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# Purchasing Power Parity (PPP) with Structural Break and Mean Reversion in Real Exchange Rate: The Case of Bangladesh Taka and US Dollar

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## *Abstract*

*This paper aims at examining the validity of purchasing power parity (PPP) both in absolute and relative terms with reference to the long run behavior of the real exchange rate of Bangladesh Taka relative to USA dollar. In doing so, the paper tests the presence of mean-reversion in the real exchange rate by using the unit root test approach i.e. Augmented Dickey-Fuller, DF-GLS, Zivot-Andrews tests. The paper verifies the long run relationship on co-integration and VAR framework. Using monthly data (01/2007-06/2013) and annual data (1986-2014), the paper finds support for both absolute and relative PPP, with an evidence of structural change (Quandt -Andrew test and CUSUM test) for only monthly data. VECM has been applied on monthly data, as there exists co-integrating equations for only monthly data (by using Johansen test). Unit root test indicates that the real exchange rate, that is the I (1) is not stationary.*

**Keywords:** Purchasing power parity, exchange rate, structural break, international trade.

**JEL Classification:** F31.

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## Introduction:

Regarding determination of the exchange rate of the two countries' currencies, the theory refers to the equilibrium rate as determined by the demand and supply of one country's currency relative to the other. However, in contrast to the theory, determining the factors that affect demand and supply of a currency is clearly subject to some challenges. Knowledge on these factors helps to understand future movements of exchange rate, which enable us to benefit from the export opportunities, foreign investments and trade, price competitiveness of foreign goods. Lothian and McCarthy (2001) find that purchasing power parity (PPP[2]) provides a good description of actual exchange rate behavior over a long run period. Furthermore, Hakkio finds that PPP explains the US Dollar's value in the market.

However, PPP validity has long been debated on the ground that empirical studies find mixed results. Some of the previous studies such as Kurihara (2009) use nonlinear unit root tests and find support for PPP for the EU countries. Meanwhile, some studies, such as, Ocal (2013) uses Zivot-Andrews unit root approach and find no evidence of PPP in Romania. According to Caglayan and Sacild (2010), unit root test such as KPSS test provides some evidence in favor of PPP for most of the OECD countries, compared to ADF and PP tests. Such deviations in results of the PPP studies are due to mainly different measurements scales used for price levels (see Terra and Abreau (2005), transportation costs, and trade restrictions (Kurihara (2009) between countries, data intervals (yearly, monthly), traditional unit root approaches.

One of the recent studies on Bangladesh has been carried out by Zaman et al (1999), Ahmed (2005), Anwar & Ahmed (2006), Hoque & Banarjee (2012, 2014), Chowdhury. This study is complementary to existing studies in the Bangladesh context with a wider range ofeconometric tools applied to probe the validity of purchasing power parity.

PPP is based on the law of one price and implies that exchange rates should equalize with the national price levels of different countries in terms of a common currency. Validity of PPP, is significant to policymakers for two reasons. First, PPP can be used to forecast exchange rate to conclude whether a currency is overvalued or undervalued. This is important for developing countries, along with countries experiencing large differences between domestic and foreign inflation rates. Second, PPP is used as the foundation for

[2] PPP is abbreviation of Purchasing power parity. PPP will be used in place of full form in this paper.

numerous theories of exchange rate determination. Therefore, the validity is important to those policymakers in developing countries who base their adjustment of exchange rate determination on the concept of PPP (Chang et al., 2010). Furthermore, estimates of PPP exchange rates are important for some practical purposes, including measuring nominal exchange rate misalignment, determining exchange rate parities, and comparing the national incomes of different countries.

Monetary authority controls interest rate, and money supply to stabilize inflation, increase output, and economic growth. Along with this, monetary authority also looks for stabilized currency, often intervenes the currency market, which is also known as managed floating.Bangladesh has adopted floating exchange rate regime since 2003, by abandoning adjustable peg system, so that market forces (supply and demand) determine the exchange rate. Exchange rate regimes affect both price levels and PPP. Under fixed exchange rate regime, the inflation rate of the foreign country to which local currency is pegged has direct effect on the local economy. Meanwhile, in a floating exchange rate regime, inflation is effected by the exchange rate fluctuations.

This paper focuses on exchange rate of Bangladesh Taka (BDT) to US Dollar (USD), because United States of America is a major trading partner of Bangladesh. According to USTR (United States Trade Representative), U.S.A. exports to Bangladesh in 2013 were $712 million, up 41.9% from 2012. Main items of exports were Machineries, Cotton, Yarn, and Fabrics, Electrical Machineries, Iron, and Steel, agricultural products. Meanwhile, U.S.A imports from Bangladesh totaled $5.4 billion in 2013, a 9.0% increase from 2012. Main categories were Woven Apparel, Knit Apparel, Miscellaneous Textile Products, Fish, Seafood (Shrimp and Prawn) and Tobacco. Apart from trade relationship, Bangladeshi migrants in U.S.A send remittances amounting over $2 billion, in fiscal year of 2013-14, chasing top remittance sending destination of Saudi Arabia and U.A.E (source: Bangladesh Bank, Statistical Table). Furthermore, US FDI (U.S. foreign direct investment in Bangladesh (stock) was $368 million in 2012, source: USTR) stimulated local production and employment. Bangladeshi people buy retail goods and services (including educational expenses) in USD. Considering, this facts, the impact of USD in the economy of Bangladesh is enormous.

Despite different methods applied to check the validity, the central idea is to test whether the behavior of real exchange rate is random walk (mean reverting) in the long run. Nominal exchange rate of Bangladeshi Taka against USD was on average of 77.72 in 2013-14 with an appreciation in value of 2.8% from 2012-12 (the rate was 79.93) (source:

Bangladesh Bank, Statistical Table). If exchange rate follows random walk, then the exchange rate in 2016 is not predictable. By random walk, it is understood that future forecast is independent of the past movements. As a result, the future exchange rate is not predictable. Meanwhile, mean reversion is the tendency of the exchange rate moves towards long term average rate. Any deviations will revert to the mean in the long run; any shock is not permanent and dies out in the long run. The paper aims to examine whether real exchange rate of Bangladeshi currency i.e. Taka is random walk and mean reverting in the long run. In addition, co-integration techniques has been employed to examine some equilibrium results at least in the long run, structural break, and non-linearity test to check the robustness of the model also applied.

## Objective of the Study:

International finance theory reflects two puzzles (Rogoff,1996 ) about PPP validity; there is no consensus on obtaining similar conclusions about PPP in the long run (the first puzzle), and the real exchange rate has a higher volatility in the short term compared with a slower mean reversion in the long run (the second puzzle) (Nicholae Ghiba,2011).

- In this respect, the specific of objectives of the study are:
- To solve the first PPP puzzle, that is the PPP is valid in the long run. In that case, both absolute and relative PPP to be examined.

To solve the second PPP puzzle. Use the modern econometric tool to test the empirical behavior of the exchange rate, including mean reverting behavior to reach long run equilibrium.

There is always some short run fluctuation in the exchange rate, which is difficult to forecast. This study does not focus on such fluctuations in exchange rate. The investor's psychology effected by many factors such as political conditions, form expectation on future exchange rate movements. In addition, Bandwagon effect, herd of investors moving in the same directions, can cause short run fluctuations. This have no link with macroeconomics, rather linked with microeconomic aspects such as investment in individual firms.

## The Theory:

According to the theory of Purchasing Power Parity (Cassel, 1918), in the absence of transaction cost and export barriers, identical goods will have the same price in different

markets when the prices are expressed in the same currency. This can be expressed as below:

$$E\left(\frac{BDT}{Us\$}\right) = P_{BD}/p_{Us} \quad (1)$$

The absolute version of the theory asserts that under these conditions, the same basket of goods and services should cost the same when expressed in terms of the same currency. Relative version of the theory asserts that the percentage change in the exchange rate between the two countries should be equal in percentage change in the national price level.

$$E = c(\frac{p}{p*}) \quad (2)$$

Absolute PPP is as follows:

$$\ln E = C + \ln P - \ln P^* \quad (3)$$

Relative PPP is as follows:

$$\Delta \ln E = \Delta \ln p - \Delta \ln p^* \quad (4)$$

According to The law of one price (LOOP), identical goods sold atthe same price in different countries if expressed in the same currency.Due to arbitrage, price differencesfor tradable goods result in international trade, until any such price differences exist, eventually dies out and equilibrium is reached at least in the long run. Based on holding of LOOP for individual commodity, PPP holds true automatically. Since the reference basket is different across countries, while considering PPP holding is true. As a result, for PPP validity, LOOP does not require to hold.

## Few Previous Literatures:

Tons of previous literatures (See for example Papell & Prodan; Chortareas & Kapetanios, 2008; Pelagatti& Colombo) can be found on the empirical test of PPP hypotheses. We can find that many studieshave attempted to test the stationary or random walktest to verify the holding of PPP theory. The empirical validation of the purchasing power parity (PPP) theory is generally based on real exchange rates using consumer price indexes (CPI). The empirical evidence fails to provide clear support to the theory, resulting in the purchasing power parity puzzle. Even if the law of one price holds for all the goods traded in two countries, real exchange rates based on CPI are not mean-reverting, and therefore, statistical tests based on them should reject the PPP hypothesis. Meanwhile, test for the consistency of the PPP hypothesis in emerging economies is an obstacle mainly due to the frequent variation in the exchange rate arrangement, which results in long periods of fixed

exchange rates. Furthermore, the same specification of the PPP hypothesis is not applicable to countries adopting different exchange rate regime. However, PPP validity tests are successful for hyperinflation economies and panel data setting.However, Ikhifa-Aigbokhan (2015) find that PPP is not valid in both hyperinflation and low inflation countries.

Many previous studies using different time series and econometric techniques, found mixed results. Although numerous studies support the existence of PPP, some of them find very little or no evidence for PPP. One explanation for this unexpected result is the use of a small data set with standard unit root tests. There is no consensus on appropriate unit root testing procedure (John et al). In the current literatures, long run PPP has been tested in most cases, and has supportedthe use of unit root test such as ADF, DF-GLS, and PP (Ghiba, 2011). Meanwhile, Yin Wong Cheung et al find that modified Dicky Fuller test exhibits better result for the PPP support. Ng and Perron (Econometrica, 2001), find better result than ADF tests due to its power and size problems.

Conversely, conventional univariate unit root tests fail to support PPP (Alba and Park). They also find evidence of non-linear mean reversion in real exchange rates. This implies that PPP holds in one threshold regime but not in any other situation.Pelagatti and Colombo prove that such real exchange rates are neither stationary nor integrated, and so both unit-root and stationarity tests should reject the null hypothesis according to their power properties. Sarno and Valente provide strong evidence that long-run PPP is valid.

There are many papers that look into stationarity of real exchange rate of Bangladesh. For example Zaman et al (1999), by using the co-integration technique, assures a long term relationship among PPP and exchange rate. Ahmed (2005) findssome empirical support only for the relative version of PPP as a theory of price determination in Pakistan. His paper also discusses potential reasons for empirical failure of PPP in developing countries. Anwar & Ahmed (2006) use Engle-Granger co-integrating relationship, on a data set of 1984 to 2002 of India, Pakistan, Bangladesh, Sri Lanka. They find that PPP holds in weaker form with respect to Pakistan, India, and Sri Lanka; meanwhile they find strong indication of lack of PPP for Bangladesh. However, Hoque & Banarjee(2012) use unit root tests with structural change for the same four countries on a 55 year data set, find that real exchange rate is not constant and no support for PPP to hold in the long run. Chowdhury applies nonlinear econometric technique on data from 1994 to 2002 in the Bangladesh context, finds strong evidence for highly nonlinear mean reversion towards a stable long run equilibrium.

There are some non-conventional approaches to measure PPP validity. Coe and Serletis (2002), use bounds testing approach, and find long run relationship without the assumption of stationarity and conintegration. Aylar (2013) adopts bootstrap stationary test, which provides high power and controlling size, finds less evidence on PPP than other asymptotic tests. Kasmanetalin the EU context employs Lagrange Multiplier based unit root test with structural breaks and fail to support PPP. Pittis et al (2008) show that when robust procedures are applied, the evidence favors the PPP hypothesis.

## Methodology:

In order to investigate the validity of PPP, unit root testing has become a very popular approach. If the real exchange rate includes a unit root, the shocks should have permanent effects and the variable will never return to its long run equilibrium. On the other hand, if the real exchange rate is stationary, shocks tend to die out in the long run and the equilibrium is achieved some time after the shock has occurred (Cuestas and Regis, 2008). Previous studies also examine existence of co-integrating relationships among price levels and exchange rate series. If there any co-integrating relationships exists, then VECM model is applied to see the short run and long run adjustments. Meanwhile, issues such as non-linearity, structural breaks, stability to regime changes and macroeconomic shocks attract the attention to find the stylized facts of the exchange rate behavior and to minimize forecasting errors.

## The Model:

The relationship between the nominal and real exchange rates and their relationship with the concept ofpurchasing power parity can be understood from the following equation:

$$q_t = e_t - p_{BD,t} + p_{FOR,t} \quad (5)$$

Where $q_t$ is the log real exchange rate, $e_t$ is the log nominal exchange rate that is the domestic currency price of a unit of the foreign currency, and $P_{BD,\,t}$ and $P_{FOR,\,t}$ is the log Bangladesh and foreign price levels, respectively. If purchasing power parity holds perfectly, t would be equal to a constant, call it q, and we can rewrite (1) as

$$P_{FOR,t}) + e_t = q_t + P_{BD,t} \quad (6)$$

## Absolute and Relative PPP test:

An empirical test includes the examination of the following relationship

for absolute PPP test:

Nominal Exchange Rate $t = \beta_0 + \beta_1 P t + \beta_2 P t * + u t$ (7)

For relative PPP test, examines the following relationships

$\Delta$Nominal exchange rate $t = \beta_0 + \beta_1 \Delta p_t + \beta_2 \Delta p_t^* + ut$ (8)

Coefficient restrictions are imposed as, $\beta_1=1$, $\beta_2= -1$, $\beta_o$ .For absolute PPP test , $\beta_1=0$ , $\beta_2=1$ , with price level used , whereas for relative version , $\beta_2=1$ is enough with price indices used.

## Unit root test:

Although there is no relationship between the two series, the regression results may suggest that there is a strong relationship. The R-square provides misleading results for time series with trends, also known as unit root processes or I(1). Such regression results are called spurious regression.

We assume that real exchange rate qt is a time series with intercept and trend

$$qt = \rho q_{t-1} + \alpha + \beta t + \varepsilon t$$

By subtracting $q_{t-1}$ from both sides, we get:

$$\Delta qt = (\rho - 1) q_{t-1} + \alpha + \beta t + \varepsilon t \quad (9)$$

In the above equation of *p* =1, then we conclude that there is unit root in the times series of real exchange rate and thus non stationary.

Testing real exchange rate stationarity through the augmented Dickey Fuller unit root test, entails three assumptions: the intercept presence, the presence of an intercept, and a time trend, and finally, the absence any deterministic element. For each supposition, we construct three different relationships:

A. Both a drift and a linear time trend

$$\Delta qt = \alpha_0 + \gamma q_{t-1} + \alpha_1 t + \varepsilon t \quad (10)$$

B. Random walk with a drift

$$\Delta qt = \alpha_0 + \gamma q_{t-1} + \varepsilon t \quad (11)$$

C. Pure random walk

$$\Delta qt = \gamma q_{t-1} + \varepsilon t \quad (12)$$

If $\gamma$ equals zero, than the real exchange rate sequence contains a unit root (the series is nonstationary).

## Co-integration:

The concept of Co-integration has been widely applied in time series analysis as time series often have either deterministic or stochastic trends. Granger and Newbold (1974) suggest the idea for co-integration between two or more I(1) series. For example, time series $y_{1,t}$ and y2,t are I(1). I(1) variables tend to diverge as t?? because their unconditional variances are proportional to t. Thus I(1) can never be expected to obey any sort of the long run equilibrium relationship. The two series with I(1) trends can be co-integrated only if there is a genuine relationship between the two, as a result there exists a co-integrating vector of coefficients , which form linear combination of variables which is I(0) or stationary. Engle and Granger (1987), followed by Johansen (1988), Johansen and Juselius (1992) use co-integration to find relationship among variables.

Purchasing power parity (PPP) implies co-integration between the nominal exchange rate and foreign and domestic prices. Price levels to be co-integrated, it is required that each price series is integrated of the same order. To demonstrate this, we have conducted augmented Dickey-Fuller and DF-GLS test. For example, the Fisher equation implies co-integration between nominal interest rates and inflation.Engle and Granger (1987) test the cointegration between a set of integrated variables of the first order: l (1). If $e_t$, $p_t$* and $P_t$refers to natural logarithms of real exchange rate, foreign price level and domestic price level respectively. Long run PPP requires that $e_t + p_t$*-$P_t$be stationary. According to Engle and Granger, if the pt and pt* are cointegrated, PPP holds in the long-run under the following conditions (Enders, 2009).

- $e t + p t^* = \beta 0 + \beta 1 p t + \mu$ between of the form exists a linear combination.
- Residua ls ($u_t$) are stationary.
- Variables have the same integration order.

## Stability Test:

OLS based inferences are biased if time series data are non-stationary (includes unit root). If there is a structural break (one or more) in times series, which reduce the ability to reject a false unit root null hypotheses. As a result, existence of structural break results in biased estimation. Though ADF (1979, 1981) is widely used to check existence of stationarity, Perron (1988, 1994, 1997, 2005), Zivot Andrews (1992) address the issue of structural break in stationarity checking process. Bai-perron (1997, 2003a) implement regression with multiple breaks. Meanwhile, CUSUM (Page, 1954) is used to monitor change detection.

## VAR and VECM:

A VAR(1) in two variables (domestics and foreign price level) can be written in matrix form as:

$$\begin{bmatrix} p1,t \\ p2,t \end{bmatrix} = \begin{bmatrix} c1 \\ c2 \end{bmatrix} + \begin{bmatrix} A1,1 & A1,2 \\ A2,1 & A2,2 \end{bmatrix} \begin{bmatrix} p1,t-1 \\ p2,t-1 \end{bmatrix} + \begin{bmatrix} e1,t \\ e2,t \end{bmatrix} \quad (13)$$

Equivalently, as the following system of two equations

p1,t=C1+A1,1 p1,t-1+A1,2 p2,t-1+e1,t

p2,t=C2+A2,1 p1t-1+A2,2P2,t-1+e2,t

For applying VAR, all variables need to be of the same order of integration (I(0) or stationary). If variables are non-stationary, they should be co-integrated. In that case, the error correction term is added in the VAR. The model becomes a Vector Error Correction Model (VECM) which can be interpreted as a restricted VAR.

Bivariate VEC , with one lagged difference can be written as :

$$\Delta p,1t = C1 + A1,1\Delta p1,t-1 + A1,2\Delta p2,t-1 + \gamma\,(p1,t-1-\alpha 0-\alpha 1\,p2,t-1) + e1,t \quad (14)$$

$$\Delta p,2t = C2 + A2,1\Delta p1,t-1 + A2,2\Delta p2,t-1 + \gamma\,(p2,t-1-\alpha 0-\alpha 1\,p2,t-1) + e1,t \quad (15)$$

## Impulse Response Function:

Impulse response is reaction of a dynamic system to an external change. We have applied impulse response function for examining regime change or any other shocks on PPP.

## Data:

The frequency and measurement type of price levels used in the study of PPP validity and its impact results. In measuring price levels, a number of yardsticks are available. Consumer Price Index (CPI) includes consumer goods (larger portion of urban consumer goods), used to calculate inflation and represents living standards, being published monthly. The disadvantage is that there are some non- tradable items included in CPI, with variations in baskets of goods among countries. Wholesale Price Index represents wide ranges of tradable items consumed by mainly industrial units, with an advantage of being published weekly. Meanwhile, GDP deflator includes no tradable items. Export value index may include larger portion of tradable items that may not match between two countries. In addition, Big Mac index may represent set (basket) of goods, which may match most among countries. The consideration of base year does not possess any significance in price level measurements.

For testing PPP, we need frequent data (such as daily, weekly) for price levels to cope with high frequency data of exchange rate. For robust results, common basket of goods considered in calculation of price levels matter as well, even better would be to include the most tradable items. Considering this, the paper uses CPI as measurements of price levels on yearly basis (base year 2010=100) from 1986 to 2014, 28 years, collected from the World Bank database. The US CPI for monthly basis has been collected from the U.S. Department of Labor Statistics and Bangladesh CPI from the Bangladesh Bank and Bureau of Statistics, (from January , 2007-June 2013, months), here ( US base = 1982, BD old base=1995, new base= 2005). Due to inaccessibility to the monthly data prior to 2007 in the case of Bangladesh, the paper does not study the case of pre and post regime change period for monthly data series. The data are collected from the World Bank database, Bangladesh Bank database (BD CPI and Exchange rate), Bangladesh Bureau of Statistics (BD CPI monthly) and US Bureau of Labor statistics (US CPI monthly).

## Empirical Results:

**Insert table1 here**

The descriptive statistics table shows data series are normal (insignificant Jarque Bera statistics), except for Bangladeshi CPI (monthly) data. The standard deviation is high for the yearly data set, comparing to that of the monthly set. Both skewness and kurtosis are positive for all series. Figures 1 and 2 present both monthly and yearly data of real and nominal exchange rates. For both the data series, there are deviations between real and nominal exchange rate. For monthly data series, in 2012, both real and nominal exchange rate intersects. However, for yearly data series, the intersection point is 2011.

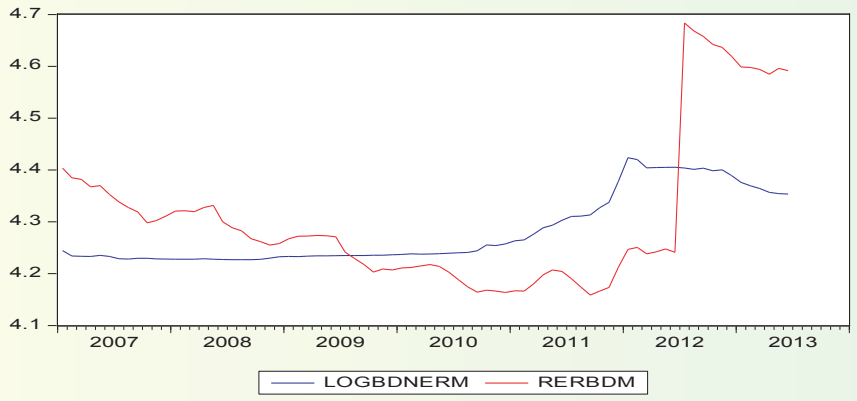



**Figure-1: Monthly nominal and real exchange rate**

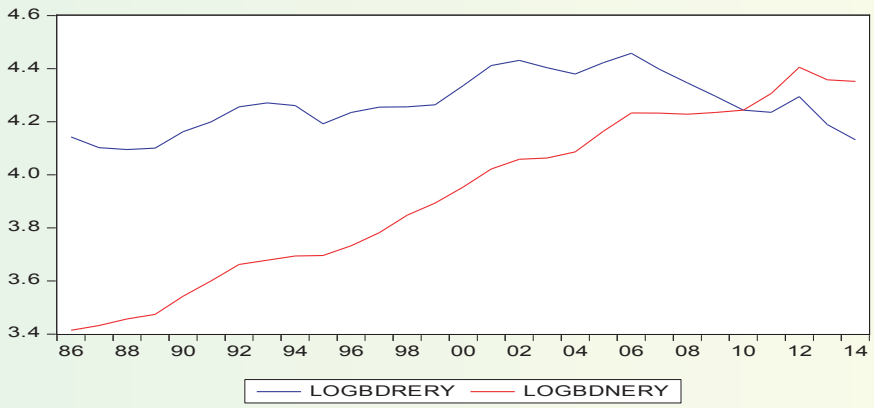


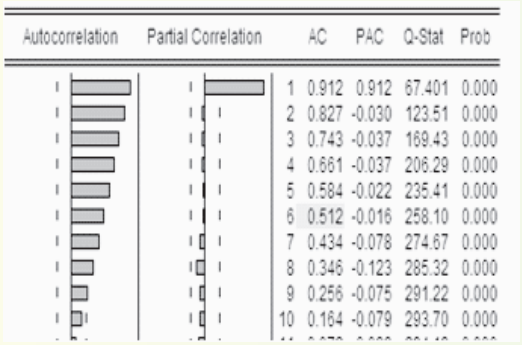

**Figure-2: Yearly nominal and real exchange rate**

**Insert table 2 here**

This paper usesADF, DF-GLS and Zivot-Andrews test (considers structural breaks) to identify order of integration of the data series. Unit root tests are conducted on both levelsand in 1st differences of data series. All the data series, nominal exchange rate, real exchange rate, Bangladeshi CPI, and the US CPI are integrated to order one ( I (1) series). For monthly data series, Zivot-Andrews test reveals that all the series contains structural break and hence I(0) (Stationary at the level). For yearly data series, due singular matrix, results cannot be derived for Zivot-Andrews test.

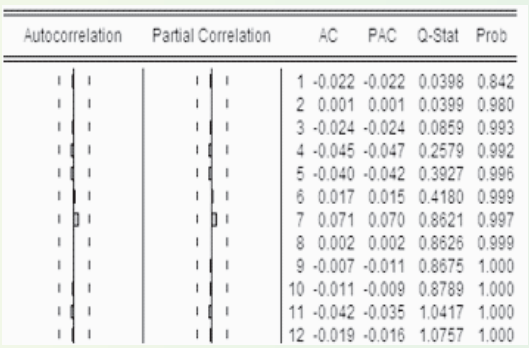
Figures 3 and 4 represent Autocorrelation and Partial Autocorrelation Function for the monthly data series of real exchange rate both in levels and in 1st differences respectively. It shows that real exchange rate is non-stationary. Meanwhile, for the yearly data series (figure 5 and 6), both Autocorrelation and Partial Autocorrelation Functions results are the same, the real exchange rate is non-stationary.

Figures 7-10 represent structural break test (by using CUSUM test), for both monthly and yearly data series, while estimating both absolute and relative PPP. It shows that for the monthly data series, there is structural break. However, for the yearly data, there is no structural break. Due to the existence of structural break in the monthly data series, estimation of absolute and relative PPP is not accurate.



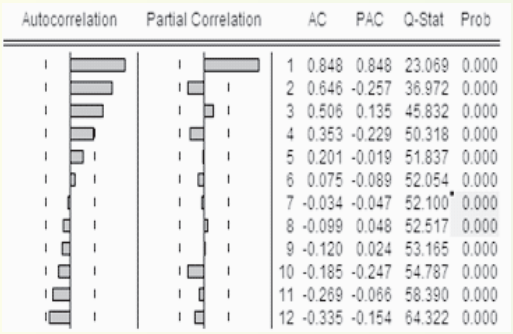
| Autocorrelation | Partial Correlation | | AC | PAC | Q-Stat | Prob |
|---|---|---|---|---|---|---|
| | | 1 | 0.912 | 0.912 | 67.401 | 0.000 |
| | | 2 | 0.827 | -0.030 | 123.51 | 0.000 |
| | | 3 | 0.743 | -0.037 | 169.43 | 0.000 |
| | | 4 | 0.661 | -0.037 | 206.29 | 0.000 |
| | | 5 | 0.584 | -0.022 | 235.41 | 0.000 |
| | | 6 | 0.512 | -0.016 | 258.10 | 0.000 |
| | | 7 | 0.434 | -0.078 | 274.67 | 0.000 |
| | | 8 | 0.346 | -0.123 | 285.32 | 0.000 |
| | | 9 | 0.256 | -0.075 | 291.22 | 0.000 |
| | | 10 | 0.164 | -0.079 | 293.70 | 0.000 |

**Figure-3 : Autocorrelation and Partial Autocorrelation Function (monthly level data)**



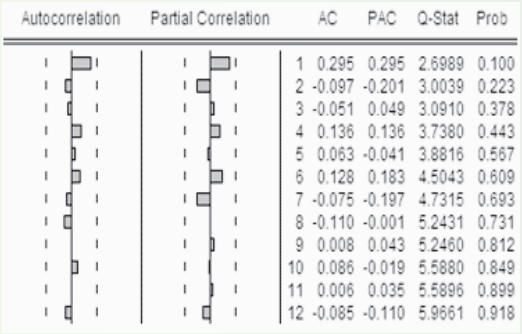
| Autocorrelation | Partial Correlation | | AC | PAC | Q-Stat | Prob |
|---|---|---|---|---|---|---|
| | | 1 | -0.022 | -0.022 | 0.0398 | 0.842 |
| | | 2 | 0.001 | 0.001 | 0.0399 | 0.980 |
| | | 3 | -0.024 | -0.024 | 0.0859 | 0.993 |
| | | 4 | -0.045 | -0.047 | 0.2579 | 0.992 |
| | | 5 | -0.040 | -0.042 | 0.3927 | 0.996 |
| | | 6 | 0.017 | 0.015 | 0.4180 | 0.999 |
| | | 7 | 0.071 | 0.070 | 0.8621 | 0.997 |
| | | 8 | 0.002 | 0.002 | 0.8626 | 0.999 |
| | | 9 | -0.007 | -0.011 | 0.8675 | 1.000 |
| | | 10 | -0.011 | -0.009 | 0.8789 | 1.000 |
| | | 11 | -0.042 | -0.035 | 1.0417 | 1.000 |
| | | 12 | -0.019 | -0.016 | 1.0757 | 1.000 |

**Figure-4: Autocorrelation and Partial Autocorrelation Function (monthly 1st difference data**



| Autocorrelation | Partial Correlation | | AC | PAC | Q-Stat | Prob |
|---|---|---|---|---|---|---|
| | | 1 | 0.848 | 0.848 | 23.069 | 0.000 |
| | | 2 | 0.646 | -0.257 | 36.972 | 0.000 |
| | | 3 | 0.506 | 0.135 | 45.832 | 0.000 |
| | | 4 | 0.353 | -0.229 | 50.318 | 0.000 |
| | | 5 | 0.201 | -0.019 | 51.837 | 0.000 |
| | | 6 | 0.075 | -0.089 | 52.054 | 0.000 |
| | | 7 | -0.034 | -0.047 | 52.100 | 0.000 |
| | | 8 | -0.099 | 0.048 | 52.517 | 0.000 |
| | | 9 | -0.120 | 0.024 | 53.165 | 0.000 |
| | | 10 | -0.185 | -0.247 | 54.787 | 0.000 |
| | | 11 | -0.269 | -0.066 | 58.390 | 0.000 |
| | | 12 | -0.335 | -0.154 | 64.322 | 0.000 |

**Figure-5: Autocorrelation and Partial Autocorrelation Function (yearly level data)**



| Autocorrelation | Partial Correlation | | AC | PAC | Q-Stat | Prob |
|---|---|---|---|---|---|---|
| | | 1 | 0.295 | 0.295 | 2.6989 | 0.100 |
| | | 2 | -0.097 | -0.201 | 3.0039 | 0.223 |
| | | 3 | -0.051 | 0.049 | 3.0910 | 0.378 |
| | | 4 | 0.136 | 0.136 | 3.7380 | 0.443 |
| | | 5 | 0.063 | -0.041 | 3.8816 | 0.567 |
| | | 6 | 0.128 | 0.183 | 4.5043 | 0.609 |
| | | 7 | -0.075 | -0.197 | 4.7315 | 0.693 |
| | | 8 | -0.110 | -0.001 | 5.2431 | 0.731 |
| | | 9 | 0.008 | 0.043 | 5.2460 | 0.812 |
| | | 10 | 0.086 | -0.019 | 5.5880 | 0.849 |
| | | 11 | 0.006 | 0.035 | 5.5896 | 0.899 |
| | | 12 | -0.085 | -0.110 | 5.9661 | 0.918 |

**Figure-6: Autocorrelation and Partial Autocorrelation Function (yearly 1st difference data)**

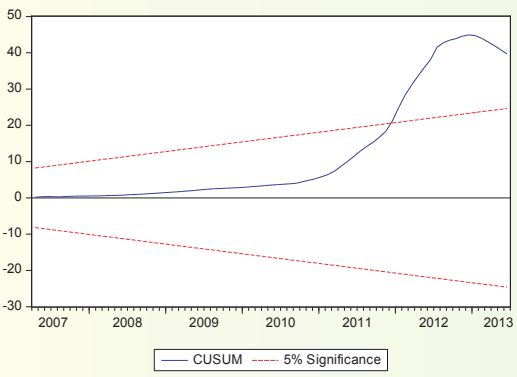



**Figure-7 : CUSUM test (structural break test for absolute PPP, monthly data )**

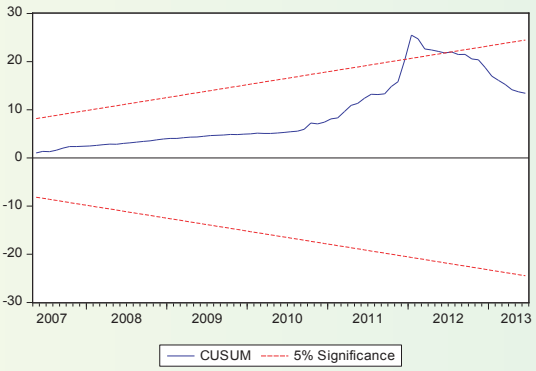



**Figure-8 : CUSUM test (structural break test for relative PPP, monthly data)**

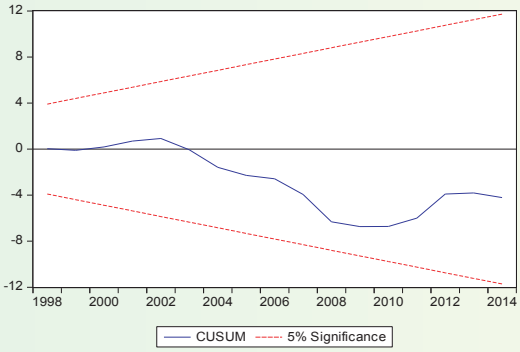



**Figure-9 : CUSUM test (structural break test for absolute PPP, yearly data)**

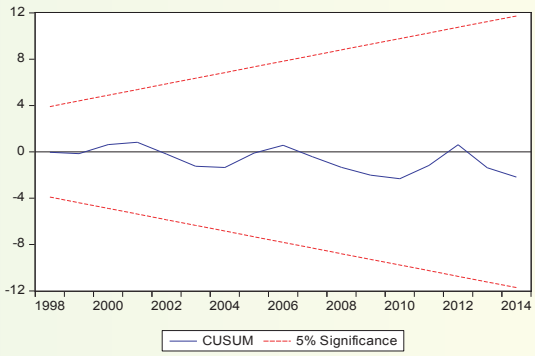



**Figure-10 : CUSUM test (structural break test forrelative PPP, yearly data)**

## Insert Table 3 here

Both absolute and relative PPP are supported by joint coefficient test and individual coefficient test. There is the evidence of structural break forthe monthly data series (for both absolute and relative PPP). Besides, there is one (01) cointegrating equation for only the monthly data series, using Johansen test.

## Insert Table 4 here

According to Johansen test, BD CPI (monthly) adjusts 65% in the short run, whereas USCPI and nominal exchange rate adjust 0.78% and 0.65% respectively.

### Insert Table 5 here

Table 5 presents the results of vector error correction model, Quandt Andrews test (structural break test), Johansen test (cointegration test), Bai-Perron test (estimation with structural break. Due to one (01) cointegrating equation, VECM can only be applied to the monthly data series. Estimation of PPP with Bai-Perron (if there is structural break) is possible with monthly data.

Figure 11 presents impulse response functions. Here, Cholesky type restrictions are imposed. Nominal exchange rate responses positively to a unit shock in Bangladeshi CPI, with neutral response to USCPI. Meanwhile, Bangladeshi CPI responses positively to a unit shock in nominal exchange rate, which dies away over time. However, such responses to the US CPI are upward and stable for Bangladeshi CPI. On the other hand, theUS CPI responses positively to nominal exchange rate and negatively to the Bangladesh CPI shocks respectively.

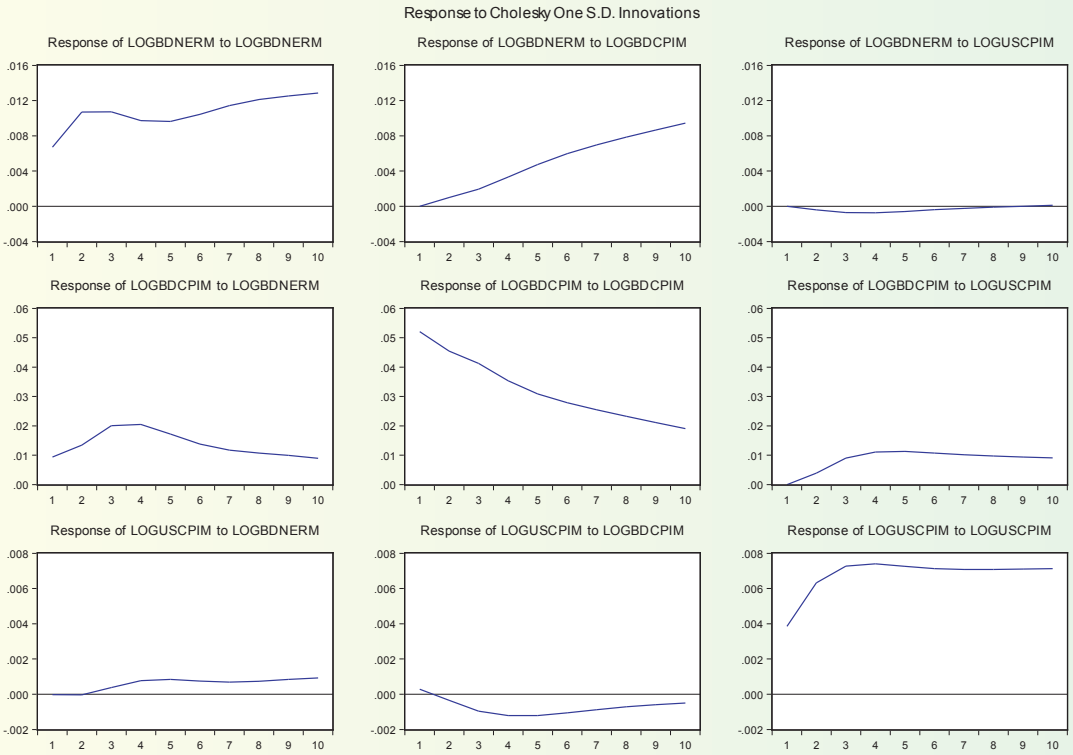



**Figure-11: Impulse response functions for monthly data (after applying VECM.**
**Insert Table 6 here**

Table 6 represents result of VECM for nominal exchange rate. Result shows that cointegrating equation is significant, which is known as error correction term, represents deviations from long run equilibrium are corrected gradually through short run adjustments.

## Conclusions

In this paper, we examined the validity of PPP in the Bangladesh-USA context, using monthly data (01/2007-06/2013) and annual data (1986-2014). Despite evidence of PPP validity (in absolute and relative terms) found for both data sets, there are structural breaks with the monthly data, producing doubt about the inferences. As real exchange rate is integrated of order one, on the basis of unit root tests and autocorrelation function, it is a random walk and not mean reverting in the long run. Meanwhile, cointegration and VAR framework provide long term equilibrium results for only the monthly data set. VECM results suggest significant short term adjustments to correct long term deviations. These results are important to forecast exchange rate and adjust any deviations between nominal and real exchange rates between the currencies in question.

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## Appendices

**Table 1–Descriptive Statistics**

| | Yearly data 1986-2014 | | | Monthly data 01/2007-06/2013 | | |
|---|---|---|---|---|---|---|
| | BDNERY | BDCPIY | USCPIY | BDNERM | BDCPIM | USCPIM |
| Mean | 53.16 | 62.26 | 79.74 | 72.52 | 215.41 | 219.37 |
| Median | 52.14 | 53.90 | 78.97 | 69.29 | 207.64 | 218.25 |
| Maximum | 81.86 | 135.28 | 108.56 | 83.41 | 270.81 | 233.50 |
| Minimum | 30.40 | 24.28 | 50.26 | 68.52 | 172.65 | 202.40 |
| Std. Dev. | 16.34 | 31.76 | 17.67 | 5.04 | 30.03 | 8.21 |
| Skewness | 0.16 | 0.85 | 0.02 | 0.97 | 0.45 | 0.04 |
| Kurtosis | 1.66 | 2.64 | 1.84 | 2.31 | 2.01 | 1.98 |
| Jarque-Bera | 2.27 | 3.66 | 1.60 | 13.99 | 5.88 | 3.38 |
| Probability | 0.31 | 0.16 | 0.44 | 0.00 | 0.052 | 0.18 |

Note: For yearly data, there are 29 observations. For monthly data, there are 78 observations

**Table 2 –Unit root tests**

| | | ADF | DF -GLS | Zivot - Andrews (with structural change) |
|---|---|---|---|---|
| yt | NomEx (Y) | A.-1.61<br>B.-.97<br>C. 3.09 | A. -1.44<br>B. -.34 | |
| | RealEx (Y) | A.-.38<br>B.-1.05<br>C. -.56 | A. -1.26<br>B. -.71 | |
| | BDCPI (Y) | A.-.68<br>B.1.48<br>C. 12.39 | A. -1.22<br>B. -.46 | |
| | USCPI (Y) | A.-1.50<br>B.-1.18<br>C. 10.84 | A. -1.82<br>B. -.24<br>C | |
| | Nom Ex (M) | A. -2.07<br>B.-1.17<br>C. .64 | A. -1.81<br>B. -1.01 | A. -3.37<br>B. -3.5* |
| | Real Ex (M) | A.-1.49<br>B.-1.02<br>C. .37 | A. -1.26<br>B. -1.10 | A.-5.34*<br>B. -6.49* |
| | BDCPI (M) | A.-1.41<br>B.-1.82<br>C.-.13 | A. -1.40<br>B. -1.29 | A. -6.30*<br>B.-7.36* |
| | USCPI(M) | A.-3.75*<br>B.-.76<br>C. 1.85 | A. -3.31*<br>B. .83 | A.-7.14*<br>B.-5.70* |

| | | | | |
|---|---|---|---|---|
| $\Delta yt$ | NomEx (Y) | A. -4.02*<br>B.-4.08<br>C.-.54 | A.-4.23*<br>B.-4.17* | |
| | RealEx (Y) | A. -3.57*<br>B. - 3.18*<br>C.-3.22* | A. -3.80*<br>B.-3.27* | |
| | BDCPI (Y) | A. -3.64*<br>B. -3.35*<br>C.-.04 | A.-3.83*<br>B.-1.92 | |
| | USCPI (Y) | A. -4.02*<br>B. -3.95*<br>C. -.82 | A.-4.33*<br>B.-4.02* | |
| | NomEx (M) | A. -2.45<br>B.-2.55<br>C.-2.44* | A.-2.11<br>B.-1.54 | A.-3.37*<br>B.-3.50* |
| | RealEx (M) | A.-8.98*<br>B.-8.80*<br>C.-8.83* | A.-9.08*<br>B.-8.39* | A.-5.34*<br>B.-6.49* |
| | BDCPI (M) | A.-8.96*<br>B.-8.80*<br>C.-8.86* | A.-9.07*<br>B.-8.67* | A.-6.30*<br>B.-7.36* |
| | USCPI(M) | A.-4.97*<br>B.-5.03*<br>C. -4.61* | A.-4.79*<br>B.-4.26* | A.-7.14*<br>B.-5.70* |

Note: * indicates 5% significance level. AIC applied to find the lag. T-stat is given. For applying DF-GLS, with trend and drift, test statistics are calculated for 50 observations and may not be accurate for a sample of 20. A B C refers to model with (drift, linear trend) and (drift) and pure random walk model. For yearly data, Zivot-Andrews test could not be conducted due to singular matrix issue.

## Table3-Absolute and Relative PPP tests

| | Full period (1986-2014, yearly ) | (01/2007-06/2013, monthly) | PPP support | Structural change | Co-integrating Eqn. (long term relation) |
|---|---|---|---|---|---|
| **Equation test** $NER_t = \beta_0 + \beta_1 P_t + \beta_2 P_t^* + u_t$ | | | | For Monthly data ,there is structural change | Yes for monthly data only |
| **Combined restricted test** $\beta_0=0$ , $\beta_1=1$, $\beta_2=-1$ | | | | | |
| Absolute ppp | F= 84500* | F=378404* | Yes | | |
| Relative ppp | F= 12.63* | F=929* | Yes | | |
| **Individual restricted test** $\beta_0=0$ , $\beta_1=1$, $\beta_2=-1$ | | | | | |
| Absolute ppp | F ($\beta_1=1$)=83* F ($\beta_2=-1$)=102* | F ($\beta_1=1$)=1100* F ($\beta_2=-1$)=501* | Yes | | |
| Relative ppp | F ($\beta_1=1$)= 28* F ($\beta_2=-1$)=11* | F ($\beta_1=1$)=2766* F ($\beta_2=-1$)=16* | Yes | | |

Note: * refers 1% significance level. ** refers 5% significance level. F stat are round ed up.

## Table 4- Adjustment coefficients (Johansen test)

| Adjustment coefficients (standard error in parentheses) | |
|---|---|
| D(LOGBDCPIM) | -0.65 (0.073) |
| D(LOGUSCPIM) | -0.0052 (0.0078) |
| D(LOGBDNERM) | 0.0065 (0.013) |

**Table 5- VEC, Quandt Andrews test, Bai-Perron**

| | VECM | Cointegration Test Johansen test | Quandt Andrews structural break test | Bai –Perron Structural change estimation |
|---|---|---|---|---|
| Yearly data (1986 - 2014) | VECM can not be applied as no Co - integrating Eqn. | No cointegrating equation | Singular matrix issue | Not applicable due to singular matrix issue |
| Monthly (01/2007 - 06/2013) | VECM can be applied as CI exists | Eigen value=.11 Test statistics=9.41 * | Wald F= 234* For relative version Wald F= 10* | Applicable |

**Table 6- VECM model for nominal exchange rate**

D(LOGBDNERM) = C(1)* (LOGBDNERM (-1) + 2.77* LOGBDCPIM (-1) - 2.40 *LOGUSCPIM (- 1) - 6.23 ) + C(2)*D (LOGBDNERM (-1)) + C(3)*D(LOGBDNERM( -2)) + C(4)*D(LOGBDCPIM( -1)) + C(5)*D(LOGBDCPIM ( -2)) + C(6)*D(LOGUSCPIM(-1)) + C(7)*D(LOGUSCPIM( -2)) + C(8)

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(1) * | 0.008859 | 0.002718 | 3.259533 | 0.0018 |
| C(2) * | 0.556705 | 0.114707 | 4.853277 | 0.0000 |
| C(3) * | -0.365175 | 0.116256 | -3.141140 | 0.0025 |
| C(4) | -0.005079 | 0.015266 | -0.332681 | 0.7404 |
| C(5) | -0.015752 | 0.015408 | -1.022323 | 0.3103 |
| C(6) | -0.081392 | 0.205011 | -0.397013 | 0.6926 |
| C(7) | 0.044092 | 0.205757 | 0.214291 | 0.8310 |
| C(8) | 0.001339 | 0.000877 | 1.526444 | 0.1316 |

Note: * indicates 5% significance.