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THE VALIDITY OF PURCHASING POWER PARITY IN CENTRAL AND EASTERN EUROPEAN COUNTRIES: A ROLLING NONLINEAR UNIT ROOT TEST

By Veli YILANCI[a]

The main aim of this paper is to examine the validity of the purchasing power parity (PPP) hypothesis for eight Central and Eastern European countries using both Kapetanios et al. (KSS) and rolling-KSS unit root tests. By employing the rolling-KSS unit root test, we aim to determine when the real exchange rates become non-stationary or nonlinear. The results of the KSS unit root test show that the PPP hypothesis is valid only for Romania while the results of the rolling-KSS unit root test reveal that the PPP hypothesiscan be rejected only for Poland in the all subsamples. On the other hand, we have found evidence of the validity of PPP for the remaining countries. Comparatively, the real exchange rates of Bulgaria and Romania were found to be characterized by nonlinearity in more subsamples in the rolling-KSS unit root test.

Keywords:
Nonlinearity
Purchasing power parity
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Unit root test

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[a]*Dr., Istanbul University, Faculty of Economics, Department of Econometrics, Beyazit, Fatih, 34452, ISTANBUL- TURKEY,*yilanci@istanbul.edu.tr

I. INTRODUCTION

Purchasing power parity (PPP) implies that the price indices of two countries are equal if measured in terms of the same currency; thus, the purchasing power of a unit of one currency would be the same in both economies (Sarno and Taylor, 2001). Although purchasing power parity was introduced as a term by Cassel in 1918, it has a history dating back to the writings of scholars of the University of Salamanca (Taylor, 2006). The event that made PPP so popular was the collapse of the Bretton-Woods fixed exchange-rate system. Under the flexible exchange-rate system, the PPP hypothesis is believed to hold continuously because the difference between the inflation series of two countries will be reflected by a nominal exchange rate (Mishra and Sharma, 2011). However, since deviations from PPP become greater in the post-Bretton-Woods system, the results of the empirical studies which tested the validity of the PPP proved that this assumption could be suspicious.

The PPP theory is now one of the most interesting and popular topics in international finance. The reason for this popularity lies in its policy implications. First, trade integration among countries is reflected by PPP (Liew et al., 2009). Second, PPP is used as a foundation for monetary exchange models (Holmes, 2001). Third, policymakers use PPP to determine whether a currency is overvalued or undervalued (Holmes, 2001) and for the international comparison of national income and welfare (Taylor et al., 2001). Fourth, if PPP holds, any short deviations such as real depreciation of a currency will cause transmission of inflation and capital movements (Kargbo, 2006).

In this study, we analyze whether the PPP hypothesis is valid for eight Central and Eastern European (CEE) economies. Although there have been an increasing number of studies, especially in the last few years, that test the validity of the PPP hypothesis for CEE countries, it still remains an unsolved phenomenon. There are two main approaches to examining the hypothesis: testing the mean reversion characteristics of real exchange rates and testing the long-run relationship among the nominal exchange rate, foreign price levels, and domestic price levels.

Several studies use linear unit root and co-integration tests to examine the hypothesis. Thacker (1995) investigated the PPP hypothesis for Hungary and Poland by employing unit root and co-integration tests over the period from January 1981 to February 1993 and failed to find supportive evidence for PPP. Christev and Noorbakhsh (2000) employed the Johansen and Stock-Watson system estimation techniques to test the validity of PPP for six CEE countries for the period from 1990 to 1998 using monthly data. The results of this study moderately supported the PPP hypothesis.

As pointed out by Perron (1989), ignoring structural breaks in unit root tests could give spurious results. Therefore, Payne et al. (2005) employed a battery of unit root tests that allow for structural breaks to test the validity of PPP for Croatia, and they found that the PPP hypothesis is not valid. On the other hand, Acaravci and Ozturk (2010) investigated whether the PPP hypothesis is valid for eight transition countries by employing standard unit root tests and unit root tests that allow for structural breaks from 1992M1 to 2009M1. The results of their paper showed that PPP did not hold for six transition countries in the analysis period; that is, there is not strong evidence supporting the PPP hypothesis in transition countries. Aslan and Kula (2011) examined the validity of the PPP hypothesis for Bulgaria, the Czech Republic, Hungary, Poland, Romania, and Russia by employing individual and panel unit root tests that allowed for structural breaks in the 1969M1–1998M12 period. They concluded by stating that they had found strong evidence of PPP for all countries. The difference between the results of this paper and those of

Acaravci and Ozturk (2010) is due to the data sets used in each. Aslan and Kula (2011) preferred to use black-market exchange rates, as opposed to Acaravci and Ozturk (2010) who preferred to use official exchange rates.

The econometric techniques used by Payne et al. (2005), Acaravcı and Ozturk (2010), and Aslan and Kula (2011) allowed for structural breaks, but in these tests the number and form of the structural breaks are pre-defined, which could create preselection bias (Maddala and Kim, 1998). To overcome this problem, Lin et al. (2011) and Chang et al. (2012) employed Fourier stationary and Fourier unit root tests. Lin et al. (2011) found that out of the nine transition countries studied in the 1995M1–2008M12 period PPP was only valid for Lithuania by employing the Fourier stationary test introduced by Becker et al. (2006). On the other hand, by employing the Fourier LM unit root test developed by Enders and Lee (2012), Chang et al. (2012) tested the validity of the PPP hypothesis for seven CEE countries using the monthly data from 1993 to 2008 and obtained the result that PPP was valid for all seven countries.

The studies mentioned above used univariate time series techniques that lose power in the case of small samples. Therefore, some other studies employed panel-data techniques to examine the PPP issue. Baharumshah and Borsic (2008) used the panel Seemingly Unrelated Regression Augmented Dickey-Fuller (SURADF) test, which allowed the researchers to test the validity of the PPP hypothesis in 13 CEE countries using the monthly data from 1984 to 2005 by determining which and how many members of the panel were stationary. Their results offered supportive evidence of PPP for Bulgaria, Croatia, Latvia, Lithuania, Macedonia, Russia, and Slovenia. Chang and Tzeng (2011a) employed the panel- Seemingly Unrelated Regression Kapetanios et. al. (SURKSS) test and found that the PPP hypothesis was valid for only Estonia and Hungary among nine transition countries from January 1995 to December 2008.

In the case of nonlinear data-generation processes, linear econometric techniques can give biased results. Due to potential factors such as transportation costs, trade barriers, government intervention to manage inflation and manipulate trade flows in the foreign exchange rate market (Bahmani-Oskooee et al., 2008), and heterogeneous market participants (Liew et al., 2009), real exchange rates could behave nonlinearly. Chang and Tzeng (2011b) and Liu et al. (2012) investigated the PPP hypothesis for CEE countries in a nonlinear framework. While the former study employed the threshold co-integration test and found strong evidence of long-run PPP for nine transition countries in the 1995M1–2008M12 period, the latter study used the threshold unit root test of Caner and Hansen (2001) over the period from January 1995 to October 2011, and the results that they obtained indicated that PPP was valid only for Romania.

This study's main contribution to the literature was using a nonlinear unit root test in a rolling window framework. Previous studies employed different econometric techniques to test the PPP hypothesis but obtained the results for the full sample of data. Contrary to these studies, by splitting the data into subsamples and applying a nonlinear unit root test to these subsamples, we determine during which periods the real exchange rates are nonlinear or nonstationary. To this end, this paper proceeds as follows: in the next section we describe the econometric methodology employed in the study, in the penultimate section we present our data, model, and empirical results, and in the final section we present our conclusions.

II. ECONOMETRIC METHODOLOGY

This study employs the unit root test of Kapetanios et al. (2003)(KSS) and the rolling-KSS unit root test. We describe the KSS unit root test first.

The null hypothesis of the unit root is tested against the alternative of a globally stationary exponential smooth transition autoregressive (ESTAR) process by employing the KSS unit root test. KSS considers the following ESTAR model:

$$\Delta y_t = \gamma y_{t-1}\left[1-exp\left(-\theta y_{t-1}^2\right)\right]+\varepsilon_t \qquad (1)$$

where y_t is the de-meaned or de-trended series of interest and $\varepsilon_t \sim iid\left(0,\sigma^2\right)$. The transition function of the exponential form is shown by $\left[1-exp\left(-\theta y_{t-1}^2\right)\right]$. If $\theta > 0$, then it determines the speed of mean reversion.

We can test the null of the unit root by testing $H_0 : \theta = 0$ against the $H_A : \theta > 0$. However, since γ is not identified under the null, it cannot be directly tested, hence KSS re-parameterizes equation 1 by first computing a Taylor series approximation under the null and obtaining the following auxiliary regression:

$$\Delta y_t = \delta y_{t-1}^3 + e$$

We obtain the test statistic to test the null hypothesis of unit root $H_0 : \delta = 0$ as $t_{KSS} = \hat{\delta} / s.e.\left(\hat{\delta}\right)$, where $\hat{\delta}$ is the OLS estimate of δ and $s.e.\left(\hat{\delta}\right)$ is the standard error of $\hat{\delta}$. KSS tabulated the asymptotic critical values for the t_{KSS} in their paper. To correct the possible serially correlated errors, the following extended model can be used:

$$\Delta y_t = \delta y_{t-1}^3 + \sum_{i=1}^{p} \rho_i \Delta y_{t-i} + e \qquad (2)$$

In the rolling-KSS unit root test, we employ a fixed length window and compute the t_{KSS} by estimating equation 2, moving this window forward by one observation. Let S and T denote the window size and sample size, respectively, and t_{KSSi} show the KSS statistic for the i^{th} window. We estimate equation 2 and compute the KSS statistics for the following periods:

$t_{KSS1} = 1,...,S$

$t_{KSS2} = 2,...,S+1$

$t_{KSS3} = 3,...,S+2$

.

.

$t_{KSS(T-S-1)} = (T-S-1),...,T$

It is clear that this procedure will be continued until to the last observation is used to test the null hypothesis. We can compute (T – S + 1) number of KSS statistics for a sample. For convenience of interpretation, we scale the test statistics by 10% critical value (-2.66). So in the relevant figures the horizontal line at 1, which is parallel to the X-axis, shows a kind of threshold (we define this line as the threshold line). The KSS statistic above this line shows the rejection of the null for the relevant date intervals, and the KSS statistic below this line implies the non-rejection of the null hypothesis of the unit root. By employing the rolling-KSS unit root test we can analyze the stability of the KSS unit root test and determine the episodic nonlinearity and nonstationarity in the data.

III. DATA, MODEL, and EMPIRICAL RESULTS

The real exchange rate can be calculated using the following equation:

$$y_t = NER_t \frac{p_t^f}{p_t^d},$$

where y_t is the real exchange rate, and NER_t, p_t^f, and p_t^d show the nominal exchange rate (this study uses the US dollar as the base currency) and foreign (US) and domestic consumer price indices, respectively. This equation can be redefined in logarithmic terms as follows:

$$\log y_t = \log NER_t + \log p_t^f - \log p_t^d$$

By using this equation, we can obtain the real exchange rates for eight Central and Eastern European countries; namely, Bulgaria, Croatia, the Czech Republic, Hungary, Latvia, Macedonia, Poland, and Romania. We use monthly data obtained from the International Financial Statistics of the IMF. Due to unavailability of certain data, we use different start dates, but end the analysis period at the same time for all the countries.

We present the date range and the KSS statistics computed for the whole analysis period in Table 1 to make a comparison with the results of the rolling-KSS unit root test. We determine the

maximum lag length using Schwert(1989)'s criteria: $p_{max} = int\left(12\left(\frac{T}{100}\right)^{0.25}\right)$ and the optimal lag length using the t-significance procedure in both the KSS and rolling-KSS unit root tests.

Table 1. KSS UNIT ROOT TEST RESULTS

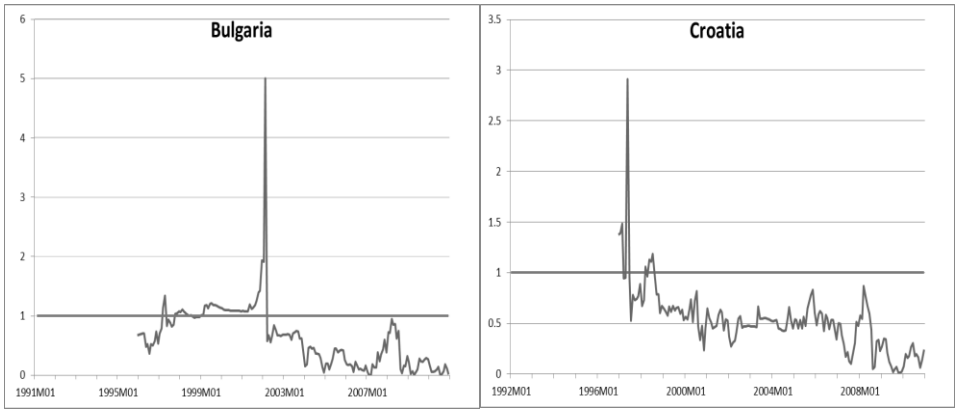
Country	KSS Statistic	Analysis Period
Bulgaria	-1.7716 (6)	1991:01-2010:12
Croatia	-1.4760 (14)	1992:01-2010:12
Czech Rep.	-1.2233 (9)	1993:01-2010:12
Hungary	-2.0827 (7)	1990:01-2010:12
Latvia	-1.7918 (13)	1992:02-2010:12
Macedonia	-2.1690 (12)	1994:01-2010:12
Poland	-1.1872 (9)	1992:01-2010:12
Romania	-4.1252[I] (13)	1990:10-2010:12

Source: Author's calculation

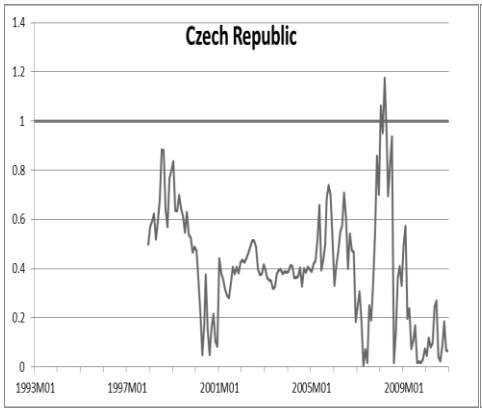
Note: Numbers in parentheses show the optimal lag lengths
[I]: statistical significance at the 1% level, which is -3.48

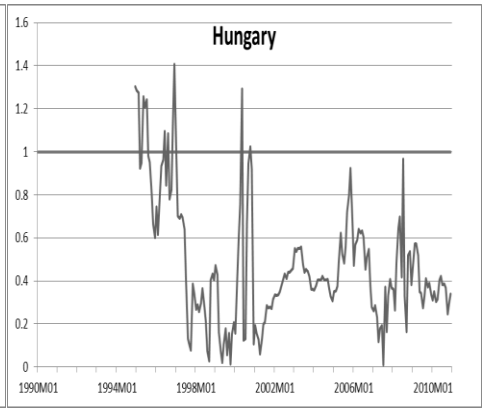
Table 1 shows that we cannot reject the unit root hypothesis for Bulgaria, Croatia, the Czech Republic, Hungary, Latvia, Macedonia, and Poland. On the other hand, only the real exchange rates (RERs) of Romania were found to be nonlinear, which shows that PPP is valid only for this country. These results showed conclusions for the whole sample, but the series can be nonlinear or nonstationary for only short time periods. We now determine this episodic characteristic of the series, applying the KSS unit root to the rolling windows.

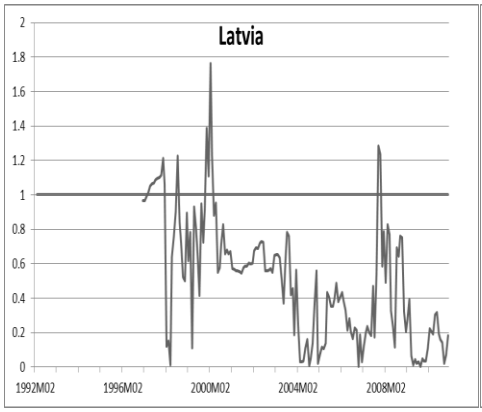
Figure 1 shows the results of the rolling-KSS unit root test. In this study, we set the size of each window at 60 observations, which corresponds to five years. In other words, we obtained the first KSS statistic from the first 60 observations. For example, we used the subsamples from 1991M01 to 1995M12 and from 1991M02 to 1996M01 to obtain the first and second KSS statistics for Bulgaria, respectively. The scaled test statistics above the threshold line demonstrate that the series in that period are nonlinear and also the validity of PPP.

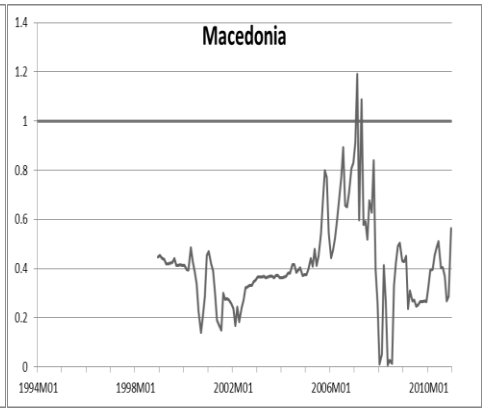

Bulgaria
6
5
4
3
2
1
0
1991M01
1995M01
1999M01
2003M01
2007M01

Croatia
3.5
3
2.5
2
1.5
1
0.5
0
1992M01
1996M01
2000M01
2004M01
2008M01


Czech Republic
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1993M01
1997M01
2001M01
2005M01
2009M01


Hungary
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1990M01
1994M01
1998M01
2002M01
2006M01
2010M01


Latvia
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1992M02
1996M02
2000M02
2004M02
2008M02


Macedonia
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1994M01
1998M01
2002M01
2006M01
2010M01

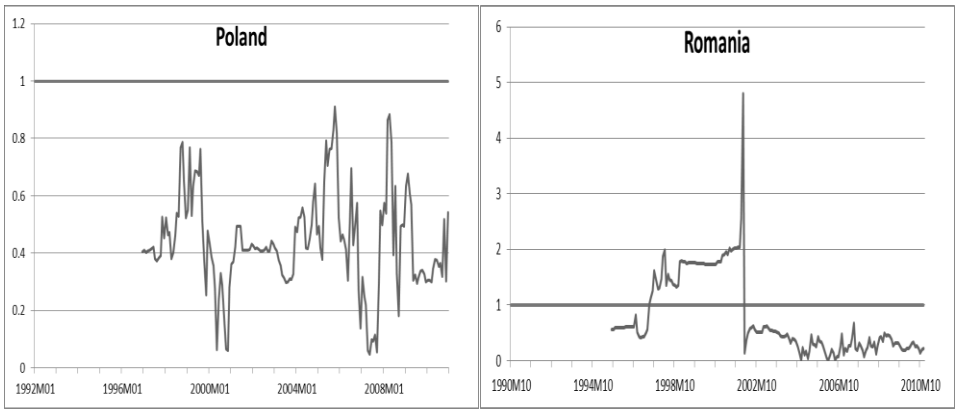


FIGURE 1. ROLLING KSS UNIT ROOT TEST RESULTS

Source: Author's calculation

When these figures are analyzed, it can be seen that the RERs of Bulgaria and Romania are characterized by nonlinearity over greater periods of time than other countries, which shows that PPP is valid in Bulgaria and Romania for relatively longer periods than other countries. On the other hand, the RERs of Poland are nonstationary in all subsamples, which indicates that PPP is not valid in the analysis period for Poland. The RERs of Croatia, the Czech Republic, Hungary, Latvia, and Macedonia are characterized by nonlinearity in short time periods. These results show the importance of testing the real exchange rates via the rolling-KSS unit root test because the real exchange rates of Romania, which were found to be nonlinear in the full sample, are nonstationary after 2002M03 while the RERs of Bulgaria, which were found to be nonstationary in the full sample, are nonlinear from 1998M11 to 2002M03.

Table 2. SUMMARY OF THE ROLLING KSS UNIT ROOT TEST RESULTS

Country	Total no. of Subsamples	No. of Nonlinear subsamples	No. of Nonstationary Subsamples	Percentage of Nonlinearity
Bulgaria	181	50	131	27.62%
Croatia	169	8	161	4.73%
Czech R.	157	2	155	1.27%
Hungary	193	12	181	6.22%
Latvia	168	17	151	10.12%
Macedon.	145	2	143	1.38%
Poland	169	0	169	0.00%
Romania	184	56	128	30.43%

Source: Author's calculation

In Table 2 we present the total number of subsamples, the number of KSS statistics that imply nonlinearity for the relevant subsamples, and the numbers of KSS statistics smaller than 10% critical value (implying nonstationarity) for each country. The results show the RERs of Bulgaria and Romania are characterized by nonlinearity in more subsamples than the other countries, which can be seen by visual analysis of the figures.

Since we investigated the PPP hypothesis in a time-varying framework, the results of this study are inconsistent with most of the literature. For example, Liu et al. (2012) found that PPP only held for Romania by employing a nonlinear unit root test. Contrary to the findings of Liu et al., we find that PPP holds also for Bulgaria, the Czech Republic, Hungary, and Latvia, which shows the importance of using a rolling nonlinear unit root test.

IV. CONCLUSION

This study examines the validity of the purchasing power parity hypothesis in the long run by employing the KSS(2003), unit root test and the rolling-KSS unit root test which distinguish episodic nonstationarity and nonlinearity for eight Central and Eastern European countries; namely, Bulgaria, Croatia, the Czech Republic, Hungary, Latvia, Macedonia, Poland and Romania. The results of the KSS unit root test show the PPP hypothesis is only valid for Romania for the whole sample. On the other hand, when we analyze the stationarity characteristics of the real exchange rates of these countries using the rolling-KSS unit root test, we find that the PPP hypothesis can be rejected only for Poland. In the remaining countries, we find the real exchange rates show episodic nonlinearity and nonstationarity. Comparatively, the real exchange rates for Bulgaria and Romania are found to be characterized by the nonlinear data generation process over longer periods of time.

The main policy implication of our findings is that the purchasing-power-parity hypothesis can be valid for only short time periods in CEE countries. Thus, the episodic behavior of the real exchange rate should be considered. On the other hand, in the subsamples in which PPP is valid, PPP can be used to determine the equilibrium exchange rate.

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VALJANOST PARITETA KUPOVNE MOĆI U ISTOČNOEVROPSKIM ZEMLJAMA: ROLLING NELINEARNI TEST JEDINIČNOG KORIJENA

Sažetak: Cilj ovog rada je ispitivanje valjanost hipoteze pariteta kupovne moći (PPP) za osam država središnje i istočne Evrope koristeći Kapetanios et al. (KKS) i rolling-KKS testove jediničnog korijena. Rolling-KKS testovima jediničnog korijena smo pokušali odrediti kada realne tečajne stope postaju nestacionarne ili nelinearne. Rezultati KKS testa jediničnog korijena pokazuju da hipoteza PPP može biti valjana samo u slučaju Rumunjske dok rezultati rolling-KKS testa jediničnog korijena pokazuju da hipoteza PPP može biti odbačena samo u slučaju Poljske i to u svim poduzorcima. S druge strane, našli smo dokaze valjanosti PPP za ostale zemlje. Usporedno, pokazalo se da su realne tečajne stope u Bugarskoj i Rumunjskoj karakterizirane nelinearnošću u više poduzoraka u rolling-KKS testu jediničnog korijena.

Ključne riječi: nelinearnost, paritet kupovne moći, rolling window procedura, test jediničnog korijena