Flexible Fourier Stationary Test in Purchasing Power Parity for Central and Eastern European Countries

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Abstract

This study applies stationary test with a Fourier function proposed by Becker, Enders and Lee (2006) to test the validity of long-run purchasing power parity (PPP) to assess the non-stationary properties of the real exchange rate for seven Central and Eastern European (CEE) countries. We find that our approximation has higher power to detect U-shaped breaks and smooth breaks than linear method if the true data generating process of exchange rate is in fact a stationary non-liner process. We examine the validity of PPP from the non-linear point of view and provide robust evidence clearly indicate that PPP holds true for two countries, namely Bulgaria and Romania. Our findings point out their exchange rate adjustment is mean reversion towards PPP equilibrium values in a non-linear way.

Keywords: *Fourier stationary test, structural change, trend breaks, purchasing power parity*

JEL Classification: C22, F31

1. Introduction

Purchasing power parity (hereafter, PPP) is a cornerstone of many theoretical models in international finance. The results from validity of PPP have important implications to decision or policy makers of central banks, multinational firms and exchange rate market participants. PPP states that the exchange rates between currencies are in equilibrium when their purchasing power is the same in each of the two countries. The basic idea behind the PPP hypothesis is that since 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. In particular, a non-stationary real exchange rate indicates that

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there is no long-run relationship between nominal exchange rate and domestic and foreign prices, thereby invalidating the PPP. As such, PPP cannot be used to determine the equilibrium exchange rate, and an invalid PPP also disqualifies the monetary approach from exchange rate determination, which requires PPP to hold true. According to Holmes (2001), the PPP is important to policy makers for two reasons. First of all, it can be used to predict exchange rate to determine whether a currency is over or undervalued. Whether a currency is over or undervalued is particularly important for les-developed countries and also for those experiencing large difference between domestic and foreign inflation rates. Secondly, the notion of PPP is used as the foundation on which many theories of exchange rate determination are built. Consequently, the validity is important to those policy makers in developing countries who base their adjustment on the PPP.

While some empirical evidence of long-run PPP for both developed countries and less developed countries seems convincing, unfortunately thus far none has been proven to be conclusive. Previous studies have identified transition economics as interesting samples to test PPP. However, these studies provided mixed results across countries. Christev and Noorbakhsh (2000) tested PPP for six CEE countries and find a higher speed of adjustment for Poland and Hungary, which adapted floating exchange rate regimes, than for the remaining transition countries. Similarly, Thacker (1995) also examined the PPP hypothesis for Poland and Hungry and did not support PPP. Choudhry (1999) tested for cointegration between relative prices and nominal exchange rates of the currencies of Poland, Romania, Russia and Slovenia vis-à-vis the US dollar. He applied fractional and the Harris Inder cointegration techniques and found evidence for the validity of PPP for the economies of Russia and Slovenia. Cholatá (2009) analyzes of the PPP between Latvia and the euro area, and between Slovakia and the euro area using the Engle-Granger and Johansen co--integration techniques and results did not confirmed the PPP validity in both analysed cases. Sideris (2006) tested for the validity of PPP for CEE countries in transition and provided support for long-run equilibrium, but the coefficients of the estimated cointegrating vectors violate the symmetry and proportionality hypotheses suggested by PPP. Furthermore, a number of recent studies have adopted Behavioral Equilibrium Exchange Rate (BEER) to examine the fluctuations of the currencies of the CEE countries. Egert, Halpern and MacDonald (2006) conduct a comprehensive survey on the topics of equilibrium exchange rates looking at currencies of the CEE. A wide range of policy concerns which may effect the movements of the local currencies and contribute to the degrees of misalignment are discussed, including high current account deficit, Dutch

Disease phenomenon, membership of exchange rate mechanism, enterprise restructuring and implication of productivity catch-ups.

Transition started in 1992 in the former Soviet Union, the process of economic transition started with a liberalization of the foreign exchange markets and a provision of currency convertibility. The economic reforms started with massive exchange rate devaluations (Lipton and Sachs, 1990), therefore, the subsequent years were characterized by trend appreciation (De Broeck and Slok, 2006), which was strengthened by income convergence and the Balassa-Samuelson effect (Égert and Halpern, 2006). These drastic steps resulted in initial deep under valuations of the national currency. At the same time, price liberalization was accompanied by very high inflation rates. Therefore, the features of CEEC transition economies provide an interesting study of PPP hypothesis test. First, there were centrally planned and fast liberalization to prices and markets, and some suffered from high inflation. Second, and most of all, the initial conditions for CEEC transition varied extensively and they may be an important indicator in explaining the magnitude of deviations from PPP.

As for methodology, recent studies of long-run PPP have mostly utilized conventional unit root tests such as the Augmented Dickey and Fuller (ADF, 1981), the Phillips and Perron (PP, 1988) – fail to reject the unit root hypothesis of the real exchange rate (hereafter, RER). It is well know that if RER follows nonlinear stationary process then tests based on linear models such as the widely used ADF unit root models will be mis-specified (Chortareas, Kapetanios and Shin, 2002). However, Sarno (2000) and Taylor and Peel (2000) also demonstrate that the adoption of linear stationarity tests is inappropriate for the detection of mean reversion if the true process of the data generation of the exchange rate is in fact a stationary non-linear process. Additionally, the existence of structure changes in the RER might imply broken deterministic time trends and the result is a nonlinear pattern (Bierens, 1997). If we omit some structural breaks it is a possible cause of the traditional unit root tests failing to reject the unit root null for RER. Perron (1989) argued that if there is a structural break, the power to reject a unit root decreases when the stationary alternative is true and the structural break is ignored. Meanwhile, structural changes present in the data generating process, but have been neglected, sway the analysis toward accepting the null hypothesis of a unit root. As we know that exchange rates might be affected by internal and external shocks generated by structural changes may be subject to considerable short-run variation. It is important to know whether or not the RER has any tendency to settle down to a long-run equilibrium level, because PPP hypothesis requires that RER evolves around a constant or a time trend. If RER is found stationary by using unit root test with structural break(s), the effects of shocks such as real and monetary shocks that cause deviations around a mean value or deterministic trend are only temporary. Then, PPP is valid in the long run. Sabate, Gadea and Serrano (2003), Narayan (2005; 2006), Narayan and Prasad (2005) provide evidence that, when structural breaks are included for individual countries, RER is stationary, implying support for PPP.

As discussed, traditional unit root tests lose power if structural breaks are ignored in unit root testing. The general method to account for breaks is to approximate those using dummy variables. However, this approach has several undesirable consequences. First, one has to know the exact number and location of the breaks. These are not usually known and therefore need to be estimated. This in turn introduces an undesirable pre-selection bias (see Maddala and Kim, 1998). Second, current available tests account only for one to two breaks. Nunes, Newbold and Kuan (1997), Lee and Strazicich (2003) and Kim and Perron (2009), among others, demonstrate that such tests suffer from serious power and size distortions due to the asymmetric treatment of breaks under the null and alternative hypotheses. Third, the use of dummies suggests sharp and sudden changes in the trend or level. However, for low frequency data it is more likely that structural changes take the form of large swings which cannot be captured well using only dummies. Breaks should therefore be approximated as smooth and gradual processes (see Leybourne, Newbold and Vougas, 1998). These arguments motivate the use of a recently developed set of unit root and stationarity tests that avoid this problem. Both Becker, Enders and Lee (2006) and Enders and Lee (2009) develop tests which model any structural break of an unknown form as a smooth process via means of Flexible Fourier transforms (i.e., an expansion of a periodic function in terms of an infinite sum of sines and cosines). Several authors, including Gallant (1981), Becker, Enders and Lee (2004), and Enders and Lee (2009), show that a Fourier approximation can often capture the behavior of an unknown function even if the function itself is not periodic. The authors argue that their testing framework requires only the specification of the proper frequency in the estimating equations. By reducing the number of estimated parameters, they ensure the tests have good size and power irrespective of the time or shape of the break.

This empirical study contributes to this line of research by determining whether or not the unit root process of RER of CEE countries using the unit root test with a Fourier function proposed by Enders and Lee (2009). Testing whether a time series can be characterized by a broken trend is complicated by the fact that the nature of persistence in the errors is usually unknown. The lack of econometric studies may be explained by the difficulties involved modeling acceding country data: only relatively few time series observations are available and structural changes have occurred frequently. Several authors showed that exchange rates are determined by long-term fundamentals including productivity, financial assets and other non-stationary variables. Therefore it is generally expected that real exchange rates are non-stationary in Eastern Europe. It is the reason that we analyze RER using the stationary test with a Fourier function unit root tests that allow for breaks in the trend and the level of a series at unknown time. With this, the current research hopes to fill the existing gap in the literature. To the best of our knowledge, this study is the first, to date, that utilizes the unit root test with a Fourier function in RER for CEE countries. This empirical study contributes to the field of empirical research by determining whether or not the unit root process is characteristic of the in RER in the CEE countries.

The remainder of this paper is organized as follows. Section 2 describes the methodology of the stationary test with a nonlinear Fourier function proposed by Becker, Enders and Lee (2006). Section 3 presents the data used in our study and discusses the empirical findings. Finally, Section 4 reviews the conclusions we draw.

2. Becker, Enders and Lee's Stationary Test with a Fourier Function

Becker, Enders and Lee (2006) implement a variant of the Flexible Fourier transform (i.e., Gallant, 1981) to control for the unknown nature of the breaks. One advantage of this Fourier function is that it is able to capture the essential characteristics of one or more structural breaks by using only a small number of low frequency components. This is true because a break tends to shift the spectral density function towards frequency zero. Especially, this test works best in the presence of breaks that are gradual and has good power to detect U-shaped and smooth breaks. Following the Becker, Enders and Lee (2006), we consider the following data generating process (DGP):

$$y_t = \alpha_0 + \beta t + \gamma_1 \sin(2\pi kt / T) + \gamma_2 \cos(2\pi kt / T) + r_t + \varepsilon_t \qquad (1)$$

where the r_t process is described as:

$$r_t = r_{t-1} + u_t \qquad (2)$$

where

ε_t – stationary errors;

u_t – independent and identically distributed (i.i.d) with variance σ_u^2.

Under the null hypothesis $\sigma_u^2 = 0$, so that the process described by equations (1) and (2) is stationary. The rational for selecting $[\sin(2\pi kt/T), \cos(2\pi kt/T)]$ is based on the fact that a Fourier expression is capable of approximating absolutely integrable functions to any desired degree of accuracy. Where k represents the frequency selected for the approximation, and $\gamma = [\gamma_1, \gamma_2]'$ measures the amplitude and displacement of the frequency component. A desire feature of Equation (1) is that the standard linear specification emerges as a special case by setting $\gamma_1 = \gamma_2 = 0$. It also follows that at least one frequency component must be present if there is a structural break. Here, if it is possible to reject the null hypothesis $\gamma_1 = \gamma_2 = 0$, the series must have a nonlinear component. Becker, Enders and Lee (2004) use this property of equation (1) to develop a test that can have more power to detect breaks of an unknown form than the standard Bai and Perron (1998) test. As the DGP in Equation (1) nests the one used to generate the common Kwiatkowski et al. (1992; Kwiatkowski, Phillips, Schmidt and Shin – KPSS) test, the Becker, Enders and Lee's (2006) stationary test with a Fourier function needs only a slight modification of the KPSS statistic. First, one needs to obtain the residuals from the following equation:

$$y_t = \alpha_0 + \gamma_1 \sin(2\pi kt/T) + \gamma_2 \cos(2\pi kt/T) + v_t \tag{3}$$

and

$$y_t = \alpha_0 + \beta t + \gamma_1 \sin(2\pi kt/T) + \gamma_2 \cos(2\pi kt/T) + v_t \tag{4}$$

Equation (3) tests the null of level stationarity while Equation (4) tests the null of trend stationarity. The test statistic is given by:

$$\tau_{KPSS}(k) = \frac{1}{T^2} \frac{\sum_{t=1}^{T} \tilde{S}_t(k)^2}{\tilde{\sigma}^2} \tag{5}$$

where

$\tilde{S}_t(k) = \sum_{j=1}^{t} \tilde{v}_j$ and $\tilde{v}_j$ are the OLS residuals from regressions (3) and (4), respectively.

As in the KPSS framework and following the PP-type approach, Becker, Enders and Lee (2006) suggest that a nonparametric estimate of σ^2 be obtained by choosing a truncation lag parameter l and a set of weights w_j, j = 1, 2, …., l.

$$\sigma^2 = \tilde{\alpha}_0 + 2\sum_{j=1}^{l} w_j \tilde{\alpha}_j \tag{6}$$

where

$\tilde{\alpha}_j$ – the *jth* sample autocovariance of the residuals $\tilde{v}_t$ from Equations (3) and (4), respectively.

Becker, Enders and Lee (2006) suggest that the frequencies in (3) and (4) should be obtained via the minimization of the sum of squared residuals. However, their Monte Carlo experiments suggest that no more than one or two frequencies should be used because of the loss of power associated with a larger number of frequencies.

3. Data and Empirical Results

We use monthly data that covers from 1993 to 2008 to apply stationary test with a Fourier function proposed by Becker, Enders and Lee (2006) in testing the validity of PPP. During this period, It is well known that CEE countries have started their liberalization programs and transited to market economies. They have undergone major structural changes during the transition period (see, e.g., Fischer, Sahay and Vegh, 1996; Fischer and Sahay, 2000; Foster and Stehrer, 2007). The CEE countries had to implement a wide range of economic reforms, aiming at price and trade liberalization, privatization, demonopolization, and establishment of market institutions, to restructure their centrally planned economies. Such structural reforms caused an increase in the volume of international trade and reorientation of trade toward the European Union. Furthermore, integration of the CEE countries with European Union during the assession period and aftermath intensified trade between these countries and older members of European Union (e.g., Cheptea, 2007; Fidrmuc, 2005). Because the CEE countries have undergone several phases of economic restructuring during the transition and accession period, it is likely that equilibrium RERs have shifted during the analyzed period. This empirical study covers 7 CEE countries: Bulgaria, Czech Republic, Hungary, Poland, Romania, Russia and Slovakia. All of these CEE countries switched from controlled to market economies, with the transition more or less prolonged and often subject to major lurches and slow downs. Further, these transition countries experienced financial or political crises, abandoned economic-policy regimes that appeared to be failing and adopted other regimes. In particular, these seven countries often relied heavily on exchange rates as a stabilization tool, using a range of exchange-rate regimes from managed floats to currency boards, and they changed exchange-rate regimes at least once in response to economic difficulties. The price series are based on the consumer price index, and the nominal exchange rates are the end period spot rates relative to the U.S. dollar (domestic price of the U.S. dollar). All data is taken from the International Monetary Fund's International Financial Statistics.

For comparison, the univariate unit root tests are first employed to examine the null of a unit root in bilateral real exchange rates for 7 CEE countries that we study. Based on the results from Table 1, there is no question that three univariate unit root tests – the ADF and PP tests all fail to reject the null of non-stationary real exchange rates among these 7 CEE countries. The KPSS test also yields the same results and further confirms the ADF and PP tests indicating all the data are non-stationarity. Our results imply that RER is a random walk process. In other words, PPP was not hold among these 7 CEE countries under study. Furthermore, we apply the non-linear unit-root test of Kapetanois, Shin and Snell (2003) to re-investigate the mean reversion behavior of exchange rate adjustment. However, results from the fifth column of Table 1 indicate that the unit-root hypothesis is also not rejected for all 7 countries.

Table 1
Tests for Unit Root and Stationarity

Country	ADF	PP	KPSS	**Nonlinear Stationarity Test** $(\hat{k})$	SSR	$F_u(\hat{k})$	$\tau_u(\hat{k})$
Bulgaria	–0.458(0)	–0.905[16]	1.242[9]***	1	1.592	6.048***	1.691***
Czech Republic	–1.159(0)	–0.392[2]	1.231[9]***	1	1.799	16.648***	1.572***
Hungary	–0.139(0)	–0.347[4]	1.199[9]***	1	1.258	5.907***	1.328***
Poland	–0.154(0)	–0.596[6]	1.145[9]***	1	1.148	21.148***	1.700***
Romania	–0.023(0)	–0.280[5]	1.099[9]***	1	1.711	1.711*	1.806***
Russia	–0.831(0)	–0.769[5]	0.747[9]***	1	2.185	24.055***	0.343***
Slovakia	–1.046(0)	–1.123[2]	1.240[9]***	1	1.489	21.489***	1.886***

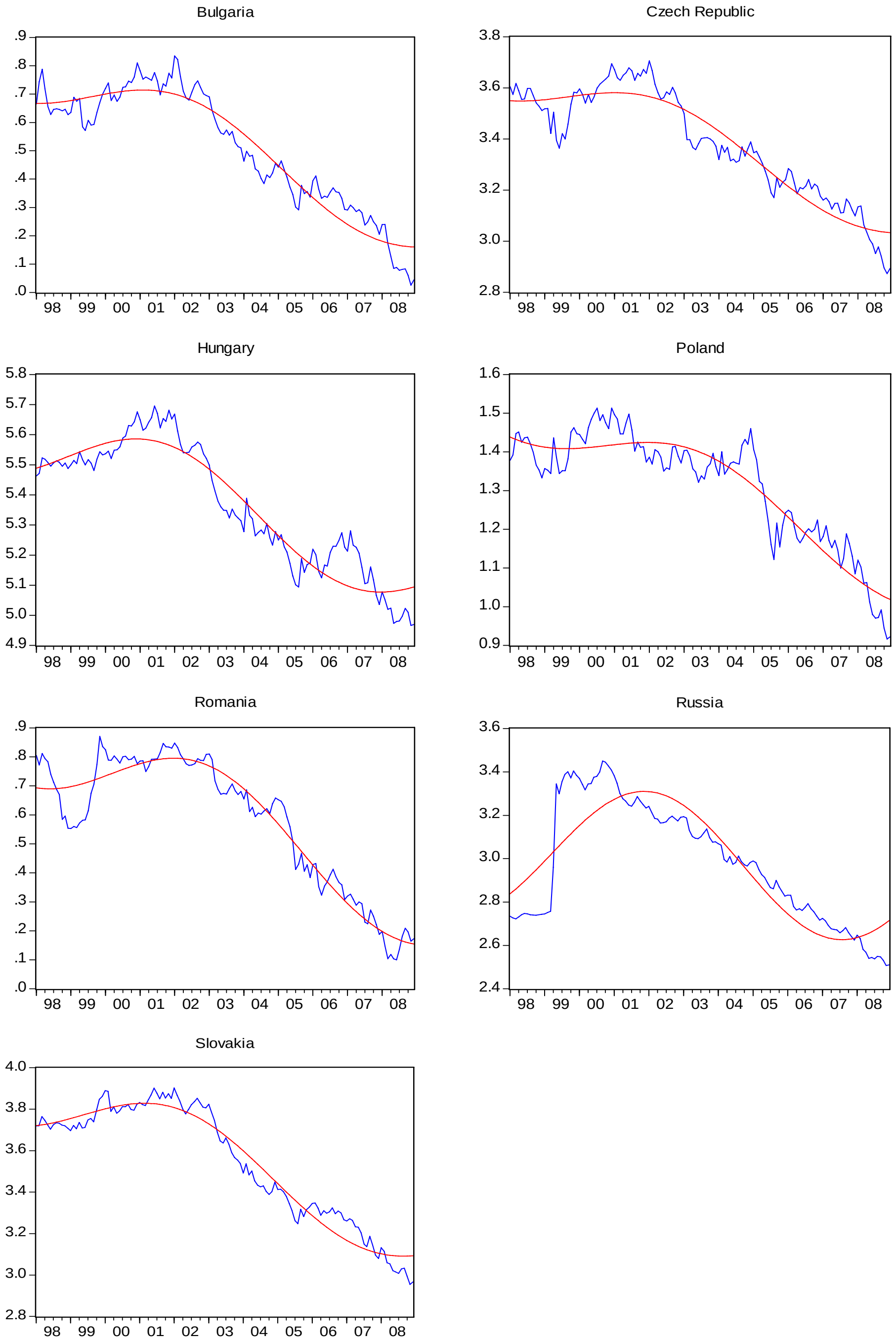
Notes: *** and ** indicate significance at the 0.01 and 0.05 levels, respectively. The number in parenthesis indicates the lag order selected based on the recursive *t*-statistic, as suggested by Perron (1989). The number in the brackets indicates the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987). The critical values of $F_u(\hat{k})$ and $\tau_u(\hat{k})$ are taken from Becker, Enders and Lee (2006).

Next, a grid-search is performed to find the best frequency, as there is no a priori knowledge concerning the shape of the breaks in the data. We use Gauss procedure RNDN and all calculations were conducted using the Gauss software version 6.0.10. First, we must select frequency component(s) to include in testing equation. We estimate Equations (3) and (4) for each integer $k = 1$ to 5, following the recommendations of Enders and Lee (2009) that a single frequency can capture a wide variety of breaks except for Russia with two frequency. Table 1 displays the residual sum of squares (RSSs) and indicates that a single frequency works best for both two series. However, if the nonlinear trend is not present in the data-generating process, it is possible to obtain increased power by using KPSS test. Thus, it becomes desirable to test for the absence of a nonlinear trend (i.e. $\gamma_1 = \gamma_2 = 0$). The usual F-test statistic for this hypothesis could be calculated against the alternative of a nonlinear trend. One can consider the following F-test statistic that is calculated against the alternative nonlinear trend with a given frequency k. It is important to note that F-test can exhibit undue power if the data are non-stationary. Table 1 shows that $F_\mu(k)$ in the CEE countries are all rejected at 1% significant level. It means the RERs in CEE countries are all exhibited nonlinear behavior.

As such, the usual KPSS-type stationary tests will diverge when nonlinear trends are ignored. This leads to over-rejections of the true stationarity null hypothesis in favor of the false unit-root hypothesis. Thus, it is important to control for nonlinear trends in stationary tests. Table 1 reports the results of stationary test with a nonlinear Fourier function based on the estimated frequencies. Given this pre-specified value of *k*, it is possible to estimate Equation (3) or Equation (4), calculate the value of $\tau_{\mu}(k)$, and perform the stationarity test using the critical values in Enders and Lee (2009)'s Table I. Further, we choose a lag of 12 for the truncation lag. In our study, we only consider a specification with a constant but without a time trend because time trend in RERs is not consistent with the long-run PPP. The null hypothesis is rejected in favor of the alternative hypothesis for only most of the cases, with the exception of Bulgaria and Romania.

In our study period, sweeping price liberalization followed with very high inflation rates in Romania and Bulgaria, often of nearly hyperinflation nature. This occurred mostly as a one-time adjustment, freeing the prices of many goods and some services. Romania is the apparent exception in and introducing a cautious stepwise liberalization. Prices of housing, utilities, and transportation, however, remained administered in these two countries well into the transition and slowly adjusted afterwards (see DeMasi and Koen, 1997). Bulgaria with hyperinflation was switched and subsided in July, 1997. These results clearly qualify the earlier findings of Liu (1992), Mahdavi and Zhou (1994), and others that PPP is most likely to hold in the case of high inflation countries. The major policy implication that emerges from this study is that PPP can be used to determine the equilibrium exchange rate for these two CEE countries. Our findings are consistent with Holmes (2001) that we can use PPP to predict exchange rate that determine whether a currency is over or undervalued and experiencing difference between domestic and foreign inflation rates. It is also in line with the work of Alba and Park (2003), who mentioned that the empirical validity of PPP remains a controversial and unsettled issue. Apparently, the stationary test with a Fourier function employed in our study provided weak evidence favoring the long-run validity of PPP for these 7 CEE countries under study. Our results are not consistent with those of the Maican and Sweeney (2006), and Solakoglu (2006), both studies found long-run PPP holds for all of the CEE countries. However, our results are consistent with those of the Christev and Noorbakhsh (2000), Acaravci and Ozturk (2010) that they found PPP holds for only some of the CEE countries.

Figure 1
Real Exchange Rates and Fitted Nonlinearities



Source: Own calculations.

The stationary test with a Fourier function employed by Becker, Enders and Lee (2006) in this study provide some evidence favoring the long-run validity of PPP for the CEE countries being studied. The process of CEEC economic transition started with a liberalization of the foreign exchange markets, and a provision of currency convertibility. These drastic steps resulted in the initial deep undervaluation of the national currencies. At the same time, price liberalization was accompanied by very high inflation rates. These results clearly qualify the earlier findings of Liu (1992), Mahdavi and Zhou (1994), and others that PPP is most likely to hold in the case of high inflation countries.

Figure 1 displays the time paths of the RERs where a positive change in the RER indicates real depreciation. We can clearly observe structural shifts in the trend of the data. Accordingly, it appears sensible to allow for structural breaks in testing for a unit root (and/or stationary). The estimated time paths of the time-varying intercepts are also shown in the Figure 1. A further examination of the figures indicates that the all Fourier approximations seem reasonable and support the notion of long swings in RER.

Apparently, the stationary test with a Fourier function employed in our study provided weak evidence favoring the long-run validity of PPP for these 7 CEE countries under study. One major policy implication of our study is that the validity of using PPP to determine the equilibrium exchange is unambiguous – but for only two of these 7 CEE countries. The governments of these two countries, Bulgaria and Romania, can use PPP to predict exchange rate that determine whether a currency is over or undervalued and experiencing difference between domestic and foreign inflation rates. Nevertheless, reaping unbounded gains from arbitrage in traded goods is not possible in these two countries.

Conclusions

This study employs a stationary test with a Fourier function recently introduced in the literature by Becker, Enders and Lee (2006). This test has the ability to test for unit roots (and/or stationary) in the presence of various types of smooth structural breaks with an unknown form. The Flexible Fourier transform introduced by Gallant (1981) captures the unknown shape of the breaks and the Monte Carlo simulations of Becker, Enders and Lee (2006) show that the test does not suffer from low power and have good size properties. We apply this stationary test with a Fourier function to test the validity of long-run PPP for a sample of CEE countries over the 1993 to 2008. The empirical results indicate that PPP does not hold true for most of CEE countries studied with the exception of Bulgaria and Romania. Our results have important policy implications for these 7 CEE countries under study. As concerns major policy, our study implies that PPP can be used to determine the equilibrium exchange rate Bulgaria and Romania two countries under study.

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