



HAL
open science

A RE-EXAMINATION OF REAL INTEREST PARITY IN CEECs USING 'OLD' AND 'NEW' SECOND GENERATION PANEL UNIT ROOT TESTS

Claudiu Tiberiu Albuлесcu, Dominique Pépin, Aviral Kumar Tiwari

► **To cite this version:**

Claudiu Tiberiu Albuлесcu, Dominique Pépin, Aviral Kumar Tiwari. A RE-EXAMINATION OF REAL INTEREST PARITY IN CEECs USING 'OLD' AND 'NEW' SECOND GENERATION PANEL UNIT ROOT TESTS. 2014. hal-01089380

HAL Id: hal-01089380

<https://hal.science/hal-01089380>

Preprint submitted on 1 Dec 2014

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

A RE-EXAMINATION OF REAL INTEREST PARITY IN CEECs USING ‘OLD’ AND ‘NEW’ SECOND GENERATION PANEL UNIT ROOT TESTS

Claudiu Tiberiu Albuлесcu^{a,b}, Dominique Pépin^b, Aviral Kumar Tiwari^c

^a Management Department, Politehnica University of Timisoara, 2, P-ta. Victoriei, 300006 Timisoara, Romania

^b CRIEF, University of Poitiers, 2 rue Jean Carbonnier, 86022 Poitiers, France

^c Faculty of Management, IBS Hyderabad, IFHE University, Dontanpalli, Hyderabad, Pin- 501203, India

ABSTRACT

This study applies ‘old’ and ‘new’ second generation panel unit root tests to check the validity of long-run real interest rate parity (RIP) hypothesis for ten Central and Eastern European Countries (CEECs), with respect to the Euro area and an average of the CEECs’ real interest rates, respectively. When the ‘new’ panel unit root tests are carried out relative to the Euro area rate as reference, we confirm the results of previous studies which support the RIP hypothesis, and of the ‘old’ tests used as benchmark. Nevertheless, when the ‘new’ tests are performed using the average of the CEECs’ rate as reference, our results are mitigated, revealing that the hypothesis of CEECs’ interest rates convergence cannot be taken for granted. From a robustness analysis perspective, our findings indicate that the RIP hypothesis for CEECs should be considered with cautions, being sensitive to the reference rate and to the countries retained in the sample.

Keywords: real interest parity, panel unit root tests, CEECs

JEL classification codes: C33; F36; G15.

I. INTRODUCTION

Since the collapse of the Gold-Exchange Standard, trade controls and barriers to international portfolios investments were progressively raised, triggering a considerable increase of the flexibility and substitutability of financial assets at international level during the last four decades. The generated financial globalization is supposed to lead to the elimination of worldwide arbitrage opportunities out of the Gold-Exchange Standard, the real interest rates observed in different countries being thus in the position of adjusting themselves based on the same global real exchange rate. This equality of the real interest rates is known as the real interest rates parity (RIP).

Yet, the RIP resulting from the national markets' interdependence is not a simple financial integration indicator. It has been shown that the confirmation of RIP depends on the extent of the uncovered interest parity (UIP), the relative purchasing power parity (RPPP) and the Fisher equation in domestic and foreign countries. Hence, confirmation of RIP encompasses elements of both real and financial market integration and, as such, it can be viewed as a more general indicator of integration or convergence (Holmes, 2002). From a policy perspective, it is desirable that a country joining a monetary union sees its real interest rate adjusting itself to those of its counterparties. In this context, the accession of a country to a monetary union entails minimal costs. On the contrary, if the condition related to the equality of the real interest rates is violated, countries adopting the same currency will experience asymmetries in their responses to monetary policy shocks. The validity of the RIP is thus subject to debates of considerable importance for countries having abandoned their monetary sovereignty or which intend to do so, and, from this point of view, they are of great interest for the Central and Eastern European Countries (CEECs), members of the European Union (EU), because most of these countries have still preserved their monetary sovereignty.

Numerous researches on RIP were carried out for developed countries. The first studies (Mishkin, 1984, Cumby and Obstfeld, 1984, Mark, 1985 and Cumby and Mishkin, 1986) found that the proofs in favor of the RIP were quite limited, and this was for sure due to the short data sets used for the tests, and to the adopted econometric methodology, ignoring the non-stationarity of the interest rate. Other studies considering the non-stationarity of the interest rate (Meese and Rogoff, 1988, Edison and Pauls, 1993, Goldberg *et al.*, 2003 and Pipatchaipoom and Norrbin, 2010) also reached inconclusive results, due to the use of short data samples and to the lack of explanatory power of standard unit roots tests in these conditions (Campbell and Perron, 1991). In order to solve this problem, it is possible to retain into the analysis a much longer time period (Lothian, 2002, Obstfeld and Taylor, 2002 and Sekioua, 2008), to perform nonlinear unit root tests or tests which take into account possible structural changes (Ferreira and León-Ledesma, 2007, Baharumshah *et al.*, 2009 and Camarero *et al.*, 2010), or to proceed to panel data analyses (Holmes, 2002 and Wu and Chen, 1998; Camarero *et al.*, 2009). Recently, the tests results proved clearly in favor of the RIP for the developed countries.

As the integration of capital markets affecting the 'peripheral' regions of the world started in the 1990s, the empirical analysis of the RIP validity was extended to cover these regions. In this line, Baharumshah *et al.* (2005, 2011), Liew and Ling (2008) and Holmes *et al.* (2011) found evidence of RIP for Asian countries. Camarero *et al.* (2010) and Ferreira and León-Ledesma (2007) showed the presence of the RIP in a sample of industrial and emerging economies. On the contrary, Singh and Banerjee (2006) found that real interest rates in the emerging markets show some convergence in the long run, but real interest rate equality does not hold. In respect of the CEECs, Holmes and Wang (2008a, 2008b), Arghyrou *et al.* (2009), Sonora and Tica (2010), Cuestas and Harrison (2010), Su *et al.* (2012), He *et al.* (2013) and Baharumshah *et al.* (2013) reached, based on diversified econometric techniques, the conclusion that the RIP is valid and that these countries should integrate the European Union:

Arghyrou *et al.* (2009) and Sonora and Tica (2010) used univariate unit root tests allowing structural breaks, Holmes and Wang (2008a) applied panel unit root tests, Holmes and Wang (2008b) employed an approach where unit roots tests are embedded within a Markov regime-switching framework, Cuestas and Harrison (2010) and Su *et al.* (2012) applied an univariate nonlinear unit root test, He *et al.* (2013) employed a panel unit root test with a Fourier function while Baharumshah *et al.* (2013) used a panel stationarity test that allows for multiple breaks. All these papers confirmed very easily the validity of the RIP theory, even if some recent researches documented, for developed countries, consistent deviation from the RIP during the 2007-2009 financial turmoil (Baba and Paker, 2009, Fong *et al.*, 2010, Hui *et al.*, 2011). Is this the case also for the CEECs?

Furthermore, the papers approaching the RIP theory for transition countries obtained consistent results, but this is not surprising having in mind the fact that it is always the US and the European rates which are used as reference interest rate. Would the RIP remain valid if a real interest rate, more representative for the CEECs, is used as reference? In our opinion, caution is required in front of these results because the RIP should be tested considering a European rate as reference interest rate, which resumes to testing the integration of CEECs into the European Union (EU), and, at the same time, it is also convenient to test the convergence of CEECs' interest rates between them. Indeed, the intra-convergence of CEECs can be seen as a prerequisite for their convergence into the EU. For this purpose, we propose to test the CEECs' RIP using a comparison with the average real interest rate of the selected CEECs, an approach which was never before investigated, as far as we know.

As it is well known that unit root tests lack explanatory power when it comes for short data samples, we use panel data analysis.¹ Consequently, in order to prove the robustness of these tests for panel data, we perform on each panel a set of 'old' and 'new' second generation unit root tests, we use different references for the international interest rate and we also proceed to a resampling method. We test the RIP hypothesis based on the second generation of test because we document cross-sectional dependence in our data. Consequently, the use of the first generation unit root tests, that are based on the cross-sectional independence assumption, might cause these tests to accept by mistake the hypothesis of a unit root (see for example O'Connell, 1998, Baltagi, 2005, Breitung and Pesaran, 2008, and Hurlin, 2010).² Besides, all unit root tests based on panel data and applied for the RIP starting with the middle of the years 2000s (Baharumshah *et al.*, 2005 and 2013, Camarero *et al.*, 2010, Liew and Ling, 2008 and Singh and Banerjee, 2006) relax the cross-sectional independence assumption.

The second generation tests we use in this study are the MP test (Moon and Perron, 2004), the Pesaran test (Pesaran, 2007) and the Choi tests (Choi, 2006). Apart these 'old' second generation standard tests considered as benchmark, we also propose the use of more recent, 'new' second generation tests, as for example those of Lupi (2011), Hanck (2013) and Costantini and Lupi (2013), which are particularly well suited for the case of short term panels and which have never before been employed to test the validity of the RIP. Furthermore, the 'new' tests show good size and power properties relative to 'old' panel unit root tests.

¹ The other three empirical studies on the RIP for the CEECs using unit root tests in panel data are those of Holmes and Wang (2008a), He *et al.* (2013) and Baharumshah *et al.* (2013). However, none of these tests proceeds to the robustness check we propose by the use of the CEECs' average real interest rate as reference for the real interest rate differential.

² Part of the first generation of panel unit root tests (the MW test - Maddala and Wu, 1999, the Choi test - Choi, 2001, the LLC test - Levin *et al.*, 2002 and the IPS test - Im *et al.*, 2003) have been successfully used for checking the RIP hypothesis for developed countries, despite the strong assumptions on which they rely. It seems thus interesting to see if similar results could be obtained when analyzing the RIP in the case of the CEECs. That is why we have applied the aforementioned tests and their findings are in line with the 'old' second generation of tests (these results can be obtained upon request). Nonetheless, the hypothesis of the cross-sections independence is rejected by our estimations and it is thus important to resort to second generation tests, in order to check the validity of the RIP theory for the CEECs.

The rest of the paper is organized as follows. Section II describes the theoretical framework and the data used in the empirical analysis. Section III describes the econometric methodology used in this study, and Section IV presents the empirical results. Section V concludes.

II. DEFINITION OF THE REAL INTEREST PARITY AND DATA ANALYSIS

II.1. Real Interest Parity

The real interest parity condition is derived in a classical way, from the *ex-ante* relative purchasing power parity, the Fisher relation for each country, and the uncovered interest parity condition. In an open economy, the RIP relies on the equilibrium in the goods and services market on the one hand and asset markets on the other hand.

Consequently, the basic postulate for the relationship between domestic (i) and foreign (i^*) interest rates, shows that substitutable financial assets denominated in domestic and foreign currencies are related according to the UIP relationship, such as:

$$\Delta s_{t,t+1}^e = i_t - i_t^* - \gamma_t, \quad (1)$$

where $\Delta s_{t,t+1}^e$ is the one-period ahead expected change in the nominal exchange rate, measured as the domestic price of the foreign currency, and where γ_t designates the interest rate differential explained by the exchange risk premium and other factors, such as transaction costs and national tax rates differential (Holmes, 2002; Sarno, 2005). Because the last factors have a reduced importance as compared to the first one,³ γ_t can be simply considered as a risk premium.⁴ Indeed, taking into account the risk premium is particularly relevant in the case of the CEECs (Sonora and Tica, 2010) or in the case of the emerging markets (Ferreira and León-Ledesma, 2007). Thus, Equation (1) is a general expression of the UIP, often simplified by the omission of the risk premium, that is $\gamma_t \equiv 0$.

The Fisher conditions for the domestic and foreign country are:

$$r_t^e = i_t - \Delta \pi_{t,t+1}, \quad (2)$$

and

$$r_t^{*e} = i_t^* - \Delta \pi_{t,t+1}^*, \quad (3)$$

where r_t^e and r_t^{*e} are the real interest rates in the domestic and foreign country respectively, while $\Delta \pi_{t,t+1}$ and $\Delta \pi_{t,t+1}^*$ are the one-period ahead expected inflation rates and π is expressed as the natural logarithm of the price level (in our case, the consumer price index – CPI).

The *ex-ante* RPPP suggests that the exchange rate responds to offset spreads in expected inflation between countries. Otherwise said, the expected exchange rate depreciation should be equal to the expected inflation differential over the same period. Actually, the RPPP can be violated because of transaction costs and non-traded goods. We can thus formulate it as an imperfect short term relationship:

$$\Delta s_{t,t+1}^e = \Delta \pi_{t,t+1} - \Delta \pi_{t,t+1}^* + \varepsilon_t, \quad (4)$$

where ε_t is the short term deviation from the RPPP. If we consider $\varepsilon_t \equiv 0$, the RPPP is verified both in the short and long runs.

Consequently, combining Equations (1)–(4), we reach the following result with respect to the real interest rates differential:

$$r_t^e - r_t^{*e} = \gamma_t + \varepsilon_t \quad (5)$$

Equation (5) has to be considered as a generalized expression of the RIP. Assuming that the risk premium is equal to zero, $\gamma_t \equiv 0$, and that the RPPP is always verified, $\varepsilon_t = 0$, we obtain the strong version of the RIP which stipulates a perfect equality between the real interest rates:

³ Al-Awad and Grennes (2002) show that observed transactions for a group of ten countries tend to decrease over time and are too small to account for differences among real interest rates.

⁴ For simplifying the notations, γ_t is the risk premium without referring to a specific pair of countries. Nevertheless, in general, this risk premium varies between countries.

$$r_t^e - r_t^{*e} = 0 \quad (6)$$

where $r_t^e - r_t^{*e}$ represents the real interest rate differential (RIRD), equal to zero according to the strong version of the RIP.

However, the existence of a risk premium and short run deviations from the RPPP prevents the RIRD from being constant at every point. If we assume that the risk premium γ_t is stationary and that the RPPP describe a long run equilibrium relationship, the generalized expression of the RIP in Equation (5) supposes that the RIRD is a stationary variable:

$$r_t^e - r_t^{*e} \sim I(0) \quad (7)$$

Supposing that the domestic and foreign interest rates are integrated of order 1, $r_t^e \sim I(1)$ and $r_t^{*e} \sim I(1)$, the stationarity of their difference shows that the RIP is verified in the long run, that is, the RIRD is mean reverting. Thus, in order to test the validity of the long run RIP equality,⁵ we must see whether the RIRD presents no unit root, as in Equation (7).

Because data on expected inflation is not readily available, unit root results are sensitive to how the inflation expectations and the real rate interest are computed (Pipatchaipoom and Norrbin, 2010). In order to assess the sensitivity of our results to the way we compute the real interest rates, we follow Cuestas and Harrison (2010) and Sonora and Tica (2010) and use *ex-ante* (rational) and *ex-post* (fitted) inflation expectations. The former implies that we obtain expected values for future inflation. In this respect, we suppose that agents use previous inflation rates π_t and π_t^* to form their expectations of future inflation rates, that is $\pi_{t,t+1} = \pi_t$ and $\pi_{t,t+1}^* = \pi_t^*$. The latter assumes perfect forecasting skills which mean that inflation expectations $\pi_{t,t+1}$ and $\pi_{t,t+1}^*$ are equal to the achieved future inflation rates π_{t+1} and π_{t+1}^* .⁶

The last technical detail of our methodology regarding the unit root tests of the RIRD, resides in the use of two different references for the international rate. First, in the line of the previous RIP analyses for the CEECs, we consider an international interest rate, namely the Euro area rate, as reference. We thus test the hypothesis of CEECs' integration into the EU. Second, we establish as reference the average level of indicators for the retained CEECs. Consequently, we test the hypothesis related to the homogeneity of CEECs' real interest rates and to the convergence towards a representative rate for these countries. Mathematically, the CEECs' real interest rates cannot be globally equal to the Euro area rate, without being equal amongst them, which can thus be considered as a prerequisite for their European integration.

II.2. Data

The monthly data are obtained from the IMF's International Financial Statistics database, and cover the period from January 2000 to April 2012. The inflation rate is computed based on the CPI, while for the nominal interest rate we have chosen the money market rate. The use of a short term rate allows to minimize, but not to completely eliminate, the exchange rate influence, which is an important risk element in the case of the long term rates (Ferreira and Leon-Ledesma, 2007). After a preliminary data analysis, in order to avoid the broken panel problem, only 10 CEECs were retained in our sample (Bulgaria, Cyprus, Czech Republic, Estonia, Lithuania, Latvia, Poland, Romania, Slovakia, Slovenia). All these countries are nowadays members of the EU and five of them have also joined the Euro area (Cyprus, Estonia, Latvia, Slovakia and Slovenia). The mean RIRD statistics, for all the analyzed cases (*ex-ante*, *ex-post*, Euro area and the average of the group as benchmark) are presented in Table 1.

⁵ The hypothesis of the RIP validity in the long run corresponds to the associated hypotheses related to the risk premium γ_t stationarity, with short term tendencies fluctuating around its long term value γ , and to an adjusted version of the RPPP, where the long term deviations from the RPPP equal a constant term ε , which is not necessarily zero.

⁶ Testing the stationarity of the RIRD calculated based on *ex-post* inflation expectations, can be considered as a robustness check for the results obtained employing the classic *ex-ante* relative purchasing power parity condition.

TABLE 1
Mean RIRD statistics

	BU	CY	CZ	ES	LI	LV	PL	RO	SK	SV	Panel
<i>ex-ante</i> (Euro area)	-0.97	-0.14	0.25	0.27	-0.54	-0.20	4.27	13.1	0.96	0.84	1.87
<i>ex-ante</i> (average)	-2.76	-1.89	-1.50	-1.51	-2.18	-2.04	2.48	11.3	-0.83	-0.93	0.10
<i>ex-post</i> (Euro area)	-0.98	-0.15	0.24	0.29	-0.56	-0.20	4.26	13.1	0.95	0.83	1.87
<i>ex-post</i> (average)	-2.76	-1.91	-1.50	-1.49	-2.19	-2.03	2.48	11.2	-0.83	-0.95	0.10

Note: BU (Bulgaria), CY (Cyprus), CZ (Czech Republic), ES (Estonia), LI (Lithuania), LV (Latvia), PL (Poland), RO (Romania), SK (Slovakia), SV (Slovenia).

We first notice that, in all the cases, Romania is less integrated in the selected group, when we assess the average RIRD. Its higher inflation during the 1990s forced the monetary authorities to practice high interest rate, with implications in the 2000s also. Consequently Romania can act as an outlier in our sample. Second, we observe that no matter the considered reference rate (Euro area or CEECs' average), the descriptive statistics are not sensitive to the way of measuring inflation expectations. Thus, the use of *ex-ante* or *ex-post* inflation expectations shall not influence the results. Third, we notice a slight difference between the RIRD calculates considering the Euro area or the average of the group as reference.

III. METHODOLOGY

We test the RIP hypothesis for the CEECs using different second generation unit root tests, assuming cross-sectional dependence: the MP test (Moon and Perron, 2004), the Pesaran test (Pesaran, 2007) and the Choi tests (Choi, 2006). In addition, we propose recent second generation tests, which have not been previously used for testing the validity of the RIP: Lupi (2011), Hanck (2013) and Costantini and Lupi (2013).

The basic model underlying the second generation tests is:

$$\Delta RIRD_{i,t} = \alpha_i + \rho_i RIRD_{i,t-1} + \sum_{k=1}^{p_i} \beta_{i,k} \Delta RIRD_{i,t-k} + v_t \quad (8)$$

for $i = 1, \dots, N$ and $t = 1, \dots, T$.

For all these tests the null hypothesis is defined as $H_0: \rho_i = 0$ for all $i = 1, \dots, N$ and the alternative hypothesis is $H_1: \rho_i < 0$ for $i = 1, \dots, N_1$ and $\rho_i = 0$ for $i = N_1 + 1, \dots, N$ with $0 < N_1 \leq N$. The alternative hypothesis allows unit roots for some (but not all) of the countries.

III.1. 'Old' second generation of panel unit root tests

The first tests retained in the 'old' second generation of unit root tests category are those of Moon and Perron (2004). The authors use a factor structure to model cross-sectional dependence, assuming that error terms are generated by common factors and idiosyncratic shocks. The MP tests consider thus the factors as nuisance parameters and suggest pooling de-factored data to construct a unit root test. The two modified t -statistics with standard normal distribution which hold under the null hypothesis are:

$$t_a = \frac{T\sqrt{N}(\rho_{pool}^+ - 1)}{\sqrt{2\gamma_e^4/w_e^4}} \xrightarrow[T, N \rightarrow \infty]{d} N(0,1) \quad (9)$$

$$t_b = T\sqrt{N}(\rho_{pool}^+ - 1) \sqrt{\frac{1}{NT^2} \text{trace}(Z_{-1} Q \wedge Z'_{-1}) \frac{w_e^2}{\gamma_e^4}} \xrightarrow[T, N \rightarrow \infty]{d} N(0,1) \quad (10)$$

where w_e^2 denotes the cross-sectional average of the long run variances of residuals e , γ_e^4 is the cross-sectional average of w_e^4 . Moon and Perron (2004) propose feasible statistics t_a^* and t_b^* based on an estimator of the projection matrix and estimators of long run variances w_{ei}^2 .

Pesaran (2007) adds the cross-section averages of lagged levels and of first differences of the individual series to the Augmented Dickey–Fuller (ADF) regressions. This way, the common factor is proxied by the cross-section mean of $y_{i,t}$ and its lagged values. The Pesaran test uses the cross-sectional ADF statistics (CADF), which are given below:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i \bar{y}_{t-1} + \delta_i \Delta \bar{y}_i + \varepsilon_{i,t} \quad (11)$$

where $\alpha_i, \beta_i, \gamma_i, \delta_i$ are slope coefficients estimated from the ADF test for the country i , \bar{y}_{t-1} is the mean of lagged levels, $\Delta \bar{y}_i$ is the mean of first-differences, $\varepsilon_{i,t}$ are the error terms.

In fact, Pesaran (2007) advances a modified IPS statistics based on the average of the individual CADF, which is denoted as a cross-sectional augmented IPS (CIPS):

$$CIPS = \frac{1}{N} \sum_{i=1}^N t_i(N, T) \quad (12)$$

where $t_i(N, T)$ is the t -statistic of the OLS estimate for the equation $y_{it} = \alpha_i + y_{it}^0$ (see Moon and Perron, 2004).

Finally, Choi (2006) uses an error-component model to specify the cross-sectional correlations. The author suggests that cross-sectional correlations and deterministic components are eliminated by the GLS-based detrending (Elliott *et al.*, 1996) and the conventional cross-sectional demeaning for panel data. Afterwards, Choi (2006) employs a standard ADF t -statistic on the regression Equation (8) without intercept, where the corrected RIRD is substituted for the original one. Based on these individual standard ADF t -statistics, Choi (2006) uses the three Fisher's type tests, advanced by Choi (2001):

$$P_m = -\frac{1}{\sqrt{N}} \sum_{i=1}^N [\ln(p_i) + 1] \quad (13)$$

$$Z = \frac{1}{\sqrt{N}} \sum_{i=1}^N \Phi^{-1}(p_i) \quad (14)$$

$$L^* = \frac{1}{\sqrt{\pi^2 N/3}} \sum_{i=1}^N \ln\left(\frac{p_i}{1-p_i}\right) \quad (15)$$

where p_i denotes the asymptotic p -values of the standard ADF t -statistics for the country i , $\Phi^{-1}(\cdot)$ is the inverse normal cumulative distribution function and P_m, Z and L^* are the first, the second and respectively the third Choi (2006)'s tests. Under the null hypothesis, all these three Fisher's type statistics have a standard normal distribution.

The asymptotics of the conventional second generation tests from our analysis (Moon and Perron, 2004; Choi, 2006; Pesaran, 2007) require $N \rightarrow \infty$ and $T \rightarrow \infty$, a quite restrictive condition for macro panel applications. However, the Monte Carlo simulations performed for these tests by their authors show that the tests have reasonably good size and power properties for finite N , and especially in the absence of deterministic components. These properties enable us to use the 'old' tests as benchmark for our analysis. However, different from the 'old' tests, the 'new' tests are conceived for small panels. Except for Pesaran (2007) who shows that the CIPS test presents satisfactory size properties even for very small sample sizes as ours (i.e., $N = 10$), on contrary, all the other 'old' tests are less performing in the case of such small panels. The 'new' tests are well suited for macro panels with small to moderate values of N , and their asymptotics do not require $N \rightarrow \infty$, which is an extremely important feature of these tests. Furthermore, the 'new' tests' Monte Carlo experiments show good size and power properties relative to the 'old' panel unit root tests.

III.2. 'New' panel unit root tests from the second generation

The first generation of panel unit root tests (Maddala and Wu, 1999; Choi, 2001) uses simple p -values combination tests and assumes that the panel units are cross-sectionally independent.

In particular Choi (2001) suggests that, under the null, the inverse normal combination test has the best overall performance:

$$Z = \frac{1}{\sqrt{N}} \sum_{i=1}^N \Phi^{-1}(p_i) \xrightarrow{d} N(0,1) \quad (16)$$

However, the assumption of cross-sectionally independence is quite restrictive and it is challenged for the first time by Hartung (1999), who studied p -value combinations from dependent test statistics. He shows that if the probits $\Phi^{-1}(p_i)$ are correlated, with a common correlation ∂ which is practically unknown, then, under the null:

$$Z_H = \frac{1}{\sqrt{N(1+\partial(N-1))}} \sum_{i=1}^N \Phi^{-1}(p_i) \sim N(0,1) \quad (17)$$

Building up on Hartung (1999), Demetrescu *et al.* (2006), propose a modification of the Choi's inverse-normal combination test that can be used when the N p -values are not independent:

$$\hat{Z}_H = \frac{\sum_{i=1}^N \Phi^{-1}(p_i)}{\left\{ N \left[1 + \left(\hat{\partial}^* + 0.2 \sqrt{\frac{2}{N+1}(1-\hat{\partial}^*)} \right) (N-1) \right] \right\}^{\frac{1}{2}}} \quad (18)$$

where $\hat{\partial}^*$ is a consistent estimator of ∂ , such that $\hat{\partial}^* = \max \left\{ -\frac{1}{N-1}, \hat{\partial} \right\}$, with

$$\hat{\partial} = 1 - (N-1)^{-1} \sum_{i=1}^N (\Phi^{-1}(p_i) - N^{-1} \sum_{i=1}^N \Phi^{-1}(p_i))^2 \quad (19)$$

A rather different viewpoint is advanced by Hanck (2013), who observes that the problem of panel unit root testing can be recast in terms of a multiple testing problem, using the intersection test presented in Simes (1986). He considers $p_{(i)}$ the ordered sequence of the N_p values of each unit root test, on each individual series. The proposed test is simple to compute, as for a pre-specified significance level α the null is rejected if $p_{(i)} \leq i\alpha/N$ for any $i = 1, \dots, N$.

Other developments are put forward by Costantini and Lupi (2013), who consider panel covariate Dickey-Fuller tests as simple extensions, based on the p -value combination methods outlined above, of the CADF test advocated in Hansen (1995). Hansen (1995) proves that the unit root test statistic under the null is no longer distributed according to a Dickey-Fuller distribution, but is instead distributed according to a weighted sum of a Dickey-Fuller and a standard normal distribution, where the weights are functions of a nuisance parameter. The testing equation is however very similar to the ordinary ADF equation:

$$a(L)\Delta y_t = \delta y_{t-1} + b(L)\Delta x_{t-1} + e_t \quad (20)$$

Under the fulfillment of some regularity conditions, Hansen (1995) shows that, under the unit root null, the t ratio for the coefficient in Equation (20) is such that:

$$\hat{t}(\delta) \xrightarrow{w} \rho \frac{\int_0^1 w dW}{\left(\int_0^1 w^2 \right)^{\frac{1}{2}}} + (1 - \rho^2)^{\frac{1}{2}} N(0,1) \quad (21)$$

where W is a standard Wiener process and $N(0,1)$ is a standard normal independent of W .

Costantini and Lupi (2013) exploit this idea and propose p -value combination following Demetrescu *et al.* (2006). Briefly, Costantini and Lupi (2013) suggest to use the average of the first difference of the other series in the panel, as the stationary covariate for each variable to be tested. This procedure aims at extracting an underlying non-stationary common factor among the observed series.

The use of Hansen's CADF test instead of the conventional ADF test ensures that the panel test has better explanatory power properties. It is named pCADF test. Furthermore, in Costantini and Lupi (2013), contrary to Demetrescu *et al.* (2006), the Hartung (1999)'s procedure for cross-correlation correction is applied only when the p -value of the cross-correlation test advocated by Pesaran (2004) is lower than a pre-specified threshold whose default value is set to 0.10.

Therefore, in the present study we apply the recent proposed test to the panel covariate augmented Dickey-Fuller test, proposed by Costantini and Lupi (2013). In addition, we also

apply an extension of the CADF tests suggested by Hanck (2013) and developed in Lupi (2011), extension related to the Simes' (1986) procedure.

IV. EMPIRICAL RESULTS

IV.1. RIRD based on ex-ante inflation expectations

In the first step, we present the results of the unit root tests for the RIRD, computed based on ex-ante inflation expectations, more exactly assuming that $\pi_{t,t+1} = \pi_t$ and $\pi_{t,t+1}^* = \pi_t^*$.

Before that, we highlight the cross-sectional dependence in our data, which recommends the use of the second generation of tests (Table 2). All the tests performed reject the null hypothesis of cross-sectional independence, either we use Euro area or the group average as reference interest rate.

TABLE 2
Cross-sectional dependence tests for panel data for ex-ante inflation expectations

	Euro area as reference			Average of the group as reference		
	Test statistic	d.f.	p-value	Test statistic	d.f.	p-value
Breusch-Pagan Chi-square (Breusch and Pagan, 1980)	878.8415	45	0.0000	2406.874	45	0.0000
Pearson LM Normal (Pesaran, 2004)	86.84052		0.0000	247.9093		0.0000
Pearson CD Normal (Pesaran, 2004)	17.71414		0.0000	8.085523		0.0000
Friedman Chi-square (Friedman, 1937)	489.2522	147	0.0000	282.8447	147	0.0000
Frees Normal (Frees, 1995)	1.307684		0.0000	2.473690		0.0000

Note: The null hypothesis is the cross-sectional independence

The entire battery of 'old' second generation tests rejects the null hypothesis of unit root for the RIRD, at all significance levels (Table 3). Moreover, these results are robust regarding the retained reference rate. Nevertheless, an exception appears for the Pesaran (2007)'s CIPS test, which does not reject the null hypothesis of unit root for the case where the RIRD is estimated based on the group's average as reference.

TABLE 3
Second generation of 'old' panel unit root tests for ex-ante inflation expectations

Tests	Test statistic		Critical values		
	Euro area as reference	Average of the group as reference	1 %	5 %	10 %
First MP test (Moon and Perron, 2004)	-20.526	-13.788	-2.3263	-1.6449	-1.2816
Second MP test (Moon and Perron, 2004)	-5.7142	-5.1461	-2.3263	-1.6449	-1.2816
First Choi's test statistic (Choi, 2006)	16.427	14.006	2.3263	1.6449	1.2816
Second Choi's test statistic (Choi, 2006)	-8.5340	-7.8596	-2.3263	-1.6449	-1.2816
Third Choi's test statistic (Choi, 2006)	-10.738	-9.4108	-2.3263	-1.6449	-1.2816
Pesaran's CIPS test (Pesaran, 2007)	-3.1107	2.9493	-2.5669	-2.3310	-2.2062

Note: In order to reject the null of unit root, the first Choi statistic has to be above its critical value, while all the other statistics must be under their critical values.

For the 'new' panel unit root tests we notice that the results are largely influenced by the reference rate. At 5% significance level, all the tests lead to the rejection of the null of non-stationarity, when the Euro area is considered as reference. A slight difference appears for the pCADF_PC test (Lupi, 2011), which rejects the null only at 10% significance level. Nevertheless, when the average of the group is taken as reference, at 5% significance level, all the tests accept the hypothesis of unit root. We notice thus the consistence of the findings provided by the 'new' generation of tests.

However, the fact that the choice of the reference rate generates opposite results according to the 'new' tests of Costantini and Lupi (2013), Lupi (2011) and Hanck (2013), bring forward an original version of the CEECs' integration. If, in general, the hypothesis of their integration with the Euro area is accepted when assuming the European rate as reference, the

hypothesis of the interest rate convergence for these countries towards a common rate is afterwards rejected. Thus, the first conclusion must be considered with caution due to the fact that the alignment of the CEECs' real interest rates with the European rate cannot be achieved without a convergence between the CEECs.

TABLE 4
Second generation of 'new' panel unit root tests for ex-ante inflation expectations

Tests	Euro area as reference			Average of the group as reference		
	Constant model	Test statistic	p-value	Test statistic	p-value	
pCADF (Costantini and Lupi, 2013)		-4.0782	0.0000	-0.9266	0.1770	
pCADF_PC (Costantini and Lupi, 2013)		-2.0041	0.0225	-1.6283	0.0517	
	Decision on H0	1%	5%	10%	1%	5%
Simes ADF (Hanck, 2013)	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
Simes pCADF (Lupi, 2011)	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
Simes pCADF_PC (Lupi, 2011)	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE

Notes: (1) pCADF test is proposed by Costantini and Lupi (2013) based on Demetrescu et al. (2006) in the presence of cross-dependence. (2) pCADF_PC test is the Panel Covariate Augmented DF test, proposed by Costantini and Lupi (2013), who assume that the panel is balanced and utilize the differenced first principal component of the N series as the stationary covariate. In the present case we use max.lag.y = 5, max.lag.x = 5. (3) Simes ADF test is proposed by Hanck (2013), based on Simes (1986). (4) Simes pCADF test is an ADF-based test proposed by Lupi (2011), advancing over Hanck (2013). (5) Simes pCADF_PC test is an ADF-based test proposed by Lupi (2011) advancing over Hanck (2013) which employs the differenced first principal component of the N series as the stationary covariate. (6) TRUE indicates that the test does not reject the null and FALSE shows that the null is rejected. (7) In each case the lag selection is based on AIC information criteria and we fix the maximum number of lags to 5.

IV.2. RIRD based on ex-post inflation expectations

In order to assess the robustness of the previous results, we proceed to new empirical estimations, relying on the ex-post inflation expectations for the RIRD computation. In this case we assume that the inflation expectations are equal to the realized inflation, that is $\pi_{t,t+1} = \pi_{t+1}$ and $\pi_{t,t+1}^* = \pi_{t+1}^*$.

Similar to the previous section, we perform a series of cross-sectional dependence tests for panel data. In this case also, all tests reject the null hypothesis of cross-sectional independence (Table 5).

TABLE 5
Cross-sectional dependence tests for panel data for ex-post inflation expectations

	Euro area as reference			Average of the group as reference		
	Test statistic	d.f.	p-value	Test statistic	d.f.	p-value
Breusch-Pagan Chi-square (Breusch and Pagan, 1980)	838.7494	45	0.0000	2363.640	45	0.0000
Pearson LM Normal (Pesaran, 2004)	82.61444		0.0000	243.3521		0.0000
Pearson CD Normal (Pesaran, 2004)	17.00877		0.0000	7.864674		0.0000
Friedman Chi-square (Friedman, 1937)	482.8802	147	0.0000	291.1025	147	0.0000
Frees Normal (Frees, 1995)	1.303532		0.0000	2.597781		0.0000

Note: The null hypothesis is the cross-sectional independence

The results of the 'old' second generation tests (Table 6) are identical with the findings obtained in the previous case. All tests confirm the rejection of the null of non-stationarity for the RIRD. We can also notice that the Pesaran (2007)'s CIPS test rejects the null of non-stationarity at 5% significance level, even if we consider the group average as reference for estimating the RIRD (different from the results reported in Table 3 above).

TABLE 6
Second generation of 'old' panel unit root tests for ex-post inflation expectations

Tests	Test statistic		p-values		
	Euro area as reference	Average of the group as reference	1 %	5 %	10 %
First MP test (Moon and Perron, 2004)	-17.082	-13.450	-2.3263	-1.6449	-1.2816
Second MP test (Moon and Perron, 2004)	-5.1345	-4.5609	-2.3263	-1.6449	-1.2816
First Choi's test statistic (Choi, 2006)	16.315	13.268	2.3263	1.6449	1.2816
Second Choi's test statistic (Choi, 2006)	-8.4363	-7.5275	-2.3263	-1.6449	-1.2816
Third Choi's test statistic (Choi, 2006)	-10.661	-8.9831	-2.3263	-1.6449	-1.2816
Pesaran's CIPS test (Pesaran, 2007)	-3.1329	-2.3753	-2.5669	-2.3310	-2.2062

Note: In order to reject the null of unit root, the first Choi statistic has to be above its critical value, while all the other statistics must be under their critical values.

In the case of the RIRD calculated based on the *ex-post* inflation expectations (Table 7), the results provided by the 'new' generation of panel unit root tests confirm the previous findings and are even more consistent, as the pCADF_PC test rejects the null at 5% of significance this time. The RIP theory can thus be accepted when the Euro area rate is considered as reference and is rejected by the 'new' tests, when the reference rate is associated with the group average.

TABLE 7
Second generation of 'new' panel unit root tests for ex-post inflation expectations

Tests	Euro area as reference			Average of the group as reference		
	Constant model	Test statistic	p-value	Test statistic	p-value	
pCADF (Costantini and Lupi, 2013)		-2.1752	0.0148	-0.8349	0.2018	
pCADF_PC (Costantini and Lupi, 2013)		-2.9547	0.0015	-0.5041	0.3070	
	Decision on H0	1%	5%	10%	1%	5%
Simes ADF (Hanck, 2013)	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE
Simes pCADF (Lupi, 2011)	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE
Simes pCADF_PC (Lupi, 2011)	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE

Notes: (1) pCADF test is proposed by Costantini and Lupi (2013) based on Demetrescu et al. (2006) in the presence of cross-dependence. (2) pCADF_PC test is the Panel Covariate Augmented DF test, proposed by Costantini and Lupi (2013), who assume that the panel is balanced and utilize the differenced first principal component of the N series as the stationary covariate. In the present case we use max.lag.y = 5, max.lag.x = 5. (3) Simes ADF test is proposed by Hanck (2013), based on Simes (1986). (4) Simes pCADF test is an ADF-based test proposed by Lupi (2011), advancing over Hanck (2013). (5) Simes pCADF_PC test is an ADF-based test proposed by Lupi (2011) advancing over Hanck (2013) which employs the differenced first principal component of the N series as the stationary covariate. (6) TRUE indicates that the test does not reject the null and FALSE shows that the null is rejected. (7) In each case the lag selection is based on AIC information criteria and we fix the maximum number of lags to 5.

This evidence can be explained in different ways. The rejection of the RIP by the 'new' tests when the group average is taken as reference can be caused by the existence of a non-stationary risk premium (see Chung and Crowder, 2004). In fact, the risk premium γ_t reflected in the generalized expression of the UIP (Equation (1)), must be stationary so that the RIRD is stationary in its turn. Or, any risk premium is based on a unit price of the risk, settled on international capital markets when they are integrated, or settled on national or regional markets when they are segmented. This premium depends in particular on the investors' risk aversion, which can be reasonably assumed as stationary, and on an amount of risks related to macroeconomic factors such as inflation, for which the stationarity assumption has been much more questionable over the past fifteen years in the case of the CEECs. The disinflation process initiated in these countries, supporting their European integration, could be at the origin of the non-stationarity of the risk premium. Another explanation for the RIP rejection in the case of the CEECs lies in the rejection of the RPPP in the long run, because the ε_t deviations from the RPPP (Equation (4)) are divergent in the long run. Finally the presence of possible outliers in the sample can generate mixed results.

IV.3. Supplementary robustness check

We notice that second generation ‘old’ tests confirm the RIP hypothesis for the CEECs, while the ‘new’ proposed tests present mixed evidence, depending on the retained reference. We therefore ask ourselves if the results are not influenced by the characteristics of the countries included in the sample. Table 1 indicates the fact that Romania can act as an outlier and can thus influence the level of the reference rate when the average of the group is considered. Consequently, in order to verify the impact of the presence of this outlier, we drop Romania from our sample and we proceed with the same estimations, for robustness purpose.

Table 8 describes the results of the cross-sectional dependence tests for panel data, for both *ex-ante* and *ex-post* inflation expectations. All the tests confirm the rejection of the null of cross-sectional independence, recommending thus the second generation of panel unit root tests.

TABLE 8
Cross-sectional dependence tests for panel data (resampling results)

	Euro area as reference			Average of the group as reference		
	Test statistic	d.f.	p-value	Test statistic	d.f.	p-value
<i>Ex-ante</i> inflation						
Breusch-Pagan Chi-square (Breusch and Pagan, 1980)	607.0290	36	0.0000	1687.120	36	0.0000
Pearson LM Normal (Pesaran, 2004)	66.23576		0.0000	193.5257		0.0000
Pearson CD Normal (Pesaran, 2004)	15.24008		0.0000	18.85885		0.0000
Friedman Chi-square (Friedman, 1937)	422.5994	147	0.0000	437.9831	147	0.0000
Frees Normal (Frees, 1995)	1.048187		0.0000	1.971604		0.0000
<i>Ex-post</i> inflation						
Breusch-Pagan Chi-square (Breusch and Pagan, 1980)	567.4752	36	0.0000	1648.390	36	0.0000
Pearson LM Normal (Pesaran, 2004)	61.57429		0.0000	188.9613		0.0000
Pearson CD Normal (Pesaran, 2004)	14.39038		0.0000	18.54373		0.0000
Friedman Chi-square (Friedman, 1937)	416.9381	147	0.0000	450.1489	147	0.0000
Frees Normal (Frees, 1995)	1.040429		0.0000	2.073373		0.0000

Note: The null hypothesis is the cross-sectional independence

The next step is the presentation of the results of the ‘old’ second generation tests (Table 9). All the tests confirm the rejection of the null of non-stationarity, also. Consequently, the presence of Romania in the data sample does not influence the results, according to the second generation of ‘old’ panel unit root tests.

TABLE 9
Second generation of ‘old’ panel unit root tests (resampling results)

Tests	Test statistic		p-values		
	Euro area as reference	Average of the group as reference	1 %	5 %	10 %
<i>Ex-ante</i> inflation					
First MP test (Moon and Perron, 2004)	-38.400	-34.208	-2.3263	-1.6449	-1.2816
Second MP test (Moon and Perron, 2004)	-8.4107	-8.3763	-2.3263	-1.6449	-1.2816
First Choi’s test statistic (Choi, 2006)	16.986	14.356	2.3263	1.6449	1.2816
Second Choi’s test statistic (Choi, 2006)	-8.6305	-7.8920	-2.3263	-1.6449	-1.2816
Third Choi’s test statistic (Choi, 2006)	-10.980	-9.5380	-2.3263	-1.6449	-1.2816
Pesaran’s CIPS test (Pesaran, 2007)	-3.2276	-3.0615	-2.5669	-2.3310	-2.2062
<i>Ex-post</i> inflation					
First MP test (Moon and Perron, 2004)	-36.830	-33.274	-2.3263	-1.6449	-1.2816
Second MP test (Moon and Perron, 2004)	-7.7043	-8.0862	-2.3263	-1.6449	-1.2816
First Choi’s test statistic (Choi, 2006)	16.862	14.010	2.3263	1.6449	1.2816
Second Choi’s test statistic (Choi, 2006)	-8.5240	-7.7610	-2.3263	-1.6449	-1.2816
Third Choi’s test statistic (Choi, 2006)	-10.895	-9.3456	-2.3263	-1.6449	-1.2816
Pesaran’s CIPS test (Pesaran, 2007)	-3.2112	-3.1619	-2.5669	-2.3310	-2.2062

Note: In order to reject the null of unit root, the first Choi statistic has to be above its critical value, while all the other statistics must be under their critical values.

Finally, Table 10 presents the results for the ‘new’ panel unit root tests, when Romania is removed from the sample. In the case of Euro area as reference rate, we notice a slight difference in the results for the *ex-post* inflation case, as the tests of Lupi (2011) and Hanck (2013) rejects the null of non-stationarity only at 10% significance level. We can state that the panel unit root tests confirm in general the outcomes of the previous studies on the RIP for the CEECs, when the European rate is considered as reference, and also the results of the studies carried out on panel data, namely Holmes and Wang (2008a) and Bararumshah *et al.* (2013). The results are the same for the ‘new’ tests, as for the ‘old’ tests considered as benchmark. The findings sustain thus the hypothesis that the CEECs’ real interest rates are integrated with the European rate, and we obtain this result without resorting to structural breaks as it is the case in the analysis of Bararumshah *et al.* (2013).

However, when the average of the group is considered as reference, the tests reject much easier the presence of unit roots, despite their loss of power caused by the decreasing size of the panel. This evidence reveals the fact that the ‘new’ tests are sensitive to the components of the panel. The presence of Romania in the data sample largely influences the average group reference rate, rejecting thus the RIP theory. The ‘old’ tests do not highlight this issue as they do not present the same level of sensitivity as the ‘new’ test do. On contrary, the ‘new’ tests, well adapted for small panels, partially question the RIP hypothesis for the CEECs. According to their results, we cannot state that the CEECs’ real interest rates are convergent towards a single common rate, especially when less integrated EU members (i.e. Romania) are included in the sample. However, the results of ‘old’ and ‘new’ second generation tests are more consistent when the level of integration of the countries retained in the analysis increases.

TABLE 10
Second generation of ‘new’ panel unit root tests (resampling results)

Tests	Euro area as reference			Average of the group as reference		
<i>Ex-ante</i> inflation						
	Constant model	Test statistic	<i>p</i> -value	Test statistic	<i>p</i> -value	
pCADF (Costantini and Lupi, 2013)		-2.8038	0.0025	-2.6604	0.0039	
pCADF_PC (Costantini and Lupi, 2013)		-2.6271	0.0043	-1.3733	0.0848	
Decision on H0	1%	5%	10%	1%	5%	10%
Simes ADF (Hanck, 2013)	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Simes pCADF (Lupi, 2011)	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Simes pCADF_PC (Lupi, 2011)	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE
<i>Ex-post</i> inflation						
	Constant model	Test statistic	<i>p</i> -value	Test statistic	<i>p</i> -value	
pCADF (Costantini and Lupi, 2013)		-2.5277	0.0057	-2.8184	0.0024	
pCADF_PC (Costantini and Lupi, 2013)		-3.5133	0.0002	-2.7414	0.0030	
Decision on H0	1%	5%	10%	1%	5%	10%
Simes ADF (Hanck, 2013)	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
Simes pCADF (Lupi, 2011)	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
Simes pCADF_PC (Lupi, 2011)	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
Notes: (1) pCADF test is proposed by Costantini and Lupi (2013) based on Demetrescu <i>et al.</i> (2006) in the presence of cross-dependence. (2) pCADF_PC test is the Panel Covariate Augmented DF test, proposed by Costantini and Lupi (2013), who assume that the panel is balanced and utilize the differenced first principal component of the <i>N</i> series as the stationary covariate. In the present case we use <i>max.lag.y</i> = 5, <i>max.lag.x</i> = 5. (3) Simes ADF test is proposed by Hanck (2013), based on Simes (1986). (4) Simes pCADF test is an ADF-based test proposed by Lupi (2011), advancing over Hanck (2013). (5) Simes pCADF_PC test is an ADF-based test proposed by Lupi (2011) advancing over Hanck (2013) which employs the differenced first principal component of the <i>N</i> series as the stationary covariate. (6) TRUE indicates that the test does not reject the null and FALSE shows that the null is rejected. (7) In each case the lag selection is based on AIC information criteria and we fix the maximum number of lags to 5.						

V. CONCLUSIONS

The purpose of this study is to perform an empirically analysis of the RIP for ten CEECs, relying on ‘new’ panel unit root tests, considering *ex-ante* and *ex-post* inflation expectations,

and successively using the Euro area and the group average interest rates as reference. The ‘old’ second generation panel unit root tests are considered as benchmark for the analysis.

Our results underline the RIP’s lack of sensitivity in respect of the way inflation expectations are defined (*ex-ante* or *ex-post*), but a moderate sensitivity regarding the selected reference interest rate and the sample composition. The RIP hypothesis is clearly accepted when considering the Euro area rate as reference, showing thus the CEECs’ integration into the EU. However, the findings are different when using the group average as reference. In this line, according to the tests of Lupi (2011), Hanck (2013) and Costantini and Lupi (2013), well suited for small panels, the RIRD non-stationarity hypothesis is clearly accepted, when less integrated countries are included in the sample.

The fact that the tests conduct to slightly different results depending on the retained reference interest rate requires additional refinement of the findings reported in the literature, which are probably too optimistic regarding the CEECs’ real interest rate convergence, especially around the recent financial turmoil. As shown in previous researches, the interest rate differential between the CEECs and the Euro area seems stationary, confirming the existence of a long term equilibrium relationship, characterizing integrated markets. Nevertheless, the interest rate differential between the CEECs does not clearly appear as stationary, leading to questioning the validity of the RIP theory.

Besides, the integration level of the CEECs countries influences the results of the ‘new’ test. Likewise, the presence of Romania in the panel impacts on the average group reference rate and conduct to the rejection of the RIP theory. However, when we remove this less integrated country from the panel, the validity of the RIP theory is confirmed in general, even if considering the group average as reference. Different from the ‘old’ tests, the ‘new’ tests are than sensitive to the panel components also.

ACKNOWLEDGEMENTS

The authors would like to thank the Editor Francis Breedon and the two anonymous referees for their valuable comments and suggestions on this paper. The authors are fully responsible for any remaining shortcomings.

REFERENCES

- Al-Awad, M. and Grennes, T.J. (2002), ‘Real Interest Parity and Transaction Costs for the Group of 10 Countries’, *International Review of Economics and Finance*, 11(4), pp. 363-372.
- Arghyrou, M.G., Gregoriou, A. and Kontonikas, A. (2009), ‘Do Real Interest Rate Converge? Evidence from the European Union’, *Journal of International Financial Markets, Institutions and Money*, 19(3), pp. 447-460.
- Baba, N. and Packer, F. (2009), Interpreting deviations from covered interest parity during the financial market turmoil of 2007–08, *Journal of Banking & Finance*, 33(11), pp. 1953-1962
- Baharumshah, A.Z., Chan, T.H., Masih, A.M.M. and Lau, E. (2011), ‘Financial Integration of East Asian Economies: Evidence from Real Interest Parity’, *Applied Economics*, 43(16), pp. 1979-1990.

- Baharumshah, A.Z., Haw, C.T. and Fountas, S. (2005), 'A Panel Study on Real Interest Rate Parity in East Asian Countries: Pre and Post-Liberalization Era', *Global Finance Journal*, 16(1), pp. 69-85.
- Baharumshah, A.Z., Liew, V.K.-S. and Chan T.H. (2009), 'The Real Interest Rate Differential: International Evidence Based on Nonlinear Unit Root Tests', *Bulletin of Economic Research*, 61(1), pp. 83-94.
- Baharumshah, A.Z., Soon, S.-V. and Boršič, D. (2013), 'Real Interest Parity in Central and Eastern European Countries: Evidence on Integration into EU and the US Markets', *Journal of International Financial Markets, Institutions and Money*, 25, pp. 163-180.
- Baltagi, B.H. (2005), *Econometric Analysis of Panel Data*, John Wiley & Sons: England.
- Breitung, J., and Pesaran M.H. (2008), 'Unit Roots and Cointegration in Panels' in L. Matyas and P. Sevestre (eds.), *The Econometrics of Panel Data*, Kluwer Academic Publishers: Suffolk.
- Breusch, T. and Pagan, A. (1980), 'The LM test and its Applications to Model Specification in Econometrics', *Review of Economic Studies*, 47(1), pp. 239-253.
- Camarero, M., Carrion-i-Silvestre, J.L. and Tamarit, C. (2010), 'Does Real Interest Rate Parity Hold for OECD Countries? New Evidence Using Panel Stationarity Tests with Cross-Section Dependence and Structural Breaks', *Scottish Journal of Political Economy*, 57(5), pp. 568-590.
- Camarero, M., Carrion-i-Silvestre, J.L. and Tamarit, C. (2009), 'Testing for Real interest Rate Parity Using Panel Stationarity Tests with Dependence: A Note', *The Manchester School*, 77(1), pp. 112-126.
- Campbell, J.Y. and Perron, P. (1991), 'Pitfalls and Opportunities: What Macroeconomists Should Know about Unit Roots', in O. Blanchard and S. Fischer (eds), *NBER Macroeconomics Annual*, 6, pp. 141-201, University of Chicago Press: Chicago.
- Choi, I. (2001), 'Unit Root Tests for Panel Data', *Journal of International Money and Finance*, 20, pp. 249-272.
- Choi, I. (2006), 'Combination Unit Root Tests for Cross-Sectionally Correlated Panels', in D. Corbae, S.N. Durlauf & B.E. Hansen (eds), *Econometric Theory and Practice: Frontiers of Analysis and Applied Research*, pp. 311-333, Cambridge University Press: Cambridge.
- Chung, S.Y. and Crowder, W.J. (2004), 'Why Are Real Interest Rates Not Equalized Internationally?', *Southern Economic Journal*, 71, pp. 441-458.
- Costantini, M. and Lupi, C. (2013), 'A Simple Panel-CADF Test for Unit Roots', *Oxford Bulletin of Economics and Statistics*, 75(2), pp. 276-296.
- Cuestas, J.C. and Harrison, B. (2010), 'Further Evidence on the Real Interest Rate Parity Hypothesis in Central and East European Countries: Unit Roots and Nonlinearities', *Emerging Markets Finance and Trade*, 46(6), pp. 22-39.
- Cumby, R. and Mishkin, F. (1986), 'The International Linkage of Real Interest Rates: The European-US Connection', *Journal of International Money and Finance*, 5, pp. 5-23.
- Cumby, R. and Obstfeld, M. (1984), 'International Interest Rate and Price Level Linkages Under Flexible Exchange Rates: A Review of Recent Evidence', in J. Bilson and R.C. Marston (eds), *Exchange Rate Theory and Practice*, pp. 121-152, University of Chicago Press: Chicago.
- Demetrescu, M., Hassler, U. and Tarcolea, A.I. (2006), 'Combining Significance of Correlated Statistics with Application to Panel Data', *Oxford Bulletin of Economics and Statistics*, 68(5), pp. 647-663.
- Edison, H.J. and Pauls, B.D. (1993), 'A Re-assessment of the Relationship Between Real Exchange Rates and Real Interest Rates: 1974-1990', *Journal of Monetary Economics*, 31(2), pp. 165-187.
- Elliott, G., Rothenberg, T. and Stock, J. (1996), 'Efficient Tests for an Autoregressive Unit Root', *Econometrica*, 64(4), pp. 813-836.

- Ferreira, A.L. and León-Ledesma, M.A. (2007), 'Does the Real Interest Parity Hypothesis Hold? Evidence for Developed and Emerging Markets', *Journal of International Money and Finance*, 26, pp. 364-382.
- Frees, E.W. (1995), 'Assessing cross-sectional correlation in panel data', *Journal of Econometrics*, 69(2), pp. 393-414.
- Fong, W-M., Valente, G. and Fung, J.K.W. (2010), Covered interest arbitrage profits: The role of liquidity and credit risk, *Journal of Banking & Finance*, 34(5), pp. 1098-1107.
- Friedman, M. (1937), 'The use of ranks to avoid the assumption of normality implicit in the analysis of variance', *Journal of the American Statistical Association*, 32, pp. 675-701.
- Goldberg, L.G., Lothian, J.R. and Okunev, J. (2003), 'Has International Financial Integration Increased?', *Open Economies Review*, 14(3), pp. 299-317.
- Hanck, C. (2013), 'An Intersection Test for Panel Unit Roots', *Econometric Reviews*, 32(2), pp. 183-203.
- Hansen, B.E. (1995), 'Rethinking the Univariate Approach to Unit Root Testing: Using Covariates to Increase Power', *Econometric Theory*, 11(5), pp. 1148-1171.
- Hartung, J. (1999), 'A Note on Combining Dependent Tests of Significance', *Biometrical Journal*, 41(7), pp. 849-855.
- He, H., Ranjbar, O. and Chang, T. (2013), 'Purchasing power parity in transition countries: Old wine with new bottle', *Japan and the World Economy*, 28, pp. 24-32.
- Holmes, M.J. (2002), 'Does Long-Run Real Interest Parity Hold Among EU Countries? Some New Panel Data Evidence', *The Quarterly Review of Economics and Finance*, 42(4), pp. 733-746.
- Holmes, M.J., Otero, J. and Panagiotidis, T. (2011), 'Real Interest Parity: A Note on Asian Countries Using Panel Stationarity Test', *Journal of Asian Economics*, 22(6), pp. 550-557.
- Holmes, M.J. and Wang, P. (2008a), 'Real Convergence and the EU Accession Countries: A New Perspective on Real Interest Parity', *Journal of Emerging Market Finance*, 7(3), pp. 215-236.
- Holmes, M.J. and Wang, P. (2008b), 'Real Convergence and Regime-Switching Among EU Accession Countries', *South-Eastern Europe Journal of Economics*, 1, pp. 9-27.
- Hui, C-H., Genberg, H. and Chung, T-K. (2011), Funding liquidity risk and deviations from interest rate parity during the financial crisis of 2007–2009, *International Journal OF Finance and Economics*, 16(4), pp. 307-323.
- Hurlin, C. (2010), 'What Would Nelson and Plosser find Had They Used Panel Unit Root Tests?', *Applied Economics*, 42, pp. 1515-1531.
- Im, K.S., Pesaran, M.H. and Shin, Y. (2003), 'Testing for Unit Roots in Heterogeneous Panels', *Journal of Econometrics*, 115, pp. 53–74.
- Levin, A., Lin, C.F. and Chu, C.S.J. (2002), 'Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties', *Journal of Econometrics*, 108(1), pp. 1-24.
- Liew, V.K.-S. and Ling, T.-H. (2008), 'Real Interest Rate Parity: Evidence from East Asian Economies Relative to China', *MPRA Working Paper*, No 7291, University Library of Munich, Germany.
- Lothian, J.R. (2002), 'The International of Money and Finance and the Globalization of Financial Markets', *Journal of International Money and Finance*, 21, pp. 699-724.
- Lupi, C. (2011), 'Panel-CADF Testing with R: Panel Unit Root Tests Made Easy', *Economics and Statistics Discussion Paper*, No. 063/11, University of Molise, Italy.
- Maddala, G.S. and Wu, S. (1999), 'A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test', *Oxford Bulletin of Economics and Statistics*, 61(Supplement 1), pp. 631-652.
- Mark, N.C. (1985), 'Some Evidence on the International Inequality of Real Interest Rates', *Journal of International Money and Finance*, 4(2), pp. 189-208.
- Meese, R. and Rogoff, K. (1988), 'Was it Real? The Exchange Rate-Interest Differential Relation Over the Modern Floating-Rate Period', *Journal of Finance*, 43, pp. 933-948.

- Mishkin, F. (1984), 'Are Real Interest Rates Equal Across Countries? An Empirical Investigation of International Parity Conditions', *Journal of Finance*, 39, pp. 1345-1357.
- Moon, H.R. and Perron, B. (2004), 'Testing for a unit root in panels with dynamic factors', *Journal of Econometrics*, 122, pp. 81-126.
- Obstfeld, M. and Taylor, A.M. (2002), 'Globalization and Capital Markets', *NBER Working Paper*, 8846.
- O'Connell, P.G.J. (1998). 'The overvaluation of purchasing power parity', *Journal of International Economics*, 44(1), pp. 1-19.
- Pesaran, M.H. (2004), 'General diagnostic tests for cross section dependence in panels', *CESifo Working Papers*, No.1233.
- Pesaran, M.H. (2007), 'A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence', *Journal of Applied Econometrics*, 22(2), pp. 265-312.
- Pesaran, M.H. (2004), 'General Diagnostic Tests for Cross Section Dependence in Panels', *Cambridge Working Papers in Economics*, 0435, Faculty of Economics, University of Cambridge.
- Pipatchaipoom, O. and Norrbin, S.C. (2010), 'Is the Real Interest Rate Parity Condition Affected by the Method of Calculating Real Interest Rates?', *Applied Economics*, 42(14), pp. 1771-1782.
- Sarno, L. (2005), 'Towards a Solution to the Puzzles in Exchange Rate Economics: Where Do We Stand?', *Canadian Journal of Economics*, 38, pp. 673-708.
- Sekioua, S.H. (2008), 'Real Interest Parity (RIP) Over the 20th Century: New Evidence Based on Confidence Intervals for the Largest Root and the Half-Life', *Journal of International Money and Finance*, 27, pp. 76-101.
- Simes, R.J. (1986), 'An Improved Bonferroni Procedure for Multiple Tests of Significance', *Biometrika*, 73(3), pp. 751-754.
- Singh, M. and Banerjee, A. (2006), 'Testing Real Interest Parity in Emerging Markets', *International Monetary Fund Working Paper*, No. WP/06/249.
- Sonora, R.J. and Tica, J. (2010), 'Real Interest Parity in New Europe', *EFZG Working Paper Series*, 1011, Faculty of Economics and Business, University of Zagreb.
- Su, C.-W., Chang, H.-L. and Liu, L. (2012), 'Real Interest Rate Parity with Flexible Fourier Stationary Test for Central and Eastern European Countries', *Economic Modelling*, 29(6), pp. 2719-2723.
- Wu, J.L. and Chen, S.L. (1998), 'A Re-examination of Real Interest Rate Parity', *Canadian Journal of Economics*, 31(4), pp. 837-851.