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Efficiency of Foreign Exchange (Rupee/Dollar) Market in India–Time Series Econometric Study under Covered Interest Arbitrage Parity Doctrine with ARIMA Forecasts

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Abstract—*This paper examines the relevance of Covered Interest Rate Arbitrage Parity (CIRAP) doctrine in Indian foreign exchange (rupee/dollar) market and its 'efficiency' over the period 27th April, 2012 - 27th February, 2015. Univariate stochastic structure of weekly spot rate* (s_t) *has been captured by ARIMA (1, 1, 0) process. This stochastic structure has been used to generate one - period ahead forecast* (s^e_{t+1}) *and four - period ahead forecast* s^e_{t+4} *series. These forecasts are MMSE forecasts and 'Rational' by nature. Forward rates* (tF_{t+4}) *is found to serve as the 'Unbiased predictor' of the spot rate* (s_{t+4}) *implying that CIRAP does hold good in the market. Again absence of 'risk premium' testifies for the 'efficiency' of the Indian foreign exchange (rupee / dollar) market over the period of study.*

Keyword*: ARIMA Forecasts, MMSE Forecasts, 'Rational' Forecasts, CIRAP Doctrine, Risk Premium, Forward Exchange Rate, Efficient Market*

JEL Classification: *E44, C58, E27, F31*

1. INTRODUCTION

The decade of 1970s brought in a turning point in the realm of international economics and finance. The Britton Woods System broke down and flexible exchange rate system replaced the fixed exchange rate system in 1970s. Determination of exchange rates became the centre-price of deliberations in international economics while the management of balance of payments became almost a non-entity. Consequently, over the last three decades a large number of theories on exchange rate grew up. On the other hand, the issues of dynamic adjustment of balance of payments were relegated to the background. The most exciting feature of this period is the growth of renewed interest of economists in the 'Interest Arbitrage Parity Doctrine 'and thus the 'Interest Rate Arbitrage Parity Theory' has emerged as an influential theory of the determination of the exchange rate since 1970s.

The 'Interest Rate Arbitrage Parity Theory' is theoretically attractive but the empirical support for the theory is mixed. Yet the research on this subject is extensive which indicates that these exists reluctance for rejecting the theory, at least in the short run. The present study is an attempt in this direction with an objective of examining how far the Rupee/Dollar exchange rates conformed to the 'Interest Rate Arbitrage Parity Doctrine' over the period (27th April, 2012 to 27th February, 2015).

2. REVIEW OF LITERATURE

Fama, Eugene F. Journal (1984), reported empirical evidence in favor of Covered Interest Parity and the existence of risk premium in the forward market. Frankel, Jeffrey A, Froot, Kenneth (1990), found some role of UIRP in the dynamics of the foreign exchange market. Guy Meredith, Menzie D. Chinn, (1991) rejected role of UIRP in exchange rate determination, although there is little consensus on why it fails. David Gruen, Gordon Menzies (1991) stressed upon failure of UIRP in the foreign exchange market even when the investor makes unsystematic mistakes while forming expectation of exchange rate changes. Bhatti, Razzaque H, Moosa, Imad, a (1995) have shown the supportive evidences of UIRP hypothesis through a cointegration analysis. The authors compare the Treasury bill rate denominated in eleven currencies to the US dollar and find a long-run relationship in all cases. Malliaropulos, D (1997) employs a multivariate GACRCH model of Risk Premium and reproduces the existence of time-varying risk-premium in deviations from UIRP. Burton Hollifield, R Uppal (1997) examine the effect of segmented commodity markets on the relation between forward and future spot exchange rates in a dynamic economy and find the presence of risk premium. McCallum, J. Monet (2000) extends the dataset used by McCallum to include the recent eight years. In most cases UIRP gets supported by the data as well as it passes all the conventional econometric tests. Jose Olmo, K. Pilbeam (2009) proposes two new profitability based tests for CIAP doctrine. UIPRP conditions are found to hold good to three of the four currencies studied.

3. OBJECTIVE OF STUDY

The present research study is an attempt to enquire into the tenets of the UIRP Doctrine and the theoretical resolutions which follow from the UIRP doctrine. More specifically, we seek to examine in the context of Indian foreign exchange market if

(i) the expected future spot rate is in parity with the corresponding future spot rate

(ii) the officially quoted forward exchange rate is the unbiased predictor of the future spot rate.

(iii) the ARIMA (p, d, q) forecast for future exchange rates is in conformity with the actual future spot rate.

(iv) CIRP holds for rupee-dollar exchange rates over the period of study.

4. DATA: NATURE, PERIOD OF DATASET, TRANSFORMATION AND SOURCES

The study is based on time series datasets on Rupee-dollar exchange rates and Forward Rate for Dollar quoted by RBI. The study involves weekly dataset on rupee-dollar exchange rates over the period (27^{th} April, 2012 - 27^{th} February, 2015) and the corresponding one month forward rates. Forward Rates were derived on the basis of the forward premium (in annualized percent) quoted by the RBI. RBI Bulletins constitute the main source of these time-series datasets. The study uses the logarithmic transformation of the level datasets on the spot rate and the corresponding quoted one month forward rate.

5. THEORETICAL ISSUES

In 'Interest Rate Parity Arbitrage' analysis we deal with four macroeconomic variables like $s_t =$ spot exchange rate (rupee/dollar) at time t.

$s_{t+n} =$ Spot exchange rate which prevails at period (t + n).

$tE(s_{t+n}) = ts^e_{t+n} =$ Expected spot exchange rate to prevail at period (t + n), when expectation is formed at time t by the market agents like speculative & hedgers.

tF_{t+n} = Forward exchange for the period (t + n) quoted at time t i.e., the official expected spot rate for the period (t + n) quoted at time t.

6. METHODOLOGICAL ISSUES

Forward Rate and ARIMA (p, d, q) Forecasting:

The MMSE forecasts for s_t can be obtained through ARIMA (p, d, q) forecast. In many cases, forecasts obtained by this method are more reliable than those obtained from the traditional econometric modeling, particularly for short term forecast.

Computation of a Forecast:

Let the ARIMA (p, d, q) model be

$$\omega_t = \varphi\, \omega_{t-1} + \ldots\ldots\ldots + \varphi_p\, \omega_{t-p} + \varepsilon_t - \theta_1\, \varepsilon_{t-1} - \ldots\ldots - \theta_q\, \varepsilon_{t-q} + \delta \quad (1.1)$$

where $y_t = \Sigma^d\, \omega_t$

The one period forecast of ω_t is $\widehat{\omega}_t(1)$. Now from eqn. (1.16) we get

$$\omega_{T+1} = \varphi_1\, \omega_T + \ldots\ldots\ldots + \varphi_p\, \omega_{T-p+1} + \varepsilon_{t+1} - \theta_1\, \varepsilon_T - \ldots\ldots - \theta_q\, \varepsilon_{T-q} + \delta \quad (1.2)$$

Taking conditional expected value of ω_{T+1} in equation (1.17) we get

$$\widehat{\omega}_T(1) = E\,[\omega_{T+1} / \omega_{T,} \ldots.]$$

$$= \varphi_1\, \omega_T + \ldots\ldots\ldots + \varphi_p\, \omega_{T-p+1} - \theta_1\, \widehat{\omega}_T - \ldots\ldots - \theta_q\, \widehat{\varepsilon}_{T-q+1} + \delta \quad (1.3)$$

where $\widehat{\omega}_T, \widehat{\omega}_{T-1}$ etc. are the observed residuals and the expected value of ε_{T+1} is 0.

Now using the one-period forecast $\widehat{\omega}_T(1)$, one can obtain two-period forecast, $\widehat{\omega}_T(2)$ such that

$$\widehat{\omega}_T(2) = E\,[\omega_{T+2} / \omega_{T,} \ldots.]$$

$$= \varphi_1\, \widehat{\omega}_T(1) + \varphi_2\, \omega_T + \ldots\ldots + \varphi_p\, \omega_{T-p+2} - \theta_1\, \widehat{\omega}_T - \ldots\ldots - \theta_q\, \widehat{\varepsilon}_{T-q+2} + \delta \quad (1.4)$$

The two-period forecast is then used to produce the three period forecast, and so on until the h-period forecast $\widehat{\omega}_T(h)$ is reached:

$$\widehat{\omega}_T(h) = \varphi_1\, \widehat{\omega}_T(h-1) + \ldots\ldots + \varphi_1\, \omega_T + \ldots\ldots$$

$$+ \varphi_p\, \omega_{T-p+1} - \theta_1\, \widehat{\omega}_T - \ldots\ldots - \theta_q\, \widehat{\varepsilon}_{T-q+1} + \delta \quad (1.5)$$

If 1>p and 1>q, this forecast will be

$$\widehat{\omega}_T(h) = \varphi_1\, \widehat{\omega}_T(h-1) + \ldots\ldots\ldots\ldots + \varphi_p \widehat{\omega}_{(1-p)}$$

Once the differenced series ω_T has been forecasted, a forecast can be obtained for the original series y_t simply by summing $\omega_{t,}$ 'd' times.

Section I

Stationarity and Integrability of Spot Rate and Forward Rate Series

Spot rate (s_t) and forward rate (tF_{t+1}) series have been subject to ADF unit root test for ascertaining the state of stationarity and integrability of the series concerned. Table-1 presents the results of the unit root tests on the series concerned.

Table 1: Result of ADF Unit Root Tests on s_t and tF_{t+1} Series

Series	ADF Test Result	Inference
s_t (Level)	Non-Stationary	I(1)
tF_{t+1} (Level)	Non-Stationary	I(1)
$ds_t = s_t$ (First Difference)	Stationary	I(0)
$d_t F_{t+4} = tF_{t+4}$ (First Difference)	Stationary	I(0)

The series (s_t) and tF_{t+1} are I (1) and offer a scope for examining their cointegrability over the period of study.

ARIMA Forecast For one - period ahead Future Exchange Rate:

Univariate stochastic structure for (s_t) has been identified as ARIMA (1, 1, 0) such that

$(s_t) = [(1\text{-}L)(1\text{-}\varphi L)]^{-1}\epsilon_t;\ \epsilon_t \sim \text{iid } N(0, \sigma^2_\epsilon)$

The estimated equation is

$(1\text{-}L)\ s_t = 0.000277 + 0.276384(1\text{-}L)\ L\ s_t$ (2)

SE (0.000390) (0.079188)

t [0.710928] [3.490210]

Prob 0.4783 0.0006

ADF test statistics for u_{t+2}, residuals from the equation (2) is -11.60136. It indicates stationarity for u_{t+2} series.

The estimated ARIMA (1, 1, 0) structure for (s_t) as given by the equation (2) may be used for generating one – period ahead forecast for (s_{t+4}). The forecast series is s^e_{t+1}. Time plots of (s_{t+4}) series along with s^e_{t+1} series are being given by Fig. 1 below.

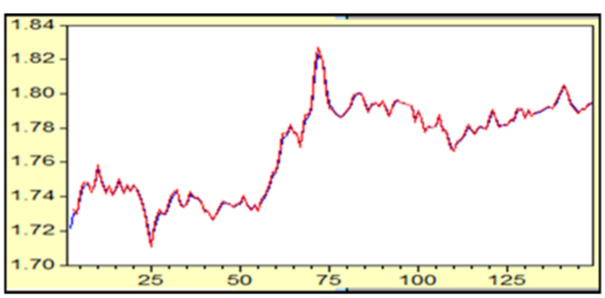


Fig. 1: Time Plots of (S_{t+1} ----) and (S^e_{t+1} ----) series

It appears from the Fig. (1) that one – period ahead forecast for s_{t+1} i.e, s^e_{t+1} almost coincide with the corresponding actual s_{t+1}.

Section II

Relation Between Forward Rate (tF_{t+4}) and the Expected Spot Rate (s^e_{t+4})

The estimated equation (2) may used to generate 4 – period ahead forecast for s_{t+4} . The forecast series represent the series for $tE(s_{t+4}) = s^e_{t+4}$. Time plots of s_{t+4} series along with the corresponding 4 – period ahead forecast s^e_{t+4} series are being presented through the Fig. 2.

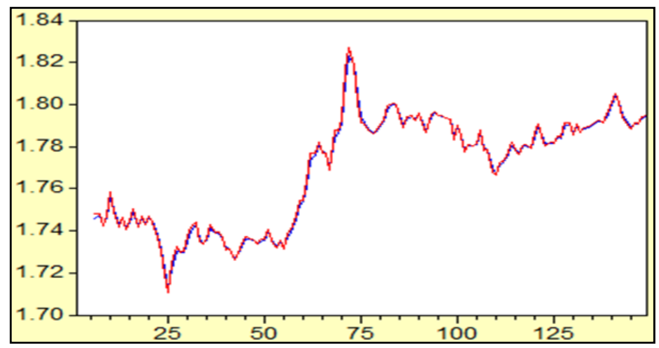


Fig. 2: Time Plots of (s_{t+4} ----) Series and 4 – Period Ahead forecast (s^e_{t+4}----) series.

$s^e_{t+4} = tE(s_{t+4})$ series represents the 4 – period ahead forecasts at period t for the future exchange rates (s_{t+4}) by the market agents like speculators and hedgers. However, Reserve Bank of India also makes forecasts at period t for s_{t+4} by quoting 1 – month forward rate through weekly statements of forward premium (annualized percentage). These official forecasts i.e, forward exchange rates ($t\ F_{t+4}$) series may be different from s^e_{t+4} series. In such case scope of profit arbitrage emerges out of the forecast differentials. If s^e_{t+4} exceeds the corresponding ($t\ F_{t+4}$) rate , then market agents take a 'Long position' in the foreign exchange market at time t and hope for reaping profit by forward buying of dollar and selling dollar spot at the higher expected exchange rate at period (t+4). If, on the other hand, $s^e_t < tE(s_{t+4})$, market agent take a 'short position' in the foreign exchange market. Market agents hope for reaping profit by selling dollar forward and buying spot at (t+4) period. This calls for examining the relationship between s^e_{t+4} series and tF_{t+4} series in the Indian Foreign Exchange Market over the period of study.

Time plots of s^e_{t+4} series and tF_{t+4} series are being presented through the Fig. 3.

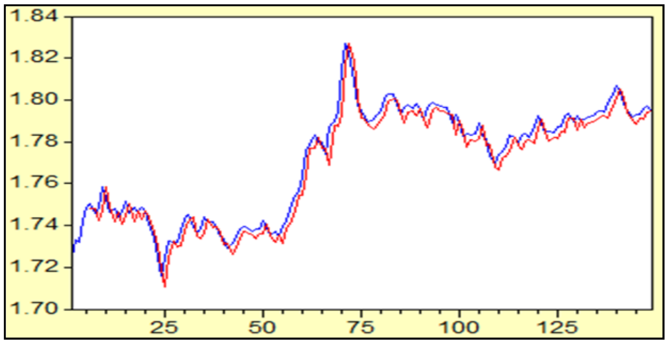


Fig. 3: Time plots of (s^e_{t+4}----) series and (t F_{t+4} -----) series

Fig. 3 shows that both the series possess almost the same dynamic texture and these series appear to share 'common trends' s^e_{t+4} ~I(1) series and tF_{t+4} ~ I(1) series, therefore,may be 'cointegrated'. The estimated 'cointegrating equation' is

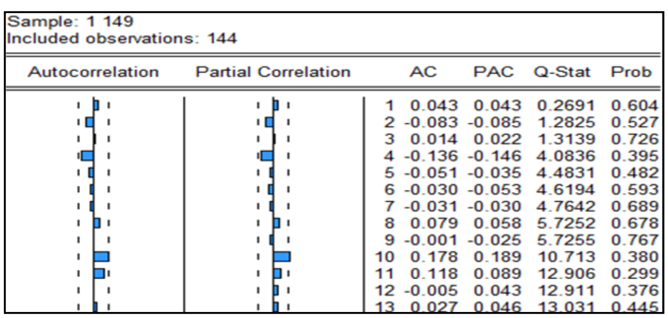
$$t\,F_{t+4} = 0.026338 + 0.986751\, s^e_{t+4} \quad (3)$$

SE (0.026170) (0.026179)

t [1.006056] [66.60480]

Prob 0.3100 0.0000

The residuals of the cointegration equation (eqn. 3) constitute ω_{t+4} series. Correlogram of ω_{t+4} series is presented in Fig. 4.


Sample: 1 149
Included observations: 144

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.043	0.043	0.2691	0.604
		2	-0.083	-0.085	1.2825	0.527
		3	0.014	0.022	1.3139	0.726
		4	-0.136	-0.146	4.0836	0.395
		5	-0.051	-0.035	4.4831	0.482
		6	-0.030	-0.053	4.6194	0.593
		7	-0.031	-0.030	4.7642	0.689
		8	0.079	0.058	5.7252	0.678
		9	-0.001	-0.025	5.7255	0.767
		10	0.178	0.189	10.713	0.380
		11	0.118	0.089	12.906	0.299
		12	-0.005	0.043	12.911	0.376
		13	0.027	0.046	13.031	0.445

Fig. 4: Correlogram of Residuals ω_{t+4} from the Equation (4)

The residuals appear to be 'white – noise' such that ω_{t+4} ~ iid N (0, $\sigma^2\, \omega_{t+4}$). Consequently, tF_{t+4} and s^e_{t+4} series are cointegrated.

It is further observed from the estimated equation (3) that

(i) the constant term in the regression equation is not statistically different from zero (even at 10% level).

(ii) the regression coefficient is significant event at 1% level.

(iii) the regression coefficient is not statistically different from unity.

All these observations indicate that

(i) $tF_{t+4} = s^e_{t+4} + \omega_{t+4}$ (4)

where ω_{t+4} ~ iid N (0, $\sigma^2\, \omega_{t+4}$)

and $tF_{t+4} \cong s^e_{t+4}$

or, $tF_{t+4} \cong tE(s_{t+4})$

Therefore, there exists no scope for profit arbitrage in the Indian rupee / dollar foreign exchange market over the period (27th April, 2012 - 27th February, 2015).

(ii) the absence of making profit through arbitrage testifies for the fact that foreign exchange market in India over the period of study was 'efficient'.

(iii) $tF_{t+4} \cong s^e_{t+4}$ Indicates that 'forward rate emerged as the unbiased predictor of future exchange rate' in the Indian foreign exchange market over the period of study.

Section III

Relation Between Forward Rate (tF_{t+4}) Series and Spot Rate (S_{t+4}) Series.

Fig. 5 presents the time plots of Forward Rate tF_{t+4} series and spot rate (s_{t+4}) series. Both the series exhibit the same type of dynamic texture over the period of study.

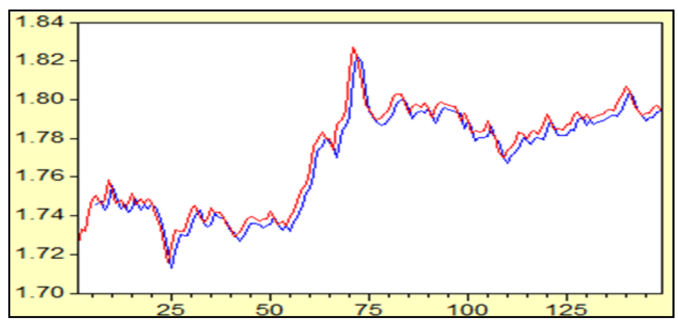


Fig. 5: Time plots of (tF_{t+4}----) Series and (s_{t+4} ----) Series

These series appear also to share the 'common trend' and, therefore cointegrated. The estimated cointegrated equation is

$$t\hat{F}_{t+1} = 0.040867 + 0.975089\, s_{t+4} \quad (5)$$

SE (0.027004) (0.015236)

t [1.513348] [63.99696]

prob 0.1324 0.0000

ADF test results of the residuals u_{t+4} series of equation (5) has been subject to ADF Unit Root Test with exogenous constant. The ADF test statistics = - 8.896342 exceeds the corresponding 1% critical value (- 3.476472). Therefore, there exists no 'unit root' in the u_{t+4} series and the series is 'stationary' indicating $u_{t+4} \sim I(0)$. Consequently, $t\hat{F}_{t+4}$ and s^e_{t+4} series are cointegrated.

The estimated equation (5) shows that

(i) the regression constant is not statistically different from zero (even at 10% level)
(ii) the estimated coefficient of s^e_{t+4} significant at 1% level.
(iii) The absolute value of coefficient of s^e_{t+4} is not statistically different from one.

These findings indicate that the equation (5) can be modified as

$$tF_{t+4} \cong s_{t+4} + u_{t+4} \qquad (6)$$

Equation (7) shows that forward rate quoted at t for the period (t+4) virtually becomes equal to the actual spot rate at period (t+4) i.e., s_{t+4} . Since the regression constant is not different from zero, there exists no risk premium in the forward exchange market. This further supports the findings that the forward exchange market in India was 'efficient' over the period (27^{th} April, 2012 - 27^{th} February, 2015).

Section IV

Summary and Conclusion

Estimated ARIMA (1, 1, 0) equation for s_t has been used to generate one – period ahead forecast (s^e_{t+1}) series and four – period ahead forecast (s^e_{t+4}) series.

(i) Forecast error (s_{t+4}- s^e_{t+4}) series are 'white – noise' which imply that these forecasts are Minimum Mean – Squared Error (MMSE) forecasts by nature.

(ii) Again forecast errors, being 'white – noise', further imply that the forecasts are 'Rational' such as

$$s_{t+4} = s^e_{t+4} + \omega_{t+4}$$

where ω_{t+4} are 'white noise'.

(iii) $s^e_{t+4} \sim I(1)$ and $tF_{t+4} \sim I(1)$ are 'cointegrated' while residuals of the corresponding equation are 'white – noise'. This implies that forward rates (tF_{t+4}) are the unbiased predictor of the corresponding spot rate (S_{t+4}) such that

$$tF_{t+4} \cong s^e_{t+4} + u_{t+4}$$

where u_{t+4} are 'white noise'.

Thus the 'Covered Interest Rate Arbitrage Parity (CIRAP) Doctrine' appears to hold good in the Indian foreign exchange market over the period of study (27^{th} April, 2012 - 27^{th} February, 2015)

(iv) Again $tF_{t+4+4} \cong s_{t+4}$ in equation (6) shows that forward exchange market in India was 'efficient' over the period (27^{th} April, 2012 - 27^{th} February, 2015).

The study, therefore, shows that in the Indian foreign exchange market over the period (27^{th} April, 2012 - 27^{th} February, 2015).

(i) ARIMA forecasts like s^e_{t+1} and s^e_{t+4} are MMSE forecasts and these forecast are 'Rational' by nature.
(ii) CIRAP holds such that forward exchange rate (tF_{t+4}) served as the unbiased predictor of the spot rate (s^e_{t+4}).
(iii) there does exist no 'risk premium' in the rupee – dollar foreign exchange market. There was no scope for spending arbitrage profit arising out of the differential forward rate and corresponding spot rate. This testifies for the 'efficiency' of Indian foreign exchange market over the period of study.

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