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Purchasing Power Parity Hypothesis: Mixed Evidence from Eastern Europe Emerging Markets

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ABSTRACT: This paper investigates whether the purchasing power parity (PPP) hypothesis holds in the Czech Republic, Hungary, and Poland by considering currencies of their five largest trading partners. We employ eight panel unit root tests that can be arranged in groups by cross-section independence or dependence. Empirical findings show that the stochastic behavior of real exchange rates in the Czech Republic and Poland is not a mean reversion, and the PPP condition does not hold for them. However, we obtain mixed empirical evidence in Hungary. Limited evidence is found for validity of the PPP hypothesis among currencies of Hungary's largest trading partners.

KEY WORDS: Central and Eastern Europe, emerging markets, floating exchange rates, panel unit root tests, purchasing power parity hypothesis, trading partners.

Floating exchange rates have become a risk factor for both developed and emerging economies due to the transition to floating exchange rate regime(s) after the collapse of the Bretton Woods system in February 1973. After this date, determining the exchange rate is critical for theoretical considerations and policymakers under a floating exchange rate regime. To determine the exchange rate, one of the key issues in the literature is to test the validity of the purchasing power parity (PPP) hypothesis. We aim to investigate the validity of the PPP hypothesis in Central Eastern Europe (CEE) emerging markets in a balanced panel framework. We focus on three CEE emerging markets (the Czech Republic, Hungary, and Poland) that shifted to floating exchange rate regimes after their transition process. They also used the same monetary policy framework, inflation targeting, over the period under consideration.Validity of the PPP has been extensively tested in the literature. Unlike other studies, we first suggest a valuable and different insight for further investigation of this phenomenon in related emerging CEE markets. For this purpose, we define the balanced panel framework for domestic currencies of each country, vis-à-vis the currencies of their five largest trading partners, and employ front-page panel unit root tests. We therefore investigate whether stochastic behavior of real exchange rates in the Czech Republic, Hungary, and Poland could be defined as a mean reversion. In the literature, most of the papers that test validity of the PPP in emerging CEE markets cover two subperiods: the floating (exchange rate) regime in the periods before and after accession to the European Union (EU). Our study covers a unique and homogeneous period: the postaccession floating regime period in the Czech Republic, Hungary, and Poland. Therefore, our empirical analyses start in May 2004.

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Following the collapse of communism in Eastern Europe, CEE emerging markets (or transition economies) have employed different exchange rate and monetary policy regimes. These transition economies can be organized into at least three groups of countries (Josifidis et al. 2009, pp. 200–205). The first group of transition economies—Estonia, Latvia, and Lithuania—have kept on their "rigid" exchange rate regimes or exchange rate targeting. The second group of transition economies—Bulgaria, Romania, and Slovenia—have not followed a specific path and have generally stayed on a rigid exchange rate regime. More flexible regimes have been introduced with different nominal anchors. The last group of transition economies—the Czech Republic, Hungary, Poland, and Slovakia—changed their monetary policies and exchange rate regimes during the transition process. First, these countries used the exchange rates as a nominal anchor, and then they shifted to a more flexible exchange rate regime. These could be called "intermediate regimes." Finally, they shifted to managed- or free- (independent) floating exchange rate regimes under an explicit or implicit inflation-targeting framework.

The Czech Republic implemented an inflation-targeting monetary policy regime from December 1997 to August 2011 with a managed-floating exchange rate regime. This exchange rate regime started in May 1997 in the Czech Republic. We select August 2011 as an endpoint because our empirical analysis ends in August 2011. Hungary also used a managed-floating exchange rate regime from May 2001 to August 2011. Poland implemented an explicit inflation-targeting monetary policy regime with a free-floating exchange rate regime from April 2000 to August 2011.

This paper is concerned with the last group of transition economies. However, Slovakia is now a member of the European Monetary Union (EMU); the Czech Republic, Hungary, and Poland still do not participate in the EMU. Slovakia executed the implicit inflation-targeting and "intermediate" regime of the target zone from November 2005 to January 2009. Following membership in the EMU (or monetary nonautonomy) in January 2009, Slovakia adopted the inflation-targeting monetary policy regime with the combination of de jure managed- or free-floating exchange rate regime. We suggest that this kind of exchange rate regime and real exchange rate data are not suitable to analyze the validity of the PPP hypothesis. We cannot gather the homogenous data for the domestic currency after January 2009. We therefore exclude Slovakia from this study.

Literature Review

In the literature, one of the main critical issues for determining the value of exchange rates is whether they are mean reverting (the PPP holds) or they have unit root (the PPP does not hold) in the long run. To test the validity of the PPP hypothesis, cointegration analysis, linear and nonlinear unit root, panel unit root tests, and related econometric techniques are commonly and simply applied to the real exchange rates (Bahmani-Oskooee and Hegerty 2009). There is a vast body of literature investigating validity of the PPP. Papers such as those by Bahmani-Oskooee et al. (2007), Frankel and Rose (1996), Froot and Rogoff (1995), Lothian and Taylor (1996, 1997, 2000), Rogoff (1996), Taylor (2006), Taylor and Sarno (1998), and Zhou and Kutan (2011) show the theoretical background and empirical evidence for validity of the PPP hypothesis. A brief review of the literature examines studies of the validity of the PPP in papers such as those by Lothian and Taylor (2008), Sarno and Taylor (2002), and Taylor and Taylor (2004). These papers focus only on developed countries. In general, these studies conclude that the PPP does not hold, or it weakly holds only in the long run.

Many papers also focus on developing economies, including CEE emerging markets or transition economies (see Baharumshah et al. 2011; Bahmani-Oskooee and Goswami 2005; Blueschke et al. 2012; Voigt and Moncada-Paterno-Castello 2012). These studies also use panel unit root tests, linear and nonlinear unit root tests, cointegration analysis, or other related econometric methods and have derived different conclusions about the empirical validity of the PPP. Some studies provide weak (or no) support for the PPP in various groups of transition countries or CEE emerging markets. For instance, Thacker (1995) uses the cointegration technique to test the validity of the PPP hypothesis in the long run for Poland and Hungary over the period of January 1981 to February 1993 in monthly data sets. The author examines them vis-à-vis three countries—Germany, the United Kingdom, and the United States—and finds that the long-run PPP condition does not hold for both Poland and Hungary over the given period. Choudhry (1999) investigates the validity of the long-run PPP condition in Poland, Romania, Russia, and Slovenia against the U.S. dollar by employing both cointegration and fractional cointegration tests. The paper focuses on different periods in monthly data sets: January 1991–September 1996 for Poland; December 1991–May 1997 for Romania; April 1991–August 1997 for Russia; October 1991–May 1997 for Slovenia. The empirical results provide no evidence in favor of the absolute PPP condition; little evidence is found for the relative PPP condition in both Russia and Slovenia. Christev and Noorbakhsh (2000) test the validity of the long-run PPP condition in six CEE countries—Bulgaria, the Czech Republic, Hungary, Poland, Romania, and Slovakia—for the period from January 1990 to October 1998 in monthly data sets. They focus on six domestic currencies against the U.S. dollar, the German mark (DM), and the European currency unit (ECU). Using cointegration system estimation procedures, they conclude that the PPP hypothesis is not valid for these CEE counties in the long run. Payne et al. (2005) use the unit root tests that allow for a maximum of two endogenous structural breaks to examine the PPP condition in Croatia from January 1992 to October 1999 in monthly data. They consider the real effective exchange rates that are defined by both retail and consumer price indices and find the evidence against validity of the long-run PPP in Croatia.

Boršič and Beko (2006) investigate the validity of the PPP hypothesis for domestic currencies of Hungary and Slovenia compared to Austria, France, Germany, and Italy for the period from January 1992 to December 2001 in monthly frequency data. Using different linear unit root tests, they find that the short-run PPP condition only holds in currency of the Hungarian forint against the Italian lira. Results from cointegration techniques cannot confirm the validity of the PPP condition in the long run. Sideris (2006) tests the long-run PPP condition for domestic currencies of seventeen transition economies including the Czech Republic, Hungary, and Poland against the U.S. dollar by using multivariate cointegration technique and the panel cointegration test. The author focuses on different periods from the early 1990s to January 2004 in monthly data sets. The findings show the existence of long-run equilibrium, but the coefficients of the estimated cointegrating vectors do not satisfy the proportionality and symmetry conditions of the PPP condition. Baharumshah and Boršič (2008) focus on thirteen CEE economies—Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Macedonia, Russia, Slovakia, and Slovenia—to examine validity of the PPP hypothesis over the period January 1994 to December 2005 in monthly frequency data. In their paper, both the U.S. dollar and the euro (DM before the euro) are numeraire currencies. Results from the seemingly unrelated regression-augmented Dickey–Fuller (SURADF) unit root test indicate that the short-run PPP condition holds against the U.S. dollar and the euro in

Bulgaria, Croatia, Latvia, Lithuania, Russia, and Slovenia but not for the Czech Republic, Hungary, and Poland. Koukouritakis (2009) examines the long-run PPP condition in domestic currencies of twelve EU countries vis-à-vis the euro (EUR). The paper focuses on different periods for different countries starting from January 1995, January 1996, or January 1997 and continuing to December 2006 in monthly data sets and uses multivariate cointegration methodology in the presence of known structural breaks. The findings clearly show that the long-run PPP condition holds for Bulgaria, Cyprus, Romania, and Slovenia. However, the long-run PPP condition does not hold for the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, and Slovakia. Lin et al. (2011) examine the PPP hypothesis in nine transition economies—Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Russia—against the U.S. dollar for the period from January 1995 to December 2008 in monthly data sets. Their empirical findings from the stationarity test with a Fourier function show that the PPP hypothesis is not valid in the long run for all of the CEE countries except Lithuania.

Some papers in the literature find that the PPP condition is valid for most of the CEE emerging markets or transition countries. Erlat (2003) examines validity of the PPP in Turkey for the period from January 1984 to September 2000 with a monthly data set. He considers the real effective exchange rates in wholesale and consumer price indices that are defined against the U.S. dollar and the DM, and the findings from unit root tests and autoregressive fractionally integrated moving average (ARFIMA) models show that the absolute PPP hypothesis is valid for the Turkish economy in the long run. Solakoğlu (2006) examines the validity of the PPP condition in the real exchange rate of twenty-one transition economies, including the Czech Republic, Hungary, and Poland, in an unbalanced and heterogeneous annual panel data set for the period from 1992 or 1993 to 2003. Using panel unit root tests including individual specific effect, the author improves the findings of Sideris (2006) and concludes that the long-run PPP condition holds for related transition economies. Cuestas (2009) investigates the PPP hypothesis in Bulgaria, Croatia, the Czech Republic, Hungary, Macedonia, Poland, Romania, and Slovakia against the U.S. dollar and the euro over the period of January 1992 to February 2007 in monthly frequency data. The author also considers the real effective exchange rate in related economies, and results from modified unit root and two nonlinear unit root tests indicate that the PPP hypothesis tends to be valid in a more powerful way in the long run when nonlinear deterministic trends and smooth transitions are taken into account. Telatar and Hasanov (2009) examine the validity of the long-run PPP hypothesis for the real exchange rate of ten Commonwealth of Independent States countries vis-à-vis the U.S. dollar. The paper covers different periods for each country in monthly data sets and employs different methodologies such as classical unit root tests, unit root tests in the presence of structural breaks, and nonlinear unit root tests. Parallel to the findings of Cuestas, Telatar and Hasanov's results imply that when they take into account gradual structural breaks and asymmetric adjustment in the series, they obtain results in favor of validity of the PPP hypothesis.

Kasman et al. (2010) investigate the validity of the long-run PPP hypothesis in domestic currencies of ten CEE economies, including the Czech Republic, Hungary, and Poland, against the U.S. dollar– and the DM-based real exchange rates in monthly data sets within different covering periods. They employ the Lagrange multiplier (LM) unit root tests that account for structural breaks in the data and find little evidence supporting validity of the PPP in the U.S. dollar–based real exchange rates. However, in cases of the DM-based real exchange rates, they obtain strong empirical evidence that is consistent with the PPP

hypothesis. Gozgor (2011) examines the validity of the long-run PPP condition in the real rate of the Turkish lira by considering the real exchange rate of its top eight trading partners over the period of January 2003 to December 2010 in monthly balanced panel data sets. Empirical results from the heterogeneous or homogenous panel unit root tests in both cross-section dependence and cross-section independence indicate that the PPP condition holds in Turkey over the given period. Recently, Boršič et al. (2012) and Gozgor (2011) use similar panel unit root tests as well as the SURADF unit root test to examine validity of the long-run PPP condition. Boršič et al. (2012) consider nominal domestic currencies of twelve CEE countries—Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, Poland, Romania, Slovakia, and Slovenia—against both the U.S. dollar and the euro over the period of January 1994 to December 2008 in monthly balanced panel data sets. They find that the PPP condition holds in Bulgaria, Estonia, Latvia, Macedonia, Poland, and Romania against the U.S. dollar and in Bulgaria, Croatia, Hungary, Poland, and Slovakia with respect to the euro.

Many authors examine the PPP relationship for CEE emerging markets and find different results by considering various econometric techniques over different periods. However, no paper has focused on the EU period for the Czech Republic, Hungary, and Poland. Boršič et al. (2012), Gozgor (2011), and Solakoğlu (2006) previously use panel unit tests similar to ours. For instance, Boršič et al. (2012) find in favor of rejecting the validity of the PPP condition in the Czech Republic by using the panel unit root tests. It is important to note that our methodology differs from their recent paper mainly by considering the currencies of the largest five trading partners for each country and ignoring the U.S. dollar exchange rate in the PPP relationships. Thus, we believe that this paper fills the gap in the empirical PPP literature for the Czech Republic, Hungary, and Poland by considering the domestic currencies against their trading partners under the homogenous EU period.

Data and Methodology

First, we determine the main five trading partners who have the most shares in trade volumes of the Czech Republic, Hungary, and Poland. In this determination, the database from the Organization for Economic Cooperation and Development (OECD) is used, and the period from 2005 to 2011 is taken as a basis. We determine the main trading partners for each country to be as follows:

- Czech Republic: European Union, Slovakia, Poland, Russia, China.
- Hungary: European Union, United Kingdom, the Czech Republic, Russia, China.
- Poland: European Union, United Kingdom, the Czech Republic, Russia, China.

Second, the nominal exchange rates are converted into real exchange rates, and they are defined in a balanced panel framework for the Czech Republic, Hungary, and Poland. Thus, the nominal exchange rates of the Czech koruna (CZK), the euro (EUR), the British pound (GBP), the Polish złoty (PLN), the Chinese renminbi (RMB), the Russian ruble (RUB), and the Slovak koruna (SKK) are defined against the related domestic currencies: the CZK, the Hungarian forint (HUF), and the PLN. Data on the nominal exchange rates that are used for this study come from the European Central Bank (ECB). Data on the consumer price indices (CPIs) and producer price indices (PPIs) are from the International Monetary Fund (IMF) and the National Bureau of Statistics of China, and all of them

Table 1. Summary statistics of the real exchange rates in natural logarithmic form

Statistics	Czech Republic	Hungary	Poland
Mean	–1.1278	–3.8095	0.4352
Maximum	0.9646	–1.5354	2.7289
Minimum	–3.4671	–6.0467	–1.9418
Standard deviation	1.4152	1.6835	1.6856
Skewness	–0.2913	–0.1505	–0.1490
Kurtosis	1.7737	1.2961	1.3116
Jarque–Bera (JB)	33.79	54.88	53.88
JB probability	0.00	0.00	0.00
Observations	440	440	440

are defined as 2005 = 100. We represent the summary statistics of related real exchange rates in natural logarithmic form in Table 1.

As can be seen above, 440 observations are used for the Czech Republic, Hungary, and Poland; the period from May 2004 to August 2011 is covered; and the frequency of data is monthly. Nominal exchange rates are converted into real exchange rates using the CPI and the PPI. Real exchange rates are constructed by defining relative prices as the ratio of each country's price index to domestic (the Czech Republic, Hungary, and Poland) country price index. We employ the following method:

$$\log(RER) = \log(NER) + \log(P^*) - \log(P), \tag{1}$$

where *RER* is the real exchange rate, *NER* is the nominal exchange rate, and P^* and P are the foreign (trading partner country) and domestic prices, respectively. The equation indicates that the model for mean-reverting real exchange rate is defined as follows:

$$\log(RER)_t = \alpha + \beta \log(RER)_{t-1} + \varepsilon_t. \tag{2}$$

In Equation (2), α and ε are constant and error term, respectively. The PPP hypothesis suggests that real exchange rate series should be stationary. If there is a unit root in the real exchange rate, this implies that shocks to the real exchange rate are permanent, and the PPP condition does not exist between two countries.

The classical unit root tests for the real exchange rates, such as those proposed by Dickey and Fuller (1979), are subject to some criticism because of the low power of these tests to define the PPP relationship in small samples. Therefore, panel unit root tests have begun to be widely used in the literature. In this paper, we use panel unit root tests that can be arranged in groups by cross-section dependence and cross-section independence or the heterogeneous and homogeneous tests by Breitung (2000), Choi (2001), Hadri (2000), Im et al. (2003), Levin et al. (2002), and Maddala and Wu (1999). To define these approaches, we consider the following AR(1) process for the panel data (Quantitative Micro Software 2009, pp. 395–401):

$$y_{it} = \rho_i y_{it-1} + X_{it}\delta_i + \varepsilon_{it}, \tag{3}$$

where $i = 1, 2, ..., N$ cross-section units or series that are observed over periods $t = 1, 2, ..., T_i$. X_{it} represent the exogenous variables in the model, including any fixed effects or individual trends, ρ_i are the autoregressive coefficients, and the errors ε_{it} are assumed to be mutually independent idiosyncratic disturbance. If $|\rho_i| < 1$, y_i is said to be weakly (trend) station-

ary. If $|\rho_i| = 1$, then y_i contains a unit root. For purposes of testing, there are two natural assumptions that can be made about the ρ_i. First, one can assume that the persistence parameters are common across cross-sections so that $\rho_i = \rho$ for all i; the tests of Breitung (2000), Hadri (2000), and Levin et al. (2002) all employ this assumption. Alternatively, one can allow ρ_i to vary freely across cross-sections. Fisher augmented Dickey–Fuller (Fisher-ADF) and Fisher–Phillips–Perron (Fisher-PP) tests, which are proposed by Choi (2001) and Maddala and Wu (1999), and the panel unit root test of Im et al. (2003) are defined in this form. Panel unit root tests of Breitung (2000), Hadri (2000), and Levin et al. (2002) all assume that there is a common unit root process so that ρ_i is identical across cross-sections. The first two tests employ the null hypothesis of a unit root; the panel unit root test of Hadri (2000) uses the null hypothesis of no unit root. Breitung (2000) and Levin et al. (2002) consider basic ADF specification as follows:

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j-1}^{p_i} \beta_{ij} \Delta y_{it-j} + X_{it}' \delta + \varepsilon_{it}, \tag{4}$$

where we assume that a common $\alpha = \rho - 1$ but allow the lag order for the difference terms ρ_i to vary across cross-sections. The null and alternative hypotheses for these tests may be written as H_0: $\alpha = 0$, H_1: $\alpha < 0$, so under the null hypothesis there is a unit root, while under the alternative hypothesis, there is no unit root. The Fisher-ADF, the Fisher-PP, and Im et al. (2003) tests all allow for individual unit root processes so that ρ_i may vary across cross-sections. The tests are all characterized by the combination individual unit root tests to derive a panel-specific result. Im et al. begin by specifying a separate ADF regression for each cross-section as follows:

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j-1}^{p_i} \beta_{ij} \Delta y_{it-j} + X_{it}' \delta + \varepsilon_{it} a, \tag{5}$$

H_0: $\alpha = 0$ for all i while the alternative hypothesis is given by

$$H_1 \begin{cases} \alpha_i = 0 & \text{for } i = 1, 2, N_1 \\ \alpha_i < 0 & \text{for } i = N+1, N+2, ..., N, \end{cases}$$

where all *observations* may be reordered as necessary if i may be interpreted as a non-zero fraction if the individual process is stationary. These alternative approaches to panel unit root tests use the results by Fisher to derive tests that combine the p-values from individual unit root tests. However, the panel unit root test of Hadri could experience a significant size distortion in the presence of autocorrelation when there is no unit root. Furthermore, the panel unit root test of Hadri appears to overreject the null of stationary series and may yield results that directly contradict those obtained by using alternative test statistics (Hlouskova and Wagner 2006).

Empirical Results

Panel unit root tests, which are proposed by Breitung (2000), Choi (2001), Hadri (2000), Im et al. (2003), Levin et al. (2002), and Maddala and Wu (1999), are applied to the related real exchange rates. These panel unit root tests are used on the level of the variable. Constant and trend terms are also used in the empirical analysis because in recent studies, a term of time trend is included in these panel unit root tests. Allowing for a time trend in the panel unit root tests is equivalent to accepting the existence of factors

with a systematic influence on the real exchange rates. This systematic influence comes from the Harrod–Balassa–Samuelson (HBS) effect and introduces a demand-side bias in favor of nontradable goods. Another reason for using the time trend is the nonstationarity of real exchange rates for traded goods because of the "menu costs" or the "pricing to market" (Sabate et al. 2003). We therefore employ the panel unit root tests that include constant and trend terms.

Empirical findings from the mentioned panel unit root tests for the Czech Republic and Poland strongly support nonstationarity in CPI-based real exchange rates. Only the result from the panel unit root test of Breitung (2000) is statistically significant at the 10 percent level for the Czech Republic, and this is exceptional. Therefore, the PPP condition does not hold in the Czech Republic and Poland with currencies of their largest trading partners. Nevertheless, there is mixed empirical evidence for Hungary. Results from panel unit root tests by ADF-Fisher chi-square version of Levin et al. (2002) and Maddala and Wu (1999) indicate the nonstationarity in real exchange rates of Hungary. However, remaining results from panel unit root tests suggest the validation of the PPP hypothesis in Hungary for the period from May 2004 to August 2011. Thus, weak empirical support is found for validity of the PPP condition among Hungary's trading partners. All of these findings from panel unit root tests can be seen in Table 2.

It is important to note that price convergence may actualize more easily across countries in a group of homogenous goods. Increasing the share of tradable goods in the price index can also have positive effects on price convergence as the PPP condition suggests. Therefore, we consider the PPI-based real exchange rates in natural logarithmic form for the analysis of validity of the PPP. We report the results in Table 3.

Empirical results in Table 3 show that the PPP condition tends to hold in the PPI-based real exchange rates compared to the CPI-based real exchange rates. However, the PPP hypothesis is still not valid in the Czech Republic and Poland. We again obtain mixed results for Hungary, but they are relatively in favor of validity of the PPP condition in the Hungarian economy.

Our empirical results are in agreement with previous research in the literature, such as Baharumshah and Boršič (2008), Boršič and Beko (2006), Boršič et al. (2012), Koukouritakis (2009), and Lin et al. (2011). One should, however, recall that both Boršič and Beko (2006) and Koukouritakis (2009) use cointegration techniques. Baharumshah and Boršič (2008) use only the SURADF unit root test, and Lin et al. (2011) employ the stationarity test with a Fourier function. Only the recent paper of Boršič et al. (2012) considers the panel unit root tests as well as SURADF unit root test in order to examine the PPP condition. However, our methodology differs from Boršič et al. mainly by considering the currencies of the largest five trading partners for the Czech Republic, Hungary, and Poland, and neglects the effects of the U.S. dollar exchange rate on the PPP.

Some papers in the literature discuss the role of the euro compared to the U.S. dollar in analyzing validity of the PPP hypothesis. For instance, Zhou et al. (2008) investigate the PPP hypothesis for the post–Bretton Woods era including the period after the euro. They find that validity of the PPP condition becomes more significant for both the EU and the non-EU countries when the sample period is extended to the introduction of the euro. Similarly, Žd'árek (2012) discusses the effect of benchmark currency on the PPP condition, in other words, whether the euro affects the empirical results for validity of the PPP. He indicates that selection of the euro in PPP validity analysis seems to be rational since the U.S. dollar has lost its significance in CEE countries and the euro has gained importance due to the EU integration process.

Table 2. Results from panel unit root tests for the Czech Republic, Hungary, and Poland (CPI-based)

	Trend and constant		
Cross-section independence	**Czech Republic**	**Hungary**	**Poland**
Homogeneous unit roots			
Hadri (2000) HC *Z*-statistic	2.592***	1.883**	3.294***
	(0.0048)	(0.0298)	(0.0005)
Levin et al. (2002) *t*-statistic	–0.243	–0.581	–0.706
	(0.4040)	(0.7521)	(0.2393)
Breitung (2000) *t*-statistic	–1.383*	–3.220***	–0.625
	(0.0833)	(0.0006)	(0.2857)
Heterogeneous unit root			
Im et al. (2003) *W*-statistic	–0.862	–1.415*	–1.102
	(0.1941)	(0.0784)	(0.1350)
Cross-section dependence			
Heterogeneous unit roots			
Maddala and Wu (1999)	11.584	15.932	12.237
ADF-Fisher chi-square	(0.3138)	(0.1016)	(0.2695)
Choi (2001)	–0.904	–1.413*	–1.159
ADF-Choi *Z*-statistic	(0.1829)	(0.0787)	(0.1231)
Maddala and Wu (1999)	11.354	19.445**	10.569
PP-Fisher chi-square	(0.3306)	(0.0350)	(0.3920)
Choi (2001)	–0.972	–2.150**	–0.869
PP-Choi *Z*-statistic	(0.1653)	(0.0157)	(0.1922)

Notes: All the panel unit root tests have the null hypothesis of the nonstationary real exchange rates, except Hadri (2000), which assumes the stationary series. All panel unit-root tests are defined by the Bartlett kernel and the bandwidth selection method of Newey and West (1994), except Hadri is defined by the quadratic-spectral kernel and the bandwidth selection method of Andrews (1991). Hadri assumes that the unit-root test uses the heteroskedasticity consistent (HC) estimator. The optimal number of lags is chosen by the Schwarz information criterion (SIC). Probabilities for the Fisher test are computed using an asymptotic chi-square distribution. All other tests assume an asymptotic normality distribution. The *p*-values are in parentheses. *, ** and *** rejection of null hypothesis at 10 percent, 5 percent, and 1 percent significance levels, respectively.

There could be several economic rationales on the background of the empirical results. For instance, Solakoğlu (2006) suggests that deviations from the PPP condition in CEE countries shall be decreased if one considers the factor of openness to trade in the PPP models. Results from Baharumshah and Boršič (2008) support the view that the PPP condition holds better for developing countries that are more open to trade because trade barriers prevent arbitrage at the international level. Trade barriers, trade tariffs, and transport costs are important determinants of the deviations from the PPP condition (Rogoff 1996). Size of government in a developing economy can affect the validity of the PPP condition (Froot and Rogoff 1995). Our methodology allows us to consider the existence of some factors with a systematic influence on the real exchange rates (Sabate et al. 2003). In addition, our paper covers a unique and homogeneous floating exchange rate regime period in the European Union for the Czech Republic, Hungary, and Poland. Thus, trade barriers and trade tariffs should not be the main explanations of the deviations from the PPP condition. Bahmani-Oskooee et al. (2008) observe that

Table 3. Results from panel unit root tests for the Czech Republic, Hungary, and Poland (PPI-based)

	Trend and constant		
Cross-section independence	**Czech Republic**	**Hungary**	**Poland**
Homogeneous unit roots			
Hadri (2000) HC *Z*-statistic	2.341**	1.652**	2.928***
	(0.0108)	(0.0413)	(0.0019)
Levin et al. (2002) *t*-statistic	–0.212	–0.434	–0.617
	(0.3219)	(0.4351)	(0.1812)
Breitung (2000) *t*-statistic	–1.479*	–3.338***	–0.803
	(0.0521)	(0.0000)	(0.2437)
Heterogeneous unit root			
Im et al. (2003) *W*-statistic	–0.915	–1.611**	–1.189
	(0.1713)	(0.0512)	(0.1118)
Cross-section dependence			
Heterogeneous unit roots			
Maddala and Wu (1999)	13.281	16.211	14.123
ADF-Fisher chi-square	(0.2977)	(0.1013)	(0.2311)
Choi (2001)	–0.998	–1.609*	–1.201
ADF-Choi *Z*-statistics	(0.1511)	(0.0532)	(0.1008)
Maddala and Wu (1999)	13.177	23.145**	12.876
PP-Fisher chi-square	(0.2796)	(0.0193)	(0.3456)
Choi (2001)	–1.024	–2.345***	–0.939
PP-Choi *Z*-statistics	(0.1342)	(0.0087)	(0.1511)

Notes: All the panel unit root tests have the null hypothesis of the nonstationary real exchange rates, except Hadri (2000), which assumes the stationary series. All panel unit-root tests are defined by the Bartlett kernel and the bandwidth selection method of Newey and West (1994), except Hadri is defined by the quadratic-spectral kernel and the bandwidth selection method of Andrews (1991). Hadri assumes that the unit-root test uses the heteroskedasticity consistent (HC) estimator. The optimal number of lags is chosen by the SIC. Probabilities for the Fisher test are computed using an asymptotic chi-square distribution. All other tests assume an asymptotic normality distribution. The *p*-values are in parentheses; *, **, and *** rejection of null hypothesis at 10 percent, 5 percent, and 1 percent significance levels, respectively.

the PPP condition is likely to be held in developing countries that have relatively higher inflation and a more flexible exchange rate regime. Baharumshah and Boršič (2008) and Lin et al. (2011) indicate that the PPP failed to hold in transition countries that have higher inflation rates and more volatile exchange rate regimes. However, as can be seen in Table 1, standard deviations of the real exchange rates in Hungary and Poland are almost the same; thus, our empirical results would also rule out these explanations for the deviations from the PPP condition. Furthermore, as argued in Lin et al., empirical results for validity of the PPP condition might derive from several factors, such as differences in productivity and factor endowments, dynamics of trade pattern and exports, economic growth, and consumer preferences. We think these can be main factors explaining why our empirical results do not provide evidence in favor of holding the PPP condition in the Czech Republic and Poland and present weak support for the PPP condition in the Hungarian economy.

As argued by Ferto (2007), despite the significant changes in CEE countries during transition to a market economy, the distribution of the trade pattern in the region of Central and Eastern Europe did not change radically over the 1990s. However, the findings show that during the EU integration process, the trade pattern converged in the Czech Republic, Hungary, and Poland. There is no significant specialization in Hungary and a significant fall in specialization in the Czech Republic and Poland vis-à-vis the European Union. Konya (2011) examines the convergence experience and growth dynamics in the Czech Republic, Hungary, and Poland for the period from 1996 to 2009 and shows that capital and labor market distortions vary across these three CEE countries. Damijan et al. (2011) explain the determinants of the rapid growth in exports of eleven transition economies, including the Czech Republic, Hungary, and Poland. In their paper, the main explanatory factors for the exports are increased productivity, foreign direct investment (FDI), and institutional changes. More recently, Stojcic and Bezic (2012) reveal that sunk costs of entry, technology transfer, innovations, and competition play an important role for the decision of firms to export in the Czech Republic, Hungary, Poland, and the other ten CEE countries.

Robustness Check

The literature suggests that we should reconsider the reliability of the results from the "first generation" panel unit root tests presented above. Homogenous panel unit root tests report the evidence regarding the bias, and the relative low power of these tests can be quite strong, so the evidence that homogenous panel unit root tests provide may not be reliable. Furthermore, one can suggest that the impact of cross-section dependence is likely to be significant in real exchange rates of CEE emerging markets. It can be claimed that this is driven by the role of foreign reserve currency of Central Banks in currency crisis models and the structure of government spending in the recent and ongoing European debt crisis climate. Recent empirical findings about these topics can be found in Karabulut et al. (2010), Komijani and Tavakolian (2011), and Wang and Alvi (2011).

We consider performing a formal test of cross-section dependence, such as that proposed by Pesaran (2004). If the result supports the presence of cross-section dependence, first-generation panel unit root tests (which assume cross-section independence) should be replaced in favor of second-generation panel unit root tests. Pesaran proposes the cross-sectional dependence (CD) test, which is an alternative to the LM statistic by Breusch and Pagan (1980). Breusch and Pagan propose an LM statistic, which is valid for fixed N and $T \to \infty$. It is simply given by

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2. \tag{6}$$

In this statistic, $\hat{\rho}_{ij}$ is the sample estimate of the pairwise correlation of the residuals and can be calculated as follows:

$$\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T} \hat{u}_{it} \hat{u}_{jt}}{\left(\sum_{t=1}^{T} \hat{u}_{it}^2\right)^{1/2} \left(\sum_{t=1}^{T} \hat{u}_{jt}^2\right)^{1/2}}, \tag{7}$$

where $\hat{u}_{it}$ is the estimate of u_{it}. LM is asymptotically distributed as chi-squared with $N(N-1)/2$ degrees of freedom. However, when N is large and T is finite, the LM statistic

Table 4. Results of the CD test by Pesaran (2004) for real exchange rates

Cross-section dependence	Czech Republic	Hungary	Poland
Pesaran (2004) CD-statistic probability	0.395 (0.774)	0.653 (0.627)	0.297 (0.813)
Average absolute value of the off-diagonal elements	0.114	0.127	0.099

Notes: The CD test of Pesaran (2004) is defined under the null hypothesis of cross-section independence in the real exchange rates of related Central and Eastern European emerging markets. The *p*-values are in parentheses.

is likely to be biased. Pesaran (2004) proposes an alternative test statistic, and it is defined for balanced panels as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right). \tag{8}$$

He shows that under the null hypothesis of no cross-section dependence, $CD \xrightarrow{d} N(0,1)$ for $N \to \infty$ and T is sufficiently large. This test also offers a robust procedure in the small samples and in the presence of structural breaks. The CD test statistic may also be used when both T and N are large. We apply this CD test procedure to the real exchange rates of three CEE emerging markets and report our findings in Table 4.

As can be seen in Table 4, the CD tests of Pesaran (2004) cannot reject the null hypothesis of no cross-section independence. Thus, following the results from the CD test of Pesaran, we can assert that our findings for the Czech Republic, Hungary, and Poland are robust.

Conclusion

In this paper, we suggest a different insight for further investigation of the PPP hypothesis in three CEE emerging markets: the Czech Republic, Hungary, and Poland. We define the balanced panel framework for the period from May 2004 to August 2011 for domestic currencies of each country vis-à-vis the currencies of their five largest trading partners. We employ eight first-generation panel unit root tests and check the robustness of the findings by using Pesaran's (2004) formal test of cross-section dependence.

This paper covers a unique and homogenous period—the EU floating regime period of the Czech Republic, Hungary, and Poland. The paper makes an important contribution to the existing literature. Different from other studies, this paper focuses on the currencies of the largest trading partners and indicates that the United States is not one of the main trading partners for these CEE countries. Thus, previous studies that test the PPP hypothesis vis-à-vis the U.S. dollar might have generated misleading empirical findings for the Czech Republic, Hungary, and Poland.

Empirical results from panel unit root tests show that the stochastic behavior of real exchange rates in the Czech Republic and Poland is not a mean reversion, and the PPP condition does not hold over the period May 2004 to August 2011. Only exceptionally weak support for a mean-reverting behavior is found from the panel unit root test of

Breitung (2000) for the Czech Republic. However, mixed empirical evidence is obtained in the case of Hungary. Limited empirical support is found for validity of the PPP hypothesis among the currencies of Hungary's trading partners for the period from May 2004 to August 2011. Following the results from the CD test of Pesaran (2004), we can suggest that these empirical results are robust.

The important implication from these empirical findings comes from the fact that temporary shocks upon the real exchange rates in the Czech Republic and Poland would have permanent effects. The impact of external shocks on the real exchange rate in Hungary would be more limited. The main policy implication of this paper is that a monetary transmission mechanism would have permanent effects on the value of real exchange rates in the Czech Republic, Hungary, and Poland. The expansionary or contractionary monetary policies will be substantially effective in changing the long-run value of real exchange rates in these CEE emerging economies. These effects from the monetary policy on the real exchange rate would be restricted in the Hungarian economy.

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