Mean Reversion of the Real Exchange Rate and the validity of PPP Hypothesis in the context of Bangladesh: A Holistic Approach

Raihan, Selim and Abdullah, S M and Barkat, Aroni and Siddiqua, Salina

Professor, Department of Economics, University of Dhaka, Dhaka – 1000, Bangladesh, Assistant Professor, Department of Economics, University of Dhaka, Dhaka – 1000, Bangladesh, Assistant Professor, Department of Economics, University of Dhaka, Dhaka – 1000, Bangladesh, Assistant Professor, Department of Development Studies, University of Dhaka, Dhaka – 1000, Bangladesh

27 February 2017

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Selim Raihan[1]
S M Abdullah[2]
Aroni Barkat[3]
Salina Siddiqua[4]

[1] Professor, Department of Economics, University of Dhaka, Dhaka – 1000, Bangladesh.
Email: selim.raihan@gmail.com
[2] Assistant Professor, Department of Economics, University of Dhaka, Dhaka – 1000, Bangladesh.
Email: abdullahsonnet@gmail.com
[3] Assistant Professor, Department of Economics, University of Dhaka, Dhaka – 1000, Bangladesh.
Email: aroni1605@yahoo.com
[4] Assistant Professor, Department of Development Studies, University of Dhaka, Dhaka – 1000, Bangladesh.
Email: selina.eco@gmail.com

Abstract

The real bilateral exchange rates in many countries have recently been found to be non-stationary in nature implying that they do not tend to revert to a long-run mean. Such empirical findings of real exchange rate being non-stationary in the long-run have thrown the well-known, yet now controversial, theory of Purchasing Power Parity (PPP) under fire. This paper aims to add to the few research works on the validity of PPP hypothesis in case of real exchange rate of Bangladesh by undertaking various approaches. We used five important real exchange rates for Bangladesh with its five important partners of international trade. For validating the PPP hypothesis the stationarity of these real exchange rates have been diagnosed. The tests range from the very rudimentary Augmented Dickey Fuller (ADF) and Phillips Perron tests and other univariate unit root tests, to the tests which addresses one/more breaks in the time series data and finally panel unit root tests that account for the possible presence of cross-sectional dependence in dataset. Such a thorough approach was taken to access the issue of the presence of unit root in real exchange rate in every way feasible, assuming the adjustment process is linear. Almost all the results corroborated each others' conclusions that the real bilateral exchange rates of Bangladesh with five of its major trading partners are in fact not mean-reverting in the long run and so PPP hypothesis does not hold. Therefore, caution must be practiced when making policies for the country where the stipulated PPP hypothesis is assumed to be accurate.

Key Words: PPP Hypothesis, Real Exchange Rate, Stationarity, Unit Root, Panel Unit Root, Cross Section Dependence, Structural Break

JEL Codes: C120, F310

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1. Introduction

The real bilateral exchange rates in many countries have recently been found to be non-stationary in nature implying that they do not tend to revert to a long-run mean. Such empirical findings of real exchange rate being non-stationary in the long-run have thrown the well-known, yet now controversial, theory of Purchasing Power Parity (PPP) under fire. The PPP hypothesis, in its simplest form, postulates that the real exchange rate of a country always reverts back to a long-run mean, because any kind of inflation differential between two economies will be exactly offset by an equivalent appreciation or depreciation of the bilateral nominal exchange rates. Thus the PPP hypothesis is essentially stipulated by the Law of One Price (LOP) which states that identical goods must have one price in an integrated, competitive and efficient market.

Empirical testing of the PPP hypothesis is especially important because it is so frequently used in practice and policy-making. For instance, it is used to determine whether a currency is overvalued/ undervalued. It serves as an underpinning on which so many other theories of exchange rate determination are built. It is also important in evaluating various financial liberalization policy-making process, structural adjustment programs and tools for monetary authorities to adjust money market and inflation targeting. The non-stationarity of the real exchange rate would mean that such corrective policies, which were prescribed, assuming the PPP hypothesis holds, are useless or even in some cases, counter-productive. The PPP hypothesis also serves as an indicator of international competitiveness and as a forecasting tool for forthcoming crisis in international markets.

If the PPP hypothesis in fact does not hold in some countries in reality, the developing emerging countries, such as Bangladesh, are more likely to be among them because they simply seem to have relatively less efficient international markets; fixed or controlled exchange rates with substantial government intervention, high rates of tariff and non-tariff barriers to trade, considerable transportations cost in international trade and sizable extent of market intervention- all characterize a typical developing country and all contribute to bring the economy further away from the ideal situation of an 'efficient and competitive' market that the PPP assumes exists.

In this paper we have aimed to find whether the validity of the PPP hypothesis holds in the case of Bangladesh. We used five important real exchange rates for Bangladesh with its five important partners of international trade. For validating the PPP hypothesis the stationarity of these real exchange rates have been diagnosed using panel approach along with conventional univariate ones. Also, effort was given to make the diagnosis process general by allowing for single and multiple structural breaks and contemporaneous correlation.

The paper is arranged with a short review on the existing literature in Section 2, methodological framework and data in Section 3, results and interpretations in Section 4 and finally Section 5 concludes.

2. A Short Review of the Existing Literature

The long-run mean reversion of the real exchange rate and in turn, the PPP hypothesis has long been the foundation for numerous exchange rate determination models and thus bears cardinal importance in policy making processes of developing, developed and transitional economies. Understanding whether the adjustment process of real exchange rate is self-equilibrating or not, is important because the efficacy of various policies and forecasts depend on it.

Initial studies of testing the validity of PPP hypothesis involved using conventional simple unit root tests like Augmented Dickey Fuller (ADF) test and Phillips Perron (PP) test, both of which had the problem of low power. Presence of unit root in the real exchange rate time series means that the process is neither mean-reverting nor stationary nor self-equilibrating and the PPP hypothesis does not hold. In almost all cases, ADF and PP tests could only show minimal support in favor of PPP hypothesis. For instance, Nusair (2003) used quarterly data from 1973:Q2 to 1999:Q4 for examining the validity of PPP hypothesis for 6 Asian countries. The study used three different conventional unit root tests- ADF, PP and KPSS- for each of the countries' exchange rate series. The null of unit root was rejected for Indonesia, Korea and Thailand while the null of stationarity was not rejected for Singapore. Eventually two alternative methods of testing for the presence of unit root became increasingly popular- either with univariate unit root tests like ADF, PP and any similar but higher-powered tests, or, with panel unit root tests. Although there was no absolute conclusion, validity of the PPP hypothesis was more likely in case of more developed/ advanced economies and less likely in case of developing/transitional economies. A number of such panel unit root tests were carried out on OECD countries. For instance, Kalyoncu and Kalyoncu (2008) investigated the validity of Purchasing Power Parity for 25 OECD countries using quarterly data spanning from 1980:Q1 to 2005:Q4. The stationarity of the real exchange rate was tested using ADF unit root test with single time series as well as, to improve the power property of the test, with IPS (Im, Pesaran and Shin, 1997) panel unit root test. It was found that while ADF unit root test showed that all the sample countries exchange rate series were exposed to unit root, the IPS panel unit root test showed the real exchange rates in the OECD countries were in fact, mean reverting and supported the long run PPP hypothesis. Another study by Aslan and Korap (2009) applied IPS and Maddala and Wu (1999) panel unit root tests using both monthly and quarterly data of 26 OECD countries over the period 1987 to 2006. The study proved strong evidence against nonstationarity feature of the real exchange rate and supported the PPP hypothesis. Chortareas and Kapetanios (2009) also checked the stationarity property of real exchange rate of 25 OECD countries. In order to obtain the country-specific stationarity results they used a method called Sequential Panel Selection Method (SPSM). Their results found strong evidence of mean reversion in real exchange rate and therefore strengthened the support for validity of the PPP hypothesis.

However, some studies were not so supportive of the theory. Wickremasinghe (2009) examined the mean reversion of real exchange rates of Papua New Guinea (PNG). They constructed a panel consisting of four exchange rates namely- Australian Dollar/Kina, US Dollar/Kina, Japanese Yen/Kina and UK Pound/Kina and applied six different panel unit root tests. The results revealed the PPP hypothesis did not hold for Papua New Guinea. Similar Panel Unit root tests were done by Wu and Chen (1999) using monthly data for eight Pacific Basin countries over the period 1980M1 to 1996M8. They applied two panel unit root tests- IPS and Maddala and Wu (1999) and results suggested that the real exchange rate series was in fact nonstationary and hence failed to support PPP hypothesis. Noman (2009) also investigated the stationarity of real exchange rate in SAARC countries using yearly data from 1971 to 2006. Along with univariate unit root tests (ADF and KPSS) the study applied panel unit root tests (IPS and Hadri LM test, 2000). The univariate unit root analysis provided a mixed scenario while the panel unit root results came up with more consistent findings. The study concluded that in general the

SAARC real exchange rates are nonstationary. Other studies on panel unit root test on real exchange rates incorporated the concept of cross-sectional dependence among countries in the data set. One such study was done by Munir and Kok (2015) who used monthly data spanning from 1968:M1 to 2009:M11 for 5 ASEAN countries. Along with regular panel unit root test they also applied Westerlund Lagrange Multiplier (LM) cointegration test. The study found that while regular panel unit root test revealed evidence against PPP, similar tests after controlling for cross sectional dependence supported PPP over the post financial crisis period, 1997. Another study that accounted for cross-sectional dependence in data was by Hung and Weng (2011). They used monthly data from January 1995 to March 2003 for 3 Central Asian countries to examine the validity of PPP hypothesis. They used country by country univariate unit root tests and then panel unit root tests allowing for cross sectional dependence. A significant support for PPP hypothesis was found in this study. Hassan, Hoque and Koku (2015) also used panel unit root test with cross-sectional depended between countries in South Asian Association of Regional Cooperation (SAARC). Their findings supported the validity of long run PPP in the sample countries as well.

A relatively recent approach of testing for the presence of unit root in a data set of real exchange rate of a country is by using non-linear unit root tests. While running the conventional unit root tests of stationarity, like ADF, PP, KPSS etc, it is assumed that there is a symmetrical relationship between the exchange rate and relative prices and that if the real exchange rate is in fact stationary, the data will symmetrically adjust itself toward the long-run PPP equilibrium. However, some have pointed out that the pre-assumption that the adjustment process must be symmetrical in nature is a fallacy and the PPP equilibrium can also be achieved by asymmetrical adjustment. Enders and Dibooglu (2001) mentioned that this asymmetry could be result of downward price stickiness. If this is true then using the conventional unit root tests which are based on linearity assumption such as the Augmented Dickey Fuller (ADF) test, Phillips-Perron (PP) test and even more powerful tests like Kwiatkowski, Phillips, Schmidt, Shin (KPSS) (Kwiatkowski et al. 1992b) test and Ng and Perron (2001) would have low power in detecting the asymmetrical adjustment process in a non-linear but stationary data set of real exchange rate. These tests have an implicit assumption of a linear stationary time series against a non-stationry time series, so unfavorable results, especially in transitional economies' real exchange rate could be due to the wrong specification of the model of the tests.

By using such a nonlinear unit root test- Kapetanious, Shin and Snell (KSS), Zhou (2008) tested the null of nonstationarity of real exchange rate of Asian-Pacific countries. The sample period was 1968Q1 to 2005Q4. For most of US, Australia and Singapore Dollar based real exchange rates, the null was rejected but the study could not do so for the majority of Japanese yen-based real exchange rate. A number of studies showed that transitional and developing economies can demonstrate the possibility of having an asymmetric adjustment in their real exchange rate compared to advanced or developed countries and nonlinear stationarity tests like the KSS test could overturn results especially in case of transitional economies. For instance, Oskooee, Kutan and Zhou (2008) tested the stationarity property of monthly real effective exchange rates of 88 developing countries. They compared the results when a null of nonstationarity was tested against an alternative of linear stationarity with a case when the same null was tested against an alternative of nonlinear stationarity. It was found that the latter one supported PPP theory in twice as many developing countries when compared to the former one. Arize (2011) adopted similar method but instead of using real exchange rate, the study utilized monthly data of real effective exchange rate (REER) from 1980:M1 to 2009:M10 of 66 developing countries. They employed two different single time series tests, KPSS (which tests the null of stationary series) and KSS (which tests the null of nonstationary series against nonlinear but globally stationary exponential smooth transition autoregressive series, ESTAR). They found overwhelming support for the long run PPP hypothesis and hence concluded that the PPP was an appropriate guide for exchange rate determination and exchange rate policy reforms in LDCs. Ahmad and Rashid (2008) studies behavior of monthly data of real exchange rate for 4 South Asian countries and China. Along with ADF and KPSS tests, they applied KSS test. This study was a little different in the sense that it used two different measures of price to calculate the real exchange rate, namely the consumer price index (CPI) and the producer price index (PPI). Usage of the PPI alone or alongside CPI can be justified by the fact that the PPI consists of prices of more manufactured tradable items, compared to the CPI which tends to reflect prices of more non-tradable items. The outcomes suggested that nonlinear tests were more successful in supporting the PPP hypothesis. Another study incorporated both panel unit root test and non-linear unit root test on real exchange rate- Emirmahmutoglu and Omay (2014) tried to address the issue that real exchange rate series exhibit asymmetric nonlinear behavior by using data from 15 European Union (EU) countries over the period 1988 to 2013. They found that in contrast to linear and symmetric nonlinear heterogeneous panel unit root test, the asymmetric nonlinear panel unit root test proposed by them supported the PPP hypothesis.

Apart from the unit root tests, PPP hypothesis can also be tested by looking for cointegration between nominal exchange rate and ratio of price levels between respective countries. For instance, with the help of cointegration technique Joyeux and Worner (1998) tested for PPP hypothesis using the bilateral exchange rate between Cambodia and Thailand. They used monthly data ranging from January 1991 to April 1997 to develop a Vector Error Correction Model (VECM) and estimate the cointegrating vector in order to test the validity of the hypothesis. The findings supported the relative version of the PPP hypothesis. Lee (1999) studied 13 Asia Pacific economies using monthly observation ranging from 1957 to 1994. With the help of a generalized error correction model the study found that this generalized dynamic specification supported PPP for more countries than as done by standard tests for stationarity. Another study that involved cointergration technique to oaccess the PPP hypothesis was done by Kim and Jei (2013) using monthly data of Japan and Korea for the period January 1974 to December 2011. They used a smooth time varying cointegrating regression model and ensured the existence of time varying cointegrating relationship between logarithm of nominal exchange rate and that of Producer Price Indices (PPI) which supported the PPP hypothesis. Sulku (2010) ran unit root tests, cointegration technique and multivariate VAR methodology for data over the period of January 1957 to December 1999 for 16 LDCs. The study considered the PPP hypothesis in both fixed and flexible exchange rate regime. For each econometric technique there was only a few and a nearly equal evidence in favor of PPP under the alternative exchange rate regime.

Although the studies mentioned above did adopt the cointegration technique to venture for the presence of the PPP hypotheis in empirical data, testing for presence of unit root in the data is sometimes preferable. This is due to the fact that testing for cointegration requires imposition of equal and opposite coefficients on relative prices. As a result, relatively more number of studies employ the unit root tests to prove or disapprove the validity of the PPP hypothesis which provides more ease in estimation. Some researchers have used a combination of several methods of testing the PPP hypothesis. For example, Carvalho and Júlio (2012) ran four classes of tests related to unit root- standard univariate unit root test, cointegration test, panel unit root test and unit root test for nonlinear framework for examining the validity of PPP hypothesis. They studied 20 developed countries for the period 1973:Q1 to 2007:Q4 but the findings suggested little evidence to support the hypothesis. A study by Wagner (2008) used a combination of unit root test, cointegration test and factor model approach (Bai and Ng, 2004) on four real exchange rate panels and found no evidence in favor of the PPP hypothesis.

A certain portion of the existing literature is on the behavioral pattern of real exchange rate in developing, transitional economies. They are of special interest for researchers in this field because these economies are rapidly changing and hence adjustment process of their real exchange rates may or may not be self-equilibrating, and if not, the PPP hypotheis will not hold in case of changing economies. Less developed countries, which are rapidly advancing and are being integrated into the world market, have much intrinsic dissimilarity compared to their advanced and developed counterparts. For instance, Hausman *et. al* (2006) found that the volatility of real exchange rates in developing nations is 2.5 times higher than those of the industrialized nations, even after real shocks are controlled. By using a panel data of 21 transitional economies over 12 years, Solakoglu (2006) found that the PPP hypothesis holds for transitional economies and the convergence is faster in "more open" transition economies than their "less open" counterparts. Tsong (2010) applied the covariance stationarity test proposed by Jansson (2004) to test the mean reverting property of real exchange rate in 15 developing countries in Asia. He used quarterly data for the period 1973:Q1 to 2007:Q4 and found strong evidence in support of the hypothesis. Liew, Lee and Lim (2009) applied the Breitung's (2001) nonparametric rank test for testing panel data of 6 Asian countries from January 1974 to February 2004. It was found that the Asian exchange rates were nonlinearly cointegrated with their relative prices as well as aggregate price levels. Thus, the long run Asian exchange rate was concluded to be in equilibrium in this study. An interesting approach was taken by Oskooee and Goswami (2005) in their paper when they tested the PPP hypothesis with monthly data of Black Market exchange rates instead of the official exchange rates in 8 developing Asian countries over the period of January 1958 to June 1989. They used the black market exchange rate as a parallel of the official exchange rate because they thought that the official exchange rates of developing countries were either fixed or under constant government interventions and as a result, it could not self-adjust to its long-run mean value. Their study did not find enough evidence to support PPP hypothesis.

Because this paper concentrated on the bilateral real exchange rate of Bangladesh and some of its major trade partners, previous literatures on testing the PPP hypothesis on data from Bangladesh were of special interest. Some researchers adopted cointegration techniques- for example Zaman and Bakshi (1999) exploited monthly data for the period 1985 to 1998 and followed a cointegration framework which showed presence of a long term relationship between exchange rate of Bangladeshi Taka and PPP. There were papers using the non-linear KSS test as well. Chowdhury (2007) examined the long run PPP hypothesis using data for Bangladesh and its four trading partners- the US, Euro Area, Japan and India over the period 1994 to 2002. His study found strong evidence of nonlinear mean reversion of real exchange rate towards stable long run equilibrium and thus validated the long run PPP hypothesis for Bangladesh. Another study by Noman and Rahman (2010) included Bangladesh as one of the four South Asian countries they tested. The study applied conventional linear unit root tests (ADF and KPPS) along with nonlinear unit root test (KSS). They have found that while linear unit root tests detected nonstationarity of real exchange rates for the sample countries, the non linear test could only partially overturn the findings. They concluded that India, Pakistan and Sri Lanka seemed to have a non-stationary real exchange rate but results were ambiguous in case of Bangladesh.

3. Methodological Framework and Data

3.1 Construction of Variable and Data

The data set of this study comprised of five bilateral nominal exchange rates of United States, United Kingdom, European Union, Canada and Japan- all against Bangladeshi currency; the data set also contained the consumer price indices of all six countries. Using the monthly values of CPIs and bilateral exchange rates between Bangladesh and five of its trading partners, monthly real exchange rates were calculated; they will be denoted as TK/USD for real exchange rates between Bangladesh and US, as TK/GBP for real exchange rates between Bangladeshi and United Kingdom's Pound, TK/EUR for real exchange rates between Bangladesh and EU, as TK/CAD for real exchange rates between Bangladesh and Canada and TK/YEN for real exchange rates between Bangladesh and Japan. The exchange rate of a currency would be called "real" when changes in the price levels are considered while measuring the value for it in terms of other currencies. It is imperative to state how we measured the real exchange rate (RER) as it is the main variable of concern in this study. Assume that RER_t denotes the real exchange rate of country at time "t". It is defined here as the relative inflation adjusted exchange rate and constructed as the product of nominal exchange rate (NER) and the ratio of consumer price index (Adler & Lehman, 1983, Jamil, Streissler & Kunset, 2012). Since we have considered the currency of partner country as the base currency, nominal exchange rate and ratio of consumer price index of the country is expressed in relation to the partner country currency and partner country consumer price index (CPI) respectively. In particular RER at time " t " is measured in the following way:

$$RER_t = \left(\frac{BDT_t}{Partner\ Country_t}\right) * \left(\frac{Partner\ Country\ CPI_t}{CPI\ of\ Bangladesh_t}\right)$$
$$= NER_t * \left(\frac{Partner\ Country\ CPI_t}{CPI\ of\ Bangladesh_t}\right)$$

The data was collected from the International Financial Statistics (IFS), IMF database and Monthly Economics Trends a publication by Bangladesh Bank, central bank of Bangladesh. The availability of the data for each of the five bilateral real exchange rates is tabulated in Annex Table 1 (Appendix). It is apparent from the table that the data set is not balanced. This will not pose any problem while running separate univariate unit root tests on each of the five data series; however, the unbalanced dataset will not allow performing panel unit root tests properly. Thus, a balanced panel of RER has been constructed using NER and CPI of all five partner countries for the period July 1999 to December 2014 comprising of a total of 930 data observations. It is worth mentioning here that prior to the year 2003, Bangladesh followed fixed exchange rate system. To protect the external competitiveness of Taka and to improve the resilience of the economy in response to shocks, Bangladesh formally adopted market-based exchange rate for the Taka from 31st May 2003 (Annual Report of Bangladesh Bank, 2002-03). Under such a system of Managed Float, the exchange rate is determined by demand-supply in the international market, but beyond a certain threshold level of appreciation or depreciation of Taka, the Bangladesh Bank has the ability to intervene by selling or buying the foreign currencies or by adopting some other measures.

3.2 Univariate Unit Root Tests for Checking Stationarity of RER

In the literature of conventional time series econometrics a series is characterized as stationary whenever if the mean and autocovariances remain independent of time. The regression models including non stationary variables won't be appropriate for inference. This problem becomes even more sever when the data series is time series. As, non stationarioty could be because of the trending nature of data which would make the regression spurious, it is of vital importance to check the stationarity property of the variables before using them in the model. Testing for the existence of unit root is the orthodox way to test the stationarity of a series. There has already been developed a good number of statistical test for the presence of unit root, nonetheless for almost each of them selection of appropriate lag length is important as including irrelevant variable would cost size and power distortion for many of these tests. Here at first we have selected the lag length for RER series by minimizing Schwarz Bayesisn Information Criteria (SIC) and Akaike Information Criteria (AIC). Annex Table 2 and Annex Figure 1 in Appendix contains the lag selecton details for different exchange rate series. After selection of proper lag length the following tests have been applied to check the stationarity of RER:

Augmented Dickey - Fuller (ADF)[5]

In order to perform the Augmented Dickey Fuller (ADF) (Dickey and Fuller 1979) to test the stationarity of RER the following test regression has been estimated:

$$\Delta RER_t = \alpha RER_{t-1} + \sum_{i=1}^{2} \gamma_i \, \Delta RER_{t-i} + x_t^{'} \delta + u_t$$

Here, $\alpha = \rho - 1$ and ρ is the coefficient of autoregressive variable in a standard autoregressive regression model for RER, x_t are exogenous regressors consisting of either drift term or both drift and trend term and u_t are assumed to be white noise. The unit root hypothesis is written as:

$$H_0 \colon \alpha = 0 \; implies \; \rho = 1, RER \; is \; Non \; Stationary$$

[5] The simple Dickey – Duller unit root test (Dickey and Fuller, 1979) is valid for AR(1) series only. Thus we went for more parsimonious option which is valid even for series which are AR(p), where p is the lag length greater than one.

$$H_1: \alpha < 0 \; implies \; |\rho| < 1$$

Thus the test is one sided. The Dickey – Fuller test statistic is the usual t – Statistic for α which is:

$$\tau = \frac{\hat{\alpha}}{SE(\hat{\alpha})}$$

The Dickey – Fuller critical values has been used to take the decision.

Phillips – Perron (PP) Test

While ADF procedure suggests augmenting the test regression with differenced lag dependent variable for controlling serial correlation, the Phillips – Perron (PP) (Phillips and Perron, 1988) proposed an alternative nonparametric method to address serial correlation problem when testing for unit root. The test regression can be expressed as follows:

$$\Delta RER_t = \alpha RER_{t-1} + x_t^{'}\delta + u_t$$

The significance of α is tested using the following test statistic:

$$\tilde{t}_\alpha = t_\alpha \left(\frac{\gamma_0}{f_0}\right)^{1/2} - \frac{T(f_0 - \gamma_0)(SE(\hat{\alpha}))}{2f_0^{1/2}S}$$

This modified test statistic assumed to have an asymptotic distribution which is independent of serial correlation in the test regression. Here γ_0 is a consistent estimate of the error variance in test regression, f_0 is an estimator of residual spectrum at zero frequency, t_α is the t – ratio of α, $SE(\hat{\alpha})$ is the coefficient standard error and S is the regression standard error.

Elliot – Rothenberg – Stock (ERS) Test

ADF test has low power in the presence of deterministic intercept and trend terms. Elliot, Rothenberg and Stock (1996) have proposed a modification of ADF test which has better power if series consists of trend component. Here the data is detrended before testing the unit root. In particular ERS suggested an approach based on “quasi differencing”. Consider the following regression model:

$$RER_t = \beta_0 + \beta_1 t + z_t \; where, z_t = \rho z_{t-1} + \varepsilon_t$$

After some algebraic operation we can write the quasi differencing regression model from the above as follows:

$$RER_t - \rho RER_{t-1} = \beta_0(1-\rho) + \beta_1[t - \rho(t-1)] + \varepsilon_t$$

By estimating the above regression we can compute

$$\tilde{z}_t = RER_t - \hat{\beta}_0(1-\rho) + \hat{\beta}_1[t - \rho(t-1)]$$

Now we can use $\tilde{z}_t$ to construct the ADF test regression and test for the presence of unit root. The test regression would be written as:

$$\Delta\tilde{z}_t = \alpha\tilde{z}_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta\tilde{z}_{t-i} + v_t$$

The ERS test statistic for the null of $\alpha = 1$ against the alternative $\alpha = \bar{\rho}$ is defined as follows:

$$P_T = \frac{(SSR(\bar{\rho}) - \bar{\rho}SSR(1))}{f_0}$$

Here, $SSR(\bar{\rho}) = \sum \hat{\varepsilon}_t^2(\bar{\rho})$ is the sum of squared residual function from quasi differencing regression model and f_0 is an estimator of the residual spectrum at frequency zero.

Kwiatkowski – Phillips – Schmidt – Shin (KPSS) Test

The unit root tests so far have been discussed above test the null of non stationary series. The KPSS test (Kwiatkowski, Phillips, Schmidt and Shin, 1992) differs in the sense that it tests the null of stationary series. The test statistic is based on the residuals of following OLS regression:

$$RER_t = x_t^{'}\delta + u_t$$

Where, x_t are exogenous regressors consisting of either drift term or both drift and trend term and u_t are assumed to be white noise. The LM statistic to test null of stationary series $(H_0{:}\, Series\ is\ Stationary)$ can be written as:

$$KPSS = \frac{\sum_t S(t)^2}{(T^2 f_0)}$$

Here, f_0 is an estimator of the residual spectrum at frequency zero and $S(t)$ is a cumulative residual function i.e. $S(t) = \sum_{s=1}^{t} \hat{u}_s$.

Ng - Perron Test

The conventional ADF and PP unit root tests suffer from low power problem against the stationary series as alternative. Besides they also face severe size distortion should the series contain large Moving Average (MA) root. Ng and Perron (2001) unit root test has dealt with both these problems. The test consists of four different test statistics. On the one hand with a view to improve the power properties the test uses GLS detrended series, on the other hand to address the size distortion it uses modified lag selection criteria. Assume that RER_t^d is the GLS detrended real exchange rate and $f_0$is the zero frequency spectrum term then consider the following term:

$$k = \frac{\sum_{t=2}^{T}\left(RER_{t-1}^d\right)^2}{T^2}$$

The modified statistics of Ng and Perron (2001) unit root test can be expressed as follows:

$$MZ_\alpha^d = \frac{\dfrac{\left(RER_T^d\right)^2 - f_0}{T}}{2k}$$

$$MZ_t^d = MZ_\alpha * MSB$$

$$MSB^d = \left(\frac{k}{f_0}\right)^{1/2}$$

$$MP_T^d = \begin{cases} \dfrac{\left(\bar{c}^2 k - \bar{c}T^{-1}\left(RER_T^d\right)^2\right)}{f_0} & if \;\; x_t = \{1\} \\ \dfrac{\left(\bar{c}^2 k + (1-\bar{c})T^{-1}\left(RER_T^d\right)^2\right)}{f_0} & if \;\; x_t = \{1, T\} \end{cases}$$

$$Where, \bar{c} = \begin{cases} -7 & if \ x_t = \{1\} \\ -13.5 & if \ x_t = \{1, T\} \end{cases}$$

All the four test statistics are subject to the specification of x_t (which can take two forms, one with intercept only and the other with intercept and linear trend) and a choice method for f_0 estimation.

3.3 Testing for the Existence of Structural Break in RER Series

One major drawback of ADF, PP, ERS, KPSS and Ng - Perron unit root test is that each one assumes stability of parameters which, if not satisfied then validity of their findings could be questioned. Therefore we have tried to examine the existence of structural break in RER series in several possible ways.

Chow Break Point Test: Exogeneous Break

Chow (1960) breakpoint test examines the existence of structural change (defined by stability of regression parameters) at an exogenously determined time. In order to perform the test the data is divided into two subsamples based on the date when structural change is expected to occur. The test is then completed comparing the residual Sum of Square (RSS) of the regressions in subsamples to that from the regression using the whole data period. The idea is that if there is no structural change then the difference between the RSS from two sets of regression should not be statistically significant. In particular the following test statistic has been used to take the decision about null, $H_0: No\ Breaks\ at\ Specific\ Break\ Points,$

$$F = \frac{(RSS_R - RSS_{UR})/k}{RSS_{UR}/(n_1 + n_2 - 2k)}$$

Here, RSS_R and $RSSu_R$ are the restricted and unrestricted RSS respectively. RSS_R is the sum of RSS from the two subsamples while $RSSu_R$ is the RSS form the regression of pooled data. Finally, n_1 and n_2 are the sample size for restricted regressions and k is the number of parameters.

Quant – Andrews Breakpoint Test: Endogeneous Break

Chow (1960) breakpoint test requires that the imposed break date is known as priori information which restricts its application. Quandt (1960) modifies this framework and relax this restrictive requirement while Andrews (1993) and Andrews and Ploberger (1994) derived the limiting distribution for the modified framework. For performing the Quant – Andrews test, Chow Breakpoint test is performed for every observation between two dates. Based on the comparison of restricted and unrestricted RSS, from every Chow Breakpoint test a likelihood ratio F – statistic was calculated. The test statistics from all those Chow tests were then summarized into one test statistic. In particular to test the null, $H_0: No\ Breakpoints\ between\ the\ Chosen\ Dates$ the following test statistic has been used:

$$MaxF = \max_{\tau_1 \le \tau \le \tau_2} (F(\tau))$$

Where, τ denotes observations or dates.

Bai – Perron Multiple Breakpoint Test: Endogeneous Break

Bai and Perron (1998) developed a procedure for testing the existence of multiple structural breaks in linear regression model with endogenous dates. Consider a multiple linear regression model for *RER* that has T periods and m endogenous breaks (hence *m+1* regimes) as follows:

$$RER_t = x_t^{'}\beta + z_t^{'}\delta_j + \varepsilon_t$$

Where $j = 0, 1, 2 \dots \dots, m$, and x_t is a vector of such explanatory variables those have time invariant effect. In contrast z_t is another vector of explanatory variables those contain time variant effect. Bai and Perron (1998) describe a double maximum test for examining the null saying that there is no structural break against the alternative *m* structural breaks where *m* is an unknown number. They have used a global optimization procedure by minimizing the sum of squared residuals of the regression model. Thus, we have minimized the following sum of squared residuals for *m* break points say $\{T\}_m = (T_1, \dots \dots, T_m)$:

$$S(\beta, \delta|\{T\}) = \sum_{j=0}^{m} \left\{ \sum_{t=T_j}^{T_{j+1}-1} RER_t - x_t^{'}\beta - z_t^{'}\delta_j \right\}$$

The test has two versions. One is termed as UDmax which chooses the alternative that maximizes the statistic across the number of breakpoints and hence characterized as equal weighted version. The other one is termed as WDmax which uses weights to the individual statistics.

3.4 Univariate Unit Root Test Addressing Structural Break

It is important to note that the standard unit root tests could possibly remain biased to a false non stationary null whenever the series is trend stationary with structural break (Perron, 1989). Thus we have used two different stationarity tests that addresses the structural break of the series. One is Zivot and Andrews (1992) that allows single structural break and the other is Clemente, Montañés and Reyes (1998) unit root test that allows for multiple structural break, more specifically two breaks.

Zivot – Andrews Unit Root Test: Allowing for Single Break

Zivot and Andrews (1992) unit root test assumes that the break date is unknown and hence treats each date as potential one for break. The test sequentially runs regressions for each possible break date. The break date selection criterion is the minimization of t – Statistics. The test regression can be specified as three different ways, which are,

Test regression allowing for one time break in intercept only,

$$\Delta RER_t = \mu + \alpha RER_{t-1} + \gamma DU_t + \sum_{j=1}^{k} d_j \Delta RER_{t-1} + \varepsilon_t$$

Test regression allowing for one time break in slope only,

$$\Delta RER_t = \mu + \alpha RER_{t-1} + \theta DT_t + \sum_{j=1}^{k} d_j \Delta RER_{t-1} + \varepsilon_t$$

Test regression allowing for one time break in intercept and as well as slope,

$$\Delta RER_t = \mu + \alpha RER_{t-1} + \theta DT_t + \gamma DU_t + \sum_{j=1}^{k} d_j \Delta RER_{t-1} + \varepsilon_t$$

Assume that T_b is the potential break point in RER series then the intercept dummy variable, DU_t and the slope dummy variable DT_t can be defined as follows:

$$DU_t = \begin{cases} 1, if\ t > T_b \\ 0, Otherwise \end{cases}$$

$$DT_t = \begin{cases} t - T_b, if\ t > T_b \\ 0, Otherwise \end{cases}$$

The null hypothesis that would be tested in the all the above three models can be written as H_0: $\alpha = 0$, which implies that RER contains an unit root.

Clemente – Montañés – Reyes Unit Root Test: Allowing for Multiple Break

The weakness of Zivot and Andrews (1992) procedure is its inability to capture more than one break present in the series. Clemente, Montañés and Reyes (1998) developed a test to address this problem which allows for the existence of double break in the series. Depending upon the structural break dynamics the test uses two different models; one is called the Additive Outlier (AO) model (here, a sudden structural change is considered), the other is Innovative Outlier (IO) model (here, the shift of the mean of the series is assumed to be gradual). The double break AO model begins with the estimation of following regression,

$$RER_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \widetilde{RER}_t$$

Where, $DU_{mt} = 1$ for $t > T_{bm}$ and *0* otherwise, for *m = 1, 2*. T_{b1} and T_{b2} are the potential break dates. $\widetilde{RER}_t$ is the residual of the regression which is used as the dependent variable in the test regression as follows:

$$\widetilde{RER}_t = \sum_{i=1}^{k} \omega_{1i} DT_{b1,t-i} + \sum_{i=1}^{k} \omega_{2i} DT_{b2,t-i} + \alpha \widetilde{RER}_{t-i} + \sum_{i=1}^{k} \theta_i \Delta \widetilde{RER}_{t-i} + e_t$$

Where, $DT_{bm,t} = 1$ for $t = T_{bm} + 1$ and *0* otherwise for m = *1, 2*. The above test regression is estimated for several pairs of T_{b1} and T_{b2} and t – statistics is minimized for testing the null, $H_0: \alpha = 1$.

The IO model can be expressed as follows:

$$RER_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \phi_1 DT_{b1,t} + \phi_2 DT_{b2,t} + \alpha RER_{t-1} + \sum_{i=1}^{k} \theta_i \Delta RER_{t-i} + e_t$$

In the above regression an estimation of α significantly less than 1 will provide evidence against the non stationary null hypothesis.

3.5 Testing Stationarity of RER in Panel

In terms of power properties panel based unit root tests are better than their individual counterparts. Also, in some of the literature testing for stationarity of real exchange rate, application of panel unit root tests altered the findings (Kalyoncu and Kalyoncu, 2008; Aslan and Korap, 2009; Chortareas and Kapetanios, 2009**).** Thus we have constructed a panel consisting of RER of Taka with respect to five different currencies namely, US Dollar, Canadian Dollar, Euro, British Pound and Japanese Yen for the period July, 1999 to December, 2014.We have applied the following panel unit root tests:

Im, Pesaran and Shin (IPS) Panel Unit Root Test (Im *et al.*, 2003)

In order to perform the test at first for each variable, an AR(1) process is estimated and then for each cross section unit an Augmented Dickey Fuller (ADF) test regression is fitted. The IPS panel unit root test in particular, examines the significance of the autoregressive coefficient attached with lagged level dependent variable in ADF regression to detect the stationarity of the variables. Therefore, for each cross section units IPS test begin with the following form of Augmented Dickey Fuller (ADF) regression:

$$\Delta RER_{it} = \alpha RER_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta RER_{it-j} + x_{it}^{'} \delta + \varepsilon_{it}$$

then the appropriate null hypothesis would be $H_0: \alpha_i = 0,\ for\ all\ i$. In the above regression RER_{it} denotes the real exchange rate of Taka with a specific currency, i at time t and x_{it} stands for other control variables. The IPS test statistic is defined as the following way:

$$W_{\overline{t_{NT}}} = \frac{\sqrt{N}(\overline{t_{NT}} - N^{-1}\sum_{i=1}^{N} E(\bar{t}_{iT}(p_i)))}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(\bar{t}_{iT}(p_i))}} \rightarrow N(0,1)$$

Here, $\overline{t_{NT}}$ denotes the average of the t – statistics for α_i from the individual ADF regressions, $t_{iT_i}(p_i)$. Thus,

$$\overline{t_{NT}} = \frac{\left(\sum_{i=1}^{N} t_{iT_i}(p_i)\right)}{N}$$

$E(\bar{t}_{iT}(p_i))$ and $Var(\bar{t}_{iT}(p_i))$ are the expected value and variance of the ADF regression t – statistics respectively.

ADF – Fisher and PP – Fisher Panel Unit Root Tests

Maddala and Wu (1999) and Choi (2001) have used Fisher's (1932) results for deriving tests that examines the stationarity of variable for panel. The test statistic is obtained by combining the *p*-values from individual unit root tests. Assume that individual *p*- values are denoted as p_i , then the test statistic is expressed as follows:

$$P = -2\sum_{i=1}^{N} lnp_i \rightarrow \chi_{2N}^2$$

Along with the above statistic Choi (2001) proposed the following statistic:

$$Z = \frac{1}{\sqrt{N}}\sum_{i=1}^{N} \Phi^{-1}(p_i) \rightarrow N(0,1)$$

Where Φ^{-1} is the inverse of the standard normal cumulative distribution function. The null and alternative hypothesis that would be tested is same as IPS panel unit root test. The advantage of these tests over IPS is that they don't require a balanced panel.

Levin, Lin and Chu (2002) Panel Unit Root Test

While the IPS, ADF – Fisher and PP – Fisher test the existence of individual unit root in the panel, Levin, Lin and Chu (2002), LLC test the presence of common unit root. Thus LLC panel unit root test assumes that the persistence parameter is identical for all countries. Therefore in the following ADF test regression

$$\Delta RER_{it} = \alpha RER_{it-1} + \sum_{j=1}^{p_i} \beta_{ij}\, \Delta RER_{it-j} + x_{it}^{'}\delta + \varepsilon_{it}$$

it assumes $\alpha = \rho - 1$ to test the null hypothesis, $H_0\colon \alpha = 0$. By using standardized and autocorrelation and deterministic component free proxies for Δy_{it} and y_{it-1} the test derives the estimates of α. The potential autocorrelation and deterministic components are removed by the following way:

$$\Delta \overline{RER}_{it} = \Delta RER_{it} - \sum_{j=1}^{P_i} \hat{\beta}_{ij}\, \Delta RER_{it-j} - X_{it}^{'}\hat{\delta}$$

$$\overline{RER}_{it-1} = RER_{it-1} - \sum_{j=1}^{P_i} \tilde{\beta}_{ij}\, \Delta RER_{it-j} - X_{it}^{'}\tilde{\delta}$$

The proxies are derived by dividing the $\Delta \overline{RER}_{it}$ and $\overline{RER}_{it-1}$ using the regression standard error in the following way:

$$\Delta \widetilde{RER}_{it} = \frac{\Delta \overline{RER}_{it}}{S_i} \; and \; \widetilde{RER}_{it-1} = \frac{\overline{RER}_{it-1}}{S_i}$$

The coefficient α is estimated from the following pooled proxy equation:

$$\Delta \widetilde{RER}_{it} = \alpha \widetilde{RER}_{it-1} + \eta_{it}$$

The significance of α is tested through the following modified t – statistic:

$$t_{\alpha}^{*} = \frac{t_{\alpha} - \left(N\tilde{T}\right) S_N \hat{\sigma}^{-2} se(\hat{\alpha}) \mu_{m\tilde{T}^{*}}}{\sigma_{m\tilde{T}^{*}}} \rightarrow N(0,1)$$

Here, t_α is the standard t – statistic for $\hat{\alpha} = 0$, $\hat{\sigma}^2$ is the estimated variance of the error term η, $se(\hat{\alpha})$ is the standard error of $\hat{\alpha}$, $\tilde{T} = T - \left(\frac{\sum_i p_i}{N}\right) - 1$, S_N is the ratio of average long run standard deviation to the innovation standard deviation and finally $\mu_{m\tilde{T}^*}$ and $\sigma_{m\tilde{T}^*}$ are the adjustment terms for mean and standard deviation.

Harris – Tzavalis (1999) Panel Unit Root Test

The cross sectional independence is a vital assumption for LLC test. Also it has some restrictive assumptions. By assuming homogeneous variance and providing relatively exact correction for small values Harris – Tzavalis (1999) have developed a panel unit root test. It also uses the same test regression suggested by LLC and can be estimated with only intercept, with intercept and trend and with no intercept and trend. The test results in all three cases are as follows:

$$No\ intercept\ and\ Trend: \sqrt{N}(\hat{\alpha} - 1) \rightarrow N\left(0, \frac{2}{T(T-1)}\right)$$

$$Only\ intercept: \sqrt{N}\left(\hat{\alpha} - 1 + \frac{3}{T+1}\right) \rightarrow N\left(0, \frac{3(17T^2 - 20T + 17)}{5(T-1)(T+1)^3}\right)$$

$$Intercept\ and\ Trend: \sqrt{N}\left(\hat{\alpha} - 1 + \frac{15}{2(T+2)}\right) \rightarrow N\left(0, \frac{15(193T^2 - 728T + 1147)}{112(T+2)^3(T-2)}\right)$$

Breitung's (2000) Panel Unit Root Test

When studying the local power of LLC and IPS panel unit root test Breitung (2000) found that both the tests loose power while individual specific trends are included. Hence Breitung (2000) suggests a test statistic without employing bias correction to improve the power properties. By removing the autoregressive components in Breitung (2000) method the standardized proxies are constructed in the following ways:

$$\Delta\widetilde{RER}_{it} = \frac{\left(\Delta RER_{it} - \sum_{j=1}^{p_i} \hat{\beta}_{ij}\Delta RER_{it-j}\right)}{S_i}$$

$$\widetilde{RER}_{it-1} = \frac{\left(RER_{it-1} - \sum_{j=1}^{p_i} \tilde{\beta}_{ij}\Delta RER_{it-j}\right)}{S_i}$$

Here, $\hat{\beta}$, $\tilde{\beta}$ and S_i are defined as the way they had been in LLC panel unit root test. After construction for transforming and detrending the following method has been used:

$$\Delta RER_{it}^{*} = \sqrt{\frac{(T-t)}{(T-t+1)}}\left(\Delta\widetilde{RER}_{it} - \frac{\Delta\widetilde{RER}_{it+1} + \cdots + \Delta\widetilde{RER}_{iT}}{T-t}\right)$$

$$RER_{it}^{*} = \widetilde{RER}_{it} - \widetilde{RER}_{i1} - \frac{t-1}{T-1}\left(\widetilde{RER}_{iT} - \widetilde{RER}_{i1}\right)$$

Finally the following pooled regression was estimated for estimating the persistence parameter, α,

$$\Delta y_{it}^{*} = \alpha y_{it-1}^{*} + v_{it}$$

For testing the significance of α, t – statistic can be used and it was shown that under null the estimated parameter asymptotically have standard normal distribution.

Hadri (2000) Residual Based Panel Unit Root Test

By generalizing KPSS test for panel data Hadri (2000) developed a residual based lagrange multiplier test for panel unit root. The test treats the panel as stationary under null against a unit root panel under alternative. The test is performed by deriving OLS residuals of RER regression on an intercept or on an intercept and trend. If both the intercept and trend terms are considered then the RER regression would be as follows:

$$RER_{it} = \alpha_i + \beta_i t + \varepsilon_{it}$$

Assuming that $\hat{\varepsilon}_{it}$ are the OLS residuals the LM statistic can be expressed as follows:

$$LM_1 = \frac{1}{N}\left(\sum_{i=1}^{N}\left(\frac{\sum_t S_i(t)^2/T^2}{\bar{f}_0}\right)\right)$$

Where, $S_i(t) = \sum_{s=1}^{t}\hat{\varepsilon}_{is}$ and $\bar{f}_0 = \frac{\sum_{i=1}^{N} f_{i0}}{N}$. The test statistic is defined as follows:

$$Z = \frac{\sqrt{N}(LM - \xi)}{\zeta} \rightarrow N(0,1)$$

Where, $\xi = 1/6$ and $\zeta = 1/45$, when there is only intercept (β_i would be 0 for all cross section units) and $\xi = 1/15$ and $\zeta = 11/6300$, when there is both intercept and trend.

3.6 Testing for the Existence of Cross Sectional Dependence in Panel of RER

The size of the aforementioned panel unit root test would be distorted when there is significant contemporaneous correlation. Therefore, it is of sheer importance to detect the presence of cross sectional dependence, as if panel does contain so then the unit root tests should be applied in such a way so that it become robust against it. In particular, we would be focusing on four different cross sectional dependence tests namely Breuch – Pagan Lagrange Multiplier (LM) (1980), Pesaran Cross Sectional Dependence (CD) (2004), Pesaran Scaled LM (2004) and Baltagi, Feng and Kao Bias Corrected Sclaed LM (2012). Each of the tests has its own pros and cons. For instance Breuch – Pagan Lagrange Multiplier (LM) (1980) is particularly applicable in the context when N (cross section units) remains fixed and T (time series) tends to infinite ($T \to \infty$). On the other hand though Pesaran Scaled LM (2004) is appropriate when $T \to \infty$ and $N \to \infty$ it probably could face substantial size distortion for large N and small T. However, Pesaran CD (2004) is regarded as the most general one as it is suitable for stationary and as well as non – stationary panels. It also consists of reasonable small sample properties. The null hypothesis that would be tested in all the tests can be stated as the residuals from the standard panel regression should be contemporaneously uncorrelated. Therefore, they would basically test whether the pair - wise covariance among residuals are zero or not. Symbolically:

$$H_0: \rho_{ij} = \rho_{ji} = Cov(\varepsilon_{it}, \varepsilon_{jt}) = 0, for\ all\ t, i \neq j$$

$$H_1: \rho_{ij} = \rho_{ji} = Cov(\varepsilon_{it}, \varepsilon_{jt}) \neq 0, for\ all\ t, i \neq j$$

Breusch – Pagan Lagrange Multiplier (LM) Test (1980)

As pointed by Pesaran (2004) the lagrange multiplier test of Breusch – Pagan (1980) is based on the average of squared pair - wise correlation of the residuals and particularly applicable in the context when N (cross section units) remains fixed and T (time series) tends to be infinite ($T \to \infty$). In order to explain the main idea behind the test, it considers the following panel data model:

$$RER_{it} = \gamma_i + \alpha_i^{'} x_{it} + \varepsilon_{it}$$

Here, $i = 1,2, - - -, N$ and $t = 1,2, - - - T$. The null hypothesis of *"no cross section dependence"* in Breusch – Pagan LM test procedure could be presented in the following way:

$$H_0: \rho_{ij} = \rho_{ji} = Cov(\varepsilon_{it}, \varepsilon_{jt}) = 0, for\ all\ t, i \neq j$$

$$H_1: \rho_{ij} = \rho_{ji} = Cov(\varepsilon_{it}, \varepsilon_{jt}) \neq 0, for\ all\ t, i \neq j$$

Here, ρ_{ij} measures the pair – wise correlation of the residuals. The sample counterpart of ρ_{ij} is calculated as follows:

$$\widehat{\rho_{ij}} = \widehat{\rho_{ji}} = \left(\sum_{t=1}^{T} \hat{\varepsilon}_{it}^2\right)^{-1/2} \left(\sum_{t=1}^{T} \hat{\varepsilon}_{jt}^2\right)^{-1/2} \sum_{t=1}^{T} \hat{\varepsilon}_{it}\hat{\varepsilon}_{jt}$$

In the above expression $\hat{\varepsilon}_{it}$ is the OLS estimate of the residuals from the previously considered panel data model. The test statistic is defined in the following way:

$$BP_{LM} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2$$

Under the null hypothesis here, BP_{LM} asymptotically distributed as $\chi^2_{N(N-1)/2}$.

Pesaran Scaled LM (2004) and Pesaran CD (2004)

The problem with the aforementioned Breusch – Pagan LM test is that it becomes inappropriate and cannot be applied whenever $N \rightarrow \infty$ (Pesaran, 2004, Baltagi, Feng & Kao, 2012). Therefore, Pesaran (2004) proposed a scaled version of LM test. The test statistic is defined in the following way:

$$CD_{Scaled\ LM} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T\hat{\rho}_{ij}^2 - 1)$$

According to Pesaran (2004) the above test statistic is asymptotically distributed as standard normal distribution with zero mean and unit variance under the null hypothesis when $T \to \infty$ and $\to \infty$.

Nonetheless as pointed out in Pesaran (2004) the above test probably could face substantial size distortion for large N and small T. It is because of the fact that small T would result in incorrect centering of $E\left(T\hat{\rho}_{ij}^2 - 1\right)$ around zero. Similarly, incorrect centering of LM statistics will be accentuated with large N. Thus, based on pair – wise correlation coefficients rather than their squares, Pesaran (2004) suggested a cross sectional dependence (CD) test with reasonable small sample properties. The test statistic is as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right)$$

The above test statistic would have exact mean of zero for fixed values of N and T for wide range of panel data models.

Baltagi, Feng & Kao Bias Corrected Scaled LM (2012)

By assuming a fixed effect homogeneous panel data model Baltagi, Feng & Kao (2012) developed a bias corrected scaled LM test for cross sectional dependence. Following Baltagi, Feng & Kao (2012) consider the following fixed effect homogeneous panel data model:

$$RER_{it} = \alpha + x_{it}^{'}\beta + \eta_i + \varepsilon_{it} \qquad (11)$$

Here, $i = 1,2,---,N$ and $t = 1,2,---T$, η_i denotes time invariant cross section effect . The $(k*1)$ vector of regressors x_{it} could be correlated with η_i but are uncorrelated with the idiosyncratic errors ε_{it} . The bias corrected LM statistic is calculated as follows:

$$LM_{BC} = \sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\left(T\hat{\rho}_{ij}^2 - 1\right) - \frac{N}{2(T-1)}$$

According to Baltagi, Feng and Kao (2012) under the null hypothesis the limiting distribution of the above test statistic would be standard normal.

3.7 Panel Unit Root Test Allowing for Cross Sectional Dependence: Pesaran (2007) CIPS Test

We have applied Pesaran (2007) panel unit root test which unlike their earlier counterparts allows for cross sectional correlation. He further augmented the usual ADF test regression with the lagged cross sectional mean and its first difference. The resulting test regression captures the contemporaneous correlation that actually results through a single factor residual model where the cross section mean and of the series and its lagged value proxy for the common factor. The Cross Sectionally Augmented Dickey Fuller (CADF) test regression can be expressed as follows:

$$\Delta RER_{it} = \alpha_i + \gamma_i t + \beta_i RER_{i,t-1} + \eta_i \overline{RER}_{t-1} + \sum_{j=0}^{p} \lambda_{ij} \Delta \overline{RER}_{t-j} + \sum_{j=1}^{p} \delta_{ij} \Delta RER_{i,t-j} + \varepsilon_{it}$$

The null and alternative hypothesis that would be tested can be written as:

$$H_0: \beta_i = 0 \; \forall \, i \quad and \; H_a: \beta_i < 0 \; for \; at \; least \; some \; i$$

Pesaran suggested averaging the t – Statistic of the coefficient attached with lagged variable after estimating the CADF regression for each cross section in the panel. This averaging will result in CIPS statistic which is expressed as follows:

$$CIPS = \frac{\sum_{i=1}^{N} CADF_i}{N}$$

4. Empirical Findings and Interpretations

4.1 Univariate Unit Root Tests: The Null of Non-Stationarity

As a preliminary step of analyzing empirical findings of tests presence of unit root in the data set of five real exchange rates, the Table 1 below shows three unit root test results, namely- Augmented Dickey Fuller test (ADF), Phillips Perron test (PP) and Elliott-Rothenberg-Stock test (ERS). For each of these three tests, to account for various possible ways that the data could have been generated, two variants of the tests were run- with constant (intercept) and with constant and linear trend.

Table 1: Results of the ADF, PP and ERS Tests

Real Exchange Rate	Augmented Dickey Fuller test (ADF)		Phillips Perron test (PP)		Elliott-Rothenberg-Stock test (ERS)	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend
TK/USD (Bangladesh-US)	-1.457	-0.866	-1.484	-0.709	13.025***	20.426***
TK/GBP (Bangladesh-UK)	-2.187	-2.063	-1.946	-1.860	3.491**	11.449***
TK/EUR (Bangladesh-EU)	-2.070	-0.976	-2.103	-0.845	118.789***	26.516***
TK/CAD (Bangladesh-Canada)	-1.566	-0.731	-1.614	-0.767	18.145***	32.765***
TK/YEN (Bangladesh-Japan)	-2.664*	-2.665	-2.447	-2.382	17.025***	30.442***

Note 1: *, **, *** denote rejection of the null hypothesis of a unit root at 10%, 5% and 1% level of significance respectively. No asterisk indicates that it was not possible to reject the null hypothesis of unit root and the process is non-stationary.

The results show that with the Augmented Dickey Fuller test (ADF) bilateral real exchange rates of Bangladesh with US, UK, EU and Canada were unequivocally non-stationary in nature, no matter whichever specification (with constant or with constant and linear trend) was used. However in case of bilateral real exchange rates between Bangladesh and Japan (TK/YEN), when the model was specified only with a constant, it was possible to reject the null of unit root at 10% level of significance; but if the specification was changed to include a linear trend, this dataset was indicated to be non-stationary. For the Phillips Perron test (PP), none of the countries showed stationarity. Overall the results showed that the data did not support the PPP hypothesis when tested with ADF and PP tests.

The first generations of the Dickey Fuller (DF), Augmented Dickey Fuller (ADF) and Phillips Perron (PP) tests have often been supplanted by a more powerful version of a second generation test called Dickey Fuller Generalized Least Square (DF-GLS) test by Elliott-Rothenberg-Stock (1996); this is also named as the ERS test as shown in the table. The DF-GLS is actually an ADF test except that the series is first transformed by a GLS regression and then the actual test is performed. Surprisingly, almost all test statistics of ERS- whether with the specification of an intercept alone or with intercept and trend- showed the datasets were stationary in nature. Such contradictory results, compared to the other two univariate unit root tests could be due to a possible presence of breaks in data, a fact that will be addressed shortly in the following discussions.

4.2 Univariate Unit Root Tests: The Null of Stationarity

In this section the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test is carried out on the same four time series dataset; the major difference of the KPSS unit root test with the other three tests mentioned in the previous section is that the KPSS uses the null hypothesis of stationarity against an alternative of unit root/non-stationarity. So for KPSS, a non-stationary real exchange rate will reject the null hypothesis. For this test too, two variants of model specifications were used- one with constant (intercept) and the other with constant and a linear trend. The results are tabulated below.

Table 2: Results of the KPSS Test

Real Exchange Rate	Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Test	
	Intercept	Intercept & Trend
TK/USD (Bangladesh-US)	5.384***	1.552***
TK/GBP (Bangladesh-UK)	1.856***	1.602***
TK/EUR (Bangladesh-EU)	1.459***	0.4260***
TK/CAD (Bangladesh-Canada)	0.632**	0.346***
TK/YEN (Bangladesh-Japan)	0.312	0.311***

Note 1: *, **, *** denote rejection of the null hypothesis of a unit root at 10%, 5% and 1% level of significance respectively. No asterisk indicates that it was not possible to reject the null hypothesis of stationarity and the process support the PPP hypothesis.

As tabulated above, bilateral real exchange rates of Bangladesh with US, UK and EU were clearly non-stationary in nature, no matter the variant in specification as in all these cases, it was possible to reject the null even at 1% level of significance. In case of TK/CAD, the null of stationarity was rejected at 5% level of significance when the model was specified with an intercept only; for bilateral real exchange rates between Bangladesh and Canada, the null of stationarity was strongly rejected at 1% level of significance when a linear trend was considered along with the intercept/constant. Just as in the ADF test of the previous section, for the real exchange rate between Bangladesh and Japan, the KPSS test could not reject null, once again suggesting that the data could be stationary for TK/YEN when only a constant is considered; that is the PPP hypothesis holds in this case. However the result completely overturns once a linear trend is added and the TK/YEN is no longer stationary and lend any evidence in favor of the PPP hypothesis.

4.3 Other Univariate Unit Root Test: The Ng-Perron test

In this section the findings from the Ng-Perron (NP) test are explained. The NP test has the same null hypothesis of non-stationarity/unit root as the usual ADF and PP tests. However, as discussed in the methodology section, the NP test has four test statistics, namely MZ_{α}, MZ_t, MSB and MPT. The first two test statistics- MZ_{α} and MZ_t – are efficient versions of the Z_{α} and Z_t test statistics and usually reported more often for interpretation of empirical results (Gregoriou *et al,* 2006; Cuestas and Harrison, 2008; Cuestas and Staehr, 2013). In this test too, two different variants in model specification are adopted.

Table 3: Results of the Ng - Perron Test (With Null of Unit Root)

Real Exchange Rate	Intercept		Intercept & Trend	
	MZ_{α}	MZ_t	MZ_{α}	MZ_t
TK/USD (Bangladesh-US)	-2.001	-1.000	-4.051	-1.129
TK/GBP (Bangladesh-UK)	-7.613*	-1.879*	-8.415	-1.911
TK/EUR (Bangladesh-EU)	0.301	0.364	-3.078	-0.934
TK/CAD (Bangladesh-Canada)	-1.709	-0.922	-2.634	-0.838
TK/YEN (Bangladesh-Japan)	-1.543	-0.878	-2.525	-0.855

Note 1: *, **, *** denote rejection of the null hypothesis of a unit root at 10%, 5% and 1% level of significance respectively. No asterisk indicates that it was not possible to reject the null hypothesis of unit root and the process is non-stationary.

Considering the more common test statistics for interpretation, values of MZ_{α} and MZ_t show that only TK/GBP could reject the null of unit root when the model was specified to have an intercept/constant. The rejection was possible at 10% level of significance. However, adding the linear trend gave test statistic that was no longer able to reject the null and overall, the results showed that the real exchange rates were non-stationary in nature and did not support the PPP hypothesis. Interestingly, real exchange rate between Bangladesh and Japan (TK/YEN), which previously showed traces of stationarity in the ADF and KPSS tests, does not seem to be stationary with the Ng-Perron test of unit root. For ease of understanding, the critical values of the Ng-Perron test are given in Annex Table 3 (Appendix).

4.4 Unit Root tests allowing for Structural Break(s)

4.4.1 Validating the Presence of Structural Break

Almost all the univariate stationarity test procedure heavily dependent on the assumption of parameter stability. The findings can be misleading should there be presence of any parameter stability driven by structural change. Also, in our case testing for structural break has more relevance as exchange rate of Bangladesh went through a policy shift in the year of 2003. We have tried to validate the presence of structural change by using exogenous as well as endogeneous tests. Annex Tables 4, 5 and 6 in Appendix contain all the test results. As the results of Chow breakpoint test reveals, the test statistics for all five bilateral RER are significant arguing that there was structural change in parameters in those particular dates. When we change the break identification method from exogenous to an endogeneous one and applied the Quandt – Andrews break point test, the test statistics for all RER series again found to be significant. However, the endogeneously selected beak dates were not uniform for all the RER series. Finally when a more general test, Clemente-Montañés-Reyes unit root test which allows for multiple endogeneous structural break has been applied, it too concludes that there lies structural breaks (more than one) in all five RER series for Bangladesh. Therefore the unit root property of all bilateral RER of Bangladesh has been tested by using the method incorporating the parameter instability.

4.4.2 Zivot-Andrews (1992) Unit Root Test: Single Endogenous Structural Break

The Zivot-Andrews (ZA) test of unit root allows for a structural break in the data series and this break is endogenously determined. Table 4 below shows the results obtained when the ZA test was run on each of the five real exchange rates using three variants in the model- (i) with trend break, (ii) with intercept break and (iii) with both trend and intercept break.

As the results demonstrate, the only real exchange rate that could reject the null of non-stationarity was between Bangladesh and EU (TK/EUR), but this too was not true for all three of the variants of model specified. When only a break in trend was considered, the TK/EUR strongly rejected null of unit root at 1% level of significance and when break in both-trend and intercept was considered- null was rejected at 5% level of significance.

Table 4: Result of the Zivot - Andrews Test (With Null of Unit Root Including Structural Break)

Real Exchange Rate	H_0= Unit root with Trend Break	H_0= Unit root with Intercept Break	H_0= Unit root with Trend & Intercept Break
TK/USD (Bangladesh-US)	-3.610 (01/06/2008)	-3.164 (01/01/2006)	-4.055 (01/08/2000)
TK/GBP (Bangladesh-UK)	-3.398 (01/06/2006)	-4.350 (01/06/2008)	-4.209 (01/06/2008)
TK/EUR (Bangladesh-EU)	-5.000*** (01/01/2008)	-2.539 (01/04/2003)	-5.399** (01/08/2008)
TK/CAD (Bangladesh-Canada)	-2.871 (01/05/2006)	-2.198 (01/04/2003)	-3.247 (01/02/2005)
TK/YEN (Bangladesh-Japan)	-3.457 (01/07/2010)	-3.794 (01/07/1991)	-3.597 (01/07/2010)

Note: *, **, *** denote rejection of the null hypothesis of a unit root at 10%, 5% and 1% level of significance respectively. No asterisk indicates that it was not possible to reject the null hypothesis of unit root and the process is non-stationary. The endogenously determined break dates are given in the parentheses.

This indicates that the TK/EUR could be a stationary process and validates the PPP hypothesis. However the same exchange rate demonstrated non-stationarity when only a break in intercept was considers. All the other four real exchange rates showed absolute non-stationarity, thus lending support against the validity of the PPP hypothesis.

4.4.3 Clemente-Montañés-Reyes (1998) Unit Root Test: Multiple Endogenous Structural Breaks

The Clemente-Montañés-Reyes (1998) Unit Root Test, just like the Zivot-Andrew test allows breaks in the data; however, the former allows two endogenously determined breaks instead of one. Moreover the Clemente-Montañés-Reyes Unit Root Test adopts two approaches to find the test statistics- one by the Additive Outlier (AO) approach where the change in mean occurs rapidly, and the other by the Innovaive Outlier (IO) approach where the change in mean is not so sudden but gradual. The results for five of the real exchange rate data series are tabulated in Table 5.

Table 5: Results of the Clemente-Montañés-Reyes (1998) Unit Root Test with Double Mean Shift

Real Exchange Rate	Additive Outlier (AO)		Innovative Outlier (IO)	
	t-statistic	Break Dates	t-statistic	Break Dates
TK/USD (Bangladesh-US)	-4.274	01/09/2000 & 01/11/2008	-3.809	01/09/1999 & 01/09/2006
TK/GBP (Bangladesh-UK)	-4.427	01/06/2003 & 01/11/2008	-5.100	01/07/2003 & 01/03/2008
TK/EUR (Bangladesh-EU)	-4.644	01/05/2003 & 01/07/2006	-3.297	01/08/2002 & 01/09/2005
TK/CAD (Bangladesh-Canada)	-2.628	01/03/2005 & 01/11/2008	-2.918	01/07/2004 & 01/03/2008
TK/YEN (Bangladesh-Japan)	-2.417	01/10/1992 & 01/9/1995	-3.546	01/02/1992 & 01/02/1995

Note: The critical value at 5% level of significance is -5.490 and ** denotes rejection of the null of unit root. No asterisk indicates that it was not possible to reject the null hypothesis of unit root and the process is non-stationary.

As the table shows, it was not possible to reject the null of unit root in any of the five cases either using the Additive Outlier (AO) approach or using Innovative Outlier (IO) approach, at least at 5% level of significance. Allowing for neither sudden changes nor gradual changes in mean could show that the data was stationary and so the Clemente-Montañés-Reyes test lend no support in favor of the validity of the mean-reverting property of the real exchange rate which would have proven the validity of the PPP hypothesis.

4.5 The Panel Unit Root Test Results

For testing the stationary property of RER of BDT in panel, five bilateral exchange rate namely, BDT against US Dollar, BDT against Canadian Dollar, BDT against British Pound, BDT against Euro and BDT against Japanese Yen for the period July, 1999 to December 2014 have been used. They were transformed to RER by following CPI conversion.

Before applying the different unit root tests for panel it was important to finalize the lag length. Annex Table 2 (Appendix) contains the results for information criteria for measuring lag selection and Annex Figure 1 (Apendix) shows the corresponding correlogram. It can be observed that both AIC and BIC is significantly minimized at a lag order of 2 indicating that a maximum of 2 lag should be considered for the different unit root test procedures.

4.5.1 First Generation Panel Unit Root Test Results

All the existing panel unit root tests can be classified into two broad categories; one which are heavily dependent on cross sectional independence assumption (first generation panel unit root tests) while the other relax the assumption and allows for cross correlation (second generation panel unit root test). Table 6 contains the first generation panel unit root test results. Here IPS (Im *et al.*, (2003)), ADF – Fisher and PP – Fisher (Maddala and Wu (1999)) tests the null of individual unit root in the panel. In contrast Harris – Tzavalis (Harris – Tzavalis (1999)), LLC (Levin *et al.*, 2002) and Breuitang (Breitung's (2000)) tests the null of common unit root in the panel. Finally, Hadri (Hadri, (2000)) test the null of stationary panel against a nonstationary one. All the tests have been performed under two specifications; one with intercept only and the other with both intercept and trend term. As the results show IPS, ADF – Fisher and PP – Fisher failed to reject the null of individual (i.e. exchange rate specific) nonstationarity of RER for BDT in both specifications. When the null is changed to the existence of common nonstationarity in the panel, all three tests statistic respectively for Harris – Tzavalis, LLC and Breuitang have come up with high *p-* values; meaning that there was not enough evidence against the existence of common unit root in the panel of RER for BDT. Finally, Hadri's Z – statistic which tests the null of stationary panel of RER was found to be statistically significant at even 1 percent level, implying that the RER series for BDT might be nonstationary. Thus, RER of Bangladesh with these countries does not revert to mean and hence does not follow PPP hypothesis.

Table 6: First Generation Panel Unit Root Test Results

Test	Intercept	Prob.	Intercept & Trend	Prob.
	H_0: Panels Contain Unit Roots (Individual)			
IPS	1.112	0.867	2.004	0.977
ADF – Fisher χ^2	5.068	0.886	3.225	0.975
PP – Fisher χ^2	5.250	0.873	3.490	0.967
H_0: Panels Contain Unit Roots (Common)				
Harris - Tzavalis	0.987	0.670	0.982	0.968
LLC	-0.028	0.488	1.505	0.933
Breuitang	-	-	2.065	0.980
H_0: Panel is Stationary				
Hadri Z- Statistic	15.042***	0.000	15.234***	0.000

Note: *** Indicates 1 per cent level of significance.

4.5.2 Second Generation Panel Unit Root Test Results

The above conclusion might be misleading should there be presence of significant correlation among the RER series of BDT for several currencies. Because, all the aforementioned tests follow the assumption of cross sectional independence. Thus, it is of vital importance to diagnose whether the panel is suffering from significant cross section dependence or not before taking the findings as an established one.

Table 7: Test Results for Cross Sectional Dependence of the Variables

Test	Statistic	Prob.
	H_0: No Cross - Section Dependence	
Breusch - Pagan LM	407.535***	0.000
Pesaran - Scaled LM	88.891***	0.000
Bias Corrected Scaled LM	88.878***	0.000
Pesarn CD	8.382***	0.000

Note: *** Indicates 1 per cent level of significance.

Table 7 contains the cross section dependence test results. It can be observed that all the four different tests turn out to be significant at 1 percent level, implying that the null of no cross correlation among the different RER for BDT can be rejected. Therefore, this true existence of cross dependency among different RER series may mislead the findings of first generation panel unit root tests. Consequently we have applied second generation panel unit root test, CIPS developed by Pesaran (2007). The test procedure allows for cross section dependence and test the null of existence of unit root in the panel. Table 8 contains the Pesaran (2007) CIPS test results. The test has been performed under two specifications; intercept only and intercept and trend. A maximum of two lag was allowed as the number was found to be significant earlier by using SIC and AIC criteria. It is evident from the results that in both specifications and successively for 0, 1 and a maximum of 2 lag length the Pesaran (2007) CIPS test statistic is insignificant with high *p*- values. Thus, there was not enough evidence against the nonstationarity feature of panel for RER of BDT with different currencies. Since the nonstationarity feature of RER has been established even in the most generalized diagnostic procedure, it can be argued with evidence that RER for BDT with US Dollar, Canadian Dollar, British Pound, Euro and Japanese Yen is non stationary and don’t revert back to their average value thus failing to follow the PPP hypothesis.

Table 8: Second Generation Panel Unit Root Test Results

Lag Order	Pesaran (2007) Panel Unit Root Test: CIPS			
	Without Trend		With Trend	
	Statistic	Prob.	Statistic	Prob.
Lag = 0	-1.222	0.921	-1.706	0.961
Lag = 1	-1.424	0.818	-1.863	0.910
Lag = 2	-1.500	0.764	-2.022	0.819

5. Conclusion

This paper aims to add to the few research works on the validity of PPP hypothesis in case of real exchange rate of Bangladesh by undertaking various approaches. The tests range from the very rudimentary Augmented Dickey Fuller (ADF) and Phillips Perron tests and other univariate unit root tests, to the tests which addresses one/more breaks in the time series data and finally panel unit root tests that account for the possible presence of cross-sectional dependence in dataset. Such a thorough approach was taken to access the issue of the presence of unit root in real exchange rate in every way feasible, assuming the adjustment process is linear. Almost all the results corroborated each others' conclusions that the real bilateral exchange rates of Bangladesh with five of its major trading partners are in fact not mean-reverting in the long run and so PPP hypothesis does not hold.

Various implications can be drawn from this finding. First, when real exchange rates are not mean-reverting, as suggested by the PPP hypothesis, shocks are typically induced by the demand-side rather than the supply-side. As for the practical implication of non-mean-reverting exchange rate, caution must be practiced when making policies where the stipulated PPP hypothesis is assumed to be accurate. Until further studies can prove clear-cut evidence of long-run stationarity of Bangladeshi real exchange rate, policies like exchange rate determination should not blindly be pivoted on the yet puzzling phenomenon of PPP hypothesis.

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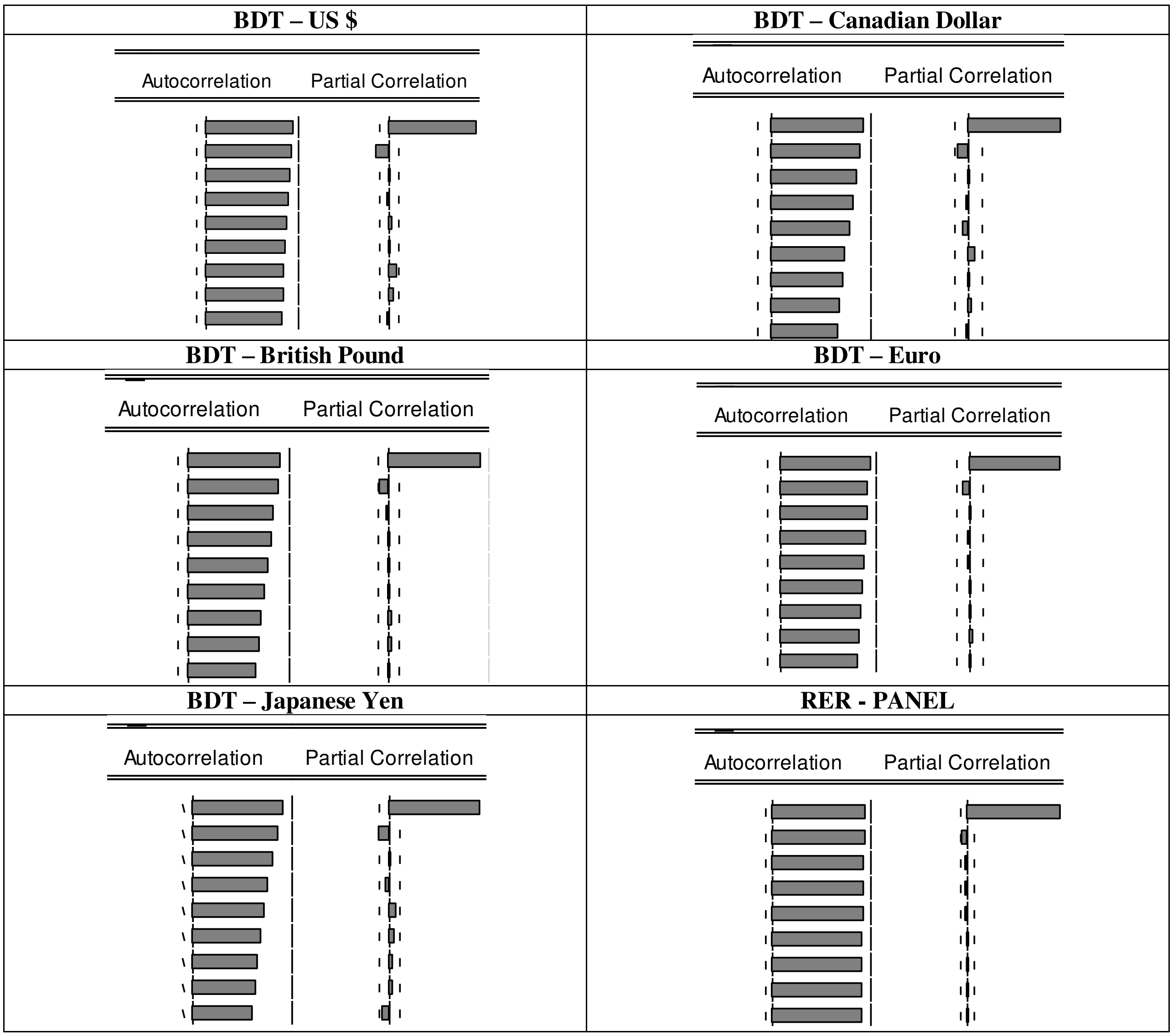
Appendix

Annex Table 1: Data Description

Real Exchange Rate	From	To	Number of Observations (Months)
TK/USD (Bangladesh-US)	January 1985	December 2014	360
TK/GBP(Bangladesh-UK)	January 1988	December 2014	324
TK/EUR(Bangladesh-EU)	July 1999	December 2014	186
TK/CAD (Bangladesh-Canada)	July 1999	December 2014	186
TK/YEN (Bangladesh-Japan)	January 1985	December 2014	360

Annex Figure 1: Correlogram for Different RER Series



Annex Table 2: Selection of Lag Length for Different RER Series

Lag Order	SIC	AIC	Probability
BDT – US $			
0	6.820	6.808	-
1	2.762	2.739	0.000
2	2.696***	2.663***	0.000
3	2.713	2.668	0.571
BDT – Canadian Dollar			
0	7.068	7.051	-
1	3.798	3.763	0.000
2	3.783***	3.731***	0.005
3	3.809	3.739	0.499
BDT – British Pound			
0	8.297	8.285	-
1	5.343***	5.320	0.000
2	5.345	5.310**	0.024
3	5.361	5.314	0.360
BDT – Euro			
0	9.243	9.226	-
1	4.509	4.474	0.000
2	4.481***	4.428***	0.001
3	4.502	4.431	0.239
BDT – Japanese Yen			
0	-1.444	-1.454	-
1	-4.400	-4.422	0.000
2	-4.414***	-4.447***	0.001
3	-4.398	-4.441	0.751
RER - PANEL			
0	10.360	10.355	-
1	4.195	4.186	0.000
2	4.159***	4.143***	0.000
3	4.165	4.144	0.381
4	4.171	4.144	0.170

Note: *** and ** indicates significant at 1% and 5% level respectively.

Annex Table 3: Critical Values of the Ng-Perron Test

Level of Significance	Critical values (With Intercept)		Critical values (With Intercept & Trend)	
	MZ_α	MZ_t	MZ_α	MZ_t
1%	-13.80	-2.58	-23.80	-3.42
5%	-8.10	-1.98	-17.30	-2.91
10%	-5.70	-1.62	-14.20	-2.62

Annex Table 4: Chow Exogeneous Breakpoint Test

Chow Breakpoint Test, H_0: *No Breaks at Specific Breakpoints*										
Break Date	BDT - US $		BDT - CAD		BDT - Pound		BDT - Euro		BDT – Yen	
	F – Stat.	Pr.	F – Stat.	Pr.	F – Stat.	Pr.	F – Stat.	Pr.	F – Stat.	Pr.
01/06/2003	74.87***	0.00	182.83***	0.00	21.88***	0.00	627.37***	0.00	10.79***	0.00
01/07/2003	71.35***	0.00	181.79***	0.00	21.08***	0.00	636.30***	0.00	10.85***	0.00
01/08/2003	68.77***	0.00	183.07***	0.00	20.61***	0.00	650.51***	0.00	10.93***	0.00

Note: *** indicates significant at 1% level.

Annex Table 5: Quant – Andrews Endogeneous Break Point Test

Real Exchange Rate	Quandt – Andrews Unknown Breakpoint Test, H_0: *No Breakpoints within 15% Trimmed Data*		
	Break Date	**Maximum LR- F-Statistic**	**Probability**
BDT - US $	01/12/1999	332.936***	0.000
BDT - CAD	01/05/2003	186.656***	0.000
BDT - Pound	01/11/2008	85.421***	0.000
BDT - Euro	01/11/2004	742.756***	0.000
BDT – Yen	01/09/1991	97.159***	0.000

Note: *** indicates significant at 1% level.

Annex Table 6: Bai – Perron Endogeneous Multiple Breakpoint Test

Real Exchange Rate (RER)	H_0: *No Breakpoints within 15% Trimmed Data,* H_1: *"m" Number of Breaks Exist*	
	UDmax Stat. (Break Dates)	**WDmax Stat. (Break Dates)**
BDT - US $	18.04**(1/06/2007)	18.55**(1/12/1990, 1/01/1996, 1/08/2000, 1/03/2006, 1/8/2010)
BDT - CAD	25.66**(1/06/2008, 1/02/2011)	29.92**(1/06/2008, 1/02/2011)
BDT - Pound	14.42**(1/10/2003, 1/06/2008)	24.18**(1/09/1992, 1/09/1996, 1/09/2000, 1/09/2004, 1/09/2008)
BDT - Euro	25.64**(1/05/2008)	25.64**(1/05/2008)
BDT – Yen	16.98**(1/07/1990, 1/05/1995, 1/12/2000, 1/10/2005, 1/08/2010)	31.82**(1/07/1990, 1/05/1995, 1/12/2000, 1/10/2005, 1/08/2010)
Critical Values	14.23	15.59

Note: ** indicates significant at 5% level, 15% Data Trimming and a maximum of 5 breaks has been allowed. Also, Heteroecedasticity and Autocorrelation Consistent (HAC) standard error, Bartlett Kernel and Newey – West fixed bandwidth were has been used and error distributions were allowed to be heterogeneous across breaks. Critical Values for all RER series were 14.23 and 15.59 respectively for UDmax and WDmax statistic except BDT – Pound RER series where corresponding values were 11.70 and 12.81. The difference occurs as for all other series breaking variables includes two lags along with constant while for BDT – Pound RER series it includes only one lag.