Purchasing Power Parity (PPP) in the Long-Run: A Cointegration Approach

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Purchasing Power Parity (PPP) in the Long-Run: A Cointegration Approach

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S. M. Woahid Murad**

Abstract: This paper intends to test the long-run purchasing power parity (PPP) in Bangladesh economy during the period 1971/72-2007/08. The cointegration tests using exchange rate and price indices from annual observations reject the PPP proposition for Bangladesh. The results indicate that deviations in domestic and foreign price levels are not reflected in nominal exchange rate movements. Instead of considering PPP as a complete model of exchange rate determination, it should be used in providing a guideline in setting exchange rates in the presence of monetary disturbances.

1. Introduction

The Purchasing Power Parity (PPP) doctrine states that the exchange rate between two currencies should be equal to the ratio of the price levels in two countries so that a given commodity has the same price in both countries when expressed in terms of the same currency. The intellectual origins of the doctrine can be attributed to the works of Wheatley (1807) and Ricardo (1821), where it appears as an extension of the quantity theory of money. Its latest revival owes much to Gustav Cassel’s writings throughout the 1920s to explain the behaviour of the dislocated European exchanges during World War I (Humphrey and Kelehar, 1982). The emergence of the floating exchange rate system after 1973 inspired an enormous resurrection of interest in PPP theory.

Numerous studies have been carried out in testing the validity of the PPP theory. Early studies of PPP centered on the European and United States economies during the 1920s. The results support the PPP hypothesis as exchange rates could not be separated from the price levels. On the contrary, PPP collapsed during the 1970s due to various structural changes in the United States economy with its trade partners (Frenkel, 1976, 1980; Krugman, 1978). In these studies, estimations were carried out without examining the time series properties of the variables. If the variables are nonstationary, we can study their behaviour only for the time period under consideration without generalizing it to other time periods. Provided that the variables are stationary as well as cointegrated, we may consider a long-run relationship among them. Besides, a number of studies were conducted on the basis of cointegration tests to identify the long-run relationship between exchange rate and price levels. Basher and Mohsin (2004) test the PPP hypothesis using panel cointegration framework for ten Asian countries. The results did not indicate any evidence in favor of PPP. The studies undertaken by Corbae and Ouliaris (1988) and Eatzaz et al. (2002) on US and Pakistan economies respectively, did not find any evidence in favor of the PPP hypothesis.

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This article aims at assessing the long-run PPP relationship in Bangladesh economy. Instead of regressing exchange rate on relative prices, the cointegration approach is adopted in testing PPP through analyzing the time series properties of the variables. Unless the two variables are cointegrated, one cannot show that there exists a long-run relationship between them. In such a case, the observed relationship may be entirely spurious.

The outline of this paper is as follows. Section 2 presents the theoretical framework, while section 3 discusses the econometric methodology. Section 4 reports the data sources and empirical results. Finally, the concluding remarks are provided in section 5.

2. Theoretical Framework

The ‘absolute’ version of the purchasing power parity (PPP) states that the equilibrium exchange rate equals the ratio of domestic to foreign general price levels. If $E$ is the nominal exchange rate measured as the domestic currency price of a unit of foreign currency and $P^d$ and $P^f$ are the domestic and foreign price indexes respectively, then PPP can be written as:

$$E = P^d / P^f$$  \hspace{1cm} (2.1)

The logarithmic version of the PPP is as follows:

$$\ln E_t = \alpha_0 + \alpha_1 \ln \left( \frac{P^d}{P^f} \right)_t + \omega_t$$  \hspace{1cm} (2.2)

where, $E$ is the nominal exchange rate (Taka per US dollar), $P^d$ and $P^f$ are the price indexes in Bangladesh and United States (US) respectively, $\alpha$’s are the coefficients to be estimated and $\omega$ is the disturbance term representing short-run deviations from PPP.

Two common price indexes used in the empirical verification of PPP are the consumer price index (CPI) and the wholesale price index (WPI). However, there exists a great deal of debate over the choice of the price index. One of the views emphasizes on commodity arbitrage in the determination of exchange rates and considers WPI to be the appropriate price index which represents the prices of tradable goods (Pigou, 1920). On the contrary, proponents of asset equilibrium in the determination of exchange rates, relies on CPI which covers a broad range of commodities (Cassel, 1928). However, WPI has been criticized to assign too much weight to traded goods. This study considers CPI to be the appropriate price index to be used in the empirical verification of the PPP hypothesis which has a greater representation of nontraded goods.

This article attempts to test of the ‘absolute’ version of the PPP hypothesis. Various disturbances from monetary shocks may not lead to the equilibrium relationship between exchange rate and the ratio of domestic to foreign general price levels in the short-run. A necessary condition for PPP to hold requires $\omega$ to follow a stationary process. In such a case, the deviations from the equilibrium value are corrected over time. A cointegrated system offers a strong evidence for the ‘absolute’ version of PPP theory.
3. Methodology

3.1 Unit Roots

The econometric methodology first examines the stationarity properties of the time series. Two procedures for detecting a unit root in exchange rate and price level data are used in our analysis: (i) The Dickey-Fuller (DF) test (Dickey and Fuller, 1979), and (ii) the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981).

The DF test is derived from the regression equation:

\[ X_t = \gamma_0 + \gamma_1 t + \delta X_{t-1} + u_t \quad -1 \leq \delta \leq 1 \]  

(3.1)

where, \( X_t \) is a random walk with drift around a stochastic trend and \( u_t \) is a white noise error term which is assumed to be uncorrelated. If \( \delta = 1 \), then \( X_t \) is nonstationary. Alternatively, we can estimate the model:

\[ \Delta X_t = \gamma_0 + \gamma_1 t + \varphi X_{t-1} + u_t \]  

(3.2)

where \( \varphi = (\delta - 1) \) and \( \Delta \) is the first-difference operator, and test the null hypothesis that \( \varphi = 0 \). If \( \varphi = 0 \) and \( \delta = 1 \), we have a unit root, implying that the time series under consideration is nonstationary. The ADF test is undertaken by adding lagged values of the dependent variable \( \Delta X_t \) if the error terms are correlated. Thus, the following regression is estimated for unit root testing:

\[ \Delta X_t = \gamma_0 + \gamma_1 t + \varphi X_{t-1} + \alpha_j \sum_{j=1}^{p} \Delta X_{t-j} + \varepsilon_t \]  

(3.3)

In model (3.3) \( X_t \) is a random walk with drift around a stochastic trend, \( \Delta \) is the first-difference operator, \( \varepsilon_t \) is a white noise error term and \( p \) is the number of lags in the dependent variable. The null hypothesis of a unit root implies that the coefficient of \( X_{t-1} \) is zero i.e., \( \varphi = 0 \). Rejection of the null hypothesis implies that the series is stationary and no differencing in the series is necessary to induce stationarity. The number of lags in the dependent variable is chosen by the Akaike Information Criterion (AIC). Unit root test identifies whether the variables are stationary or nonstationary. The test is applied on both the original series (in logarithmic form) and to the first differences. In addition, both models with and without trend are tried. The DF and ADF tests are carried out by replacing \( X_t \) with \( \ln E_t \) and \( \ln (P_d/P_f)_t \) in equations (3.2) and (3.3) respectively.

3.2 Cointegration Tests

Time series should to be checked for cointegration. For two or more variables to be cointegrated, the time series must have similar statistical properties i.e., they must be integrated of the same order. The Engle-Granger two-step method (Engle and Granger, 1987) is used for this purpose. The order of integration of the variables are identified in the first step while in the second step the residuals are estimated from the Ordinary Least Squares
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(OLS) regression on the levels of the variables from equation (2.2). Thus, according to the Engle-Granger method, two variables, exchange rate (LnEt) and relative price \([\text{Ln}(P_d/P_f)_t]\) are considered to be cointegrated if they are integrated of the same order i.e., \(I(d)\) and the residuals in the regression of LnEt on \(\text{Ln}(P_d/P_f)_t\) (or vice versa) is integrated of order less than \(d\).

The presence of a long-run equilibrium relationship between exchange rate and relative price is also tested through Johansen (1988) maximum likelihood procedure. In Johansen’s procedure, exchange rate and relative price are assumed to follow the first order Vector Auto Regressive (VAR) representation as follows:

\[
E_t = \Pi_{11} E_{t-1} + \Pi_{12} R_{t-1} + \epsilon_{Et}
\]

\[
R_t = \Pi_{21} E_{t-1} + \Pi_{22} R_{t-1} + \epsilon_{Rt}
\]

Subtracting lagged dependent variables from the respective equations, the system can be written in matrix notation as follows:

\[
\begin{bmatrix}
\Delta E_t \\
\Delta R_t
\end{bmatrix} = \begin{bmatrix}
\Gamma_{11} & \Gamma_{12} \\
\Gamma_{21} & \Gamma_{22}
\end{bmatrix} \begin{bmatrix}
E_{t-1} \\
R_{t-1}
\end{bmatrix} + \begin{bmatrix}
\epsilon_{Et} \\
\epsilon_{Rt}
\end{bmatrix}
\]

where \(\Gamma_{11} = \Pi_{11}-1, \Gamma_{22} = \Pi_{22}-1, \Gamma_{12} = \Pi_{12}\) and \(\Gamma_{21} = \Pi_{21}\) and \(E_t\) and \(R_t\) are first difference stationary i.e., \(I(1)\). The existence of a cointegrating relationship depends on the rank of the matrix \(\Gamma\) which must be equal to one as there can be up to one linearly independent cointegrating vectors. Johansen’s procedure gives two likelihood ratio tests for the number of cointegrating vectors \(r\) which are found by the trace and the maximum eigen value tests as follows:

\[
\lambda_{\text{trace} (r)} = -N \sum_{r+1}^k \ln (1 - \lambda_i) \quad (3.6)
\]

\[
\lambda_{\text{max} (r+1)} = -N \ln (1 - \lambda_{r+1}) \quad (3.7)
\]

where, \(\lambda_i\)'s are the characteristic roots of the matrix \(\Gamma\) and \(N\) is the sample size. The null hypothesis of at most \(r\) cointegrating vectors is tested in both the trace test as well in the maximum eigen value test. In the trace test, the alternative hypothesis is that the number of cointegrating vectors is equal to or less than \(r+1\), whereas it is equal to \(r+1\) in the maximum eigen value test. The Johansen’s maximum likelihood procedure is carried out by replacing \(E_t\) with LnEt and \(R_t\) with \(\text{Ln}(P_d/P_f)_t\) in equations (3.4) and (3.5) respectively.

4. Data Sources and Empirical Results

The study is based on annual data for the period 1971/72-2007/08. Nominal exchange rates (period average) are expressed as units of local currency (Taka) per US dollar. Data on exchange rates have been gathered from various issues of Economic Trends, published by the
Bangladesh Bank. The relative price is the domestic price index divided by a similar US price index. The CPI (Base: 1989-90=100) has been used as the appropriate price index. Data on CPI for Bangladesh and US have been obtained from different publications of Statistical Yearbook of Bangladesh and IMF International Financial Statistics (IFS) Yearbook, respectively. Econometric estimations have been performed using STATA (version 9.2).

The results in Table-1 indicate that in all cases, the level of the logarithm of exchange rate and relative price (measured by consumer price index) are nonstationary. Thus to achieve stationarity the variables must be first-differenced. The DF and ADF statistics are significant only for the first-differenced series. Thus, exchange rate and relative price series appear to be $\sim I(1)$.

<table>
<thead>
<tr>
<th>Variables</th>
<th>DF</th>
<th>ADF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Trend</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levels</td>
<td>First Difference</td>
</tr>
<tr>
<td>Ln E</td>
<td>-2.20</td>
<td>-4.18***</td>
</tr>
<tr>
<td>Ln (P_d/P_f)</td>
<td>-2.29</td>
<td>-4.31***</td>
</tr>
</tbody>
</table>

Notes: i) Figures within parentheses indicate lag lengths chosen by the Akaike information criterion (AIC); ii) *** and ** denote rejection of the null hypothesis of unit root at the 1% and 5% levels respectively.

<table>
<thead>
<tr>
<th>Cointegrating Regressions</th>
<th>With Trend</th>
<th>Without Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DF</td>
<td>ADF</td>
</tr>
<tr>
<td>Ln E_t = 3.91+1.83 Ln (P_d/P_f)_t</td>
<td>-3.13</td>
<td>-3.19 (1)</td>
</tr>
<tr>
<td>Ln (P_d/P_f)_t = -1.70+0.42 Ln E_t</td>
<td>-3.11</td>
<td>-3.14 (1)</td>
</tr>
</tbody>
</table>

Notes: i) Figures within parentheses indicate lag lengths chosen by the Akaike information criterion (AIC); ii) The null hypothesis of unit root in the residuals cannot be rejected at the 1%, 5% and 10% levels respectively.
The results reported in Table-1 provide the basis for the test of cointegration. The DF and ADF statistics for the cointegration tests are presented in Table-2. The results show that exchange rate and relative price series for Taka-US Dollar are not cointegrated. The residuals of the cointegrating regressions are nonstationary indicating that deviations between exchange rate and relative price continue indefinitely without reconciling together in the long-run.

### Table-3: Johansen’s Maximum Likelihood Procedure

<table>
<thead>
<tr>
<th>Null</th>
<th>Trace</th>
<th>λ-Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>r = 0</td>
<td>r ≤ 1</td>
<td>r = 0</td>
</tr>
<tr>
<td>Alternative</td>
<td>r ≤ 1</td>
<td>r ≤ 2</td>
</tr>
<tr>
<td>Ln E, Ln (Pd/Pf)</td>
<td>11.97</td>
<td>1.69</td>
</tr>
</tbody>
</table>

Notes: i) The lag lengths are chosen by Akaike’s Final Prediction Error (FPE) criteria; ii) r denotes the number of cointegrating vectors; iii) The null hypothesis of no cointegration cannot be rejected at the 1% and 5% levels.

Table-3 provides the results of the Johansen’s maximum likelihood procedure for determining the number of cointegrating vectors r. The results show that the null hypothesis of no cointegration (r = 0) cannot be rejected. Therefore, it can be confirmed that exchange rate and relative price are not cointegrated i.e., PPP does not hold for the Bangladesh economy.

### 5. Conclusion

The aim of this paper has been to test the ‘absolute’ version of the PPP hypothesis in Bangladesh Economy for the period 1971/72-2007/08. Exchange rate and relative price were nonstationary in levels, but stationary in first difference i.e., they are integrated of order one, \( I(1) \). The study applies cointegration technique of economic time series to verify the existence of a stable relationship between exchange rate and relative price. The results indicate that there is no cointegrating relationship between the variables i.e., deviations in domestic and foreign prices due to disturbances are not reflected in nominal exchange rate movements in Bangladesh. Thus, PPP should not be considered as a complete theory of exchange rate determination. Instead of providing a general trend, the PPP theory may be used as a guide for fixing exchange rate in the event of any monetary disturbance.

### References


