

DOES THE UNCOVERED INTEREST PARITY HOLD? EVIDENCE FOR CENTRAL AND EASTERN EUROPEAN COUNTRIES

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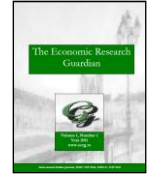
Abstract

This study applies nonlinear quantile unit root test with Fourier function to test the validity of long-run uncovered interest parity (UIP) to assess the non-stationary properties of the interest differentials convergence for ten Central and Eastern European (CEE) countries. We find that our approximation has higher power to detect U-shaped breaks and smooth breaks than linear method if the true data generating process of risk premium convergence is in fact a stationary non-linear process. We examine the validity of UIP from the non-linear point of view and provide robust evidence clearly indicate that UIP holds true for six CEE countries. Our findings point out the risk premium adjustments of the six CEE countries are mean reversion towards UIP equilibrium values in a non-linear way.

Keywords: Quantile Unit Root Test, Structural Change, Trend Breaks, Uncovered Interest Parity

JEL classification: C22, F36

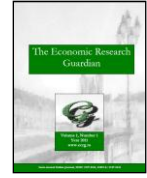
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1. Introduction

With the increasingly close association of the global financial markets, the integration of international capital market getting more attention than before. The relationship between exchange rate and interest rate has been an active topic in open economy macroeconomics. Especially, there has been a resurgence of attention over the past decade to the various aspects of how interest rates and exchange rates are linked by arbitrage conditions. Based on the uncovered interest parity (UIP) hypothesis, the long-term trend of country-specific interest rate is convergent since the free movement of capital and the interdependence among regions. In essence, this hypothesis stipulates that if the interest rate differential between countries is different from the market's expected rate of changes of the spot exchange rate, risk neutral agents tend to move their uncovered funds across financial markets until equality is re-established. The UIP hypothesis has been receiving a great attention for both international finance scholars and practitioners in recent years and states that the difference between domestic and foreign interest rates should correspond to the expected exchange rate change plus risk premium. The UIP suggests that interest rate differentials could cause the change of exchange rate through international capital movements (Obstfeld and Rogoff, 1995; Merlevede *et al.*, 2003). Though the UIP suggests no-arbitrage condition between a domestic foreign currency denominated asset market, and no independent and effective monetary policy to influence the real economy, most studies have found the opposite evidence. High interest rate countries over quite lengthy periods have often experienced currency appreciation rather than depreciation, and it is described as the “forward premium puzzle”. On the other hand, if the UIP holds, capital markets should show efficiency and there will be no arbitrage opportunity (Cook, 2009). However, in fact, the phenomenon of “carry trades” which is a violation of the UIP has been studied in lots literatures in recent years (Brunnermeier *et al.*, 2009; Clarida *et al.*, 2009; Menkhoff *et al.*, 2012; Moore and Roche, 2012 and Doskov and Swinkels, 2015).

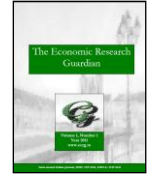
Previous literatures mostly focus on the applicability of the UIP in developed countries, and researches on emerging markets shows a relatively deficiency (Pasricha, 2006). However, literatures on foreign exchange market efficiency in transition economies are relatively abundant due to the financial liberalization in emerging markets (Alper *et al.* 2007). It is important to exam the UIP among European transition countries such as Central and Eastern European (CEE) countries. Flood and Rose (1996) investigate European currencies exchange rate regimes and argue that, when fixed currency regimes are implemented, a large number of the forward puzzle vanishes. Choudry (1999) investigates forward market efficiency and find forward puzzle is not always existing. Bansal and Dahlquist (2000) find that lots of emerging countries do not show the characteristic of the forward puzzle. Flood and Rose (2001) argue the UIP is more applicable when financial crisis occurs. However, the difference in UIP between developed and emerging countries are not taken into account. Frankel and Poonawala (2006) find that emerging markets seems to have a less severe forward premium bias. Ferreira and León-Ledesma (2007) find evidence of interest rate in a sample of industrialized and emerging economies. Mansori (2003) finds that the UIP shows its effectiveness during the period of 1994-2002, and he argues that structural breaks could be one of the factors. Transition started in 1992 in the former Soviet Union, the process of economic transition started with a liberalization of the foreign exchange markets and a provision of currency convertibility.



These drastic steps resulted in initial deep under valuations of the national currency. At the same time, price liberalization was accompanied by very high inflation rates and interest rate. Therefore, the features of CEE countries transition economies provide an interesting study of UIP hypothesis test. First, there were centrally planned and fast liberalization to prices and markets, and some suffered from high inflation and high interest rate. Second, and most of all, the initial conditions for CEE countries transition varied extensively and they may be an important indicator in explaining the magnitude of deviations from UIP. The debate about UIP remains unsettled and we aim to contribute to the literature by investigating UIP among those CEE countries. These countries are of interest because the extent to which economies are integrated is of particular importance to those countries either aiming to join a monetary union, or who have recently joined a monetary union. The more highly integrated economies are, the more likely they are to have synchronized business cycles and the closer their real rates of interest are likely to approximate to each other.

According to the UIP hypothesis, the difference in the return on identical assets from two different countries should be fully offset by the differential of the spot and the expected future exchange rate at the points in time when the interest-bearing assets are bought and redeemed. For the short-term horizon, UIP is rejected due to frictions, like irrational expectations (Mark and Wu, 1998; Frankel and Froot, 1989; Carlson and Osler, 1999), forecast errors (Lewis, 1989; 1995) and/or non-linearities (Flood and Rose, 1996; Flood and Taylor, 1996 and Bansal and Dahlquist, 2000; Baillie and Kilic, 2006; Sarno *et al.*, 2006). If using the linear model critically underestimates the velocity of adjustment of long-term equilibrium, and usually we accept the null hypothesis because of the low power of traditional unit root test. Traditional unit root tests may suffer from an omission of structural breaks, and it may be failed to reject the null hypothesis of the existence of unit roots. Perron (1989) argues that structural breaks can decrease the power to reject the null of a unit root when the stationary alternative is true in the traditional unit root test. Furthermore, structural changes that have been neglected in the DGP may lead the traditional tests to accept the null hypothesis of a unit root.

As discussed, traditional unit root tests lose power if structural breaks are ignored in unit root testing. Liu and Maynard (2005) argue that high persistence in forward premium can provide a partial explanation of the bias. Through a stochastic partial break model, Sakoulis and Zivot (2000) show that ignoring structural breaks may cause spurious persistence in forward premium, which may result in forward premium bias. Similarly, Choi and Zivot (2007) show that accounting for structural breaks significantly reduce the observed persistence in the forward premium. Traditionally, the using of dummy variables is a general way to deal with breaks. However, dummy variables cannot identify breaks effectively in lots of cases. First, the location and the exact amount of breaks cannot measure in advance, and it would therefore cause a bias estimation (Maddala and Kim, 1999). Second, this method is invalid when potential breaks are far more than one or two. Finally, the use of dummy variables can only apply on sharp and sudden changes in the trend or level. Leybourne *et al.* (1998) argue that, the dummy variables method is invalid when frequency of series is low. Becker *et al.* (2006), Enders and Lee (2012), and Christopoulos and León-Ledesma (2010) proposed a Flexible Fourier transforms method, which is effective in detecting any structural break of an unknown form as a smooth process. The effectiveness of the Fourier approximation has been verified in ample literatures (Gallant, 1981; Becker *et al.*, 2006; Enders and Lee, 2012; Christopoulos and León-Ledesma, 2010). This method is more effective with respect to using dummy variables in detecting breaks, and the only requirement is to choose a proper frequency in the estimating equations. The



power of this method has been ensured by reducing the number of estimated parameters and more importantly, this method also accounts for the distribution of data in different quantiles.

The contributions of this paper are as follows. We investigate the existence of the quantile unit root process of interest rate differentials against US interest rate of 10 CEE countries with a Fourier function proposed by Li and Park (2016). Since the nature of persistence in the errors is usually unknown, testing whether a time series can be characterized by a broken trend is complicated. The lack of econometric studies may be explained by the difficulties involved modeling acceding country data: only relatively few time series observations are available and structural changes have occurred frequently. This paper tests the risk premium of UIP with using Quantile unit root test with Fourier function to detect unknown breaks in the trend and the level of the data. As a supplement to the previous literature, this study contributes to empirically find out if the unit root process is characteristic of the UIP theory for CEE countries.

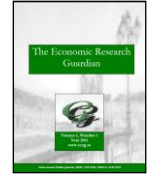
This paper is arranged as follows: in next section we outline the theory of UIP and the methodology we will use quantile based unit root with flexible Fourier function suggested by Li and Park (2016). In section 3, we apply the quantile unit root with flexible Fourier function to analyze the characteristics of UIP theory for 10 CEE countries. And our conclusion is presented in last section.

2. The theory of uncovered interest parity & quantile unit root test with Fourier function

The relationship between interest rates differentials and exchange rates has been one of the focus issues in international economics for a long time. Almost each standard theoretical model of exchange rate determination has described the relationship between these two financial variables, and a great deal of empirical researches has also been undertaken to study such a relationship. In which, the uncovered interest parity (UIP) condition is one of the most important theoretic framework to explain the relationship between exchange rate (defined as the domestic-currency price of foreign currency) and interest rate differential (approximately the domestic interest rate minus the foreign interest rate). Based on Chinn(2006), we rewrite the UIP condition as follows:

$$F_t - S_t = i_t - i_t^* \quad (1)$$

Where F_t stands for forward exchange rate, and S_t is spot exchange rate, i_t and i_t^* are the domestic and foreign interest rates, respectively. The above equation implies that nominal interest rate differential between two countries must be equivalent to the future change in the spot exchange rate. When equilibrating expected excess returns and holding the foreign interest rate and expected future exchange rate as constant, the UIP condition suggest a negative relationship between interest rate differentials and exchange rates.



We can also rewrite the above function under VAR model framework by repeated substitution as follows,

$$\Delta S_{t+k} = \lambda_0 + \lambda_1(i_t - i_t^*) + \varepsilon_{t+k} \tag{2}$$

Where ε_{t+k} represents the interest rate differential and rational expectation's forecast error, we also explain ε_{t+k} as UIP risk premium. The UIP theory assumes the risk premium is constant (Wolters, 2003). This hypothesis suggests that countries' long-term interest rates differential should be stationary, which means that the series of UIP risk premium follows a stationary process. When we test the UIP condition, the null hypothesis of equation (2) can be expressed as $H_0 : \lambda_1 = 1$. It is important to note that the UIP risk premium may present asymmetric characteristic in different distribution, then we assume that the risk premium data generating process can be written as Equation (3) based on quantile function form.

$$Q_{\lambda_t}(\tau | \zeta_{t-1}) = \rho_1(\tau)\lambda_{t-1}^3 + \sum_{i=1}^m \rho_{i+1}(\tau)\Delta\lambda_{t-i} + \varepsilon_t \tag{3}$$

Where $Q_{\lambda_t}(\tau | \zeta_{t-1})$ is τ_{th} quantile of λ_t condition on the past information set, ζ_{t-1} . Optimum lags are selected by the Bayesian information criterion (BIC).

The coefficients of $\rho_1(\tau)$, $\rho_2(\tau)$, ..., $\rho_{k+1}(\tau)$ are estimated by minimizing sum of asymmetrically weighted absolute deviations:

$$\begin{aligned} \min \sum_{t=1}^n (\tau - I(e_t < \alpha_0(\tau) + \alpha_1(\tau)e_{t-1} + \sum_{k=1}^{k=l} \alpha_{1+k}(\tau)\Delta e_{t-k})) |e_t - \alpha_0(\tau) \\ + \alpha_1(\tau)e_{t-1} + \sum_{k=1}^{k=l} \rho_{1+k}(\tau)\Delta e_{t-k} \end{aligned} \tag{4}$$

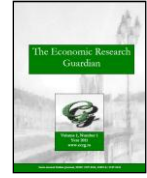
Where $I=1$ if

$$e_t < \alpha_0(\tau) + \alpha_1(\tau)e_{t-1} + \sum_{k=1}^{k=l} \alpha_{1+k}(\tau)\Delta e_{t-k}$$

and $I=0$, otherwise. As suggested by Koenker and Xiao

(2004), after solving Equation (4), we can test the stochastic properties of e_t within the τ_{th} quantile by using the following t ration statistic:

$$t_n(\tau_i) = \frac{\hat{f}(F^{-1}(\tau_i))}{\sqrt{\tau_i(1-\tau_i)}} (E' P_X E_{-1})^{1/2} (\hat{\alpha}_1(\tau_i) - 1) \tag{5}$$



Where E^{-1} is the vector of lagged dependent variable e_{t-1} , P_X is the projection matrix onto the space orthogonal to $X = (1, \Delta e_{t-1}, \dots, \Delta e_{t-k})$. $\hat{f}(F^{-1}(\tau_I))$ is a consistent estimator of $f(F^{-1}(\tau_I))$. Koenker and Xiao (2004) suggest that it can be expressed as:

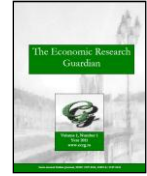
$$\hat{f}(F^{-1}(\tau_I)) = \frac{(\tau_i - \tau_{i-1})}{x'(\beta(\tau_i) - \beta(\tau_{i-1}))} \quad (6)$$

Where $\beta(\tau_i) = (\rho_0(\tau_i), \rho_1(\tau_i), \rho_2(\tau_i), \dots, \rho_{1+k}(\tau_i))$, $\tau_i \in [0.1, 0.9]$. As can be seen, using $t_n(\tau_i)$ statistics, we are able to test the unit root hypothesis in each quantile while ADF and other conventional unit root tests examine the unit root only on the conditional central tendency.

3. Data and empirical findings

We use monthly data that covers from January 1997 to September 2016 to apply quantile unit root test with a Fourier function proposed by Li and Park (2016) in testing the validity of UIP. During this period, CEE countries started their liberalization programs and transited to market economies. The data of our empirical study consists of the 10 CEE countries: including Belarus, Bulgaria, Croatia, Czech Republic, Hungary, Latvia, Macedonia, Poland, Romania and Russia Fed. For nominal interest rate we use money market rate or deposit rate, specifically, Belarus(weighted average rate offered by banks on deposits in national currency), Hungary(simple arithmetic rate offered by banks on deposits), Macedonia(lowest rate on household deposits), Bulgaria(LEONIA reference rate), Czech Republic(money market rate), Latvia(weighted average rate on overnight loans in national currency transacted in the interbank market), Poland(money market rate), Romania(daily average rate on deposits between commercial banks in national currency), Russian Fed(money market rate), Croatia(short-term rate determined on the Zagreb Money Market), US (money Market Rate). For exchange rate we use end of period spot price of domestic currency in units of US dollar. All the interest rate and exchange rate data is taken from the International Monetary Fund's International Financial Statistics and the OECD Main Economic Indicators database. We have then computed the risk premium for 10 CEE countries against the US.

To gain more accurate results, we apply a newly developed Quantile-based unit root test with Fourier Function as proposed by Li and Park (2016) to enhance estimation accuracy. We first estimate Equation (5) and report the results in Table 1. After a grid-search we find the optimum frequency various for different countries. Also the results of the F statistics as shown indicates that both sine and cosine terms should be included in the estimated model. To gain more insight, we also display the time paths of residuals of interest rate parity and the estimated Quantile unit root with Fourier function in Figure 1, which displays the time paths of the risk premium convergence where a positive change in the risk premium indicates real adjustment. We can clearly observe structural shifts in the trend of the data. Accordingly, it appears sensible to allow for structural breaks in testing for a unit



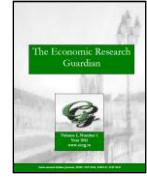
root (and/or stationary). A further examination of the figures indicates that the all Fourier approximations seem reasonable and support the notion of long swings in UIP. Besides, We also can see that after experiencing the financial crisis of 2007-08 associated with an ever-increasing inflation and even a short period of severe hyperinflation, these countries have undertaken a major turnaround in its policies and have achieved considerable progress in price-level stability for more recent years. Accordingly, it appears sensible to allow for structural breaks in testing for a unit root, and it also suggests that all of the Fourier approximations seem to be reasonable and support the notion of long swings in inflation rates. With using the Quantile based unit root test with a Fourier function, this paper tests the real interest differentials follows: First, considering no prior knowledge to ensure the shape of breaks in series, we use a grid-search to find the best frequency. Li and Park (2016) have verified that a wide variety of breaks can be detected in a single frequency, we first estimate the coefficients of both $\alpha_0(\tau)$ and $\alpha_1(\tau)$ from Equation (4) by applying the OLS to get residuals from Equation (5) over quantiles $\tau_i \in [0.1,0.9]$.

The results in Table 1 shows that the values of $\alpha_0(\tau)$ display almost monotonically rising pattern for all countries, which indicate that the larger values of τ , the bigger the values of $\alpha_0(\tau)$ across all these countries. Moreover, when $\tau = 0.5$, the magnitude of shock is not significantly different from zero at the 10% level for all countries. We know that $\alpha_0(\tau)$ denotes the size of the observed shock within each τ quantile that hits the risk premium. When $\alpha_0(\tau)$ is less (more) than zero, meaning the shock is negative (positive). Besides, for all countries the size of shocks is negative for quantiles $\tau \in [0.1,0.5]$ and positive for quantiles $\tau \in [0.6,0.9]$ except for Romania and Russian Federation which are negative during quantiles $\tau \in [0.1,0.4]$ and positive during quantiles $\tau \in [0.5,0.9]$. Besides, the size of shocks is negative when quantiles $\tau \in [0.1,0.6]$ and positive for quantiles $\tau \in [0.7,0.9]$ for Hungary. For Poland and Bulgaria, it shows an upward straight pattern, and reveals that negative shocks to interest rate differentials series have transitory effects and disappear in short run while positive shocks have permanent effects. This also indicates that the long-run path of interest rate differentials series in these two countries will be unbounded. In contrast, for Czech Republic, Latvia, Belarus, Romania and Croatia, it shows downward straight pattern or concave downward curve, implying that positive shocks to UIP risk premium have only transitory effect while negative shocks have permanent effects.

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Finally, we look at the estimated values of $\alpha_1(\tau)$ and QKS statistics reported in Table 1, which are the key to making a judgment of stationarity of the UIP risk premium in each quantiles. Overall speaking, the risk premium has a unit root in some quantiles, but is stationary in other quantiles.



According to the p -values for QKS statistic, we find that the null hypothesis of unit root is rejected for all countries except Latvia, Belarus, Croatia and Macedonia, FYR. In a global way, these results supporting risk premium stationary and the global mean reversion results also imply that even if the shocks to risk premium are respectively short and long-lived in small and large quantiles. This finding is highly relevant for central banks in judging whether the exchange rate expectation have been anchored to exchange rate target, and helps them to assess the proper actions for achieving the target.

To be specific, for Czech Republic, Bulgaria, Poland, Romania, Hungary and Russian Federation, the estimated values of $\alpha_1(\tau)$ are significant rejecting the unit root null hypothesis in each quantiles. The interest rate differentials for these six countries have consistent convergence and do not reveal a rather volatile evolution. For Poland, the $\alpha_1(\tau)$ coefficients are significant at quantiles $\tau \in [0.1, 0.6]$, but cannot reject the null hypothesis of unit root for quantiles $\tau \in [0.7, 0.9]$. This result indicates that when the risk premium is at low level, it is stationary, but contain a unit root when it stay relatively high level, which implies that government would take corresponding measures to intervene the high risk premium. For Poland and Latvia, the $\alpha_1(\tau)$ coefficients can reject the null hypothesis of unit root at quantiles $\tau \in [0.1, 0.6]$ and quantiles $\tau \in [0.3, 0.8]$ respectively. This implies that when the interest rate differentials are extremely low or high, then the risk premium would contain a unit root with feature of random walk. For Romania, the $\alpha_1(\tau)$ coefficients are significant except for the 50% quantile, implying that the risk premium will behave like a unit root process and thus shocks to risk premium are permanent in the 50% quantile. For Croatia, the $\alpha_1(\tau)$ coefficients are significant except for the 10% quantile, meaning that the risk premium follows random walk and the shocks to risk premium are permanent in the 10% quantile. At last, the $\alpha_1(\tau)$ coefficients are significant except for $[0.2, 0.4]$ and $[0.8, 0.9]$ quantiles, indicating that the risk premium shows stationary during low and high quantiles, but in the extreme low quantile(0.1) and medium quantiles $[0.5, 0.7]$, the interest rate differentials behave like a unit root process. For Czech Republic, Bulgaria, Belarus, Hungary and Russian Federation, the $\alpha_1(\tau)$ coefficients are significant during all quantiles. Apparently the empirical results provide strong evidence in support of stationary of inflation rate for five Eastern European countries under study. Combining with both $\alpha_0(\tau)$ and $\alpha_1(\tau)$ coefficients of each quantile, we further find that shocks to risk premium adjust more quickly at lower quantile levels than that of higher quantile levels, which means that the shock effects to the risk premium in the ten Central and Eastern European countries are asymmetric. Besides, the results of $\alpha_0(\tau)$ and $\alpha_1(\tau)$ reveal that in the presence of negative shocks, the risk premium would revert to its long-run equilibrium level, but extreme positive shocks appear to lack the ability to induce mean reversion.

These results are similar to the findings of Henry and Shields (2004). With the usage of Caner and Hansen's (2001) threshold unit root method, they find that for Japan and the UK, the risk premium behave like a unit root process in the upper regime whereas they are stationary in the lower regime.

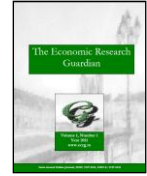
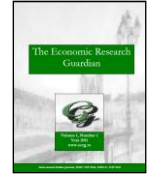


Table 1 also estimates the half-life based on the estimated values of $\alpha_1(\tau)$. The half-life can tell us the speed of mean reversion in the inflation rates after a shock. As shown by Table 1, in the extreme low quantile (10%), the half-lives for the ten Central and Eastern European countries are generally short, which indicates that when hit by a large (in absolute value) negative shock, the risk premium can return to the long-run level very fast. However, in the extreme high quantile (90%), the risk premium have no tendency to revert back to its long-run equilibrium due to infinite half-lives. Specifically speaking, for Czech Republic, Bulgaria, Belarus and Russian Federation, the half-lives are found to be finite among all quantiles, and range from 0.186 months (Bulgaria) in 90% quantile to 40.426 months (Czech Republic) in 60% quantile. For the other countries, the half-lives are proved to be infinite in some quantiles while finite in the other quantiles. Among them, Latvia has the shortest half-lives of 7.615 months in 70% quantile, as well as infinite half-lives among quantiles 10%, 20% and 90%. We also find that Romania have the longest finite half-lives in the quantile of 60% and goes to infinite in the 50% quantile.

Compared with the present participants in 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 four countries still had significant restrictions on foreign exchange transactions and face high inflation. Furthermore, incomplete institutional reforms may contribute to higher default risks and positive transaction costs, whereas relatively volatile economic conditions and weaker macroeconomic fundamentals may contribute to higher currency and default risks both in magnitude and volatility. For example, Belarus, the debate between central bank and government about exchange rate intervention, the inflation target and the effect of fiscal policy on inflation leads to increasing uncertainty about the future development. For the stability of the exchange rate, Croatia adopted a euro-based currency board since the economic and financial crisis in 1997. Furthermore, government of Croatia also launched a complex plan to stimulate the economy, which included trade and price liberalization, social sector reform, and divesting in state-owned enterprises.

On the other side, the quantile based stationary test with a Fourier function employed by Li and Park (2016) in this study provides some evidence favoring the long-run validity of UIP for the 10 CEE countries being studied. 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 been a significant reduction in discrepancies. For example, the Czech Republic has adopted a monetary policy regime of inflation targeting since 1998, which allowed the country to fight inflation successfully. Also, the existing managed floating exchange rate regime is fully compatible with the EU membership. 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 in 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. Taken together our results provide strong support for UIP for CEE countries and point that these six countries are non-linear stationary, implying that deviations of real interest rate convergence is mean reverting towards the UIP equilibrium. As mentioned earlier, The CEE countries faced the second stage of economic



transition in the aftermath of the collapse of socialism; the establishment of Euroland at the turn of the century. This study investigates the market mechanisms in the early nineties and establishment and enlargement of Euroland acted on real interest rate convergence. These CEE transition countries performed wide range of market based reforms during 20 years, removing obstacles to capital mobility, reducing risk premiums and performing institutional reforms. Obviously, such an environment provides interesting opportunity to estimate effects of reforms on the real interest rate convergence, as well as interventions in the monetary markets, could be behind this nonlinear behavior.

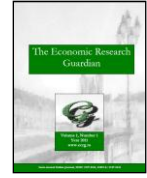
4. Conclusions

This study applies Quantile-based unit root test with a Fourier function proposed by Li and Park (2016) to test the validity of long-run uncovered interest parity (UIP) to assess the non-stationary properties of the interest differentials convergence for ten Central and Eastern European (CEE) countries. The framework is flexible enough to allow for asymmetries of risk premium persistence across a range of quantiles. Moreover, the method allows for the possibility that shocks of different signs and sizes have different impacts on risk premium and accounts for possible asymmetric adjustment of the risk premium towards to its long-run equilibrium. We provide robust evidence of dynamic behavior of risk premium for these ten Central and Eastern European countries.

Our results show that the approximation has higher power to detect U-shaped breaks and smooth breaks than linear method if the true data generating process of risk premium convergence is in fact a stationary non-linear process. We examine the validity of UIP from the non-linear point of view and provide robust evidence clearly indicate that for Czech Republic, Bulgaria and Lithuania, the inflation rates are stationary at each quantiles, in other words, the risk premium in the three countries are also globally stationary. While for the other four countries, Poland, Estonia, Romania and Latvia, the inflation rates are stationary within some quantiles whereas follow a unit root process within the others. However, among them, the validity of UIP in Romania and Latvia are globally stationary as shown by the p -values for QKS statistic. We can also find that the speed of risk premium adjustment towards to its long-run equilibrium for each country is asymmetric. These findings also imply that under the circumstance of both negative growth and inflation shocks prevailing, these Central and Eastern European countries should reinforce a supportive monetary policy framework so as to focus on defending negative growth shocks and lift potential growth closer to pre-crisis levels.

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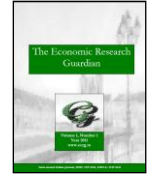
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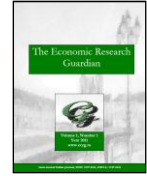
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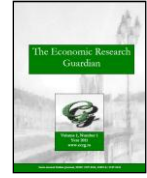
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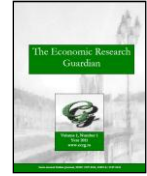
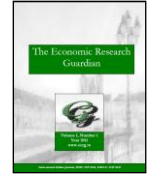


Table 1 - Empirical results of quantile estimation and unit-root test for each quantile (taking into smooth breaks-Fourier Function)

Country	τ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
Czech Republic	$\alpha_0(\tau)$	-0.244***	-0.217***	-0.119***	-0.083***	-0.059	0.044***	0.357***	0.493***	0.604***	
	$\alpha_1(\tau)$	0.761**	0.754**	0.952***	0.979***	0.928***	0.983**	0.916**	0.939***	0.928***	
	Half-lives	2.538	2.455	14.091	32.659	9.276	40.426	7.900	11.013	9.276	
	QKS for quantiles of 10-90%		6.443***								
	Optimal Frequency		0.3 F-Statistics for Optimal Frequency 32.162***								
Poland	$\alpha_0(\tau)$	-0.692***	-0.411***	-0.218***	-0.147***	-0.026	0.043	0.166***	0.242***	0.575***	
	$\alpha_1(\tau)$	0.937***	0.974**	0.986**	0.953***	0.966**	0.982**	0.977	0.984	1.036	
	Half-lives	10.652	26.311	49.163	14.398	20.038	38.161	∞	∞	∞	
	QKS for quantiles of 10-90%		5.449**								
	Optimal Frequency		0.2 F-Statistics for Optimal Frequency 24.166***								
Bulgaria	$\alpha_0(\tau)$	-5.225***	-2.138***	-0.337***	-0.154	-0.006	0.139	0.374***	0.527***	1.244***	
	$\alpha_1(\tau)$	0.024***	0.583***	0.702***	0.826***	0.815***	0.839***	0.831***	0.811***	0.766***	
	Half-lives	0.186	1.285	1.959	3.626	3.388	3.949	3.744	3.309	2.600	
	QKS for quantiles of 10-90%		24.332***								
	Optimal Frequency		0.3 F-Statistics for Optimal Frequency 9.441***								
Latvia	$\alpha_0(\tau)$	-0.855***	-0.643***	-0.318***	-0.104***	-0.006	0.175***	0.262***	0.529***	0.771***	
	$\alpha_1(\tau)$	0.974	0.950	0.966**	0.952**	0.968**	0.954***	0.913***	0.967**	0.983	
	Half-lives	∞	∞	20.038	14.091	21.312	14.719	7.615	20.656	∞	
	QKS for quantiles of 10-90%		1.032								
	Optimal Frequency		0.8 F-Statistics for Optimal Frequency 102.013***								
Belarus	$\alpha_0(\tau)$	-0.813***	-0.501***	-0.377***	-0.074***	-0.002	0.229***	0.273***	0.529***	0.731***	
	$\alpha_1(\tau)$	0.955*	0.926***	0.901***	0.933***	0.957***	0.948***	0.944***	0.969**	0.927**	
	Half-lives	15.054	9.016	6.649	9.995	15.771	12.980	12.028	22.011	9.144	
	QKS for quantiles of 10-90%		1.844								
	Optimal Frequency		0.4 F-Statistics for Optimal Frequency 44.199***								
Romania	$\alpha_0(\tau)$	-1.528***	-0.813***	-0.559***	-0.272***	0.004	0.168**	0.474***	0.796***	1.228***	
	$\alpha_1(\tau)$	0.927***	0.941**	0.975*	0.983**	0.988	0.992**	0.984***	0.981***	0.972***	
	Half-lives	9.144	11.398	27.378	40.426	∞	86.296	42.974	36.134	24.407	
	QKS for quantiles of 10-90%		4.617***								
	Optimal Frequency		0.5 F-Statistics for Optimal Frequency 33.881***								
Croatia	$\alpha_0(\tau)$	-0.614***	-0.420***	-0.317***	-0.102***	-0.010	0.155**	0.294***	0.461***	0.739***	
	$\alpha_1(\tau)$	0.991	0.983**	0.960***	0.954**	0.947***	0.982*	0.989*	0.975***	0.941	
	Half-lives	∞	40.426	16.980	14.719	12.729	38.161	62.666	27.378	∞	
	QKS for quantiles of 10-90%		2.968								
	Optimal Frequency		1.1 F-Statistics for Optimal Frequency 72.094***								
Hungary	$\alpha_0(\tau)$	-0.973*	-0.924**	-0.861***	-0.775**	-0.669	-0.291**	0.073***	0.116*	0.264*	
	$\alpha_1(\tau)$	0.901*	0.838**	0.801***	0.788*	0.729*	0.838**	0.862***	0.904*	0.915**	
	Half-lives	6.649	3.922	3.124	2.909	2.193	3.922	4.668	6.868	7.803	
	QKS for quantiles of 10-90%		5.992**								
	Optimal Frequency		0.7 F-Statistics for Optimal Frequency 41.966***								
Macedonia, FYR	$\alpha_0(\tau)$	-0.882**	-0.794**	-0.726**	-0.633	-0.287	0.006***	0.136	0.174**	0.255	



	$\alpha_1(\tau)$	0.995	0.986**	0.981**	0.974*	0.967	0.961	0.958	0.949**	0.942***	
	Half-lives	∞	49.163	36.134	26.311	∞	∞	∞	13.242	11.601	
	QKS for quantiles of 10-90%		0.166								
	Optimal Frequency		0.2		F-Statistics for Optimal Frequency		28.975***				
Russian Federation	$\alpha_0(\tau)$	-0.741**	-0.629**	-0.418**	-0.273***	0.016	0.237**	0.515**	0.669***	0.722*	
	$\alpha_1(\tau)$	0.858**	0.831***	0.826**	0.814**	0.793***	0.788**	0.776*	0.758*	0.741***	
	Half-lives	4.526	3.744	3.626	3.368	2.989	2.909	2.733	2.502	2.312	
	QKS for quantiles of 10-90%		7.038***								
	Optimal Frequency		0.7		F-Statistics for Optimal Frequency		55.044***				

Note: ***, **, * signify significance at 1%, 5% and 10% levels, the half-lives are calculated when $\alpha_1(\tau)$ is significantly different from unity; otherwise, half-lives are set at infinity.

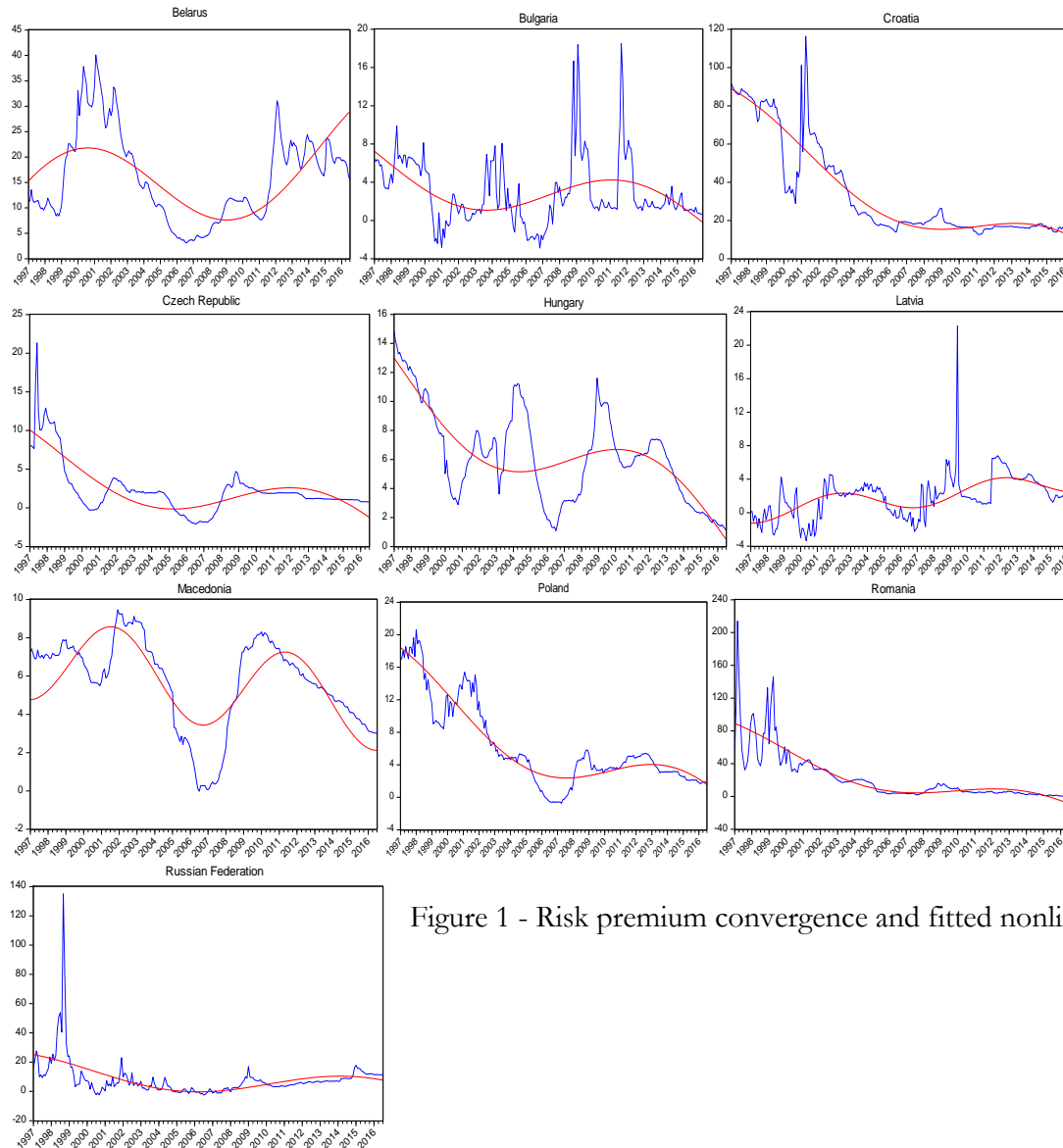


Figure 1 - Risk premium convergence and fitted nonlinearities