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Testing the Validity of Purchasing Power Parity in the BRICS: Further Evidence

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Abstract: The study re-investigates the validity of purchasing power parity (PPP) for Brazil, Russia, India, China (PR) and South Africa. These countries trade amongst themselves and are known as BRICS. We test if nominal exchange rates and relative prices are cointegrated for these countries and also find out if the cointegration is of linear or nonlinear form. A rank test for cointegration and a score test for nonlinearity are employed in our analysis. Our results failed to reject the null of no cointegration between nominal exchange rates and relative prices for all the five countries, however, there is cointegration between nominal exchange rate, CPI for China (PR) and CPI for US. Further analysis shows that the long-run relationship between nominal exchange rate, CPI for China and CPI for US is nonlinear. The results imply that we cannot use PPP as a basis in determining the equilibrium exchange rates for Brazil, Russia, India and South Africa because of the existence of arbitrage opportunities which traders are likely to exploit, however, it is difficult to make unbounded gains from arbitrage in traded goods in China (PR). The study provided new evidence on the validity of PPP in the BRICS by the use of nonlinear cointegration rank and score test.

Keywords: Purchasing power parity; BRICS; Rank test; Score test; nonlinear cointegration

JEL Classification: C22; F31

1. Introduction

Purchasing power parity (PPP) is based on the law of one price. The law of one price states that prices of goods should be the same in all locations. Thus if purchasing power is the same, exchange rates between the countries should remain in equilibrium. The validity or otherwise of PPP has important implications. One of these implications when PPP is valid is that arbitrage opportunities are non-existent on the markets of the countries under study. Testing the validity of PPP have been researched into. The works of Taylor (1995), Rogoff (1996), Taylor and Peel (2000), Sarno and Taylor (2002) and Lothian and Taylor (2008) have made important contributions to the literature of PPP and the real exchange rate. It is to be stated that most of these earlier works employed linear cointegration tests, however, linear cointegration tests have being argued by researchers not to provide accurate results especially when there is a nonlinear relationship between exchange rate and relative prices. Studies of researchers such as Balke and Fomby (1997), Taylor and Peel (2000) and *Taylor et al*. (2001) argue that linear cointegration tests have a reduced power when there is a nonlinear relationship between exchange rate and relative prices. Testing PPP on the BRICS countries have been done by researchers like *Chang et al*. (2010) who used a test advanced by Enders and Siklos (2001) known as the "momentum threshold tests" to investigate if there were asymmetric adjustment discernible for BRICS. Their study concluded that PPP holds for the BRICS countries in the long- run. *Chang et al.* (2012) also employed the Autoregressive Distributed Lag (ADL) test for threshold cointegration to test if PPP of the BRICS countries is valid in the long-run. It was reported that PPP holds in the BRICS countries except Brazil. Furthermore, *Sua et al.* (2012) investigated the validity of the long-run

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Purchasing Power Parity (PPP) for the BRICS countries using linear and nonlinear unit root tests with stationary covariates. It was reported that the PPP is valid for all the BRICS countries. Recently, Gyamfi and Adam (2016) tested the validity of the PPP in the BRICS by investigating if real exchange rates (RER) were mean reverting. Their findings after employing a Detrended Fluctuation Analysis (DFA) in absolute form and through time in a rolling window approach showed persistence in real exchange rates; an indication not supporting the theory of PPP in the five countries. Due to the existence of trade barriers (Killian & Taylor, 2003) and interventions by governments in the foreign exchange markets, there might be a nonlinear behaviour in the real exchange rates (Taylor, 2004), therefore, in identifying reasons why there might be a nonlinear behaviour in real exchange rates into consideration, this study used a nonparametric Breitung (2001) rank and score test which has power in both linear and nonlinear frameworks to test if nominal exchange rates and relative prices for Brazil, Russia, India, China and South Africa (BRICS) are cointegrated. If these variables are cointegrated, we use the score test to find out if the cointegration is either linear or nonlinear. The rest of the article is organised as follows: Section 2 describes the data and the Breitung (2001) rank and score test employed in this study. Section 3 presents the empirical results and discusses the findings and Section 4 concludes the article.

2. Data and Methodology

Monthly data on nominal exchange rates against the US dollar and consumer price indexes (CPI) [based on 2005=100] for Brazil, Russia, India, China PR (Macao) and South Africa were obtained for the period from January, 1993 to December, 2015. The data which was obtained from the International Financial Statistics (IFS) of the International Monetary Fund (IMF) was transformed into natural logarithms before the analysis.

Rank and Score Test of Breitung (2001)

The rank test investigates the null of no cointegration between two or more variables. We test the null of no cointegration between nominal exchange rate (denoted e_t) and relative prices (denoted r_t) against an alternative of cointegration of either linear or nonlinear form. If the null hypothesis of the rank test is rejected, we use the score test to investigate if the cointegration between nominal exchange rate and relative prices is linear or nonlinear.

Rank Test

Following Breitung (2001), we let y_t be a series and R (y_t) be the rank of y_t among ($y_1\ y_2\ y_3\ ,\ldots,y_T$) where y_t = {e_t,r_t} and T is the sample size.

Based on the differences between the sequences of ranks, Breitung (2001) defined two rank test statistics as:

Equation 1

$$B_1 = \frac{sup_{1<t<T}\ |d_t|}{T}$$

Equation 2

$$B_2 = \sum_{t=1}^{T} \frac{d_t^2}{T^3}$$

where d_t=$R(e_t) - R(r_t)$ assuming that $R(e_t)$ and $R(r_t)$ are both monotonically increasing or decreasing. Since e_t and r_t are assumed to be mutually serially uncorrelated random walks, Breitung (2001) relaxed this assumption and made corrections to the two statistics as:

Equation 3

$$B_1^* = \frac{sup_{1<t<T}\,|d_t|}{T\hat{\sigma}_{\Delta d}}$$

Equation 4

$$B_2^* = \sum_{t=1}^{T} \frac{d_t^2}{T^3 \hat{\sigma}^2{}_{\Delta d}}$$

where $\hat{\sigma}^2{}_{\Delta d}$=$T^{-2}\sum_{t=1}^{T}(d_t - d_{t-1})^2$ is used to adjust for the possible correlation between e_t and r_t. To extend cointegration among more than two variables, Breitung (2001) specified a rank test statistic for multivariables as:

Equation 5

$$B_3^*[k] = T^{-3}\sum_{t=1}^{T} (\hat{\mu}_t^R)^2 \Big/ \hat{\sigma}^2{}_{\Delta\hat{\mu}}$$

where $\tilde{\mu}_t^R$= $R(e_t) - \tilde{b}\,R(r_t)$ in which $\tilde{b}$ is the least squares estimates from a regression of $R(e_t)$ on $R(r_t)$ and $\tilde{\mu}_t^R$ are the estimated residuals. We use $\hat{\sigma}^2{}_{\Delta d}$=$T^{-2}\sum_{t=2}^{T}(\tilde{\mu}_t^R - \tilde{\mu}_{t-1}^R)^2$ to adjust for possible correlation amongst the variables.

In this study, $B_3^*[k]$ was extended to test for the long-run relationship between nominal exchange rate e_t, domestic prices p_t and foreign prices p_t^*. Here, $\tilde{\mu}_t^R$= $R(e_t) - \widetilde{b_1}\,R(p_t)$-$\tilde{b}_2 R(p_t^*)$ where $\tilde{b}_1$ and $\tilde{b}_2$ are the least squares regression estimates from a regression of $R(e_t)$ on $R(p_t)$ and $R(p_t^*)$ and k=2.

The null of no cointegration is rejected if the critical values are greater than the test statistic. The critical values are thus presented in Table 1:

Table 1. Critical values of the Rank test

Significance level	B_1^*	B_2^*	$B_3^*[1]$	$B_3^*[2]$
1%	0.3156	0.0130	0.0130	0.0119
5%	0.3635	0.0188	0.0197	0.0165
10%	0.3941	0.0232	0.0248	0.0197

Score Test for Nonlinearity

The score test for nonlinearity is employed if the null of the rank test is rejected. Thus if e_t and r_t are cointegrated, we proceed to find if the cointegration relationship is linear or nonlinear. A bivariate score test statistic $T.R^2$ was suggested by Breitung (2001) from the following regression:

Equation 6

$$\tilde{\mu}_t = c_0 + c_1 r_t + c_2 R(r_t) + \vartheta_t$$

Where R^2 is the coefficient of determination of the regression in equation (6), $\tilde{\mu}_t$ is for the residuals of the regression of e_t on a constant and r_t. Thus $\tilde{\mu}_t = e_t - (\tilde{\alpha}_0 + \tilde{\alpha}_1 r_t)$ where $\tilde{\alpha}_0$ and $\tilde{\alpha}_1$ are the least squares estimates.

A multivariate score test statistic to test the linearity of cointegration relationship amongst e_t, p_t and p_t^* can be obtained from the following regression:

Equation 7

$$\tilde{\mu}_t = c_0 + c_1 p_t + c_2(p_t^*) + c_3 R(p_t) + c_4 R(p_t^*) + \vartheta_t$$

Where $\tilde{\mu}_t$ is for the residuals of the regression of e_t on a constant, p_t and p_t^*.

The score test statistic is asymptotically Chi-squared (χ 2) distributed with one degree of freedom. The null of linear cointegration (i.e. if $c_2 = 0$ (for bivariate) and $c_3 = c_4 = 0$ (for multivariate)) is rejected in favour of a nonlinear cointegration if the test statistic $T.R^2$ exceeds the χ 2 critical values of 6.63, 3.84 and 2.71 (for bivariate) and 9.21, 5.99 and 4.61 (for multivariate) for the 1%, 5% and 10% significance levels respectively.

3. Empirical Results and Discussion

From Table 2, the autocorrelation adjusted test statistics of bivariate and multivariate rank tests are reported. It is observed that the null of no cointegration between nominal exchange rate and relative prices is failed to be rejected for Brazil, Russia, India and South Africa because the test statistics are greater than their respective critical values for these four countries in all significance levels. However, there is cointegration between nominal exchange rate and relative prices for China (PR). Also, there is cointegration between exchange rate, China CPI and US CPI. Because cointegration exists between e_t and r_t and also between e_t, p_t and p_t^* for China from Table 2, we move to test the form of the long-run relationship between these variables using a Score test for nonlinearity. The Score test results are presented in Table 3. The results from the Score test in Table 3 show that there is a nonlinear long-run relationship between exchange rate, China CPI and US CPI at the 1% significance level.

Table 2. Results of Bivariate and Multivariate Rank test for cointegration

	Bivariate: e_t,r_t		Multivariate: e_t,p_t, p_t^*	
Country	B_1^*	B_2^*	$B_3^*[1]$	$B_3^*[2]$
Brazil	0.757	0.042	0.045	0.083
Russia	0.784	0.078	0.085	0.032
India	0.688	0.136	0.246	0.041
China (PR)	0.261***	0.008***	0.009***	0.013**
South Africa	0.673	0.129	0.238	0.042
Critical Values				
1%	0.3156	0.0130	0.0130	0.0119
5%	0.3635	0.0188	0.0197	0.0165
10%	0.3941	0.0232	0.0248	0.0197

Table 3. Results of Bivariate and Multivariate Score test for nonlinearity (NA means 'not applicable' because no cointegration exists.)

Country	**Bivariate** $T.R^2$	**Multivariate** $T.R^2$
Brazil	NA	NA
Russia	NA	NA
India	NA	NA
China (PR)	133.17***	125.746***
South Africa	NA	NA

4. Discussion

The results from the rank test provide a strong evidence against the validity of PPP in these countries but for China. Thus, nominal exchange rate and relative prices move independently for Brazil, Russia, India and South Africa. This means the exchange rates are not able to go back to its PPP values in the long-run as evidenced in Gyamfi and Adam (2016) but contradicting the findings of *Chang et al.* (2010 & 2012). We cannot therefore use PPP to determine the equilibrium exchange rates for these countries. However, the finding of long-run nonlinearity between nominal exchange rate, China CPI and US CPI confirmed the results obtained by Chang & Su (2013). The nonlinear relationship might be due to government intervention and transportation costs in the pricing system during the sample period according to Killian & Taylor (2003) and Juvenal & Taylor (2008).

5. Conclusions

This study employed the Breitung (2001) rank and score test to investigate the validity of PPP in the BRICS from January, 1993 to December, 2015. The results obtained showed strong evidence against the validity of PPP in the long-run as there was no cointegration between nominal exchange rate and relative prices. There was a nonlinear relationship between nominal exchange rate, China CPI and US CPI which are attributed to government intervention and transportation costs in the pricing system during the sample period. Our results have important policy implications.

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