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TRESHOLD EFFECTS IN REAL INTEREST RATE PARITY FOR THE CENTRAL AND EASTERN EUROPEAN COUNTRIES

This study applies a nonlinear threshold unit-root test to assess the nonstationary properties of the real interest rate parity (RIRP) for twelve Central and Eastern European (CEE) countries. We find that the non-linear threshold unit-root test has a higher power than the linear method suggested by Caner and Hansen (2001) if the true data generating process of real interest rate convergence is in fact a stationary nonlinear process. We examine the validity of RIRP from the nonlinear point of view and provide robust evidence which clearly indicates that RIRP holds true for nine countries. Our findings point out that real interest rate convergence is mean reversion towards RIRP equilibrium values in a nonlinear way.

Keywords: nonlinear threshold unit-root test, real interest rate parity

1. INTRODUCTION

In an open economy, real interest rate parity (RIRP) provides an indication of whether countries are economically and financially integrated or autonomous. When RIRP holds, it implies assets with identical risk, liquidity and maturity with the same expected return across different countries. The RIRP states that, if agents make their forecasts using rational expectations and arbitrage forces are free to act in the goods and assets markets, then real interest rates between countries will equalize. Meanwhile, the extent of product market integration might provide useful information for countries seeking to join a monetary union. In this study, we analyze whether RIRP holds in the Central Eastern European (CEE) countries due to their increasing importance in view of joining with the European Economic and Monetary Union (UEM) or the European Union (EU, depending on the

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country). The features of transition economies in CEE countries provide an interesting study of the RIRP hypothesis test. First, there was centrally planned and fast liberalization of prices and markets, and some suffered from high inflation. Second, and most of all, the initial conditions for the CEE countries transition varied extensively and this may be an important indicator in explaining the magnitude of deviations from RIRP.

Numerous studies on RIRP have been done for developed countries, such as Mishkin (1984), Cumby and Mishkin (1987), and Fujii and Chinn (2001). These studies find that the evidence of RIRP is relatively limited due to the short term data which are used for test. When it comes to a long time span, Lothian (2002) finds supportive evidence for the RIRP hypothesis among developed countries. While some empirical evidence of RIRP for both developed countries and emerging countries seems convincing, unfortunately due to the different span so far none has been proven to be conclusive. Camarero *et al.* (2009) indicate that there is no evidence in favour of the weak version of the RIRP since one of the common factors that have been estimated is non-stationary. Pipatchaipoom and Norrbin (2010) argue that the mixed findings are a result of the different methods used to calculate the real interest rate and indicate that the connection between real interest rates tends to be sensitive to the computational method of the real interest rate. Thus, the authors have to be careful when comparing results across existing studies, since the type of computational method might be responsible for differences in conclusions of the validity of the RIRP. In particular, the literature dealing specifically with the Central and Eastern European (CEE) countries and other European transition countries is relatively scarce. Singh and Banerjee (2006) suggest that real interest rates in the emerging markets show some convergence in the long run but real interest parity does not hold. Arghyrou *et al.* (2009) have analyzed the CEE countries and find evidence in support of the RIRP hypothesis in some of the investigated countries. Holmes and Wang(2008) investigate the RIRP based on real interest rate differentials either switch between regimes of stationarity and nonstationarity in a Markov regime-switching framework for the EU accession countries. Cuestas and Harrison (2010) analyze the convergence of RIRP for some CEE countries and find that the results support the RIRP, especially when the nonlinearities in real interest rate differential are considered. Sonora and Tica (2010) strongly support the RIRP condition in the CEE countries, and relatively much weaker when taking structural breaks into account.

During recent years we can see vast literature concerning the application of nonlinear econometrics in testing old, fundamental hypotheses in the

economy. In particular, some research was done in the field of measuring the impact of the international business cycle on a small open economy; see Smith and Summers (2005), Artis *et al.* (2007), Chen and Shen (2007). Also purchasing power parity hypothesis was considered in the field of nonlinear cointegration approach; see Michael *et al.* (1997), Baum *et al.* (2001), Sarno *et al.* (2004), Peel and Venetis (2005). Some authors revisited very fundamental and old money-output causality hypothesis and provided empirical testing on the basis of nonlinear models; see Lütkepohl *et al.* (1999), Teräsvirta and Eliasson (2001), Escribano (2004), Haug and Tam (2007), Seo (2004), Seo (2006), Kapetanios *et al.* (2006), Rothman *et al.* (2001). Empirical evidence on the stationarity of the real interest rate convergence is abundant, but unfortunately, so far, the results are not conclusive. From previous studies, one possible explanation for the inconsistencies in the existing empirical evidence on the RIRP hypothesis is that the prior studies implicitly assume that interest rate behaviour is inherently linear in nature. It is well known that if real interest rate differential follows a nonlinear stationary process then tests based on linear models such as the widely used augmented Dickey-Fuller (ADF) unit root models will be mis-specified (Chortareas *et al*., 2002). However, Sonora and Tica (2010) also demonstrate that the adoption of linear stationarity tests is inappropriate for the detection of mean reversion if the true process of the data generation of the real interest rate differential is in fact a stationary nonlinear process. The presence of nonlinear mean-reverting adjustment for real interest rates has been advanced by recent theoretical developments that emphasize the role of transaction costs, imperfect capital mobility and incomplete institutional reforms. An alternative view is that nonlinearity at the aggregate level is caused by other influences, such as the effects of official interest rate intervention. Additionally, the existence of structure changes in the RIRP might imply broken deterministic time trends and the result is a nonlinear pattern (Cuestas and Harrison, 2010).

The central aim of this study contributes significantly to this field of research because, first of all, we examine evidence for RIRP for the CEE countries, using the threshold autoregressive model (TAR) and the test statistics suggested by Caner and Hansen (2001). The main advantage of this procedure is that it allows to simultaneously test for nonlinearities and nonstationarity. Secondly, to the best of our knowledge, this study is the first of its kind to utilize the threshold unit root test for long-run RIRP in the CEE countries.

The remainder of this study is organized as follows. Section II describes the methodology of the nonlinear threshold unit root test. Section III

presents the data used in our study and discusses the empirical findings. Finally, Section IV reviews the conclusions we draw.

2. THE THEORY OF REAL INTEREST RATE PARITY AND THRESHOLD UNIT-ROOT TEST METHODOLOGY

The RIRP theory contends that the real interest rate between two countries should be equal (Taylor and Sarno, 2004; Mark and Moh, 2005). According to Ferreira and León-Ledesma (2007), RIRP defines that real interest rate differential is constant. Real interest rate differentials can be calculated using either en-ante or ex-post real returns, as well as alternative definitions for nominal interest and inflation rates. Following the majority of existing studies we use ex-post real returns so as to bypass the empirically tricky subject of approximating empirically inflation expectations. Here we define real interest rate differential as $rid_t = r_t - r_t^*$, where r_t and r_t^* are the real interest rate of two countries. The RIRP theory implies that the rid is a stationary process, since the existence of adjustment costs and imperfect information prevent the rid from being constant at every point. This implies that we can represent rid in Vector Autoregressive (VAR) form as follows:

$$rid_t = c_0 + c_1 rid_{t-1} + \varepsilon_t \quad (1)$$

which can be represented as

$$\Delta rid_t = \theta_0 + \theta_1 rid_t + \sum_{i=2}^{p} \lambda_i \Delta rid_{t-i+1} + \varepsilon_t \quad (2)$$

Now for RIRP to hold empirically, we need to test $H_0 : \theta_1 = 0$ *vs.* $H_1 : \theta_1 < 0$, which we do by testing for unit roots in the rid. Note that we allow $\theta_0 \neq 0$, since different countries may have a different risk premium (Ferreira and León-Ledesma, 2007). In order to test RIRP in CEE countries, we apply the threshold effect on the unit root process of the real interest rate differential series r_t using the threshold unit root model developed by Caner and Hansen (2001), who consider a two regime TAR(k) model:

$$\Delta r_t = \theta_1' x_{t-1} I_{\{Z_t \leq \lambda\}} + \theta_2' x_{t-1} I_{\{Z_t > \lambda\}} + e_t, \quad t = 1, \ldots, T \quad (3)$$

where $x_{t-1} = (r_{t-1}, v_t', \Delta r_{t-1}, \ldots, \Delta r_{t-k})'$, $I_{\{\bullet\}}$ is the indicator function, e_t is

an *i.i.d.* disturbance, $Z_{t-1} = r_{t-1} - r_{t-m}$ for some $m \geq 1$ is the threshold variable, v_t is a vector of exogenous variables including an intercept and possibly a lineartime trend, λ is a threshold parameter and $k \geq 1$ is the autoregressive unit root. The components of θ_1 and θ_2 can be partitioned as follows:

$$\theta_1 = \begin{pmatrix} \rho_1 \\ \beta_1 \\ \alpha_1 \end{pmatrix}, \quad \theta_2 = \begin{pmatrix} \rho_2 \\ \beta_2 \\ \alpha_2 \end{pmatrix}$$

where ρ_1 and ρ_2 are scalar terms. β_1 and β_2 have the same dimensions as v_t, and α_1 and α_2 are *k*-vectors. Thus (ρ_1, ρ_2) are the slope coefficients on r_{t-1}, (β_1, β_2) are the slopes on the deterministic components, and (α_1, α_2) are the slope coefficients on $(\Delta r_{t-1}, \ldots, \Delta r_{t-k})$ in the two regimes.

The threshold effect in Equation (3) has the null hypothesis $H_0 : \theta_1 = \theta_2$, which is tested using the familiar Wald statistic: $W_T = W_T(\hat{\lambda}) = \sup_{\lambda \in \Lambda} W_T(\lambda)$. The stationarity of the process r_t can be established in two ways. First, when there is a unit root in both regimes. Here the null hypothesis is of the form $H_0 : \rho_1 = \rho_2 = 0$, which is tested against the unrestricted alternative $\rho_1 \neq 0$ or $\rho_2 \neq 0$ using the Wald statistic. The parameters ρ_1 and ρ_2 of Equation (3) control the regime-dependent unit root process of the real interest rate differential. If $\rho_1 = \rho_2 = 0$ holds, the real interest rate differential has a unit root which can be described as a rejection of RIRP. This statistic is:

$$R_{2T} = t_1^2 + t_2^2 \tag{4}$$

where t_1 and t_2 are the *t* ratios for $\hat{\rho}_1$ and $\hat{\rho}_2$ from the ordinary least squares estimation. However, Caner and Hansen (2001) claim that this two-sided Wald statistic may have less power than a one-side version of the test. As a result, they propose the following one-sided Wald statistic:

$$R_{1T} = t_1^2 I_{\{\hat{\rho}_1 < 0\}} + t_2^2 I_{\{\hat{\rho}_1 < 0\}} \tag{5}$$

R_{1T} tests H_0 against the one-side alternative $\rho_1 < 0$ or $\rho_2 < 0$. Caner and Hansen (2001) show that both tests R_{1T} and R_{2T} will have power against both alternatives.

3. DATA AND EMPIRICAL RESULTS

We use monthly data from 1997 to 2011 to apply the Caner and Hansen (2001) threshold unit test in testing the validity of RIRP. During this period, the CEE countries started their liberalization programs and transited to market economies. The data of our empirical study consists of the 12 CEE countries: Belarus, Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, Russian Federation, and Ukraine. In order to compute real interest rates our measure of actual rates of inflation is derived from the annual increase in the Consumer Price Index (CPI). For nominal interest rate we use the money market rate or deposit rate, specifically, Belarus, Hungary, Moldova, Ukraine (deposit rate), Bulgaria, the Czech Republic, Estonia, Lithuania, Latvia, Poland, Romania, Russian Federation, US. (money market rate). All data is taken from the International Monetary Fund's International Financial Statistics. We have then computed the interest rate differential for 12 CEE countries against the US.

First, we use the Wald test W_T to examine whether or not we can reject the linear autoregressive model in favour of a threshold model. The results of the Wald test are in Table 1, and also report the bootstrap critical values generated at conventional levels of significance. The bootstrap *p*-value for threshold variables of the form $Z_{t-1} = r_{t-1} - r_{t-m}$ for delay parameters *m* is ranged from 1 to 12. The parameters *m* are generally unknown; there is no reason to think the optimal delay parameter will be the same across countries. To circumvent this, Caner and Hansen (2001) suggest making *m* endogenous by selecting the least squares estimate of *m* that minimizes the residual variance. This amounts to selecting *m* at the value that maximizes the W_T statistic. Taken together, these results imply strong statistical evidence against the null hypothesis of linearity of at least 5% in the CEE countries indicating that simple linear models are inappropriate. Subsequently, these are our preferred models.

Table 1

Threshold test

Country	*m*	W_T	Bootstrap critical values (%)			Bootstrap *p*-value	Threshold
			10	5	1		
Belarus	4	184.938	44.154	48.429	56.309	0.000	-5.873
Bulgaria	1	34483.700	100.249	163.316	605.514	0.000	-1.087
Czech Rep.	11	214.018	86.283	124.126	143.844	0.001	2.189
Estonia	4	81.519	45.752	50.268	59.285	0.000	-2.149
Hungary	1	67.638	42.261	45.164	55.812	0.000	0.633
Lithuania	6	87.285	44.691	48.386	56.789	0.000	1.690
Latvia	2	144.792	80.732	95.878	139.679	0.009	1.974
Moldova	10	67.078	42.352	46.525	53.513	0.002	-7.626
Poland	2	60.721	41.475	44.723	52.269	0.001	0.768
Romania	3	279.207	61.237	69.419	101.005	0.000	3.667
Russian Fed.	5	333.254	63.107	75.582	108.328	0.000	7.256
Ukraine	9	45.699	40.029	43.726	53.512	0.035	-1.949

Source: author's calculation

Next, we explore the threshold unit root properties of real interest rate differential based on R_{1T} statistic for each delay parameter *m*, ranging from 1 to 12, paying particular attention to the results obtained for our preferred model. The R_{1T} test results, together with the bootstrap critical value at the conventional levels of significance and the bootstrap *p*-value, are reported in Table 2. We are able to reject the unit root null hypothesis for Belarus, Bulgaria, Latvia, Romania, Russian Federation and Ukraine at the 1% level, for Estonia and Poland at the 5% and for Hungary at the 10% level. However, we are unable to reject the threshold unit root hypothesis for the Czech Republic, Lithuania and Moldova. Compared with the present participants in the European Economic and Monetary Union, the money markets of the CEE countries still, consequently, show distinct deficits in integration. The transaction costs may be attributed to the influence of capital controls and other inefficiencies related to the underdevelopment of the financial sector. These three countries still had significant restrictions on foreign exchange transactions and face high inflation. For example, the Czech Republic has adopted a monetary policy regime of inflation targeting since 1998, which allowed the country to fight inflation. Also, the existing managed floating exchange rate regime is compatible with the EU membership. Lithuania has made considerable progress in liberalizing and stabilizing its economy. The country established a currency board vis-à-vis the US dollar in 1994 and

since 2002 has pegged its currency to the euro. The efforts of Moldova to improve living standards and economic efficiency have reduced fiscal and monetary discipline and have led to persistent current account deficits. As a result, higher demand and unit labour costs, together with higher food and energy prices, have contributed to higher inflation rates. On the other side, our results taken together provide strong support for RIRP for nine CEE countries and point that these countries are nonlinear stationary, implying that deviations of real interest rate is a mean reverting towards the RIRP equilibrium. Most of these countries managed to reduce the excessive fiscal deficits of the 1990s, have kept inflation under control, and have reduced the debt-to-GDP ratio and there has been a significant reduction in discrepancies. For example, since 2000, Romania has implemented tight fiscal and monetary policies along with structural reforms designed to support growth and improve financial discipline in the private sector. These reforms have placed the country's public finances and the financial system on a firmer footing. Further, Romania is currently considering a currency board vis-à-vis the euro, in order to reduce inflation and gain monetary policy credibility. As mentioned earlier, barriers to capital mobility, as well as interventions in the monetary markets, could be behind this nonlinear behaviour. The validity of RIRP is important to policy makers in nine CEE countries who base their determination on interest rate adjustments. The result means that the unbounded gains from arbitrage in traded portfolios are impossible among these nine countries.

Table 2

Threshold unit root test

Country	R_{1T}	Bootstrap critical values (%)			Bootstrap *p*-value
		10	5	1	
Belarus	32.695	11.379	14.107	21.545	0.001
Bulgaria	783.404	21.387	222.811	86.150	0.001
Czech Rep.	0.279	16.170	22.767	46.627	0.934
Estonia	18.772	9.701	12.366	18.856	0.011
Hungary	11.187	9.467	11.561	17.062	0.055
Lithuania	7.313	9.264	11.976	17.484	0.177
Latvia	20.563	15.321	213486	42.129	0.059
Moldova	9.725	12.017	15.062	20.787	0.166
Poland	15.653	9.853	11.826	16.002	0.012
Romania	146.665	0.000	0.0473	1.550	0.000
Russian Fed.	42.052	14.494	20.151	36.107	0.005
Ukraine	17.896	9.854	12.046	17.464	0.009

Source: author's calculation

The threshold unit root tests of the real interest rate employed in this study provide some evidence favouring the long-run validity of RIRP for the studied CEE countries. The major policy implication that emerges from this study is that RIRP can be used to determine the equilibrium real interest rate convergence for these nine CEE countries. Most of these countries managed to reduce the excessive fiscal deficits of the 1990s, have kept inflation under control, and have reduced the debt-to-GDP ratio and seen a significant reduction in discrepancies. For example, following the 1997 economic and financial crisis, Bulgaria adopted a euro-based currency board to stabilize its exchange rate, and implemented a comprehensive economic plan, which included trade and price liberalization, social sector reform, and divesting state-owned enterprises. The efforts of Bulgaria improve living standards and economic efficiency has reduced fiscal and monetary discipline. Belarus, in between central bank and government exchange rate intervention, the inflation target and the effect of fiscal policy on inflation has led to increasing certainty about future development. The monetary authorities in Poland implemented a free-floating exchange rate regime for its currency and changed its monetary policy regime to inflation targeting. It seems that the inflation problems and exchange rate stability problems in Poland have allowed converging. Similarly, since 2000, Romania has implemented tight fiscal and monetary policies along with structural reforms designed to support growth and improve financial discipline in the private sector. These reforms have placed the country's public finances and the financial system on a firmer footing. Furthermore, Romania is currently considering a currency board vis-à-vis the euro, in order to reduce inflation and gain monetary policy credibility. Our findings are similar with Cuestas and Harrison (2010) that CEE countries are in favour of the empirical fulfillment of RIRP, particularly when taking into account the possibility of nonlinearities in the real interest rate differential. This means that we can use RIRP to test whether national real interest rates were bound to converge, the scope for international portfolio diversification would be significantly reduced; and national monetary policy as a tool of effective macro-management would be restricted to the degree it affects the international real interest rate (Mark, 1985). The implication of RIRP holds that assets of these CEE countries with identical risk, liquidity and maturity characteristics offer the same expected return across different countries. The extent to which the RIRP holds therefore serves as an indicator of the degree of product and financial market integration. This might be important for several reasons and ever since Grubel (1968) it has been well known that diversifying a portfolio

along international lines might improve the portfolio's risk-return characteristics. If all other things are equal, the international portfolio diversification in the CEE countries will be most attractive to investors when there are differences in real rates of interest across countries. Meanwhile, the extent of product markets integration in the CEE countries might provide useful information for countries seeking to join the EU monetary union. The validity of the RIRP is important to policy makers in the CEE countries who base their determination on interest rate adjustments.

4. CONCLUSION

In this empirical study, we apply nonlinear threshold unit-root test to assess the nonstationary properties of the real interest rate for 12 CEE countries. The test has higher power than the linear method if the true data generating process of interest rate is in fact a stationary nonlinear process. This study examined the validity of the RIRP from the nonlinear point of view and its findings provide robust empirical evidence supporting the validity of the long-run RIRP, suggesting to these nine countries that their real interest rate adjustment is a mean reversion towards RIRP equilibrium values in a nonlinear way. This implies that transaction costs may be affecting the portfolio decisions of the international investors. This might offer an alternative explanation for the difficulty researchers have encountered in rejecting the unit root hypothesis for real interest rate convergence.

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