2. REVISITING PURCHASING POWER PARITY FOR NINE TRANSITION COUNTRIES USING THE RANK TEST FOR NONLINEAR COINTEGRATION

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Abstract

This study applies the powerful rank test for nonlinear cointegration proposed by Brietung (2001) to test the validity of long-run purchasing power parity (PPP) for nine transition countries from January 1995 to December 2008. The empirical results indicate that PPP holds true for all nine transition countries studied. Our results have important policy implications for these nine transition countries.

Keywords: Rank Test for Nonlinear Cointegration; Purchasing Power Parity; Transition Countries

JEL Classification: C22, F31

I. Introduction

Over the past several decades, empirical economic research has paid increasing attention to testing the validity of the long-run purchasing power parity (hereafter, PPP) hypothesis because it has important implications for the international macroeconomics. The PPP hypothesis states that the exchange rates between currencies are in equilibrium when their purchasing power is the same in each of the two countries. This relationship means that the exchange rate between any two countries should equal the ratio of the two currencies' price level of a fixed basket of goods and services. The basic idea behind the PPP hypothesis is that because any international goods market arbitrage should be traded away over time, we should expect the real exchange rate to return to a constant equilibrium value in the long run.

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Studies on this issue are critical not only for empirical researcher but also for policymakers. In particular, a non-stationary real exchange rate indicates that there is no long-run relationship between nominal exchange rates and domestic and foreign prices, thereby invalidating the purchasing power parity hypothesis. If this is the case, the PPP cannot be used to determine the equilibrium exchange rate. Moreover, invalid PPP also disqualifies the monetary approach to exchange rate determination, which requires that PPP to hold true. Some references in the field are McDonald and Taylor (1992), Taylor (1995), Rogoff (1996), Taylor and Sarno (1998), Lothian and Taylor (2000, 2008), Sarno and Taylor (2002), and Taylor and Taylor (2004) who have provided in-depth information on the theoretical and empirical aspects of PPP and the real exchange rate.

While some empirical evidence of long-run PPP for both developed countries and less- developed countries seems convincing, none of it has been conclusive. As for methodology, recent studies of long-run PPP have mostly utilized cointegration tests for the relationship between various measures of domestic and foreign prices as well as nominal exchange rates. The conclusions drawn from these studies have primarily been based on linear tests of cointegration. However, ample evidence has indicated that this linear testing procedure may be defective if the PPP holds with nonlinear adjustment (see, for instance, Taylor and Peel, 2000; Taylor and Taylor, 2004; Taylor, 2006). In this study, instead of assuming a linear cointegrating relationship, as in the previous literature, we follow Haug and Basher (2010) and test for a general nonlinear form of the cointegrating relationship. This approach is different from testing for a nonlinear error correction, or equivalently, a nonlinear equilibrium-correction and moves towards a linear long-run cointegrating relationship.

The present empirical study contributes significantly to this field of research by using the rank test of nonlinear cointegration proposed by Brietung (2001). It proposes to determine whether long-run PPP exists in a sample of nine transition countries. Specifically, what we find is that long-run PPP holds for all nine of the transition countries studied.

This paper is organized as follows. Section II discusses a theoretical model of real exchange rates and the theory of PPP. Section III presents the data used in our study. Section IV briefly describes the nonlinear rank test for cointegration. Section V first presents our empirical results and then discusses some economic and policy implication of our empirical findings. Section VI concludes the paper.

II. The Theoretical Model of Real Exchange Rates and the Theory of PPP

The 'absolute version' of the PPP doctrine states that the exchange rate is equal to the ratio of prices of two countries in the long-run:

$$e_t = p / p^*_t \qquad [1]$$

where: e_t is the nominal exchange rate defined in local currency units per U.S. dollar and p_t and p_t^* are the domestic and foreign price levels. We use the consumer price

index (CPI) in our study. Taking the logarithm of both sides of Eq. [1] and adding a constant α and a stochastic error (u_t) term yields the unrestricted estimable version of Equation [1]:

$$e_t = \alpha + \beta_1 p_t - \beta_2 p_t^* + u_t \quad [2]$$

where: α is a constant reflecting differences in units of measurement; β_1 and β_2 are coefficients; and u_t is a covariance stationary mean-zero error term representing the deviations from PPP. The absolute version of PPP also requires that $\alpha = 0$. The 'restricted version' of Equation [2] is given by:

$$e_t = \alpha + \beta\left(p_t - p_t^*\right) + u_t \quad [3]$$

The unrestricted model hypothesizes a proportional relationship between exchange rates and relative prices, given by $\beta_1 = 1$ and $\beta_2 = -1$. Equation [2] also treats the property of symmetry as a testable hypothesis given by $\beta_1 = -\beta_2 = 1$. Equation [3] assumes that the symmetry property holds while the proportionality property is a testable hypothesis, such that $\beta_1 = -\beta_2$. The unrestricted version, as given by Equation [2], allows us to examine the weak version of PPP, which condition is required for long-run PPP to hold if a linear combination of the nominal exchange rate and price ratio is stationary. The restricted version (Equation [3]), by imposing the proportionality and symmetry conditions a priori, defines the strong form of the PPP hypothesis. In this paper, we also consider two nonlinear versions of the PPP relationship. The two nonlinear versions are given by the following equations:

Restricted (bivariate) Model A: $e_t = \alpha + f(p_t - p_t^*) + u_y$ [4]

Unrestricted (trivariate) Model B: $e_t = \alpha + f(p_t, p_t^*) + u_y$ [5]

With respect to cointegration in this study, we carry out the Breitung's (2001) rank tests to determine whether u_t is stationary when $f(\bullet)$ is nonlinear.

III. Data

Our empirical analysis covers nine transition countries: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Russia. We employ monthly data in our empirical study and cover a time span from January 1995 to December 2008. All consumer price indices, CPI (based on 2000 = 100), and nominal exchange rates relative to the USA dollar data, respectively, are taken from Datastream. Each of the consumer price indices and nominal exchange rate series was transformed into natural logarithms before the econometric analysis. Testing for PPP against the USA dollar is based on the argument that international foreign exchange markets are mostly dollar dominated. In addition, funds for economic reconstructions are being provided by US sponsored institutions. Visual inspection of the real exchange rate series for these nine- country pairs reveals significant upward

or downward trends in the real exchange rate series for most of the countries against the U.S. dollar during the sample period. The figures in most of the series seem to exhibit some nonlinear adjustment patterns.

IV. Brietung's (2001) Rank Tests and Score Test

A. Rank Test for Nonlinear Cointegration

The first step is to test for cointegration between two time series, y_t and x_t. Consider y_t as a function of x_t, which may be represented by:

$$y_t = f(x_t) + u_t, \quad [6]$$

where: y_t and $f(x_t)$ are both integrated or order one. That is, $y_t \sim I(1)$ and $f(x_t) \sim I(1)$, and u_t stands for the stochastic disturbances. The cointegration tests in the past have been developed under the assumption that $f(x_t)$ is a linear function of x_t. Brietung (2001) showed that residual-based linear cointegration tests are inconsistent for some classes of nonlinear functions. To overcome this problem, he proposed a cointegration test based on rank transformation of the time series. The rank test exploits the property that a sequence of ranks is invariant to monotonic transformation of the data. In other words, if x_t is a random walk then the ranked series of x_t behaves like a random walk as well. Similarly, if two series are cointegrated, possibly nonlinearly, then the ranked series are cointegrated as well. The rank transformation, therefore, allows the avoidance of specific functional forms of the cointegrating relationship. An advantage of rank tests is that we do not have to be explicit about the exact functional form of the nonlinear cointegrating relationship.

The rank test is based on a measure of the squared distance between the ranked series. When the test statistic takes on a value smaller than the appropriate critical value, this result is evidence against the null hypothesis of no cointegration in favor of the alternative hypothesis of cointegration because, in this case, the variables move closely together over time and do not drift too far apart. Such a test checks whether the ranked series move together over time towards a long-run cointegrating equilibrium that may be linear or nonlinear.

Following the Brietung study (2001), we can define a ranked series as $R(w_t) =$ Rank of w_t among $(w_1, w_2, ..., w_T)$, where $w = \{y, x\}$. Two consistent rank-test statistics based on the difference between the sequences of ranks are as follows:

$$B_1 = T^{-1} \sup_{1<t<T} | d_t |, \quad [7]$$

and

$$B_2 = T^{-3} \sum_{t=1}^{T} d_t^2, \quad [8]$$

where: $d_t = R(y_t) - R(x_t)$, based on the assumption that $R(y_t)$ and $R(x_t)$ are both monotonically increasing or decreasing. The basic idea of these rank tests is that the sequences of ranks tend to evolve similarly if there is cointegration between the two series, y_t and x_t; otherwise, the sequences of ranks tend to diverge. The null hypothesis of no (nonlinear) cointegration between y_t and x_t is rejected if these tests statistics are smaller than their respective critical values.

One should note that the above test statistics are developed under the assumption that two time series y_t and x_t are mutually and serially uncorrelated random walks. To relax this somewhat unrealistic assumption, Breitung (2001) suggests that the monotonic functions of x_t and y_t are converged with correlation coefficient ρ. If the value of $|\rho|$ is small, the test statistics show the following corrections:

$$B_1^* = \frac{\sup_{1<t<T} | d_t |}{T\hat{\sigma}_{\Delta d}}, \qquad [9]$$

and

$$B_2^* = \frac{\sum_{t=1}^{T} d_t^2}{T^3 \hat{\sigma}_{\Delta d}^2}, \qquad [10]$$

where: $\hat{\sigma}_{\Delta d}^2 = T^{-2} \sum_{t=1}^{T} (d_t - d_{t-1})^2$ is used to adjust for possible correlation between the two series of interest. If $|\rho|$ is close to 1, the test statistics B_1^* and B_2^* should be obtained as:

$$B_1^{**} = \frac{B_1^*}{1 - 0.174(\rho_t^R)^2}, \qquad [11]$$

and

$$B_2^{**} = \frac{B_2^*}{1 - 0.462(\rho_t^R)^2}, \qquad [12]$$

where: ρ_T^R is the correlation coefficient for differences of ranks as follows:

$$\rho_T^R = \frac{\sum_{t=2}^{T} \Delta R_T(x_t) \Delta R_T(y_t)}{\sqrt{\left(\sum_{t=2}^{T} \Delta R_T(x_t)^2\right)\left(\sum_{t=2}^{T} \Delta R_T(y_t)^2\right)}} \qquad [13]$$

The asymptotic distribution of the test statistics B_1^{**} and B_2^{**} are the same as B_1^* and B_2^*, respectively. The null hypothesis of no cointegration is rejected if the critical value exceeds the test statistics.

As indicated by Brietung (2001), his rank test can also be generalized to test cointegration among *k*+1 variables $y_t, x_{1t}, ..., x_{kt}$, where it is assumed that $R(y_t)$ and $R(x_{jt})$ for $j = 1, ..., k$ are monotonic functions. As such, one may compute the following multivariate rank statistic:

$$B_3[k] = T^{-3} \sum_{t=1}^{T} (\tilde{u}_t^R)^2 \quad [14]$$

where:

$$\tilde{u}_t^R = R(y_t) - \sum_{j=1}^{k} \tilde{b}_j R(x_{jt}) \quad [15]$$

in which $\tilde{b}_1, ..., \tilde{b}_k$ are the least squares estimates from a regression of $R(y_t)$ on $R(x_{1t}), ..., R(x_{kt})$, and $\tilde{u}_t^R$ are the estimated residuals.

While the bilateral rank tests are one-sided tests that are applicable to functions that are known to be either monotonically increasing or decreasing, multivariate rank tests are two-sided tests that are useful when it is unknown whether the functions are monotonically increasing or decreasing. Again, to circumvent the possible correlation between the series, the statistics can be modified through the following equations:

$$B_3^*[k] = B_3[k] / \hat{\sigma}_{\Delta\tilde{u}}^2 \quad [16]$$

where:

$$\hat{\sigma}_{\Delta\tilde{u}}^2 = T^{-2} \sum_{t=2}^{T} (\tilde{u}_t^R - \tilde{u}_{t-1}^R)^2 \quad [17]$$

The null hypothesis of no (nonlinear) cointegration between y_t and x_t is rejected if these tests statistics are smaller than their respective critical values. Critical values obtained from Monte Carlo simulations of B_1, B_2, B_1^*, B_2^*, B_1^{**}, B_2^{**} and $B_3^*[k]$ are given in Table 1 of Breitung (2001).

B. Score Tests for Neglected Nonlinearity

To assess whether the cointegration found by the rank test is linear or nonlinear, Breitung (2001) suggests the score test statistic $T \cdot R^2$ as follows:

$$\tilde{u}_t = c_0 + c_1 x_t + c_2 R(x_t) + e_t \quad [18]$$

where: T is the sample size, R^2 is the coefficient of determination of regression [18], and $\tilde{u}_t = y_t - (\tilde{a}_0 + \tilde{a}_1 x_t)$, where $\tilde{a}_0$ and $\tilde{a}_1$ in turn, are the least squares estimates from a regression of y_t on a constant and x_t. Under the assumptions that u_t is a zero-mean white noise and that x_t is exogenous, the score test statistic $T \cdot R^2$ is

asymptotically Chi-squared (χ^2) distributed with one degree of freedom. The null hypothesis of linear cointegration, c_2 = 0, may be rejected in favor of nonlinear cointegration when $T \cdot R^2$ exceeds the χ^2 critical value. However, Brietung (2001) points out that, in many cases, x_t is endogenous. He proposes the adoption of the cointegration regression of Stock and Watson (1993) for adjustment, accomplished by appropriately truncating the infinite sums in the following specification:

$$y_t = \alpha_0 + \sum_{j=1}^{\infty} \alpha_j y_{t-j} + \beta_1 x_t + \sum_{j=-\infty}^{\infty} \gamma_j \Delta x_{t-j} + \varepsilon_t \quad [19]$$

The least squares estimated residual $\tilde{\varepsilon}_t$ is then regressed on the regressors of Equation [18] and $R(x_t)$. Under the null hypothesis of a linear cointegration relationship, the resulting $T \cdot R^2$, where R^2 is the coefficient of determination of regression [17], is also asymptotically Chi-squared (χ^2) distributed with one degree of freedom. The Monte Carlo simulations by Brietung (2001) show that, for a wide range of nonlinear models. the rank tests perform better than their parametric competitors.

V. Empirical Results

A. Unit Root Test

Several traditional unit root tests are first employed to examine the null of a unit root in bilateral nominal exchange rates and CPIs for the nine transition countries that we study. ADF and PP tests both fail to reject the null of a unit root for the nominal exchange rates and CPIs in these nine transition countries. The KPSS test also yields the same results. Our results signify that the nominal exchange rates and CPIs for these nine transition countries are all random processes. Unit root test results are not included here for space considerations but are available upon request.

B. Results from the Rank Tests

Table 1 reports both the bivariate and trivariate cases of the rank tests. We compute the autocorrelation adjusted test statistics, $B_3^*[K]$, where K=1 for the bivariate case. As shown by the $B_3^*[1]$ statistic in Table 1, the null hypothesis is rejected for all nine of the transition countries examined in this study because the test statistics are smaller than the critical values at the 1% level of significance. As such, we observe cointegrating relationships between the nominal exchange rates and relative prices for all of the nine transition countries. These results indicate that the rank test employed in this study provides evidence of the validity of the long-run PPP. These findings are further supported by the multivariate rank test, $B_3^*[2]$, because the null hypothesis that no cointegration exists between the nominal exchange rates and the domestic and US CPIs is also rejected for all the cases.

Table 1

Results of rank tests for cointegration in model A

	Bivariate Rank Test					Multivariate Rank Test	rank sum linearity tests
Country	B_1^*	B_1^{**}	B_2^*	B_2^{**}	ρ_T^R	$B_3^*[1]$	$T \cdot R^2$
Bulgaria	0.65439178	0.65455336	0.10345794	0.10168838	-0.037666188	0.0062134796***	6.4433522**
Czech Republic	0.62733016	0.62762344	0.062564804	0.061101903	-0.051822493	0.0063799867***	0.022686289
Estonia	0.99725457	0.99989900	0.24829843	0.26329520	0.12328573	0.0060927298***	2.9416464*
Hungary	1.1178014	1.1187748	0.26242051	0.27128326	0.070713683	0.0060896627***	3.7369866*
Latvia	0.76513273	0.76517542	0.14226912	0.14345585	0.017905727	0.0061467807***	1.8586482
Lithuania	0.226338***	0.22639***	0.005966***	0.006064***	0.035229252	0.012057220***	11.142594***
Poland	0.74594122	0.74693612	0.10830651	0.11286889	0.087493279	0.0061941653***	0.79861374
Romania	1.2705617	1.2714877	0.49789050	0.51323010	0.064693356	0.0060755308***	25.903336***
Russia	1.6554537	1.6563587	0.70848902	0.72731851	0.056036621	0.0060736385***	20.189849***
Critical Value (%)							
10	0.3941	0.0232				0.0248	2.71
5	0.3635	0.0188				0.0197	3.84
1	0.3165	0.0130				0.0136	6.63

Notes: a. Model A: $e_t = \alpha + \beta(p_t - p_t^*) + u_t$ *. The null hypothesis of the rank test is that no cointegration exists between the exchange rate and relative price; the alternative hypothesis is otherwise. The null hypothesis is rejected when the critical value exceeds the test statistic. The multivariate rank test is adjusted for autocorrelation. The critical values are tabulated in Table 1 of Breitung (2001).*

*b. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.*

The bivariate and multivariate rank tests employed in this study provide strong evidence favoring the long-run validity of PPP for the nine transition countries under study. Our results are not consistent with those of Alba and Papell (2007) and Lu et al. (2011), who found that long-run PPP only holds for some of the transition countries. We believe that our results are more reliable because we use the more powerful nonparametric rank test of cointegration proposed by Brietung (2001).

C. Results from the Score Test

Based upon the cointegration relationships identified above, we go on to distinguish between linear and non-linear cointegration, using the score test of Breitung (2001). It is clearly shown from Table 2 that the null hypothesis of linear cointegration in the bivariate calculation is rejected for more than half of the cases. The score test results clearly indicate that a nonlinear cointegrating relationship exists between the nominal exchange rates and relative prices for six out of the nine countries under study (which include Bulgaria, Estonia, Hungary, Lithuania, Romania, and Russia; The Czech Republic, Latvia, and the Poland are the three exceptions). However, according to the multivariate score test statistics, the null hypothesis of the nonlinear cointegration is only rejected for three countries: Hungary, Lithuania, and Russia.

Table 2

Results of rank tests for cointegration in model B

	Multivariate Rank Test	rank sum linearity tests
Country	$B_3^*[2]$	$T \cdot R^2$
Bulgaria	0.0062467277***	1.2259555
Czech Republic	0.0061149440***	0.54672352
Estonia	0.0061326805***	0.24106458
Hungary	0.0061200565***	6.8982753**
Latvia	0.0061692330***	1.9188653
Lithuania	0.0078284926***	6.8541872**
Poland	0.0060960268***	1.4492620
Romania	0.0061961681***	2.4130447
Russia	0.0061658117***	45.766896***
Critical Value (%)		
10	0.0197	4.61
5	0.0165	5.99
1	0.0119	9.21

Notes: a. Model B: $e_t = \alpha + \beta_1 p_t - \beta_2 p_t^* + u_t$. *The multivariate rank test is adjusted for autocorrelation. The null hypothesis of the rank test is that no cointegration exists between exchange rate and the domestic and US prices; the alternative hypothesis is otherwise. The null hypothesis is rejected when the critical value exceeds the test statistic. The critical values are tabulated in Table 1 of Breitung (2001).*

*b. *** and ** denote significance at the 1% and 5% levels, respectively.*

D. Economic and Policy Implications

The findings on the nonlinear interrelationships between the nominal exchange rates and the domestic and US CPI for these three countries may be due to the transaction costs, trade barriers, as well as government intervention in the pricing system during the sample period. Kilian and Taylor (2003) and Juvnal and Taylor (2008) also suggest that nonlinearity may arise from the heterogeneity of opinion in the foreign exchange markets concerning the equilibrium level of the nominal exchange rate (i.e., as the nominal rate takes on more extreme values, a greater degree of consensus develops concerning the likely direction of exchange rate movements, and traders act accordingly).

We know that the nine transition countries examined in this study started their liberalization programs in the late -1980s and early 1990s. In some of these countries, this period was characterized by dramatic improvements in budget deficits, debts, and inflation. As these countries became increasingly open to trade (and inflation and growth rates converged to those of developed countries), we expected to find more favorable evidence of the parity condition (using data from recent years). A survey by the Organization of Economic Cooperation and Development (OECD) reported that even early in the transition process, international firms were impressed by how well the nine countries adjusted after the transition and by their commitment to a newly adopted market system (OECD, 1994). Indeed, many of these countries adopted trade policies that mimicked those of the European Union (EU) to assist in their membership process. As the reform process (price liberalization and trade opening) intensified, we expected a reduction in persistent shocks to international parity. The present results are consistent with those of Sideris (2006), Solakoglu (2006), Cuestas (2009), Koukouritakis (2009), Teletar and Hasanov (2009), and Kasman et al. (2010), who all found that PPP held true for most of the transition countries that they investigated.

The major policy implication that emerges from our study is that PPP can be used to determine the equilibrium exchange rates for all of the nine transition countries under study and that unbounded gains from arbitrage in traded goods are not possible among these nine transition countries.

VI. Conclusions

This study applies the rank test for nonlinear cointegration proposed by Brietung (2001) to test the validity of the long-run purchasing power parity (PPP) hypothesis for a sample of transition countries from January 1995 to December 2008. The empirical results indicate that the PPP hypothesis holds true for all of the nine transition countries studied and that the nominal exchange rates and the domestic and US CPIs are nonlinearly interrelated for only some of these countries. Our results have important policy implications for these nine transition countries under study. One of the most important policy implications stems from the finding that the PPP was able to determine the equilibrium exchange rate for all nine of the examined transition countries and that unbounded gains from arbitrage in traded goods are not possible among these nine transition countries.

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