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Real interest rate differentials between Central and Eastern European countries and the euro area

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Keywords: *real interest rates; Central and Eastern Europe; Economic and Monetary Union; financial integration*

Abstract
Research background: The question of changes in real interest rates differentials between the Euro Area and the CEE countries in the last years is raised because of two main reasons. The first rationale is related to the growing importance of external financial factors for the CEE economies and their monetary autonomy. The second reason is associated with the unprecedented shift in monetary conditions in the EMU, brought about by negative interest rates policy and unconventional policies, and the way it impacts the real rates in the CEE economies.
Purpose of the article: This paper aims at exploring the relationship between real interest rates in the Euro Area and ten countries: Albania, Bulgaria, the Czech Republic, Hungary, North Macedonia, Moldova, Poland, Romania, Turkey, and Ukraine. The analysis covers the years of 1999-2018, including periods before and after the financial and economic crisis.
Methods: We employ Markov-switching regression to construct the ex-ante real interest rates series in each country, using monthly data on short-term interest rates and CPI inflation rates. A battery of unit root and stationarity test, both standard and panel ones, is applied to examine the real interest rate parity, also allowing for a structural break in the rate differentials.
Findings & Value added: We provide detailed evidence on the real interest rates differentials for all of the CEE countries vis-à-vis the Euro Area. We find that, while panel stationarity tests point to the stability of real rate differentials, there are significant dissimilarities across the countries, and the results of the univariate tests are often mixed. At least half of the economies, however, reveal similar patterns of stationarity in real rates relationships. At the same time, we find differentials for the Czech Republic, Hungary, and Poland, countries highly integrated into the EMU economy, to be unstable over time.

Introduction

Starting in the 1990s, a group of Central and Eastern European (CEE) countries has undergone rapid transition concerning their integration to the European and global economies. The pace of this integration has nonetheless varied across the region, with important diversification in terms of levels of economic and financial development, international trade ties, or exchange-rate regimes of those countries. At the same time, the Economic and Monetary Union (EMU) also experienced profound changes, with a prolonged downturn and historically low interest rates. All of this poses a series of questions regarding the financial integration of the CEE countries with the EMU. How tight are these bounds? Have they become stronger? Are monetary conditions in the CEE countries becoming more dependent on those in the EMU? Many of those issues may be addressed by assessing differentials of real interest rates between economies.

The aim of this paper is to examine ex-ante real interest rates differentials for ten economies vis-à-vis the EMU over the period of 1999 to 2018. We focus both on the EU member states that have not adopted the euro (Bulgaria, the Czech Republic, Hungary, Poland, Romania) and Eastern European economies outside of the EU (Albania, North Macedonia, Moldova, Turkey, Ukraine). Using monthly data on short-term interest rates and CPI inflation, we perform an array of unit root and stationarity tests, both single-equation and panel ones, allowing for an endogenous structural break in the interest rate series.

The novelty of this paper lies mainly in the detailed analysis of the real interest rate differentials since the launch of the EMU. Unlike other studies, we construct ex-ante real interest rates based on a regime-switching regression model. We shed light on the problem of a structural break in real interest rates relationship, covering a relatively long time-span of twenty years and a large group of economies.

We find that even though, as a group, the CEE economies may be characterized by a stable real interest rate relationship with the EMU, there are significant dissimilarities across the countries. For the majority of countries, the evidence points out to mean-reverting behaviour of differentials, indicating similar patterns and strong connections with the EMU. The early years of the sample (1999–2002) and the onset of the economic crisis (ca. 2008–2009) mark a structural change in the real interest rate relationships for most of the countries. Unexpectedly, we document some evidence of non-stationarity of real interest rate differentials for the Czech Republic, Hungary, and Poland.

The paper is organized as follows. The next section provides an overview of the empirical literature on real interest rates differentials. Subsequently, we discuss the methods and data used in the study. Results are presented and discussed in the next two parts of the paper. The last section concludes and suggests directions for further research.

Literature review

Differentials of inflation-adjusted interest rates between a given country and a reference (numeraire) country are closely related to the idea of the real interest rate parity. In its strong version, the real rate parity postulates that real interest rates tend to equalize across economies over time (Bhatti & Moosa, 1997). This hypothesis, however, requires relatively strong assumptions: the Fisher condition, ex-ante purchasing power parity, and uncovered interest parity must hold simultaneously. In a weaker form, the parity implies long-run stationarity of real rates differentials (Öge Güney & Hasanov, 2014). Such a relationship provides a synthetic indication of economic and financial integration between countries and is a crucial factor in real exchange rate dynamics. Moreover, the existence of the parity markedly limits the ability of monetary authorities in smaller economies to influence domestic economic conditions effectively.

The first wave of empirical tests on real interest rate differentials, conducted in the 1980s and early 1990s, deals with advanced economies, mostly evaluating a country's real interest rates against the US. Even though some of the studies confirmed this relationship (Mark, 1985), very often, as in Meese and Rogoff (1986), the short-run real interest parity conditions are statistically rejected. The instability of this relationship is explained by the relative importance of financial market disturbances, the existence of transaction costs, or real shocks, for instance, changes in productivity. Such results, however, may be partly attributed to fairly short time-series of interest rates (e.g., Chinn and Frankel (1995) investigate the real rates in just over ten years), which may not allow capturing mean-reverting properties of the real rates differentials.

Recent studies on the real interest rate parity have generally yielded mixed results, partly due to the diversity of analysed samples and econometric methods. In an important paper, Ferreira and León-Ledesma (2007) investigate a group of five developed economies and five emerging markets. Although they can prove that some of the tests confirm interest rate parity for most of the countries, competing tests often lead to different conclusions. Arghyrou *et al.* (2009), who study this parity in the EU before the crisis, generally support the notion of real interest rate convergence in the majority of the countries. Interestingly, the authors do not confirm this hypothesis for Poland, Hungary, the UK, Spain, and Greece. Studying the G7 countries, Chang and Su (2015) find evidence of real rate parity among the economies from 1977 until 2005, although they document various breaks and potential non-linearity in those relationships.

Research focusing specifically on the CEE economies have so far produced even more ambiguous outcomes. Cuestas and Harrison (2010) perform a set of univariate unit root tests for three-month interest rates differential from 1994 to 2007. They conclude that the real interest parity holds for all of the then-new EU member-states, except Estonia, Latvia, and Poland. Similarly, Sonora and Tica (2014) find that up to 2009, real rates differentials among the CEE countries revealed strong irregularities, but stationarity is generally more pronounced once structural breaks are introduced. The authors also show that short-term interest rates and adaptive (model-based) expectations tend to produce stronger evidence in favour of the real interest rate parity.

In a study going marginally beyond the crisis period, Baharumshah *et al.* (2013) employ panel tests with breaks to 13 CEE countries (including some that adopted the euro later on). The authors conclude that the real interest rates generally reverse to the parity over the period 1996–2011, both against the EMU and the US[1]. These results, however, are only partly confirmed by Albulescu *et al.* (2016) who highlight the sensitivity of real interest rates stationarity to the choice of benchmark rates, as well as the shortcomings of panel unit root tests.

In a study also related to the present analysis, Öge Güney and Hasanov (2014) focus on post-Soviet economies and document the stability of real interest rate differentials between Germany and almost all of those countries, including Ukraine and Moldova, also examined in this paper. The authors then conclude that stationary of rate differentials imply the growing integration of ex-soviet republics with the global economy.

Research methodology

The initial part of the empirical study requires calculating inflation-adjusted interest rates. The expected rate of inflation, π_t^e, comes from a Markov-chain auto-regression (MSAR) of the order of four (see Kim, 1994):

[1] Chang (2014) also investigates real interest rates in the CEE countries against the US and finds that until 2011 their differentials are stationary for most of the cases.

$$\pi_t = \alpha_{0,S} + \sum_{p=1}^{4} \alpha_p \pi_{t-p} + \varepsilon_t^{\pi}, \qquad (1)$$

where π_t is the actual rate of inflation, and parameter $\alpha_{0,S}$ is allowed to differ across two states. Transition probabilities of the Markovian process are assumed to be constant. Parameters on auto-regressive coefficients are common for both states, and ε_t^{π} is white noise.

The expected inflation rate is approximated by theoretical values from the estimated MSAR models, $\pi_t^e = \hat{\pi}_t$. Hence, ex-ante real interest rates are determined according to the Fisher equation, by subtracting the short-term nominal interest rate from the expected inflation rate:

$$r_t = i_t - \pi_t^e. \qquad (2)$$

Once the calculations are performed for all countries, we obtain real interest rate differentials as a restricted relationship, by taking a simple difference between real ex-ante interest rate in each CEE country (r_t^i) and the corresponding rate in the EMU (r_t^E)[2].

The main task is to assess the progression of the differentials over time. If the differentials prove to be weakly (covariance) stationary, we can claim that the real interest rate parity holds. Due to adjustment costs or informational friction, it may not be constant at every single point in time, but such transitory shocks dissipate, and the differential reverts to its long-run level. Any deviation from this property negates such a conclusion. However, the interpretation of disparity will vary, depending on whatever the differentials may be described as a random walk or a trend-stationary process.

The basic test equation that we use resembles the augmented Dickey-Fuller (ADF) test with a constant and deterministic trend, in the form (see Ferreira & León-Ledesma, 2007):

$$\Delta\left(r_t^i - r_t^E\right) = \alpha + \beta t + \gamma\left(r_{t-1}^i - r_{t-1}^E\right) + \sum_{s=1}^{m} \delta_s \Delta\left(r_{t-s}^i - r_{t-s}^E\right) + \varepsilon_t, \qquad (3)$$

where Δ is difference operator, t denotes time, α, β, γ and δ_s are parameters to be estimated, while ε_t is assumed to be white noise. If we cannot reject the null hypothesis of $\gamma = 0$, the differential is regarded as non-stationary, and the relationship between the interest rate in a given country and the EMU may be claimed to be unstable over time.

[2] Another intuitive approach is to test for a co-integrating relationship, such as in Camarero *et al.* (2009). However, given the ambiguity regarding the level of integration of variables reported in the latter parts of the paper, and a plausible interpretation of real rates differentials, the paper focuses solely on interest rate differentials.

In order to get a more detailed picture of the real rates convergence, we proceed in three steps. In the first step, we perform a set of standard univariate tests for each pair: CEE country–EMU. Even though they may be biased due to the presence of structural breaks — the concern which is addressed below — the results of these tests serve as an important benchmark for the evaluation of the interest rate differentials. We employ the ADF unit root test, as well as its modification by Phillips and Perron (PP), with the t-test statistic correction for autocorrelation and heteroscedasticity. In a usual manner, recognizing the low power of those tests, we complement this part of the analysis by utilizing the KPSS test in which the covariance stationarity is the null hypothesis. All three tests are conducted in specifications with a constant and a constant and linear trend, to control for potential trend-stationarity.

Second, following Perron's (1989) influential work, we employ the unit root test with an endogenous, unknown breakpoint. We are specifically interested in dealing with the situation when standard tests point to the existence of a unit root when there is, in fact, a break in the deterministic trend of a time-series. Taking into consideration shifts in policy regimes and the transformation of economic and financial environments, both in the CEE countries and in the EMU, as well as the economic recession followed by the Eurozone crisis, it seems justified to expect that real interest rate differentials undergo structural breaks.

The test that we use in the third step is based on works by Zivot and Andrews (1992), in a version built in EViews 10. Since there are multiple specifications of these tests, we calculate statistics for equations with a structural break in intercept, and with the deterministic trend and intercept, allowing for a break in both. Regarding the type of structural change, we allow for an innovation outlier, when a series incrementally diverges from its previous behaviour, and an additive outlier, implying a sudden shift in a series[3]. Breakpoint selection is based on the minimization of the Dickey-Fuller t-statistics.

In the third step, we employ a panel stationarity test with an unknown break proposed by Hadri and Rao (2008). The construction of this test is based on the Lagrange multiplier and aimed at alleviating the bias in standard stationarity test (i.e., KPSS) to reject the null hypothesis and point to non-stationarity. A major advantage of this method stems from multiple specifications of breaks in the levels and deterministic trends of tested time-series. Models estimated to obtain individual (country-level) statistics are

[3] Due to the similarity between the results, only the former specification is reported in the paper, and the latter is available upon request.

corrected for serial correlation of residuals, while the panel test accounts for the cross-sectional dependence among interest rate differentials. Following Ranjbar *et al.* (2015), a break-type model for each series is selected using BIC, with the maximum number of lags set to 14, as in a standard ADF test regression. Critical values in the panel test are calculated using bootstrap techniques[4].

The study covers a group of ten economies mentioned above. The monthly data cover the period of 1999:01–2018:09 and come from the International Financial Statistics database by the IMF. The percentage change of the consumer prices index over the corresponding month the previous year is used as a measure of the inflation rate. We focus on short-term rates, mainly because the computation of inflation expectations for such rates seems to be more reliable. Nominal interest rates are either money market rates or deposit rates, depending on their availability for each country in the entire timespan of analysis[5].

Results

This section presents the results of the empirical analysis. We start by estimating the parameters of MSAR models (see Table 1). For the EMU and all the countries except Romania, the estimated models show two distinct constants, one significantly higher than the other, indicating regimes of high and low average rates of inflation. They also point out to high persistence in inflation rates, with AR(1) parameters often above one. Regime switches in transition economies are generally more frequent than in the Euro Area, as suggested by their expected duration, with repeated shifts to a higher inflation regime in the earlier part of the period under study. Based on the regression results, we calculate expected rates of inflation and ex-ante real rates, to finally obtain the rate differentials. The outcome of these calculations is displayed in Figure 1. Inspection of the graphs reveals vast disparities in absolute values of rate differentials across countries (e.g., Poland and Ukraine), with some of the extreme values going over 50 points. It also suggests that some of the countries, such as the Czech Republic and Romania after 2010, experience long periods of stability in those

[4] The Gauss routines used to compute the Hadri and Rao test have been prepared and made available by Ranjbar *et al.* (2015).

[5] A similar approach in selecting the interest rate series is followed by Cuestas and Harrison (2010). We use money market rates for Bulgaria, Czechia, Poland, Romania, and Ukraine.

series. Others, such as Bulgaria or Hungary, exhibit periods of continuous growth or decline of differentials.

Turning first to standard univariate unit root tests, we find evidence against the presence of unit roots in the differentials for as many as seven of the countries, all but Czechia, Hungary, and Poland (Table 2). When compared to the outcomes of the KPSS tests, those results are somewhat less conclusive. The null hypothesis of stationarity is rejected for at most five of the countries[6]. The notable exceptions are Moldova, North Macedonia, Romania, Turkey, and Ukraine. For these economies, all three tests lead to a solid conclusion of differentials being I(0).

Tests for the Czech Republic, Hungary, and Poland, on the other hand, imply the opposite outcome. As both ADF and PP reject the unit root for the first differences of series, there is substantial evidence of real interest rate differentials following an I(1) process. Closer inspection of the interest rate differentials for those countries exposes the fact that they experienced a decline in differentials from the early 2000s to 2008, with sharp shifts around 2008–2009. The results for two remaining economies, Albania and Bulgaria, are less clear-cut, as they exhibit incompatibility of results from two unit root tests and the KPSS test.

Taking this into consideration, we proceed to the unit root tests with an endogenously determined break, introduced as an innovation outlier (Table 3). The breakpoint test supports the results that we get from the standard tests in four cases: Moldova, Romania, Turkey, and Ukraine, all of them with high absolute values of t-statistics. Those are also the countries for which breaks, both in intercept and trend, are detected for dates early in the analysed period. For example, in the case of Ukraine, the break occurs in the very beginning of the sample (1999m10), the differential is quite large and volatile, but stays close to its average value.

Based on the second set of tests, Albania and Bulgaria may be added to the group of countries with stable rate differentials. However, some evidence of trend-stationarity is present for both of them. On the other hand, the initial conclusion for North Macedonia must be revised. The test statistics for this country are not statistically significant at conventional levels, and we cannot reject the existence of unit root, with a break either in 2004 (intercept) or 2008 (trend and intercept). Again, test statistics in the remaining three cases (Czechia, Hungary, Poland) do not reject the null hypothesis, confirming the outcome of standard tests. Even though the p-value

[6] As expected, when we test the series in their first differences, the KPSS test indicates stationarity.

calculated for Poland equals 0.058 for the test equation with intercept, it jumps to 0.256 when the deterministic trend is introduced.

Eventually, we compute panel stationarity tests by Hadri and Rao, together with individual testing model specifications with a breakpoint (Table 4). There are just two cases in which the tests indicate non-stationarity of real rate differentials: Albania (only at 10% significance level) and Poland, in line with the standard KPSS test results. In all other cases, we fail to reject the null hypothesis of rate differentials being stationary. Moreover, the estimated breakpoint dates are mostly consistent with the ones identified before. For Bulgaria, Moldova, Romania, Turkey, and Ukraine, this corroborates the outcomes of the unit root tests with a break. On the contrary, with respect to Czechia, Hungary, and North Macedonia, this goes against the previous conclusions.

The Hadri and Rao panel test statistics are lower than the empirical critical values, both when we allow for serial correlation or not. This shows that, taken as a whole, there is no evidence of non-stationarity of rates differentials. We then split the panel into two sub-samples based on a country's membership in the EU. Still, at any conventional significance levels, the tests do not reject the null of stationarity.

Discussion

First of all, it must be noted that the properties of real rates differentials proved to be comparatively heterogeneous across the CEE countries. Results from the panel tests, exposing potentially strong cross-section dependence, seem to bend towards stationarity. Based solely on those, one would claim that the real interest rate relationships are stable over time. However, the results of the country-level tests point out to the rejection of this claim for some of the countries. They also suggest that real interest differential series are prone to structural breaks. The breakpoints are mainly located in the early years of the sample (1999–2003) when many CEE economies still experienced the disinflation processes. In some of the cases (Bulgaria, the Czech Republic, North Macedonia, Poland), breaks occur around the financial and economic crisis.

Nevertheless, the results from three groups of tests are reasonably consistent for five of the countries. Interest rate differentials calculated for Bulgaria, Moldova, Romania, Turkey, and Ukraine are all found to be mean-reverting, and the identification of breakpoints does not change this conclusion. The evidence in favour of unstable differentials is stronger but often not univocal for Albania, the Czech Republic, Hungary, North Macedonia, and Poland, where the tested time-series display non-stationarity in some of the tests.

Our results are, to some extent, comparable to those obtained by Sonora and Tica (2014) and Albulescu *et al.* (2016). Similarly, we find that real interest rate differentials exhibit significant instabilities, and although in general the interest rate parity holds for the CEE countries, there are exceptions to this rule. On the contrary, our findings diverge from those formulated by Baharumshah *et al.* (2013), who find much stronger evidence on the stationarity of real interest rate differentials.

Hence, the most unexpected results of the study come from the observation that the Czech Republic, Hungary, and Poland display non-stationary rate differentials against the EMU, unlike the countries like Bulgaria, Ukraine, or Turkey. It may indicate that three Central European countries, ones that joined the EU in 2004, have the highest levels of GDP per capita, and robust trade and investment ties with Germany, show a lower degree of financial and economic integration with the EMU than economies outside of the EU. It may also suggest, as often implied (e.g., Cuestas & Harrison, 2010), that there is room for monetary authorities in those countries to impact real variables effectively, but costs of monetary integration and adoption of the euro would be considerable. This conclusion, however, must be treated with adequate caution.

Even though all of the CEE countries may be described as transition economies, their pace of economic and financial development has been distinct since the 1990s. The Czech Republic, Hungary, and Poland were first to successfully finalize disinflation processes, and placed themselves on a relatively fast track to the European integration. With some exceptions, they have maintained floating exchange-rates against the euro, and their central banks adopted inflation targeting regimes. Consequently, it may be the case that risk premia on domestic interest rates in those economies are time-varying, notably diminishing in some periods, especially in the first years of the sample, but with significant volatility driven by various macroeconomic factors (see Engel, 2016). This, in turn, may shed some light on the instability of the real rate differentials observed in this study.

What is more, monetary conditions in the EMU significantly changed after 2009, and particularly after 2012, when the ECB turned to unconventional monetary policies, lowering interest rates in the EMU to unprecedented levels. The natural interest rates have also substantially declined in the Eurozone since the onset of the crisis, adding to a relative change in monetary conditions in the EMU vis-à-vis the CEE countries[7]. Therefore,

[7] According to Holston *et al.* (2017), the short-term equilibrium interest rate in the Euro

our results must be correlated with evidence from different sources, such as business cycle synchronization or similarity of macroeconomic shocks in the Central European countries and the EMU core (see Beck & Janus, 2016), to assess the potential effectiveness of single monetary policy in these countries.

Finally, granting we cannot support the stationarity hypothesis for some of the countries included in the sample, we also do not detect any systematic divergence of real interest rate differentials in any of the cases. There is no evidence that differentials display an upward trend in any of the economies after 2009, which proves that their integration with the EMU economy is not in reverse.

Conclusions

This aim of this paper was to examine the stability of real interest rate differentials between ten CEE economies and the EMU from 1999 to 2018. We employed a battery of unit root and stationarity tests to ex-ante real interest rates obtained through the Markov-Switching AR, using monthly data on short-term interest rates and CPI inflation. The study controls for a structural break in tested time-series, allowing for potential shifts in the long-run relationship between interest rates.

We find that the real interest rate relationships of the CEE economies and the EMU are not straightforward. When taken as a whole, countries in the sample exhibit stable real interest rate differentials, indicating significant financial and economic ties to the EMU. This finding also has substantial implications for real exchange rate determination. At the same time, the individual results are less clear-cut, pointing to idiosyncratic sources of the real interest rate disparity, e.g. domestic real shocks. We find differentials for the Czech Republic, Hungary, and Poland, countries highly integrated into the EMU economy, to be unstable over time.

It is worth noting that measuring ex-ante real interest rates differentials relies on a set of assumptions outlined in the paper and poses thought-provoking questions, many of them going beyond the scope of this study. The research in this area may then be enhanced by explicitly taking into consideration the changes in currency risk premium in the UIP condition and focusing more closely on determinants that spur those changes.

Area in 2016 was slightly negative, compared to 2.1% in 2007 and 2.5% in 1990.

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Annex

Table 1. Estimation results of Markov-switching regressions for inflation rates

Country	Constant		Auto-regressive coefficients				Expected duration	
	Regime 1	Regime 2	AR(1)	AR(2)	AR(3)	AR(4)	Regime 1	Regime 2
EMU	1.937	1.304	1.082	0.035	-0.194	0.030	78.858	19.525
	(0.333)	(0.381)	(0.086)	(0.126)	(0.112)	(0.073)		
Albania	3.632	2.100	1.234	-0.330	-0.150	0.146	3.258	12.611
	(0.364)	(0.349)	(0.081)	(0.140)	(0.158)	(0.089)		
Bulgaria	4.149	6.571	1.335	-0.333	-0.075	0.033	32.768	8.443
	(1.195)	(1.223)	(0.079)	(0.145)	(0.137)	(0.072)		
Czechia	1.745	2.934	1.133	-0.075	0.002	-0.115	27.842	19.454
	(0.455)	(0.454)	(0.080)	(0.121)	(0.117)	(0.075)		
Hungary	5.397	3.744	1.303	-0.308	0.059	-0.073	11.756	98.443
	(1.471)	(1.455)	(0.071)	(0.116)	(0.114)	(0.069)		
N.	5.504	1.689	0.842	0.189	-0.006	-0.130	11.460	67.914
Macedonia	(0.544)	(0.477)	(0.066)	(0.088)	(0.088)	(0.065)		
Moldova	8.267	14.206	1.540	-0.515	-0.033	-0.018	117.866	5.248
	(2.928)	(3.010)	(0.065)	(0.114)	(0.112)	(0.065)		
Poland	2.764	2.134	1.593	-0.749	0.206	-0.066	4.500	18.300
	(1.296)	(1.292)	(0.097)	(0.192)	(0.189)	(0.093)		
Romania	2.656	-0.646	1.365	-0.241	-0.203	0.070	19.028	26.549
	(6.883)	(6.884)	(0.067)	(0.119)	(0.103)	(0.054)		
Turkey	12.911	18.940	1.439	-0.196	-0.303	0.048	76.666	2.978
	(7.521)	(7.541)	(0.078)	(0.147)	(0.131)	(0.067)		
Ukraine	17.452	12.609	1.901	-1.263	0.493	-0.160	3.828	46.397
	(3.147)	(3.104)	(0.076)	(0.139)	(0.163)	(0.096)		

Notes: model specification as in Equation (1); standard errors in brackets; expected duration in months.

Table 2. Standard univariate unit root and stationarity tests for real interest rate differentials

Country	ADF		PP		KPSS	
	int	t + int	int	t + int	int	t + int
Albania	-4.075	-4.290	-4.023	-4.232	0.850***	0.130*
	(0.001)	(0.004)	(0.002)	(0.005)		
Bulgaria	-3.298	-4.582	-3.346	-4.663	0.971***	0.083
	(0.016)	(0.001)	(0.014)	(0.001)		
Czechia	-2.094	-2.619	-2.214	-2.731	0.500**	0.098
	(0.247)	(0.272)	(0.202)	(0.225)		
Hungary	-2.254	-2.245	-2.695	-2.703	0.233	0.164**
	(0.188)	(0.462)	(0.076)	(0.236)		
N.	-2.881	-3.119	-3.659	-3.559	0.240	0.070
Macedonia	(0.049)	(0.104)	(0.005)	(0.036)		
Moldova	-3.000	-3.045	-2.994	-3.069	0.234	0.115
	(0.036)	(0.122)	(0.037)	(0.116)		

Table 2. Continued

Country	ADF		PP		KPSS	
	int	t + int	int	t + int	int	t + int
Poland	-1.927	-2.145	-2.106	-2.401	0.823***	0.315***
	(0.320)	(0.517)	(0.243)	(0.378)		
Romania	-4.966	-4.979	-8.661	-8.511	0.303	0.032
	(0.000)	(0.000)	(0.000)	(0.000)		
Turkey	-6.482	-8.244	-5.449	-5.435	0.074	0.067
	(0.000)	(0.000)	(0.000)	(0.000)		
Ukraine	-4.513	-4.502	-4.917	-4.907	0.103	0.103
	(0.000)	(0.002)	(0.000)	(0.000)		

Notes: ADF denotes the Augmented Dickey-Fuller t-statistics; PP is the Phillips-Perron test statistic; KPSS is the Kwiatkowski-Phillips-Schmidt-Shin LM statistic; int – test with exogenous constant; t + int – test with exogenous constant and linear trend; for ADF and PP, p-values in brackets; for KPSS, ***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

Table 3. Unit root test with an endogenously determined structural break for real interest rate differentials

Country	Intercept			Trend + intercept		
	t-stat	p-value	Break date	t-stat	p-value	Break date
Albania	-5.344	<0.01	2013m08	-5.103	0.061	2013m09
Bulgaria	-5.021	<0.01	2008m07	-5.204	0.047	2003m11
Czechia	-3.831	0.222	2008m02	-3.932	0.568	2008m10
Hungary	-3.390	0.448	2001m06	-3.482	0.821	2003m02
N. Macedonia	-3.659	0.302	2004m09	-4.578	0.203	2008m09
Moldova	-5.926	<0.01	1991m11	-6.420	<0.01	2002m02
Poland	-4.386	0.058	2001m10	-4.457	0.256	2001m11
Romania	-13.642	<0.01	2000m09	-12.033	<0.01	2000m10
Turkey	-9.220	<0.01	2000m10	-10.489	<0.01	2001m04
Ukraine	-5.376	<0.01	1999m10	-5.908	<0.01	1999m10

Notes: tests include an innovation outlier breakpoint; for the test with the trend and intercept we allow for a structural break in both.

Table 4. Hadri and Rao tests for panel stationarity of real interest rate differentials

Individual test statistics						
Country	Test statistics	10%	5%	1%	Model	Break date
Albania	0.093	0.088	0.108	0.157	t + int	2002m04
Bulgaria	0.064	0.099	0.123	0.183	t + int	2001m02
Czechia	0.028	0.053	0.062	0.083	t + int	2009m01
Hungary	0.034	0.095	0.118	0.171	t + int	2001m08
N. Macedonia	0.041	0.107	0.133	0.201	int	2009m01
Moldova	0.053	0.090	0.111	0.162	t + int	2002m02
Poland	0.083	0.054	0.064	0.086	t + int	2010m03
Romania	0.090	0.118	0.145	0.210	t + int	1999m09
Turkey	0.094	0.105	0.129	0.188	t + int	2000m08
Ukraine	0.054	0.112	0.140	0.203	t + int	1999m12

Table 4. Continued

Panel: no serial correlation						
All	0.045	0.792	0.915	1.192	-	-
EU-5	0.039	0.874	1.048	1.443	-	-
Non-EU-5	0.050	0.875	1.048	1.431	-	-
Panel: serial correlation allowed						
All	0.063	0.218	0.280	0.439	-	-
EU-5	0.060	0.129	0.160	0.238	-	-
Non-EU-5	0.067	0.360	0.483	0.805	-	-

Notes: individual statistics calculated with a correction for serial correlation; 10%, 5%, and 1% indicate critical values at respective significance levels; int – break in a constant; t + int – break in a constant and linear trend; empirical distribution of panel test statistic with bootstrap using 20000 replications based on Ranjbar *et al.* (2015).

Figure 1. Real interest rates differentials between the CEE countries and the EMU (1999m05–2018m09; percentage points)

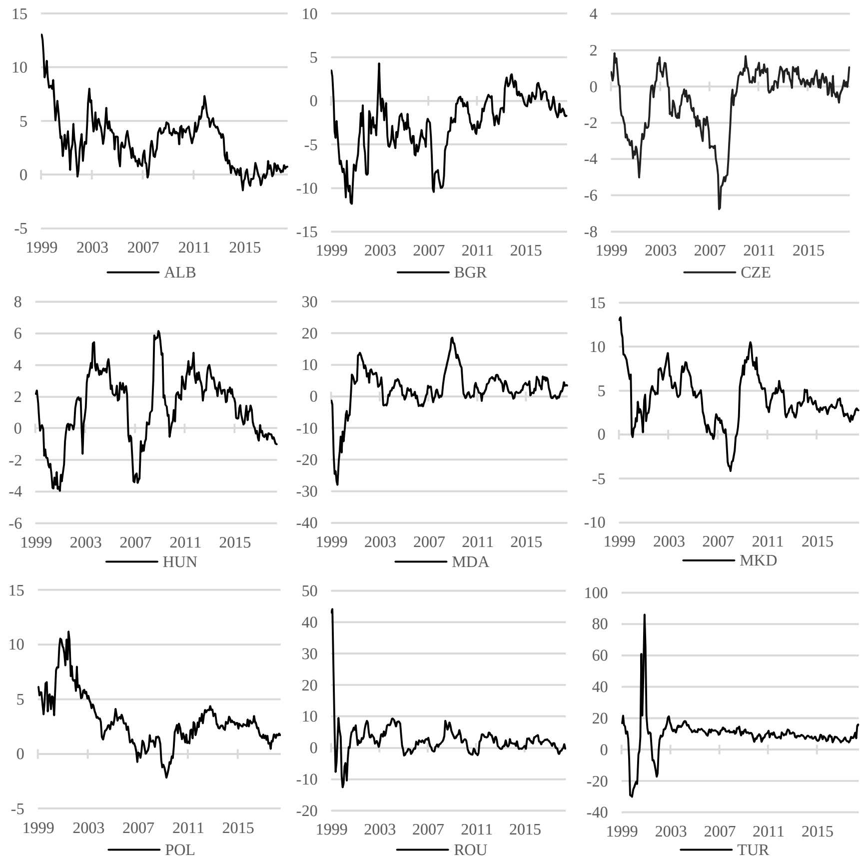

Figure 2. Continued