in addition to their relevance for economic theory. The interest parity/market efficiency nexus provides insights about market participants risk attitudes and the extent of capital market integration. In particular, the failure of either parity, or market efficiency may indicate that foreign securities are imperfect substitutes for domestic ones of equivalent maturity and that market participants require compensation in the form of a risk premium if they are to hold the domestic currency. The CIP condition, in particular, can be viewed as a test of whether risk free arbitrage profit opportunities exist for potential investors. Finally, these three equilibrium conditions carry significant policy implications, in particular, they concern the capacity of the domestic monetary authorities to control interest rates and to intervene in foreign exchange markets. These capacities are extremely important in small, open economies such as the Australian economy. It behoves the researcher to accommodate the effects of risk premia and domestic monetary policy actions on these three equilibrium conditions.

UIP underpins a number of models of the balance of payments and the exchange rate and in terms of policy implication, if the UIP condition holds sterilised foreign exchange market intervention is ineffective. The failure of UIP does mean that sterilised intervention can have real effects and that the portfolio balance model of exchange rate intervention may be preferred to the monetary models of the balance of payments. Little wonder that Taylor, (1995, p.14) views UIP as the cornerstone condition for foreign exchange market efficiency.

The two interest parity conditions also have important implications for international capital mobility. Following Feldstein and Horioka (FH, 1980) changes in a country's savings rate affects its rate of investment and provides evidence of low capital mobility. If capital is perfectly mobile, a shortfall in savings in one country should be easily made up by borrowing from abroad and need not drive up the domestic rate of interest and crowd out domestic investment. The relevance of this international capital mobility issue in the present context is that CIP and UIP are two of four definitions of perfect capital mobility. These also include the FH hypothesis and the real interest parity condition. It follows that the failure of either or both CIP and UIP implies imperfect capital mobility, a matter of immediate importance for agents in this market.

The initial analyses of CIP, UIP and FME are conducted in the absence of monetary policy and risk premium effects. This initial stage is attended by data problems and econometric issues and requires a battery of formal tests, including West's (1988) corrected

OLS, Phillip and Hansen's (1990) fully modified OLS (FM-OLS) and Phillips (1995) fully modified least absolute deviation model (FM-LAD). The results of this initial phase are of interest: CIP holds for the entire sample period (December 2: 1985 – December 29 2000) and no further tests of CIP are conducted given the general applicability of CIP.

Initial tests for UIP and FME suggest that both conditions should be rejected with one notable exception. Both UIP and FME hold in the 90 day market and for sub sample 2 (2 January 1992 to 29 December 2000) only, neither condition holds in the 90 or 180 day markets otherwise. Further research is indicated, in particular, to allow for the presence of a risk premium or for policy effects. Allowance for the presence of a time-varying risk premium is made in a (GARCH-M) model of the UIP and FME conditions. Three interpretations of the GARCH-M process are applied: GARCH (1,1)-M, EGARCH and GJR-GARCH. Generally, there is no evidence for the presence of a time varying risk premium in either the 90 or 180 day market. However, the risk premium effect is evident on occasions when domestic monetary policy is included in the GARCH models. Monetary policy is represented by the Australian overnight cash rate which has a significant impact on the time varying risk premium in both markets suggesting that domestic policy does affect the volatility of the Australian dollar against foreign currencies.

These conclusions are reached via an analysis structured in the following way. Section 2 is dedicated to a review of relevant literature while the properties of the data set are discussed in a third section. Section 4 contains the complete analysis of the CIP condition, while initial analyses of the UIP and FME conditions are disclosed in the fifth and sixth sections of the paper and policy effects on exchange rate volatility are analysed in the penultimate section. Policy implications and conclusions are drawn in a final section.

2. Relevant Literature and Theoretical Background

CIP is an implied relationship between the forward and spot exchange rates ($F_{t,k}$ and S_t) and the spread between domestic and foreign interest rates ($i_{t,k}$ and $i^*_{t,k}$) on securities with the same term (k) to maturity. This relationship may be expressed in terms of the determination of the forward exchange rate:

$$F_{t,k} = S_t \frac{(1 + i_{t,k})}{(1 + i^*_{t,k})} \tag{1}$$

Subject to the assumption that there are no transaction costs involved, the interest rate spread defined above should be of equal but opposite sign to the forward exchange rate premium or discount on the foreign currency. The expression (1) encapsulates the arguments of early writers such as Keynes (1923), Einzig (1937) and Kindleberger (1939) and emphasises the absence of arbitrage profits in establishing equilibrium. The expression (1) is a formal representation of a particular trading strategy, namely, that the return on a forward contract can be replicated exactly by borrowing in one currency, converting into another currency and on lending: Felmingham and Coleman (1995: p.465).

An alternative statement of CIP is provided by the following:

$$f_{t,k} - s_t = \frac{(i_{t,k} - i^*_{t,k})}{(1 + i^*_{t,k})} \approx i_{t,k} - i^*_{t,k} \qquad (2)^{1}$$

where $f_{t,k}$ and S_t are the natural logarithms of $F_{t,k}$ and S_t.

The use of natural logarithms in (2) and in formulating the UIP condition eschews a potential difficulty arising from Siegel's (1972) paradox which indicates that the levels of the

[1] The CIP is usually written as $F_{t,k}(1 + i^*_{t,k}) = S_t(1 + i_{t,k})$. This reduces to $F_{t,k} - S_t / S_t = \frac{(i_{t,k} - i^*_{t,k})}{(1 + i^*_{t,k})} \approx i_{t,k} - i^*_{t,k}$ or $F_{t,k} - s_t = (i_{t,k} - i^*_{t,k})$ when $(1 + i_{t,k})$ and $(1 + i^*_{t,k})$ are close to 1.

forward rate and the expected future spot rate implies a contradiction. Should the proposition be true for the foreign/domestic currency exchange rate, it could not also be true for the domestic/foreign currency exchange rate since Jensen's inequality requires that $E(1/x) > 1/E(x)$ when x has a positive variance. Roper (1975) and Boyer (1977) show that it is legitimate to express the CIP and UIP condition in logarithmic form to resolve this paradox.

The CIP condition is usually tested by estimating the following regression equation:

$$f_{t,k} - s_t = \alpha + \beta\left(i_{t,k} - i^*_{t,k}\right) + u_t \tag{3}$$

where α, β are parameters and u_t the error term. CIP holds exactly if $\hat{\alpha} = 0$ and $\hat{\beta} = 1$, which literally implies that the interest spread predicts the forward discount exactly.

Early studies of the CIP condition indicate that it holds: see for example Aliber (1973), Frenkel and Levich (1975, 1977). Deviations from CIP are evident increasingly in the post Bretton Woods era. Aliber (1973) attributes the failure of CIP to political risk, while Prachowny (1970), Frenkel (1973), Otari and Tiwari (1981), Dooley and Isard (1980) explain its failure in terms of capital market imperfections or exchange controls. Taylor (1987) argues that CIP fails in some studies because the timing of interest rate and exchange rate observations differ. Taylor eschews this problem by using synchronous, high frequency interest and exchange rate data to find that CIP holds for the British pound, German mark and the US dollar. Speculative trading is seen in the early discussion[2] of CIP as a potentially disturbing influence on CIP. Taylor (1989) deliberately includes periods of turbulence in the behaviour of the British pound and finds that speculation creates opportunities for profitable arbitrage and consequently the failure of CIP. However, CIP holds in periods of relative calm and deviations from CIP are more likely to occur in relation to longer term securities.

[2] Keynes (1923), Einzig (1937), Kindleberger (1939), Branson (1969).

Some researchers prefer cointegrative techniques to conventional regression analysis because of the former's focus on long run relationships which can be combined with error correction to describe short run adjustments of the deviation from CIP. Abeysekerra and Turtle (1990) examine four currencies relative to the US dollar (Canadian dollar, mark, yen and pound) using these techniques and find that CIP does not hold in general because of the existence of a neutral zone; a time varying function of unexamined factors including transactions costs, settlement procedures, risk premia, regulatory or capital constraints. Crowder (1995) provides a novel twist for the same four currencies plus the French franc against the US dollar by determining the length of time it takes for the forex market to eliminate deviations from CIP. Crowder finds that the CIP relationship holds only in the Mark–US dollar market where profitable CIP deviations are eliminated in one day. Deviations persist much longer in the four remaining markets leading to the rejection of CIP in them.

Australian evidence begins with Turnovsky and Ball (1983) who examine the market for the AUD/USD spot rate in the 1970s on both quarterly and monthly data. These authors find that the conventional form of the CIP hypothesis (the interest rate differential is the dependent variable) is not rejected (rejected) on quarterly (monthly) data. In a further test featuring the forward margin as the dependent variable, the reaction function version of the CIP holds on both quarterly and monthly data sets. This is interpreted as evidence that the Reserve Bank of Australia (RBA) set the forward margin in response to current and past interest differentials prior to foreign exchange market deregulation in 1983. However, Karfakis and Phipps (1994) using an error correction framework find that the forward discount Granger causes the interest differential challenging the argument that the RBA set the margin in the Australian market prior to deregulation. Finally, Moosa (1996) finds that CIP holds in the case of the Australian/New Zealand dollar with the notable exception of a deviation in 1985 explained by political risk associated with the reinstatement of capital controls in New Zealand.

This review reveals a decidedly mixed outcome for the CIP condition, thereby establishing the case for a further analysis of it, in particular using a daily time series for the US/AUD exchange rate.

The uncovered interest parity condition (UIP) postulates an equilibrium relationship between the expected change of the exchange rate and the short term interest spread on perfectly comparable financial assets denominated in different currencies. Arbitrage moves the exchange rate to the point where the expected return on the investment in the home or foreign currency is equalised. Two assumptions underpin this relationship: first, international capital is freely mobile allowing agents to borrow and lend at practically the same rate in both countries: second, agents perceive domestic and foreign financial assets as perfect substitutes. The following algebraic condition is commonly used as a basis for the UIP:

$$E_t\left(S_{t+k} \middle| \Omega_t\right) = \frac{S_t\left(1 + i_{t,k}\right)}{\left(1 + i^*_{t,k}\right)} \tag{4}$$

$E_t\left(S_t \middle| \Omega_t\right)$ is the conditional expectation of the future spot rate at time t and Ω_t is the information set available at t. The basic relationship (4) is frequently simplified as follows:

$$E_t\left(s_{t+k} \middle| \Omega_t\right) - s_t = i_{t,k} - i^*_{t,k} \tag{5}$$

In this case, $E_t\left(S_{t+k} \middle| \Omega_t\right)$ is the conditional expectation of the natural logarithm of the future spot rate while the expression (5) in its entirety suggests that the expected depreciation of the home currency is equal to the interest spread. Rational expectations are assumed to apply throughout this analysis, consequently the expost values of spot exchange rates should provide a suitable proxy for the k period's earlier values:

$$S_{t+k} = E_t\left(S_{t+k} \middle| \Omega_t\right) + v_{t+k} \tag{6}$$

where v_{t+k} is a disturbance term with zero mean. Finally, the test vehicle usually applied to test the UIP hypothesis assumes the following form:

$$E_t s_{t+k} - s_t = \alpha + \beta\left(i_{t,k} - i^*_{t,k}\right) + \mu_t \qquad (7)$$

UIP holds if $\hat{\alpha} = 0$ and $\hat{\beta} = 1$. The UIP hypothesis is usually rejected; in studies using (7), $\hat{\beta}$ is usually very small and occasionally negative, in direct contradiction of the hypothesis. In fact, negative values of $\hat{\beta}$ suggest that countries with large positive differentials experience appreciation. This in a nutshell constitutes the "forward premium puzzle". Froot and Thaler (1990) in reviewing the literature about this find few cases where $\hat{\beta}$ is positive and not a single case where $\hat{\beta}$ >1. The average value of $\hat{\beta}$ is –0.88 in this review. Similar results are cited in a survey by McDonald and Taylor (1992). McCallum (1994) ($E_t\ s_{t+k}$ - s_t) on the forward discount ($f_{t,k}$ - s_t) and finds that $\hat{\beta}$ is approximately –3. McCallum's explanation is that the domestic monetary authorities manage interest spreads to prevent rapid exchange rate movements. Christensen (2000) gives some credence to this policy response hypothesis in his re-examination of McCallum's approach.

Engel's (1996) survey of the forward discount puzzle attributes the failure of UIP partly to the presence of a time varying risk premium and partly to the failure of rational expectations. Engel's results suggest that the analysis of the UIP hypothesis must at some point accommodate a risk premium.

Many countries do not operate freely floating exchange rate regimes and in the case of a fixed rate regime the failure of UIP may be explained by the presence of a peso problem. This arises when market expectations of exchange rate movements are not fulfilled over long periods and consequently the forward rate gives biased predictions of expected spot rates. Krasker (1980) develops the theory underpinning this argument while recent applications are to be found in analyses by Bekaert et al (2001) in relation to US interest rate expectations, the failure of the UIP condition in Brazil identified by Sachsida (2001) and Kaminsky's (1993) study of the US dollar/pound spot exchange rate since 1973.

Chinn and Meridith (2000) find that the failure of UIP among the G7 countries is explained by the data basis of such tests which is often short horizon data. In a related paper Meridith and Chinn (1998) attribute the failure of UIP to the system structure of the macroeconomy. Thus a temporary disturbance of the UIP causes depreciation of the spot relative to the future exchange rate leading to higher output, inflation and interest rates. Higher domestic rates are typically associated with expost appreciation in the short term consistent with the forward discount bias typifying the findings of several empirical studies. In the longer term, temporary short term effects fade and the fundamentals of the UIP prevail.

Australian studies of the UIP are few in number. Bhatti and Moosa (1995) include the Australian dollar in tests of the UIP against the US dollar along with eight European currencies, the Canadian dollar and the Yen. Bhatti and Moosa find that these spot rates are cointegrated and that $\hat{\alpha} = 0, \hat{\beta} = 1$ in all cases suggesting that UIP holds in all eleven individual cases. These findings contradict the general conclusion that UIP fails in many cases. Bhatti and Moosa's explanation relies on the argument that increasing capital market integration produces market conditions which are conducive to UIP. King (1998) tests the UIP for four currencies, US and Australian dollars, the yen and the British pound all against the New Zealand dollar. King's results indicate that the UIP only holds for the Australian/New Zealand dollar exchange rate, but fails in all other cases. The argument for viewing Australian and New Zealand securities as perfect substitutes is stronger given the close relationship between the Australian and New Zealand economies and particularly their capital markets.

The Forward Market Efficiency (FME) principle requires that expectations of spot exchange rates should be incorporated in corresponding forward exchange rates given that market participants are rational and risk neutral. A straightforward test of FME involves the regression of the log of the expected future value of the spot rate ($s_{t+k} = \log S_{t+k}$) on the corresponding forward rate ($f_{t,k}$)

$$s_{t+k} = \alpha + \beta f_{t,h} + \mu_{t+k} \tag{8}$$

FME holds if $\hat{\alpha} = 0$ and $\hat{\beta} = 1$. The problem with this representation of FME is that the time series s_{t+k} and $f_{t,k}$ may be non-stationary prompting us to follow Granger and Newbold (1974) in transforming (8) into its stationary form:

$$s_{t+k} - s_t = \alpha + \beta(f_{t,k} - s_t) + \mu_t \tag{9}$$

If CIP holds exactly and the forward discount ($f_{t,k} - s_t$) equals the interest differential $(i_{t,k} - 1^*_{t,k})$ then, given rational expectations, the expression (9) provides a vehicle for testing both UIP and FME.

The earliest studies by Cornell (1977), Levich (1979) and Frenkel (1980) were based on (8) above and generally support FME. Later studies acknowledge non stationarity and apply expression (9). Included among these are studies by Bilson (1981), Fama (1984), Froot and Frankel (1989). The reported estimates of $\hat{\beta}$ in (9) are low and often negative leading to the rejection of FME or UIP. The apparent discrepancy between the results generated by estimates of (8) and (9) has proven to be somewhat controversial. In particular, some researchers argue that provided the variables s_{t+k} and $f_{t,k}$ are cointegrated over the long run, these time series techniques give similar inferences to OLS estimates of (9). The connection between cointegration and FME is explored by Hakkio and Rush (1989), Barnhart and Szakmary (1991), Jung et al (1998) and Liuntel and Paudyal (1998). The results, as they relate to FME, are mixed and depend on how cointegration is modelled. FME holds in studies based on Phillips and Hansen's (1990) full modified OLS procedure. Included among these are studies by Sosvilla-Rivero and Park (1992), McFarland et al (1994) and Ngama (1994).

Australian evidence about the FME hypothesis is provided by Tease (1988), who finds that FME holds for the 15 and 90 day forward markets but efficiency does not apply in the 15 and 30 day markets. Kearney and McDonald (1991) also examine the relationship between spot and forward Australian/US dollar rates for the one, three and six month forecast horizons and universally reject FME. These studies are based on a data set which terminates in the mid eighties, so it will be interesting to determine if FME and UIP hold in more recent times.

The UIP and FME conditions are also tested in the presence of a risk premium by Felmingham and Buchanan (1993), who find that a risk premium drives a wedge between the forward and expected future spot rates in 1985, the most volatile period for the Australian dollar since forex market deregulation in December 1983. In a subsequent study Felmingham and Mansfield (1997) find that the premium disappeared once the volatility experienced in 1985 had subsided. The susceptibility of the Australian currency markets to the presence of a risk premium suggests that the present analysis should accommodate tests for a time varying risk premium.

3. Properties of the Data Set

The full data set comprises daily observations of spot, 90-day-forward as well as 180-day-forward AUD/USD exchange rates, and Australian and US 90-day as well 180-day Treasury note (T-note) interest rates over the period 2 December 1985 – 20 December 2000 and 5 December 1985 – 29 December 2000 respectively. Therefore, the data set comprises 3697 and 3694 observations for the 90-day and 180-day maturities respectively. The CIP, UIP and FME models are all estimated on the full data set. Two sub-samples were also chosen: Sub-sample 1 comprises 1493 and 1490 daily observations for the 90-day and 180-day maturities respectively from six consecutive financial years, 2 December 1985 – 31

December 1991; Sub-sample 2 comprises 2204 observations and covers nine consecutive financial years over the period 2 January 1992 – 29 December 2000. Care was taken to ensure that all points were contemporaneously sampled to the day, which means certain observations were omitted because of non-aligned public holidays. On the other hand, the selection of sub-periods 1 and 2 requires no detailed explanation, as there was an Australian policy change in interest rates, which could be expected to have profound effects on the structure and behaviour of the foreign exchange market. Therefore, Sub-sample 1 involves a policy transition period from the very high interest rates of the eighties and early nineties to the much lower rates in late 1991. It is of interest to determine if this switch in monetary policy had any impact on the CIP, UIP or FME relationship. Further the comparison of results for the two sub periods should allow us to detect any shift in the nature of these relationships at two different points in time.

Augmented Dicker Fuller (ADF) and Phillips Perron (PP) tests are conducted on each of the time series applied in this study, to determine their stationarity properties. Data relating to the spot AUD/USD exchange rate and forward rate as well as interest rate data were sourced from the Reserve Bank of Australia[3] while the US interest rate was obtained from the Reserve Bank of St. Louis, USA.[4] The data set requires some further discussion in relation to the UIP model. In particular, the task of matching spot and forward rates is complicated by the effects of non-trading days on the length of the forecast interval (k). This is the relevant concept in the current context, because trade can only be transacted on those days when trading facilities are available. Therefore, a forecast interval of 90 and 180 calendar days must be adjusted for the effects of weekends and public holidays. The point of this data analysis is that the forecast interval of 90 or 180 calendar days must be converted to trading

[3] Downloadable from www.rba.org.au (verified on 15 April 2001).
[4] Downloadable from www.stls.frb.org (verified on 15 April 2001)

days. Following the approach undertaken by Felmingham and Buchanan (1993), calendar days are converted to trading days in each period by applying the proportion of trading to calendar days in each period to the 90 or 180 calendar days comprising the forecast intervals. Hence, the estimated number of trading days in the forecast interval[5] of 90 and 180 calendar days are 61 and 121 respectively rounded, to the nearest whole day for each period.

Table 1 contains the t and F statistics associated with both ADF and PP tests for stationarity. Tests for the significance of these for each individual are conducted at the 10 percent level. This rather low significance level is chosen so that any non stationarity problems are emphasised. The general conclusion from Table 1 is that most of the individual time series employed in this study have the I(1) property. The standout exception to this general outcome is in the case of the UIP model in both the 90 and 180 day market where the dependent variable $s_{t+k} - s_t$ is clearly I(0). Some doubt surrounds the results for the dependent variable in the standard form of the CIP ($f_{t+k} - s_t$) in the 90 day market where the PP, F stat is significant and in the case of the UIP $\left[i_{t+k} - i^*_{t,k} / 1 + i^*_{t,k}\right]$ where the ADF (but not the PP) test suggests that stationarity in levels applies to this variable in the 180 day market for the UIP and CIP models. This could create an identification problem in the CIP and UIP models which must be considered where appropriate.

Table 1 here

4. Tests for CIP

It is apparent from Table 1 that the forward margin ($f_{t,k} - s_t$) is I(o) according to the non parametric PP test, although the ADF test suggests that the forward margin is I(1). In cases of conflict between the ADF and PP tests the PP test is preferred because of its non

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[5] The estimated number of trading days in the forecast interval of 90 (or 180) calendar days = the number of trading days in the sample/the number of calendar days in the sample *90 (or 180).

parametric property. However the possibility that the left hand side of the CIP relationship is I(o) while the right hand side is I(1) cannot be dismissed lightly. To avoid this possibility, the equation (2) representing the CIP condition, is transformed so that the variables on both sides of the CIP relationship are I(1). The following transformed relationship is used as a test vehicle:

$$f_{t,k} = \alpha + \beta\left[s_t + \frac{i_{t,k} - i^*_{t,k}}{1 + i^*_{t,k}}\right] + \mu_{t+k} \tag{10}$$

The CIP condition is deemed to hold if the estimation of (10) produces the outcome $\hat{\alpha} = 0, \hat{\beta} = 1$.

The estimation regime applied to (10) is comprised of three steps. The first step in our estimation regime is to fit (10) by OLS subject to West's (1988) correction of the t-statistics from the OLS estimates because they are not fully efficient. The correction gives these a limiting normal distribution. The second step of the CIP test design is to apply the fully modified Ordinary Least Squares (FM-OLS) technique to expression (10). This estimator is developed by Phillips and Hansen (PH) (1990) to accommodate the problems of non stationarity of log-level time series and serially dependent errors. While the FM-OLS technique is designed to deal with non stationarity, it was not designed to deal with data such as exchange rates where there is prominent outlier activity. Exchange rate data often presents as leptokurtic and heavy tailed. Phillips (1995) develops the fully modified least absolute deviations (FM-LAD) technique as an extension of the least absolute deviation (LAD) estimator. The FM-LAD estimator is robust and widely applicable in time series applications according to Bloomfield and Steiger (1983) and in models with autoregressive roots – Knight (1989) and Phillips (1991).

The FM-LAD procedure possesses all the robustness of LAD while maintaining the desirable properties of FM-OLS, in particular, its capacity to treat non stationary, serially dependent errors and endogeneity. Moreover, the FM-LAD procedure also applies regardless of the tail thickness of the data and is valid when the data have no finite variances as evident in Koedijk et al's (1990) study of exchange rate series and Phillips (1995) analysis of the Australia-US dollar exchange rate series. This is the third step in testing for CIP in the Australian forward markets.

From Table 2, it is clear that CIP does not hold in the 90 or 180 day markets when OLS procedures are applied. The reported $\hat{\alpha}$'s are statistically significant implying the existence of transactions costs, political risks or capital controls, while the $\hat{\beta}$s are generally significantly different from one using the West corrected t-ratios. The FM-OLS estimates based on the full sample indicate that CIP holds in the shorter term 90 day market but CIP fails in the 180 day market because the hypothesis $t_{\hat{\alpha}} = 0$ is rejected.

Table 2 here

The CIP condition does hold universally, under the more robust FM-LAD procedures, CIP holds because $\hat{\beta}$ is not significantly different from one and $\hat{\alpha}$ is not significantly different from zero in all cases. It does appear as if the application of the FM-LAD procedure has made a substantial difference and that the CIP holds generally when this estimator is applied. This is sufficient for us to conclude the CIP holds in the 90 and 180 day forward markets and no further tests for CIP are applied.

4. UIP and FME Results

The UIP condition in equation (4) is not in a form suitable for estimation because the expected rate of depreciation, which is the dependent variable in this case is I(o) from table 1, while the right hand side representing the interest spread $\left(\frac{i_{t,k} - i^*_{t,k}}{1 + i^*_{t,k}}\right)$ is I(1) according to the

ADF test. Some modification of Equation (4) is required to avoid the effects of this misspecification. The following reformatted version of the UIP condition applies:

$$s_{t+k} = \alpha + \beta\left(s_t + \frac{i_{t,k} - i^*_{t,k}}{1 + i^*_{t,k}}\right) + \mu_{t+k} \tag{11}$$

From Table 1 it is clear that both s_{t+k} and the bracketed expression in (11) could be interpreted as I(1) series and so (11) is a more appropriate specification. The outcomes applying to the parameter estimates of (11) are $\hat{\alpha} = 0$ and $\hat{\beta} = 1$ if UIP is to hold. The same estimation regime as the one applied to tests of the CIP condition are applied to (11), namely, West corrected OLS; FM-OLS, and FM-LAD procedures.

It is clear from Table 3 that there is no evidence to support the UIP condition in the case of the corrected OLS estimates of (11) and this result applies in both the 90 and 180 day markets with the notable exception of sub sample 2 (SS2) in the 90 day market. By way of contrast, the FM-OLS procedure does yield evidence supporting the UIP condition in all three samples. The application of this procedure fails to lead to the rejection of the null hypotheses: $H_\alpha : \hat{\alpha} = 0$ and $H_\beta : \hat{\beta} = 1$ for both the 180 and 90 day markets.

The more robust FM-LAD procedure indicates that the hypotheses supporting the presence of the UIP condition $(\hat{\alpha} = 0, \hat{\beta} = 1)$ are not rejected in the case of the 90 day market but for sub sample 2 only. In all other cases the UIP does not hold. The FM-LAD procedure is the more robust of the three estimators applied here and so greater emphasis is placed on the results given by this methodology. In summary, the evidence for the UIP condition in the Australian 90 and 180 day markets is mixed. UIP fails to hold for the entire sample and the two sub samples in the case of the 180 day market. This outcome applies also to the 90 day market in relation to the full sample and to sub sample 1 which relates to the experiences of the Australian forward markets in the 1980s. The strongest case for the UIP condition arises in SS2 for the 90 day market where all three estimation methods produce the same inference: $\hat{\alpha} = 0$, $\hat{\beta} = 1$ so that UIP holds in more recent times, namely, the late nineties.

Table 3 here

Forward Market Efficiency (FME) is tested by applying the data to equation (9) and by basing the test for FME on the non rejection of the usual null hypotheses about the parameters of (9), namely that $\hat{\alpha} = 0, \hat{\beta} = 1$. The same estimation regime as the one applying to both the CIP and UIP conditions is adopted for the FME condition, namely the estimators OLS (corrected), FM-OLS, and FM-LAD. The results are indicated on Table 3. Results from the corrected OLS procedure suggest that FME fails to apply in both the 90 and 180 day Australian markets because the hypotheses $\hat{\alpha} = 0, \hat{\beta} = 1$ are rejected in most cases. FM-OLS procedures again support FME in both markets, however the limitations of FM-OLS must be acknowledged and our scepticism remains about the robustness of this estimator for the problem at hand. The more robust FM-LAD method again produce results for FME, which are closer to the OLS outcomes in particular the FM-LAD estimates suggest that the 90 day market is efficient in SS^2 alone while the 180 day market is not efficient in any of the three samples. These results infer that FME does not hold in either the 90 day or 180 day Australian market using the full sample and the 90 day market displays efficiency as defined in SS2 only.

5. The Effects of a Risk Premium and Monetary Policy on the UIP and FME Conditions

The failure of UIP and FME conditions in the 90 and 180 day forward markets for the Australian dollar may simply be explained by market inefficiency. To confirm this conclusion, it is appropriate to eliminate another possibility, namely, that a risk premium is present in these markets. There are two concerns about the presence of a risk premium in the forward exchange market: the first is that a premium drives a wedge between the expected value of the spot rate and the forward rate and the second is that variations of the premium are a potential source of exchange rate volatility. Felmingham and Buchanan (1993) attribute most of the volatility of the Australian dollar in its most turbulent, post deregulation period in 1985 to the presence of a risk premium. However, these authors made their assessment of volatility based on discrete shifts of the risk premium when it is possible that the premium was changing more frequently. It is appropriate in light of this to test the UIP and FME conditions subject to the presence of a continuously varying risk premium.

It is also likely that the failure of the UIP and FME conditions can be attributed to the effects of monetary policy. The hypothesis, here, is that domestic policy actions impact on volatility which destabilises the market thereby violating the UIP conditions and market efficiency.

We follow a substantial literature on the modelling of risk premia in foreign exchange markets by setting the UIP and FME conditions in a Generalised Auto Regressive Heteroskedastic (GARCH) framework. GARCH models provide a ready representation of the risk premium in foreign exchange markets in the form of the conditional variance (h_{t+k}):

$$\varepsilon_{t+k} N|\Omega_t \sim (0, h_{t+k}) \tag{12}$$

where Ω_t is the information set available at time t. The UIP and FME conditions are formulated to incorporate the time varying risk premium in the form of the standard deviation of the conditional covariance $\left(h_{t+k}^{\frac{1}{2}}\right)$.

GARCH models have been developed to treat particular characteristics, but following a large literature on this subject, our analysis of GARCH effects on the MUIP and MFME begins with the simplest interpretation labelled GARCH (1,1) – M as follows:

MUIP

$$s_{t+k} = \alpha + \beta\left(s_t + \frac{i_{k,t} - i_{k,t}^*}{1 + i_{k,t}^*}\right) + \delta h_{t+k}^{\frac{1}{2}} + \left(1 - \gamma, L - \gamma_2 L^2 - \ldots - \gamma_k L^k\right)\varepsilon_{t+k} \tag{13}$$

MFME

$$s_{t+k} = \alpha + \beta f_{t,k} + \delta h_{t+k}^{\frac{1}{2}} + \left(1 - \gamma_1 L - \gamma_2 L^2 - \ldots - \gamma_k L^k\right)\varepsilon_{t+k} \tag{14}$$

GARCH (1,1)

$$h_{t+k} = \varphi_0 + \varphi_1 \varepsilon_{t+k-1}^2 + \varphi_2 h_{t+k-1} + \theta CR_t \tag{15}$$

The mean equations for the MUIP and MFME models are expressions (13) and (14) respectively and they contain some common characteristics which are briefly explained. Both expressions are based on the rational expectations assumption: $E_t s_{t+k} = s_{t+k}$. Further, the time varying risk premium is proxied by the conditional standard deviation $\left(h_{t+k}^{\frac{1}{2}}\right)$ while the autocorrelated error term is modelled as a weighted (γ_i) moving average error process, L representing lagged innovations in that process. Autocorrelation enters because there is an overlapping observations problem. This eventuates because the time series data applied to this study is observed daily, while the forecast interval is k = 180 and 90. This leads to potentially autocorrelated errors[6].

Two of several alternative econometric responses are available. The first is to estimate (13) and (14) by the more efficient maximum likelihood method and to rely on the MA error process to achieve consistency. A second approach is to estimate (13) and (14) by GMM and not rely on any separate representation of the error process. This second procedure will yield consistent estimates, but it does involve a loss of efficiency. We have chosen to use ML methods and rely on the MA error process to counteract any autocorrelation present.

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[6] To demonstrate, consider the forecasting equation $E(Z_{t+k}|\Omega_t) = X_t\theta$, where X_t is a vector of elements of Ω_t and θ is a vector of parameters where $\mu_{t+k} = Z_{t+k} - E(Z_{t+k}|\Omega_t)$ is the forecast error observable at t + k, but Z_{t+k} is not observable at t. As a consequence, if data is sampled more finely than k then:

Cov $(\mu_{t+k}, \mu_{t+k-n}) \neq 0$ for n = 1, 2, … , k – 1

and Cov $(\mu_{t+k}, \mu_{t+k-n}) = 0$ for n ≥ k.

The GARCH (1,1) equation (15) takes into account the potential effects of monetary policy on volatility. The overnight cash rate (CR_t) is the Reserve Bank of Australia's monetary policy target. The inclusion of CR_t in expression (15) provides a direct test of the effects of monetary policy on exchange rate volatility.

The problem with the GARCH (1,1) – M representation of the GARCH process is that it imposes symmetry on the conditional variance structure. In particular, Nelson (1991) emphasises the restrictive nature of the GARCH specification which imposes a quadratic mapping of the past history of ε_{t+k} on h_{t+k} and that negative coefficients in expression (15) may lead to a negative conditional variance. Nelson proposes that the following exponential or EGARCH model be fitted to the data. In the case of the EGARCH (1,1) – M process, the following models apply:

<u>MUIP</u>

$$s_{t+k} = \alpha + \beta\left(s_t + \frac{i_{t,k} - i^*_{t,k}}{1 + i^*_{t,k}}\right) + \delta \log(h_{t+k}) + \left(1 - \gamma_1 L - \gamma_2 L^2 - \ldots - \gamma_k L^k\right)\varepsilon_{t+k} \quad (16)$$

<u>MFME</u>

$$s_{t+k} = \alpha + \beta f_{t,k} + \delta \log(h_{t+k}) + \left(1 - \gamma_1 L - \gamma_2 L^2 - \ldots - \gamma_k L^k\right)\varepsilon_{t+k} \quad (17)$$

$$\log(h_{t+k}) = \varphi_0 + \varphi_1\left(\frac{\varepsilon_{t+k-1}}{h_{t+k-1}}\right) + \varphi_2\left(\left|\frac{\varepsilon_{t+k-1}}{h^{\frac{1}{2}}_{t+k-1}}\right| - \left(\frac{2}{\Pi}\right)\right)^{\frac{1}{2}} + \varphi_3 \log(h_{t+k-1}) + \theta CR_t \quad (18)$$

The time varying risk premium (TRP) is represented in (16) and (17) as log (h_{t+k}) which replaces $h^{\frac{1}{2}}_{t+k}$. The EGARCH representation has two advantages over the GARCH model. The logarithmic construction of this model ensures that the estimated conditional variance is strictly positive not requiring the imposition of non negative constraints as is the case in the estimation of GARCH or ARCH models. Second, the parameter φ_3 typically enters (18) negatively signed, so that bad news, $\varepsilon_{t+k} < 0$ will generate more volatility than good news.

An alternative approach to the asymmetry issue is proposed by Glosten, Jagannathan and Runkle (GJR), (1993) in the following GARCH representation:

MUIP

$$s_{t+k} = \alpha + \beta\left(s_t + \frac{i_{t,k} - i^*_{t,k}}{1 + i^*_{t,k}} \right) + \delta h_{t+k} + \left(1 - \gamma_1 L - \gamma_2 L^2 - \ldots - \gamma_k L^k\right)\varepsilon_{t+k} \tag{19}$$

MFME

$$s_{t+k} = \alpha + \beta f_{t,k} + \delta h_{t+k} + \left(1 - \gamma_1 L - \gamma_2 L^2 - \ldots - \gamma_k L^k\right)\varepsilon_{t+k} \tag{20}$$

$$h_{t+k} = \varphi_0 + \varphi_1 \varepsilon^2_{t+k-1} + \varphi_2 I_{t+k-1}\varepsilon^2_{t+k-1} + \varphi_3 h_{t+k-1} + \theta CR_t \tag{21}$$

GJR GARCH differs from GARCH (1,1) – M in two important respects: first in (19) and (20) the TRP is represented by h_{t+k} and not $h^{\frac{1}{2}}_{t+k}$ which is the case in the GARCH (1,1) – M case and most significantly the GARCH process (21) incorporates an indicator function I_t. This assumes the value I if $\varepsilon_t < 0$ and the value 0 when $\varepsilon_t > 0$. The GJR – GARCH (1,1) – M model generates larger values from h_{t+k} given a negative shock ($\varepsilon_t < 0$) than for a positive shock ($\varepsilon_t < 0$) of equal magnitude. GJR – GARCH (1,1) – M differentiates the impact of good from bad news also, but the parameters of (21) are constrained to be non negative.

The maximum likelihood algorithm developed by Berndt et al (1974) is applied to the estimation of the three representations of GARCH: This comprises equations (13), (14) and (15) for GARCH (1,1) – M; equations (16), (17) and (18) for EGARCH and expressions (19), (20) and (21) for GJR – GARCH. These equations are estimated for three time series: the full sample dating from 12/2/85 to 12/29/00 containing 3,697 observations and two sub samples: the first (sub sample I) dating from 12/2/85 to 12/31/91 and sub sample 2 which dates from

1/2/92 to 12/29/00. Sub Sample 1 and 2 comprise 1493 and 2204 observations respectively. Sub period estimation is motivated by two considerations: the first is a potential policy impact on the Australian capital markets in the second half of 1991 when the RBA halved the cash rate and the second is the potential impact of increasing international capital market integration on the behaviour of the Australian currency markets. This influence might be expected to create conditions conducive to the UIP and FME conditions, for example, a closer degree of substitutability between domestic and foreign securities.

There are three GARCH tests for the TRP and policy impacts on the MUIP and MFME; a total of six models in all. These six models are tested on the three data sets defined above and referred to as the Full Sample (FS) (12/2/1985 to 12/29/00, Sub-Sample One (SSI) (12/2/85 to 12/31/91) and Sub-Sample Two (SS2) (1/2/92 to 12/29/00). The results from these eighteen experiments are discussed on four tables: Table 4 and 5 contain the results of tests for the MUIP condition in the Australian 90 and 180 day forward markets and Table 6 and 7 includes the test results for the MFME condition in the 90 and 180 day markets.

The MUIP holds precisely if the estimated values of $\alpha(\hat{\alpha})$ and $\beta(\hat{\beta})$ accord with the following hypotheses: $H_0 : \hat{\alpha} = 0$ and $H_0 : \hat{\beta} = 1$ and there is no risk premium in which circumstance $H_0 : \hat{\delta} = 0$. These are tested by the use of the Wald statistics at the foot of each table. Monetary policy impacts on the spot exchange rate provided $H_0 : \hat{\theta} \neq 0$ holds. The MFME holds in the same circumstances: $H_0 : \hat{\alpha} = 0$, $H_0 : \hat{\beta} = 1$, $H_0 : \hat{\delta} = 0$ in equation (20) while policy effects depend on the significance or otherwise: the parameter $\hat{\theta}$ = 0 is accepted in (21).

Table 4 here

One result stands out among the Wald Statistics on Table 4, namely that the conditions under which MUIP may hold in the 90 day market are violated in relation to either or both of the hypothesis: $H_0 : \hat{\delta} = 0$ and $H_0 : \hat{\beta} = 1$ both are rejected and usually at the 5 or 1 percent level of significance in the case of the FS and SS1. These Wald statistics also suggest that our three null hypotheses hold in the case of SS2. This interpretation applies in all three interpretations of GARCH. A time varying risk premium is also present in SS1 and FS, because $H_0 : \hat{\delta} \neq 0$ is accepted. The discovery of a TRP in Sub-Sample 1 (12/2/85 to 12/31/91) is consistent with previous analyses of the risk premium issue, for example, Felmingham and Mansfield (1997) who find that the USD/AUD spot exchange rate is subject to a constant but not time varying risk premium over the period 1983 to 1991. The calmer seas which appear to surround Australia's forex markets in the 1990s are evident in the apparent absence of a TRP in SS2.

Policy effects $(\hat{\theta} \neq 0)$ are not a common occurrence in relation to the MUIP condition in the 90 day market. There is no particular instance of $\hat{\theta} \neq 0$ on Table 4. Finally, in relation to the properties of the GARCH estimation for the MUIP in the 90 day market, no IGARCH effects are evident. The null hypothesis $H_0 : \phi_1 + \phi_2 = 1$ is rejected for the GARCH (1,1) – M model while the parameter b is not significant in either the EGARCH or the GJR-GARCH cases. In these cases b is the slope parameter in the following regression:

$$h_{t+k} = a + bh_{t+k-1} + e_{t+k} \tag{20}$$

If the hypotheses $\hat{b} = 1$ is accepted then IGARCH is deemed to hold. From Table 4, the hypothesis $\hat{b} = 1$ is rejected suggesting no evidence of an IGARCH effect in EGARCH and GJR-GARCH estimates of the MUIP in the 90 day markets.

Table 5 here

Table 5 reports outcomes of tests for the MUIP condition in the 180 day market. There is no single case where the necessary conditions for the presence of the MUIP condition are met. In eight of the nine GARCH tests for the MUIP in the 180 day market

$\hat{\alpha} = 0$ and $\hat{\beta} \neq 0$. In the remaining instance, Sub-Sample 2 for the GJR-GARCH model $\hat{\alpha} = 0$ but $\hat{\beta} \neq 0$, so the MUIP does not hold in this case either.

The presence or otherwise of a TRP is determined by testing the hypothesis $H_0 : \hat{\delta} = 0$. It is evident from Table 5 that the null hypothesis $\hat{\delta} = 0$ is rejected in only two situations in Australia's 180 day market suggesting that a time varying premium is present in these instances. These two occasions are Sub-Sample 2 using GARCH (1,1) – M and Sub-Sample 1 for the EGARCH model. In all remaining cases $H_0 : \hat{\delta} = 0$ is accepted suggesting that no TRP is evident in the 180 day market and the MUIP model. It is also evident from Table 5 that the policy variable, the cash rate, has an impact on spot rate volatility of the 180 day market when GARCH (1,1) – M, or GJR GARCH is applied to the data, however, there is some evidence that $\hat{\theta} \neq 0$ when the EGARCH representation applies. This is indicated by the small nature of the standard errors associated with $\hat{\theta}$ against the actual estimates of $\hat{\theta}$ on Table 5 for EGARCH. Finally, IGARCH effects are deemed not to be present when GARCH (1,1) – M is applied because the hypothesis $H_0 : \varphi_1 + \varphi_2 = 1$ is rejected. A similar interpretation applies to the GJR-GARCH estimate of $\hat{b}$ for EGARCH in SS1 and SS2. However, there is some evidence of an IGARCH effect in SS2 (EGARCH) and for FS (GJR GARCH).

Tables 6 and 7 include results for the tests of MFME in the 180 and 90 day markets respectively. The results for the 180 day markets are analysed first. From Table 6, the conditions for MFME, namely, $\hat{\alpha} = 0$ and $\hat{\beta} = 1$ are satisfied in two cases: first in SS2 when GARCH (1,1) – M is applied to the data and again in SS2, $\hat{\alpha} = 0$ is rejected although $\hat{\beta} = 1$ is accepted. In all remaining combinations of the sample period and GARCH methodology, the conditions for MFME do not pertain.

Table 6 here

The conclusion drawn from Table 6 about the presence of a TRP in tests for the MFME condition in the 180 day is that such evidence is confined to the FS and SS1 (GJR-GARCH) and the FS (GARCH (1,1) – M). In all remaining instances, there is no evidence to support the existence of the TRP in the 180 day market. Further, there is no evidence of IGARCH effects flowing from the application of GARCH (1,1) – M for $H_0 : \varphi_1 + \varphi_2 = 0$ is rejected in all three samples. Some evidence exists for asymmetric responses to shocks (EGARCH, GJR-GARCH) in the 180 day market, particularly in the case of the FS (EGARCH) and in SS2 (GJR-GARCH). Policy effects are evident in the 180 day version of the MFME, because the standard errors of $\hat{\theta}$ are low in comparison with the value of $\hat{\theta}$ in SS1 when GARCH (1,1) is applied. However, $\hat{\theta}$ is not significant in any of the remaining GARCH tests for the 180 day market and the MFME condition.

Table 7 here

Results for the GARCH tests of the MFME condition in the 90 day market and for each of three samples are reported on Table 7. These results are briefly summarised: according to the Wald tests contained in Table 7, the conditions for the FME are not met in eight of nine cases. These conditions $\left(\hat{\alpha} = 0, \hat{\beta} = 1\right)$ are met in sub sample 2 when EGARCH is applied. However, there is evidence for the presence of a risk premium as $\hat{\alpha} \neq 0$ in SS2 (EGARCH). This outcome applies also in the case of GARCH (1,1) – M in SS2; to EGARCH estimates in SS1 and applies to the GJR-GARCH estimates in SS2. Policy effects are generally not evident in the case of MFME in the 90 day market as $\hat{\theta} = 0$ applies in all cases with the possible exception of SS1 (EGARCH). IGARCH effects are not evident: in the case of GARCH (1,1) – M the hypothesis of $\hat{\phi}_1 + \hat{\phi}_2 = 1$ is rejected in GARCH (1,1) – M and $\hat{b} \neq 1$ is not rejected in FS or SS2, although there is some evidence of IGARCH $\left(\hat{b} = 1\right)$ in SS1 (EGARCH) and for the FS in GJR-GARCH is applied to the data.

5. Conclusions

This study examines a class of equilibrium models of the relationship between interest rates and spot and forward exchange rates in the Australian context: covered interest parity (CIP), uncovered interest parity (UIP) and forward market efficiency (FME). It extends the models of UIP and FME to test empirically for the presence of a time-varying risk premium and the potential effects of Australian monetary policy on exchange rate volatility.

Consequently, we have considered the CIP, UIP and FME relationships over the period 1985–2000. For ease of application, the analyses are focused on the foreign exchange relationships between two countries, Australia and the United States of America. To overcome the problem of non-stationary data, new estimation techniques are introduced and applied. The UIP and FME models are modified in order to take in the issue of a time-varying risk premium in the foreign exchange market. Finally, the study addresses more directly the issue of the impact of RBA policy on the foreign exchange market, in the context of the relationship between the time-varying risk premium and the policy variable. The main results of the study are summarised in the following paragraph.

The CIP theorem holds in Australia's 90 and 180 day markets, implying that there is an absence of pure arbitrage opportunities and, as such, it can be taken as evidence of market efficiency. This result also suggests that the Australian and the US financial markets are highly integrated. With the equalisation of covered interest rates, the country premium between Australia and the US has been eliminated. While substantial deviations from CIP are a good indication that capital mobility is less than perfect, the holding of CIP, however, is consistent with either high or low capital mobility (see Willett et al., 2000). In terms of the modern theory that combines the CIP and speculative theories of the forward rate, the appropriate measure of capital mobility is the extent to which uncovered rather than covered interest parity holds. In an influential paper, Edwards and Khan (1985) make use of the UIP approach to estimate capital mobility. Looking at the UIP results, the degree of capital mobility between Australia and the US has increased substantially. The UIP is rejected over the period of 2 December 1985 – 31 December 1991 but holds over the later period of 2 January 1992 – 29 December 2000 in the 90-day market. This may be seen as a result of the liberalisation of the financial sectors in both countries and by the demolition of barriers to capital and trade flows. On one hand, it encourages inflows of foreign direct and portfolio investment and greatly supports economic growth; it also reduces the independence of the country's domestic monetary and fiscal policies and causes problems of over-heating and resource miss-allocation on the other hand.

MUIP models are developed to test for a time-varying risk premium. However, there is no concrete evidence of such a premium. However, the inclusion of the cash rate does change this outcome as there is strong evidence supporting the presence of a time-varying risk premium over the sub-sample 1 period in the 90-day market. This implies that there is a close relationship between the cash rate and the time-varying risk premium, suggesting that the cash rate plays an important role in influencing the market participants' perceptions about the riskiness of the foreign exchange market.

CIP holds in all cases for both the 90-day and 180-day markets implying that there is no potential arbitrage profit opportunity for a market trader at a point in time. On the other hand, it also suggests the effectiveness of forward market facilities in providing cover from the risk associated with forward trading in Australia. Furthermore, investors and traders require no country premium (between Australia and the US) when transacting in the financial markets, as there is no covered interest differential.

In terms of the FME and/or MFME models, the forward rate only acted as an unbiased predictor of the spot rate over the period 2 January 1992 – 29 December 2000 in the 90-day market. However, when the cash rate is considered simultaneously, the forward rate in the 180-day market turns out to be an unbiased predictor of the spot rate. Further a time-varying risk premium was found in the 90-day market over the same time period. It suggests that the cash rate tends to influence market participants in the shorter-term market, that is, the 90-day market. It can be concluded that the predictability of the spot exchange rate through the forward rate has improved over time. This is indeed good news to investors and traders who are engaged in international transactions involving both Australian and the US dollars.

Table 1: Stationarity Tests for Individual Time Series Over the Full Sample: 12/2/85 to 12/29/00

Model/ Variable	Level				First Difference			
	ADF		PP		ADF		PP	
	t-stat[(2)]	F-stat	t-stat	F-stat	t-stat	F-stat	t-stat	F-stat
CIP – 90 day								
$f_{t,k} - s_t$	-3.045	3.832	-3.086	4.335*	n.a.	n.a.	n.a.	n.a.
$\frac{i_{t,k} - i^*_{t,k}}{1 + i^*_{t,k}}$	-3.503*	3.561	-2.500	3.077	n.a.	n.a.	n.a.	n.a.
$f_{t,k}$	-1.657	1.666	-1.834	1.893	-7.757*	20.084*	-60.922*	1237.200*
$s_t + \frac{i_{t,k} - i^*_{t,k}}{1 + i^*_{t,k}}$	-1.651	1.674	-1.820	1.889	-7.739*	19.990*	-60.711*	1228.800*
CIP – 180 day								
$f_{t,k} - s_t$	-2.643	2.875	-3.317*	4.335*	n.a.	n.a.	n.a.	n.a.
$\frac{i_{t,k} - i^*_{t,k}}{1 + i^*_{t,k}}$	3.503*	4.539*	3.035	3.920	n.a.	n.a.	n.a.	n.a.
$f_{t,k}$	-1.657	1.660	-1.865	1.936	-7.533*	19.946*	-61.091*	1244.10*
$s_t + \frac{i_{t,k} - i^*_{t,k}}{1 + i^*_{t,k}}$	-1.676	1.688	-1.837	1.932	-7.316*	17.870*	-60.512*	1220.600*

Table 1: Continued

Model/ Variable	Level				First Difference			
	ADF		PP		ADF		PP	
	t-stat(2)	F-stat	t-stat	F-stat	t-stat	F-stat	t-stat	F-stat
UIP – 90 day								
$s_{t+k} - s_t$	8.085*	21.800*	-5.448*	9.903*				
$\frac{i_{t,k} - i^*_{t,k}}{1+i^*_{t,k}}$	-3.106	3.636	-2.463	3.016				
s_{t+k}	-1.569	1.537	-1.759	1.733	-7.213*	17.357*	-60.238*	1209.500*
$s_t + \frac{i_{t,k} - i^*_{t,k}}{1+i^*_{t,k}}$	-1.612	1.718	-1.693	1.853	-7.583*	19.185*	-59.924*	1196.900*
UIP – 180 day								
$s_{t+k} - s_t$	-4.592*	7.224*	-3.993*	5.331*				
$\frac{i_{t,k} - i^*_{t,k}}{1+i^*_{t,k}}$	-3.558*	4.653*	-3.077	3.976				
s_{t+k}	-2.235	3.172	-1.813	1.876	-8.098*	21.883*	-59.707*	1188.300*
$s_t + \frac{i_{t,k} - i^*_{t,k}}{1+i^*_{t,k}}$	-1.990	1.779	-2.102	2.025	-7.592*	19.225*	-59.176*	1167.300*

Table 1: Continued

Model/ Variable	Level				First Difference			
	ADF		PP		ADF		PP	
	t-stat(2)	F-stat	t-stat	F-stat	t-stat	F-stat	t-stat	F-stat
FME – 90 day								
s_{t+k}	-1.569	1.564	-1.759	1.733	-7.213*	17.357*	-60.328*	1209.500*
$f_{t,k}$	-1.774	1.832	-1.708	1.855	-7.602*	19.276*	-60.145*	1205.800*
FME 180 day								
s_{t+k}	-2.235	3.172	-1.813	1.876	-8.098*	21.883*	-59.707*	1188.300*
$f_{t,k}$	-2.186	2.028	-2.136	2.044	-7.314*	17.838*	-59.825*	1193.600*

[1] The ADF format contains both a constant and trend term, although it is noted that alternative formals, in particular, a model with constant but no trend term does not alter the interpretation of this table. Truncation log (k) selected by SHAZAM 7.0 program.

[2] The critical values for the ADF t and F-test for the constant with trend format are –3.13 and 4.03 respectively at the 10% level of significance, * indicates significance.

Table 2: Results of Tests for CIP

Model	Market	Period	Estimation Method	Coefficients, Standard Errors & t-tests					
				$\hat{\alpha}$	$s^z_{\hat{a}}$	$t_{\hat{a}=0}$	$\hat{\beta}$	$s_{\hat{\beta}}$	$t_{\hat{\beta}=1}$
CIP	90-day	Full sample	OLS	-0.00018973	7.4601E-05	-2.54327[(b)]	0.9993353	0.000209	-3.19926[(c)]
			FM-OLS	-0.00013261	0.000325	-0.4080361	0.99916493	0.0009103	-0.9173448
			FM-LAD	-1.27E-04	0.00154049	-8.27E-02	0.9987042	0.0043149	-0.30031
	180-day	Full sample	OLS	-0.00102881	0.00012762	-8.07853[(c)]	0.99902225	0.0003497	-2.7963[(c)]
			FM-OLS	-0.00100372	0.00034961	-2.87099[(c)]	0.99895148	0.0009599	-1.0922749
			FM-LAD[7]	-1.36E-03	0.00384621	-3.54E-01	0.999418	0.0105608	-0.05514

[1] [(a)], [(b)] and [(c)] denote rejection at the 10%, 5% and 1% level respectively using a conventional t-test.
[2] The reported standard errors for the OLS estimates are corrected according to West (1988) and the corresponding t-tests make use of the West corrected standard error.

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Table 3: Results of Tests for UIP (Equn 11) and FME (Equn 9)

Market	Sample	Method	Coefficients t-Scores							
			UIP (11)				FME (9)			
			$\hat{\alpha}$	$t_{\hat{\alpha}=0}$	$\hat{\beta}$	$t_{\hat{\beta}=1}$	$\hat{\alpha}$	$t_{\hat{\alpha}=0}$	$\hat{\beta}$	$t_{\hat{\beta}=1}$
90 day	Full	OLS	0.010	2.942***	0.960	-4.288***	0.010	2.978***	0.961	-4.196***
		FM-OLS	-0.018	-0.722	1.042	-0.722	-0.018	-0.739	1.05	0.618
		FM-LAD	0.015	0.010	0.942	-2.086**	0.011	1.130	0.944	-1.971**
	SS1	OLS	0.066	12.937***	0.722	-17.369***	0.066	13.118***	0.722	-17.607***
		FM-OLS	0.001	0.015	0.943	-0.523	0.002	0.042	0.931	-0.559
		FM-LAD	0.076	4.510***	0.701	-5.626***	0.077	4.630***	0.697	-5.751
	SS2	OLS	0.001	0.306	1.016	1.480	0.001	0.235	1.019	1.722*
		FM-OLS	-0.012	-0.398	1.053	0.645	-0.013	-0.419	1.057	0.689
		FM-LAD	0.001	0.435	0.998	-0.029	0.061	4.360	1.001	0.309
180 day	Full	OLS	0.039	7.978***	0.863	-10.001***	0.040	8.324***	0.862	-10.081***
		FM-OLS	-0.057	-0.961	1.142	0.846	-0.058	-0.973	1.148	0.881
		FM-LAD	0.042	3.500***	0.826	-5.149***	0.045	3.840***	0.820	-5.355***
	SS1	OLS	0.103	16.741***	0.562	23.562***	0.105	17.199***	0.588	-23.900***
		FM-OLS	0.016	0.167	0.834	-0.575	0.018	0.189	0.832	-0.593
		FM-LAD	0.129	6.980***	0.470	-9.533***	0.130	7.110***	0.469	-9.601
	SS2	OLS	0.025	4.175***	0.963	2.191**	0.025	4.147***	0.968	-1.926*
		FM-OLS	-0.043	-0.669	1.155	0.884	-0.044	-0.690	1.163	0.929
		FM-LAD	0.035	1.990***	0.902	-2.058**	0.035	1.980**	0.907	1.959*

(1) Samples: Full 12/2/85 to 12/29/00
Sub sample 1 (SS1): 12/2/85 to 12/31/91
Sub sample 2 (SS2): 1/2/92 to 12/29/00
(2) Repeated t-scores based on West corrected OLS standard errors.
(3) *** **: reject** $t_{\hat{\alpha}=0}, t_{\hat{\beta}=0}$ **at 1%**

** **: reject** $t_{\hat{\alpha}=0}, t_{\hat{\beta}=0}$ **at 5%**

* **: reject** $t_{\hat{\alpha}=0}, t_{\hat{\beta}=0}$ **at 10%**

Table 4: Results of Tests for the MUIP Condition: 90 Day Market

Coefficients/ Tests	GARCH (1,1) – M Equations (13), (14), (15)			E-GARCH Equations (16) , (17), (18)			GJR – GARCH Equations (19), (20), (21)		
	Full Sample	Sub Sample 1	Sub Sample 2	Full Sample	Sub Sample 1	Sub Sample 2	Full Sample	Sub Sample 1	Sub Sample 2
α	0.014 (0.006)	0.075 (0.008)	0.014 (0.003)(1)	0.027 (0.003)	0.066 (0.001)	0.003 (0.005)	0.001 (0.001)	0.006 (0.000)	0.009 (0.007)
β	0.932 (0.015)	0.679 (0.009)	0.996 (0.008)	0.905 (0.008)	0.705 (0.001)	1.010 (0.016)	0.949 (0.006)	0.719 (0.005)	1.004 (0.002)
δ	-0.006 (0.188)	0.003 (0.002)	0.006 (0.123)	1.953 (2.124)	1.888 (0.027)	-1.554 (3.493)	0.017 (1.290)	0.462 (0.145)	-2.642 (3.825)
ϕ_0	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-1.964 (0.486)	-3.635 (0.006)	-2.697 (0.963)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
ϕ_1	0.577 (0.114)	0.957 (0.650)	0.589 (0.096)	0.047 (0.079)	0.006 (0.001)	-0.005 (0.122)	0.466 (0.005)	0.466 (0.046)	0.477 (0.108)
ϕ_2	0.067 (0.064)	0.000 (0.002)	0.002 (0.005)	1.21 (0.143)	1.671 (0.010)	1.595 (0.292)	0.002 (0.007)	0.025 (0.067)	0.207 (0.230)
ϕ_3	na	na	na	0.519 (0.083)	0.640 (0.009)	0.519 (0.008)	0.051 (0.002)	0.051 (0.27)	0.012 (0.003)
θ	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.191 (0.139)	0.006 (0.001)	-0.191 (0.139)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
$\hat{b}$				0.089 (0.017)	0.026 (0.026)	0.004 (0.022)	0.063 (0.017)	0.023 (0.026)	0.015 (0.022)
Wald Tests(2)									
H_0: $\alpha = 0$	5.825**	8634.07***	0.173	74.819***	164667***	0.003	37.421***	6395***	1.866
H_0: $\beta = 1$	22.126***	1123.5	0.190	147.550***	68089***	0.371	80.149***	3151***	0.043
H_0: $\delta = 0$	0.001	175.25***	0.263	0.844	4758***	0.198	0.000	10.162***	0.477
H_0: $\phi_1 + \phi_2 = 1$	13.241***	0.004	18.155***						

(1) Standard Errors in brackets. Parameters estimate significance indicated by * = 10%, ** = 5%, *** = 1%.
(2) Wald test distributed as χ^2 with 1 degree of freedom, *, **, *** refer to rejection of H_0 at the 10, 5 and 1 percent levels.

Table 5: Results of Tests for the MUIP Condition: 180 Day Market

Coefficients/ Tests	GARCH (1,1) – M Equations (13), (15)			E-GARCH Equations ( ) ( )			GJR – GARCH Equations ( ) ( )		
	Full Sample	Sub Sample 1	Sub Sample 2	Full Sample	Sub Sample 1	Sub Sample 2	Full Sample	Sub Sample 1	Sub Sample 2
α	0.032 (0.000)	0.157 (0.004)	0.004 (0.000)$^{(1)}$	0.002 (0.000)	0.123 (0.004)	0.044 (0.015)	0.025 (0.012)	0.167 (0.011)	0.026 (0.053)
β	0.903 (0.001)	0.381 (0.0011)	0.953 (0.000)	0.917 (0.005)	0.481 (0.015)	0.886 (0.000)	0.854 (0.039)	0.376 (0.026)	0.940 (0.001)
δ	0.006 (0.538)	-0.087 (0.216)	0.454 (0.003)	0.003 (0.410)	1.706 (0.518)	2.511 (28.018)	-0.372 (2.489)	-1.547 (0.988)	-0.007 (20.376)
ϕ_0	0.000 (0.000)	0.000 (0.000)	0.001 (0.000)	-3.175 (0.101)	-2.639 (0.007)	-3.728 (0.448)	0.000 (0.000)	0.000 (0.000)	0.003 (0.000)
ϕ_1	0.214 (0.000)	0.391 (0.108)	0.230 (0.000)	-0.085 (0.006)	-0.038 (0.005)	-0.081 (0.257)	0.240 (0.055)	0.848 (0.275)	0.198 (0.000)
ϕ_2	0.024 (0.064)	0.005 (0.002)	0.002 (0.003)	0.912 (0.005)	1.747 (0.006)	0.652 (0.002)	0.016 (0.074)	0.028 (0.020)	-0.024 (0.313)
ϕ_3	na	na	na	0.660 (0.017)	0.729 (0.016)	0.444 (0.005)	0.004 (0.010)	0.000 (0.000	0.045 (0.181)
θ	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.017 (0.000)	0.020 (0.001)	-0.068 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
$\hat{b}$				0.33 (0.016)	0.048 (0.026)	0.004 (0.021)	0013 (0.016)	0.165 (0.026)	0.044 (0.021)
Wald Tests$^{(2)}$									
H_0: $\alpha = 0$	617501***	1446***	2122***	251***	1268***	8.07***	4.155**	256***	0.238
H_0: $\beta = 1$	54735***	3041***	2976***	257***	2449***	332629***	18.628***	599***	3.622***
H_0: $\delta = 0$	0.000	0.168	28186***	0.004	10.854***	0.008	0.022	2.545	0.000
H_0: $\phi_1 + \phi_2 = 1$	143***	34.195***	652***						

(1) Standard Errors in brackets. Significance of parameter estimates indicated by * = 10%, ** = 5%, *** = 1%.
(2) Wald test distributed as χ^2 with 1 degree of freedom, *, **, *** refer to rejection of H_0 at the 10, 5 and 1 percent levels.

Table 6: Results of Tests for the MFME: Australia 180 Day Market

Coefficients/ Tests	GARCH (1,1) – M Equations ( ), ( )			E-GARCH Equations ( ) ( )			GJR – GARCH Equations ( ) ( )		
	Full Sample	Sub Sample 1	Sub Sample 2	Full Sample	Sub Sample 1	Sub Sample 2	Full Sample	Sub Sample 1	Sub Sample 2
α	0.049 (0.000)	0.139 (0.008)	0.012 (0.130)(1)	0.052 (0.003)	0.135 (0.001)	0.012 (0.002)	0.042 (0.008)	0.116 (0.008)	0.025 (0.107)
β	0.802 (0.002)	0.451 (0.002)	0.969 (0.424)	0.813 (0.007)	0.453 (0.003)	0.978 (0.001)	0.823 (0.003)	0.500 (0.002)	0.934 (0.319)
δ	0.058 (0.013)	0.048 (0.037)	0.187 (2.792)	2.386 (2.205)	1.621 (4.660)	0.474 (1.063)	-1.918 (0.737)	-4.478 (2.490)	-2.150 (25.028)
ϕ_0	0.000 (0.000)	0.000 (0.000)	0.002 (0.002)	-2.230 (0.712)	-2.492 (1.234)	-3.945 (0.240)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
ϕ_1	0.918 (0.027)	0.355 (0.040)	0.000 (0.000)	-0.026 (0.010)	-0.016 (0.008)	-0.096 (0.024)	0.516 (0.006)	0.303 (0.008)	0.222 (0.380)
ϕ_2	0.012 (0.002)	0.000 (0.004)	0.030 (0.069)	1.406 (0.254)	1.233 (0.137)	0.784 (0.081)	-0.002 (0.008)	-0.006 (0.134)	-0.036 (0.617)
ϕ_3	na	na	na	0.757 (0.063)	0.746 (0.062)	0.409 (0.022)	0.018 (0.008)	0.000 (0.000)	0.008 (0.022)
θ	0.001 (0.003)	0.001 (0.001)	0.002 (0.001)	0.003 (0.002)	0.006 (0.002)	0.002 (0.009)	0.001 (0.003)	0.001 (0.009)	0.001 (0.003)
$\hat{b}$				0.087 (0.017)	0.027 (0.026)	0.003 (0.025)	0.096 (0.016)	0.035 (0.026)	0.008 (0.021)
Wald Tests(2)									
$H_0: \alpha = 0$	142314***	292***	0.009	335***	12456***	58***	34.141***	200***	0.053
$H_0: \beta = 1$	8578***	576***	0.005	756***	34053***	2.506	47.008***	467***	0.042
$H_0: \delta = 0$	2021***	1.660	0.004	1.171	0.121	0.199	6.768***	3.234**	0.007
$H_0: \phi_1 + \phi_2 = 1$	426***	227***	135***						

(1) Standard Errors in brackets. Significance of parameters is indicated by * = 0.10, ** = 0.05, *** = 0.01.
(2) Wald test distributed as χ^2 with 1 degree of freedom, *, **, *** refer to rejection of H_0 at the 10, 5 and 1 percent levels.

Table 7: Results of Tests for the MFME Condition: Australian 90 Day Market

Coefficients/ Tests	GARCH (1,1) – M Equations ( ), ( )			E-GARCH Equations ( ) ( )			GJR – GARCH Equations ( ) ( )		
	Full Sample	Sub Sample 1	Sub Sample 2	Full Sample	Sub Sample 1	Sub Sample 2	Full Sample	Sub Sample 1	Sub Sample 2
α	0.008 (0.002)[1]	0.092 (0.000)	0.003 (0.000)	0.007 (0.003)	0.064 (0.003)	0.003 (0.004)	0.010 (0.000)	0.009 (0.003)	-0.005 (0.000)
β	0.949 (0.006)	0.630 (0.024)	1.012 (0.003)	0.976 (0.007)	0.696 (0.008)	0.997 (0.009)	0.936 (0.000)	0.646 (0.014)	1.020 (0.007)
δ	0.007 (0.009)	0.121 (0.340)	0.090 (0.009)	-1.108 (2.665)	3.952 (1.356)	7.824 (2.989)	2.197 (2.584)	0.730 (1.195)	1.457 (0.081)
ϕ_0	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-2.950 (0.665)	-1.794 (0.208)	-2.768 (0.529)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
ϕ_1	0.428 (0.050)	0.449 (0.130)	0.243 (0.002)	0.220 (0.007)	-0.049 (0.017)	-0.012 (0.059)	1.141 (0.002)	1.037 (0.049)	0.434 (0.005)
ϕ_2	0.039 (0.025)	0.000 (0.000)	0.012 (0.003)	1.448 (0.208)	1.520 (0.156)	0.847 (0.127)	0.012 (0.041)	0.002 (0.004)	0.037 (0.019)
ϕ_3	na	na	na	0.640 (0.007)	0.805 (0.003)	0.634 (0.052)	-0.287 (0.315)	-0.131 (0.008)	0.159 (0.005)
θ	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.015 (0.002)	0.634 (0.052)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
$\hat{b}$				0.022 (0.017)	0.075 (0.026)	0.020 (0.022)	0.049 (0.017)	0.032 (0.026)	0.039 (0.022)
<u>Wald Tests</u>[2]									
$H_0: \alpha = 0$	112.77***	135***	201***	6.282***	624***	0.772	127024***	502***	1828***
$H_0: \beta = 1$	56.38***	235***	12.39***	9.676***	1578***	0.077	22646***	580***	7.33***
$H_0: \delta = 0$	0.571	0.126***	86***	0.173	8.488***	6.861***	0.723	0.373	323
$H_0: \phi_1 + \phi_2 = 1$	91.255***	17.87***	91.184***						

[1] Standard Errors in brackets. Parameter estimates significance denoted by * = 10%, ** = 5%, *** = 1%.
[2] Wald test distributed as χ^2 with 1 degree of freedom, *, **, *** refer to rejection of H_0 at the 10, 5 and 1 percent levels.

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