



Is there a unit root in real effective exchange rate in India? evidence from structural break unit root tests

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ABSTRACT

Unit root tests used to examine non stationarity in a series at times give misleading results if possible structural breaks in the series are ignored. This study examined the presence of unit root in REER in India in the presence of structural breaks in the post reform period by using recent endogenous structural break unit root test. The results of the study reveal that there is no unit root in REER implying that it follows mean reversion.

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Introduction

The issue of presence of a unit root in real effective exchange rate (REER) has been important both from theoretical and practical point of view. If REER does not contain a unit root it implies that it would return to its mean over time. It would also imply that Purchasing Power Parity (PPP) holds good in the long run. On the contrary, if REER contains a unit root, it implies that it would follow a random walk and implies that REER is unpredictable.

The behavior of REER has been subjected to extensive investigation over the years. While the recent empirical studies have tended to be more supportive of the mean reversion hypothesis (long-run PPP), the earlier studies have shown random walk. However, the growing body of literature that supports long-run PPP for the post-Bretton Woods period has evidences which seem mixed and inconsistent.

One possible reason for such evidences could be choice of unit root tests that are widely used to examine the random walk behavior of REER. Perron (1989) argues that in presence of a structural break, the conventional unit root tests such as ADF (1979) and Phillip-Perron (1988) are biased towards non rejection of the null hypothesis. Subsequently, Zivot and Andrews (1992), Perron and Vogelsang (1992), Perron (1997), Lee and Strazicich (2004) suggested test statistics that allow endogenous single structural break in the series while testing for unit roots. It has been further argued that a single endogenous break in a series is insufficient and leads to loss of information when actually more than one break exists. Motivated by this, the studies by Lumsdaine and Papell (1997), Clemente, Montanes and Reyes (1998), Lee and Strazicich (2003) gave unit root tests based on multiple structural breaks. The present paper examines the presence of unit root in 36 currency REER in post reform period using the conventional unit root tests, the KPSS test, the next generation unit root tests and tests with single and multiple structural breaks. Since such study has not been attempted in the Indian context, the present paper tries to fill the gap at an empirical level. The rest of the paper is organized into five

sections. The second section of the paper gives a brief review of the relevant literatures on PPP. Section III describes the data used and methodology of the study, section IV discusses the results and the paper concludes with section V.

A brief review of literature

There are quite a few studies investigating the mean reversion in real exchange rates. In the 1980s, empirical studies commonly failed to support mean reversion, as the hypothesis of mean reversion for the real exchange rate was outperformed by the random walk hypothesis. Adler and Lehmann (1983), Huizinga (1987), Edison (1987), Corbae and Ouliaris (1988) show that the real exchange rate follows a random walk and fails to support PPP. This inability to detect mean reversion has often been interpreted as indicating that real exchange rates are governed by permanent shocks.

The various studies have used various approaches to examine mean reversion in real exchange rate i.e. use of long time series, tests with improved power, panel data methods, and cointegration techniques. Using longer time periods, the studies by Abauf and Jorian (1990), Johnson (1990), Kim (1990), Glen (1992), Grili and Kaminsky (1991), Lothian (1997), Olekalns and Wilkins (1998), Breuer (1994), MacDonald (1995). Lothian and Taylor (1996), Kuo and Mikkola (1999) and Chen and Wu (2000) find that shocks to real exchange rates have finite life. The use of long time series has however been criticized, as it combines regimes of fixed and floating rates, and can be subject to large sample biases (Engel, 2000) and may spuriously reject unit root in presence of breaks. The other approach using tests with improved power and advanced time series techniques has given mixed results. Following this approach, Abuaf and Jorion (1990), Sarno and Taylor (1998), and Kuo and Mikkola (1999) provide results that support long-run PPP. At the same line, Lothian and Taylor (1997) state that rejection of PPP reflects the low power of unit root tests. Cheung and Lai (1998) test for PPP by using sequential unit root tests which extend the ADF test to account for possible breaks in the real exchange rate series and they argue that permanent shocks are not relevant in PPP

analysis over the current float. Subsequently, pioneered by Perron (1989), unit root tests that allow for break in deterministic components, have come into existence. There are quite a few studies on validity of PPP using panel data and cointegration techniques. Since the present study focus on the unit root tests, review of those studies have been not included here.

Literature on behaviour of REER in Indian context has been scanty. Kohli (2002) has examined mean reversion in Indian context using four versions of real exchange rates for time period from 1993 to 2002 at monthly frequency. The Unit root, variance ratio and cointegration tests employed in the study support mean reversion in case of CPI and WPI/CPI deflated series of real exchange rates, but reject stationarity in 5 currency and 36 currency REER series. The study has used both the conventional unit root tests as well as efficient unit root tests, suggested by Elliott (1996) and Park and Fuller (1995), to examine presence of unit root in REER. Other studies by Pattnaik *et al.* (2003), and Moore and Pentecost (2006) applied a bivariate vector autoregressive (VAR) model of the nominal and real exchange rates to examine the main source of variation in real exchanges. They employed the restriction of Enders and Lee (1997), which assumes that nominal shocks have a lasting effect on the nominal exchange rate but not on the real exchange rate. Pattnaik *et al.* (2003) used data from the period between April 1993 and December 2001, whereas Moore and Pentecost (2006) used data from the period between March 1993 and January 2004. Both the studies have concluded that real shocks are the main sources of the fluctuations in both nominal and real exchange rates for India. A similar study by Inoue and Hamori (2009), using structural VAR, with three variables i.e. nominal exchange rate, real exchange rate and relative output of India and US/Euro Area from 1999 to 2009 concludes that real shocks are the main drives of the fluctuations in real and nominal exchange rates.

Materials and Methods

The present study has used 36 currency trade based REER from April 1993 to June 2010 as proxy of REER. The data used is of monthly frequency. Data has been taken from various publications of Reserve Bank of India. The various tests have been employed on the log of 36 currency REER.

To begin with, the standard unit root tests, namely, ADF (1979), Phillips and Perron (1988) and KPSS (1993) tests are employed on the series. The first two tests have nonstationarity as null hypothesis in contrast to the latter which has stationarity as null hypothesis. However, the first two tests are known to be less powerful and biased towards non rejection of null of unit root. In other words, the unit root tests may incorrectly conclude that there is a unit root in the real exchange rate. Next, efficient root tests proposed by Elliott-Rothenberg-Stock (ERS, 1996), namely, Dickey-Fuller generalized least squares (DF-GLS) and DF GLS^u test proposed by Elliott (1999) are employed. The other test proposed by Ng and Perron (2001) is also used to test the presence of unit root in the series. The test statistics of Ng-Perron test, MZ_{α} and MZ_t are the modified versions of the Phillips (1987) and Phillips and Perron (1988) Z_{α} and Z_t tests; the MSB is modified version of Bhargava (1986) $R1$ test; and, finally, the MP_T test is a modified version of the Elliot *et al.* (1996) point optimal test.

Perron and Phillips (1987) and West (1988) suggested that conventional unit root tests namely ADF and Phillips-Perron may suffer from lack of power when the deterministic time trend

is mis-specified. Further, if there are structural breaks in the series, these tests may conclude that the series analyzed are I(1) when in fact they are stationary around a deterministic time trend or even around a broken time trend (Rappoport and Reichlin, 1989 and Perron, 1989, 1990). To overcome this, Perron proposed a model allowing for known or exogenous structural break in the ADF tests. The model imposes the null hypothesis that a given series has a unit root with drift and an exogenous structural break against the alternative of stationarity about a deterministic trend which has an exogenous structural break. However, the problem with imposing an exogenous structural break is that selecting the break point *a priori* based on an *ex post* examination or knowledge of the data could lead to an over rejection of the unit root hypothesis (Perron and Vogelsang, 1992). Perron's (1989) model is further extended by Zivot and Andrews (1992) by endogenising break point determination. They proposed three models for testing unit root tests namely (i) crash model-allows for a break in level (or intercept) of series (Model A) (ii) changing growth model – allows for a break in slope or the rate of growth (Model B) (iii) crash cum growth- allows both effects to occur simultaneously (Model C) i.e. one time change in both the level and the slope of the series. The three models are specified as follows:

$$\Delta x_t = \alpha_0 + \alpha_1 DU_t + \beta t + \rho x_{t-1} + \sum_{i=1}^p \phi_i \Delta x_{t-1} + \varepsilon_t$$

... (A)

$$\Delta x_t = \alpha_0 + \gamma DT_t^* + \beta t + \rho x_{t-1} + \sum_{i=1}^p \phi_i \Delta x_{t-1} + \varepsilon_t$$

... (B)

$$\Delta x_t = \alpha_0 + \alpha_1 DU_t + \gamma DT_t^* + \beta t + \rho x_{t-1} + \sum_{i=1}^p \phi_i \Delta x_{t-1} + \varepsilon_t$$

... (C)

Where the dummy variables are defined as follows:

$$DU_t = \begin{cases} 1 & \text{if } t > TB, \\ 0 & \text{otherwise} \end{cases}$$

$$DT_t^* = \begin{cases} t - TB & \text{if } t > TB, \\ 0 & \text{otherwise} \end{cases}$$

The null hypothesis in the above equations is that $\rho=0$, which implies that there is unit root in x_t . The alternative hypothesis is that $\rho < 0$, which implies that x_t is breakpoint stationary. We have used Model A and Model C to determine the stationarity in our study. The break date is selected where the t-statistic from the ADF test of unit root is at a minimum (most negative). Consequently a break date is chosen where the evidence is least favorable for the unit root null. To implement the sequential trend break model, some region must be chosen such that the end points of the sample are not included. The trimming region used in the study is (0.10T and 0.90T) where T is the sample size. Lag length (k) is selected based on general to specific approach, setting maximum number of lags equal to twelve and used 10% critical value to determine the significance of the t-statistics on the last lag.

Perron and Vogelsang (1992) and Perron (1997) proposed a class of test statistics that allows for two different forms of structural break i.e. Additive Outlier (AO) and Innovational Outlier (IO) models. The AO model allows for a sudden change in mean (crash model) while the IO models allow for more gradual change only in intercept (Model IO1) and gradual change in slope with intercept (Model IO2). Perron and Vogelsang (1992) applied these two models for non-trending

data while Perron (1997) modified them for use with trending data.

The other test proposed by Lumsdaine and Papell (1997) extends Zivot and Andrews models to allow for two structural breaks. The extended model of Model A (called Model AA) allows for two breaks in the intercept and the extended model C (called model CC) allows for two breaks in the intercept and slope of the trend.

Model AA is represented as :

$$\Delta x_t = \alpha_0 + \alpha_1 DU1_t + \alpha_2 DU2_t + \beta t + \rho x_{t-1} + \sum_{i=1}^p \phi_i \Delta x_{t-1} + \varepsilon_t$$

Model CC is represented as :

$$\Delta x_t = \alpha_0 + \alpha_1 DU1_t + \gamma_1 DT1_t + \alpha_2 DU2_t + \gamma_2 DT2_t + \beta t + \rho x_{t-1} + \sum_{i=1}^p \phi_i \Delta x_{t-1} + \varepsilon_t$$

The null and hypothesis are the same as in the one break case. $DU1_t$ and $DU2_t$ are indicator dummy variables for a mean shift occurring at $TB1$ and $TB2$, respectively, where $TB2 > TB1+2$ and $DT1_t$ and $DT2_t$ are the trend shift variables:

$$DU1_t = \begin{cases} 1 & \text{if } t > TB1, \\ 0 & \text{otherwise} \end{cases}$$

$$DU2_t = \begin{cases} 1 & \text{if } t > TB2, \\ 0 & \text{otherwise} \end{cases}$$

$$DT1_t = \begin{cases} t - TB1 & \text{if } t > TB1, \\ 0 & \text{otherwise} \end{cases}$$

$$DT2_t = \begin{cases} t - TB2 & \text{if } t > TB2, \\ 0 & \text{otherwise} \end{cases}$$

The lag length is selected using general to specific approach and the break points are chosen using the same approach as Zivot and Andrews (1992) test.

As noted by Nunes, Newbold and Kuan (1997) and Lee and Strazicich (2001), the weakness of the DF type endogenous break unit root test is that they exclude the possibility of a unit root with break. If a break exists under the null of unit root, they will exhibit size distortions and consequent spurious rejection such that the null of unit root hypothesis is rejected too often, as well as they will tend to estimate the break point incorrectly. Lee and Strazicich (2003, 2004) propose alternative endogenous break unit root tests that are unaffected by structural breaks, based on Lagrange Multiplier (LM) principle are modified version of Schmidt and Phillips (1992) unit root test by incorporating structural break(s) in mean (Model A) both mean and in trend (Model C).

Empirical Results

The standard unit root tests like ADF (1979), Phillips and Perron (1988) and KPSS (1992) employed on the series by and large reject unit root in 36 currency REER series. Next, efficient unit root tests namely, DF GLS and DF GLS^u suggested by Elliott (1996) and Elliott *et al.*, respectively are employed on the series. The efficient root tests reject unit root in 36 currency REER for both the model with constant and the model with constant and trend. Ng-Perron test also rejects unit root in the series for both the models. The results of these tests are presented in table 1. Since the above tests have been

acknowledged to be neglecting the presence of possible structural breaks, it is felt that the issue should be examined using unit root tests that would take care of structural breaks endogenously.

To examine unit root in the REER series in presence of break, first we have employed Zivot and Andrews (1992) and Lee and Strazicich (2004) tests which allow one break in the series. The results of these tests are presented in table 2. Zivot and Andrews test rejects unit root in 36 currency REER for both Model A and Model C. Lee and Strazicich (2004), one break LM unit root test, which possesses more power, also rejects unit root in 36 currency REER for both the models. Perron (1997), which uses Additive Outlier and Innovative Outlier models for structural breaks, reject unit root in REER series at 5% significance (Table 2). These results are consistent with the result of standard unit root tests which reject unit root in 36 currency REER.

Next, endogenously determined two break test proposed by Lumsdaine and Papell (1997) was employed on the series. The test rejected unit root in REER for both Model AA and Model CC at 5% significance. The result of Lumsdaine and Papell (1997) test is supported by minimum Lagrange Multiplier test proposed by Lee and Strazicich (2003). Lee and Strazicich (2003) test too rejects unit root in REER series at 5% at significance.

Though the break dates given by the various tests are not the same, they are mostly concentrated in 2008, which was a period of subprime crisis in US and there was global economic slowdown impacting the global trade.

Concluding Remarks

In the present study 36 currency REER has been used as a proxy of REER for examining unit root in REER of Indian Rupee. The study refers to the post reform period from April 1993 to July 2010. First, the study has used the standard unit root tests namely ADF (1979), PP (1988) and KPSS (1992) tests, next generation unit root tests namely DF GLS and DF GLS^u for examining unit root in REER. All the above tests rejected unit root in REER. In contrast to findings of Kohli (2002), the present study strongly rejects unit root in REER using conventional unit root tests, efficient unit root tests. Since structural breaks can alter inference concerning unit roots, unit root tests with endogenously determined one break and two breaks are employed. The single break tests of Perron (1997), Zivot and Andrews (1992) and Lee and Strazicich (2004) and also two break tests of Lumsdaine and Papell (1997) and Lee and Strazicich (2003) have been used. All the structural break unit root tests with one break and two breaks have rejected unit root in the series for both Model A (AA) and C (CC). Thus the study shows a strong evidence of mean reversion in REER in Indian context.

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Table 1: Unit Root Statistics

Tests	Constant	Constant and Trend
ADF	-3.2677 ^b (1)	-3.2963 ^b (1)
PP	-3.0270 ^b (3)	-3.0826(4)
KPSS	0.1099(10)	0.0969(10)
ADF ^m	-3.660 ^a (6)	-3.6999 ^b (6)
DF GLS	-3.562 ^a (6)	-3.719 ^a (6)
DF GLS ^u	-3.673 ^a (6)	-3.718 ^a (6)
Ng-Perron (MZ _a)	-18.011 ^a (2)	-19.342 ^b (2)
Ng-Perron (MZ _t)	-2.998 ^a (2)	-3.109 ^b (2)
Ng-Perron (MSB)	0.166 ^a (2)	0.161 ^a (2)
Ng-Perron (MP _T)	1.370 ^a (2)	4.717 ^a (2)

^a and ^b indicate significance level of 1% and 5%, respectively. ADF^m stands for modified ADF test on detrended series with general to specific as lag selection criteria. DF GLS and DF GLS^u are the tests proposed by Elliott *et al.* (1996) and Elliott (1999), respectively. MZ_a, MZ_t, MSB, MP_T are the tests proposed by Ng-Perron (2001). Figure in parentheses are the lag length based on AIC for ADF, Berellet Newey using Bartlett kernel for PP and KPSS, general to specific criteria for DF GLS and DF GLS^u and MIC for Ng-Perron Tests.

Table 2: Unit Root Statistics with Endogenous Structural Breaks

	TB	t-statistics	k	TB	t-statistics	k	Possible Cause
Single Break	Model A			Model C			
Zivot and Andrews (1992)	Sept 2008	-5.2172 ^b	8	Feb 2000	-5.2099 ^b	8	Feb 2000: Global economic recovery in post East Asian crisis, low domestic inflation. Sept 2008 : Subprime crisis
Lee and Starzicich (2004)	April 2008	-4.8368 ^a	8	Mar 2008	-5.3056 ^a	8	Mar 2008: Subprime crisis April 2008: Subprime crisis
	Innovative Outlier			Additive Outlier			
Perron 97	July 2008	-5.2603 ^b (IO1)	8	Dec 2006	-4.6973 ^b	8	Dec 2006: High domestic inflation and interest rate, steep rise in international commodity price especially crude oil. July 2008: Subprime crisis
	Dec 1999	-5.1947 ^b (IO2)	8				
Multiple Break	Model AA			Model CC			
Lumsdaine and Papell (1997)	August 1995	-7.2630 ^a	8	August 1995	-6.8465 ^b	8	August 1995: Period of rising interest rate, surge in FII inflow, Rupee strengthened against major currencies. August 2008 : Subprime crisis
	August 2008			August 2008			
Lee and Starzicich (2003)	October 1996	-5.1081 ^a	8	December 1999	-6.8025 ^a	10	October 1996: High domestic inflation and interest rate, steep rise in international commodity price especially crude oil. December 1999: period of economic reforms. India rated as stable market by international rating agencies April 2008 : Subprime crisis July 2008 : Subprime crisis
	April 2008			July 2008			

^a and ^b indicate significance level of 1% and 5%, respectively. IO1 and IO2 represent innovative Perron (1997) statistics with change in constant and constant with slope, respectively. TB stands for trend break; k is lag length.