Are Taylor Rules Valid in Central Eastern European Countries?[1]

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Abstract

This study applies a stationary test with the flexible Fourier function proposed by Enders and Lee (2012) to test the validity of Taylor rules to assess the non-stationary properties of the convergence of the real exchange rates for ten Central Eastern European countries. We find that our approximation has a higher power to detect U-shaped breaks and smooth breaks than the linear method if the true data-generating process of exchange rate convergence is in fact a stationary non-linear process. We examine the validity of Taylor rules from the non-linear point of view and provide robust evidence that Taylor rules holds true for seven Central Eastern European countries. These results imply that the choices and effectiveness of the monetary policies in Central Eastern European economies are highly influenced by Taylor rule, and also influenced by external factors originating from the United States.

Keywords: *Taylor rules, Fourier Stationary Test, structural change, trend breaks*

JEL Classification: C22, F36

1. Introduction

Since the mid-1980s, most central banks have used interest rates as a policy instrument rather than controlling an aggregate measure of the money supply. This development has an important implication for exchange rate models. Instead

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of using the exogenous interest rate as an explanatory variable for the exchange rate, one must use an endogenous monetary policy rule (Engel, Nelson and Kenneth, 2008). According to Taylor (1993), the interest rate reaction function known as the Taylor rule, in which the nominal interest rate responds to the inflation rate, the difference between inflation and its target, the output gap, the equilibrium real interest rate, the lagged interest rate and the real exchange rate, has become the dominant method for evaluating monetary policy. By specifying Taylor rules for two countries and subtracting one from the other, an equation is derived with the interest rate differential on the left-hand side and the inflation and output gap differentials on the right-hand side. The Taylor rule incorporates the features that monetary theory has identified as associated with good monetary policy: transparency, accountability and credibility. In particular, a central bank that adheres to a Taylor rule reveals to the public that it is committed to price stability, and systematically takes steps to achieve it. The public therefore keeps its expectations of inflation low and stable, and the financial markets anticipate the central bank's next move and increase market interest rates immediately when inflation picks up. If one or both central banks also target the purchasing power parity (PPP) level of the exchange rate, the real exchange rate (RER) will also appear on the right hand side. Positing that the interest rate differential equals the expected rate of depreciation by the uncovered interest rate parity (UIRP) and solving for these expectations, an exchange rate equation is derived. The endogeneity of monetary policy can be modeled by means of a Taylor rule with the interest rate as the policy instrument. In such an environment, interest rates respond to inflation, the output gap and possibly the exchange rate as well. It turns out that a model of the open economy with a Taylor rule displays exchange rate behavior that is quite different from that in traditional exchange rate models. It is widely accepted that well-designed monetary policy can counteract macroeconomic disturbances and dampen cyclical fluctuations in prices and employment, thereby improving overall economic stability and welfare (Orpahanides and Whilliams, 2007).

Standard monetary models of the determination of exchange rates have long been discredited by their failure to explain exchange rate behavior, as forcefully documented by Meese and Rogoff (1983), Meese (1990), and Flood and Rose (1995). A new strand of literature identifies one of the major shortcomings of traditional exchange rate models in paying too little attention to the market's expectations of future values of the macroeconomic fundamentals and allows for the endogeneity of monetary policy by incorporating Taylor rule reaction functions into otherwise standard exchange rate models (Engel and West, 2004; 2005; 2006; Bacchetta and van Wincoop, 2006; Engel, Nelson and Kenneth, 2008). Such models display exchange rate behavior quite differently than do traditional exchange rate models. For example, whereas in standard flexible-price monetary models an increase in the current inflation rate causes the exchange rate to depreciate, in Taylor rule models the exchange rate appreciates because higher inflation induces expectations of tighter future monetary policy (Clarida and Waldman, 2008). The emerging evidence on the empirical performance of Taylor rule models of the open economy is quite encouraging.

In this study, we analyze whether Taylor rules hold for Central Eastern European countries (CEECs) because of the increasing importance in view of these countries after joining the UEM (Union Economique et Monetaire) or the European Union (depending on the country). At the same time, price liberalization was accompanied by very high inflation rates in the earlier period, and then disinflate successfully after exchange rate regimes switch. A standard approach to describe such monetary policy switching is to estimate a Taylor-like interest rate reaction function (Frömmel, Garabedian and Schobert, 2011). The empirical literature concludes that the monetary policy by most successful central banks in large industrial countries can be described by such a reaction function, while relatively poor for transition economies (Clarida, Jordi and Mark, 1998). Therefore, the features of CEECs transition economies provide an interesting study of whether Taylor rule hypothesis test exists. There are many reasons for us to study CEECs. First, they are the centrally planned and rapid liberalization of prices and markets, and some markets suffered from high inflation. Second, and most importantly, the initial conditions for CEEC transition varied extensively, and they may be an important indicator in explaining the magnitude of deviations from Taylor rules. Frömmel, Garabedian and Schobert (2011) explore monetary policy rules for CEECs by explicitly accounting for changes in policy settings. The process of economic transition started in 1992 in the former Soviet Union was complied 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 currencies.

There are several literatures have been done in testing Taylor rules in CEECs. Maria-Dolores (2005) and Paez-Farell (2007), for example, estimate Taylor rules for the Czech Republic, Hungary, Poland and Slovakia and prove that Taylor rule captures fairly well the behaviour of short-term interest rates in some Accession Countries which explicitly adopt inflation targeting, while it also helps to slightly predict interest rate behaviour where there is no news about an inflation-targeting adoption. Angeloni, Flad and Mongelli (2007) set up interest rate rules for the Czech Republic, Hungary and Poland, introducing the US dollar interest rate as a proxy for inflationary pressures of global origin, where the coefficients on inflation are significant (except in Hungary). Moreover, Remo and Vasicek (2009) apply a DSGE) model to Czech data, and conclude that the focus of the Czech National Bank was mainly on inflation. Yilmazkuday (2008) and Jakab and Vilagi (2008) consider structural breaks in their estimates of Taylor rules for CEECs and robust results can be researched in the estimated Taylor rules, especially in the introduction of an inflation targeting regime. Horváth (2008) and Vasicek (2012) also estimates non-linear Taylor rules for CEECs which apply inflation targeting regimes, and takes the rules as judgments of asymmetric monetary policies. Sznajderska(2014) investigate whether the reaction function of the National Bank of Poland is asymmetric according to the level of inflation gap and the level of output gap. Our findings are in line with these literatures where we prove that Taylor rules hold true in flexible exchange rate with inflation targeting CEECs while not true in CEECs which are under the fixed exchange rate regimes. Moons and van Poeck (2008) find that the accession countries do not differ substantially from the current EMU members with respect to the interest rate setting behavior, and that there has been increased convergence. Horváth (2009) also estimates various specifications of simple Taylor-type monetary policy rules and indicates a substantial interest rate convergence to levels comparable to the euro area. In our paper we also come to the conclusion that Taylor rule hold true for seven CEECs which indicates a interest rate convergence to the levels comparable to the euro area, and that it could be used to predict equilibrium exchange rate for CEECs.

We would like to compare CEECs to the United States in this paper as they are deeply influenced by the U.S. economy. For example, initially it seemed that the region was immune from the credit crunch as banks were not linked to U.S. sub-prime mortgages. However, with collapsing global demand, exports stagnated, investors pulled their money out, and the region's currencies started to collapse. Job cuts, spiraling debts and shrinking output were the consequences. Therefore, CEECs' economies are tightly connected with the world economy so that with the economic condition of the U.S.

Usually, the Taylor rule is a linear algebraic interest rate rule that specifies how the central bank must adjust its interest rate to the inflation rate and the output-gap. This interest rate rule characterizes a monetary policy strategy for achieving the objectives of monetary policy: price stability and maximum employment. This linear interest rate rule represents an optimal policy rule under the condition that the central bank minimizes a symmetric quadratic loss function, and that the aggregate supply function is linear (Svensson, 2000; Clarida, Jordi and Mark, 1998; 2001). However, both theoretical and empirical reasons exist to suggest that the central bank may follow a non-linear Taylor rule. Nobay and Peel (2003), Ruge-Murcia (2003), Dolado, Maria-Dolores and Naveira

(2005), Surico (2007), and among others hold the view that if the central bank minimizes an asymmetric loss function in which negative and positive inflation and output-gap deviations are assigned different weights, then a non-linear Taylor rule is optimal. Engel and West (2005) use the Taylor rule model as an example of present value models in which asset prices (including exchange rates) will approach a random walk as the discount factor approaches one. Engel and West (2006) construct a “model-based” RER as the present value of the difference between home and foreign output gaps and inflation rates and find a positive correlation between the “model-based” rate and the actual RER. Because we know that the RER might be affected by the internal and external shocks generated by structural changes, they may be subject to considerable short-run variation. It is important to know whether the RER has any tendency to settle down to a long-run equilibrium level because Taylor rules requires that RER revolves around a constant or a time trend. If RER is found to be stationary using a unit root test with structural break(s), the effects of shocks such as real and monetary shocks that cause deviations around a mean value or deterministic trend are only temporary. Then, Taylor rules are valid in the long-run.

As for methodology, recent studies of long-run RER have mostly utilized conventional unit root tests such as the Augmented Dickey Fuller test (1981, ADF), the Phillips-Perron test (1988, PP), and the Kwiatkowski et al. test (1992, KPSS) and fail to reject the unit root hypothesis of the RER. It is well known that if the RER follows a nonlinear stationary process, then tests based on linear models such as the widely used ADF unit root models will be misspecified (Chortareas, Kapetanios and Shin 2002). Moreover, Sarno (2000) and Taylor and Peel (2000) 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 exchange rate is in fact a stationary non-linear process. Additionally, the existence of structure changes in the RER might imply broken deterministic time trends and the result is a nonlinear pattern (Bierens, 1997). Perron (1989) argued that if there is a structural break, the power to reject a unit root decreases when the stationary alternative is true and the structural break is ignored. Therefore, we need to apply a technical method that could be significance when structural breaks occur. The general method to account for breaks is to approximate those using dummy variables. However, this approach has several undesirable consequences. First, when the break dates are unknown, it is useful to have information regarding the presence or absence of a change to investigate the potential presence of a unit root. But these are usually not known and therefore need to be estimated. This introduces an undesirable pre-selection bias (see Maddala and Kim, 1998). Second, the currently available tests account only for one to two breaks. Nunes, Newbold and Kuan (1997), Lee and Strazicich (2003) and Kim and Perron (2009), among others, demonstrate that such tests suffer from serious power and size distortions due to the asymmetric treatment of breaks under the null and alternative hypotheses. Third, the use of dummies suggests sharp and sudden changes in trend or level. As a result, the test may reject the unit root null when the noise component is integrated but the trend is changing, leading to spurious evidence in favor of broken trend stationarity.

These arguments motivate the use of a recently developed set of unit root and stationary tests that Enders and Lee (2012) developed to avoid this problem. Enders and Lee (2012) develop tests that model any structural break of an unknown form as a smooth process through flexible Fourier transforms. Several authors, including Gallant (1981), Becker, Enders and Lee (2006), Pascalau (2010) and Enders and Lee (2012) show that a Fourier approximation can often capture the behavior of an unknown function even if the function itself is not periodic. The authors argue that their testing framework requires only the specification of the proper frequency in the estimating equations. By reducing the number of estimated parameters, they ensure that the tests have good size and power irrespective of the time or shape of the break. One advantage of this Fourier function is that it is able to capture the essential characteristics of one or more structural breaks using only a small number of low-frequency components. This is true because a break tends to shift the spectral density function towards a frequency of zero. In particular, this test works best in the presence of breaks that are gradual and have good power to detect U-shaped and smooth breaks.

This empirical study explores the link between an interest rate rule for monetary policy and the behavior of the RER. Whereas Engel and West (2006) use the model to explain the RER exclusively in terms of observable macroeconomic aggregates, we link these fundamentals with the transitory component of the exchange rate and also let both the transitory and the long-run equilibrium RER be influenced by random determinants. We base our analysis on a variant of the two-country Taylor rule model introduced by Engel and West (2006). It contributes to this line of research by determining the unit root process of RER of ten CEECs using Taylor rules and the unit root test with a Fourier function proposed by Enders and Lee (2012). We analyze RER using Lagrange Multiplier (LM) unit root tests that allow for breaks in the trend and the level of a series at an unknown time. With this, the current research hopes to fill the existing gap in the literature. To the best of our knowledge, this study is the first to date that utilizes the unit root test with a Fourier function in RER based on Taylor rules for CEECs. This empirical study contributes to the field of empirical research by determining whether the unit root process is a characteristic of the Taylor rules in CEECs.

The remainder of this empirical study is organized as follows. Section 2 describes the Taylor rules model. Section 3 presents the methodology of the Fourier unit root test. Section 4 presents the data used and discusses the empirical findings and policy implications. Section 5 reviews the conclusions we draw.

2. The Taylor Rule Model

We follow Engel and West (2006) in using a two-country model, with most variables defined as the difference between a home country (the United States in our empirical work) and a foreign country. As CEECs are deeply influenced by the U.S., we choose the U.S. as the home country. We assume that the home country follows the Taylor rule of the following form

$$i_t = c_1 y_t^g + c_2 \pi_t + \varepsilon_t \quad (c_1 > 0,\ c_2 > 1) \tag{1}$$

where

π_t – the inflation rate,

y_t^g – defined as output gap,

ε_t – a shock to the monetary policy rule that contains omitted terms.

Taylor (1993) originally analyzes the federal funds rate and finds out that the parameters for inflation and the output gap are closely approximated by the rule with $c_1 = 0.5$ and $c_2 = 1.5$. Because most studies about Taylor rules in CEECs do not use significant parameters of c_1 and c_2, we will assume that the rule in CEECs has the same parameters as the standard Taylor rule. The assumption that the home country and foreign country have the same monetary policy parameters c_1 and c_2 is made for convenience.

Let "*" indicate the foreign country. The foreign country follows a Taylor rule that explicitly includes exchange rates

$$i_t^* = -c_0(s_t^* - \bar{s}_t^*) + c_1 y_t^{g*} + c_2 \pi_t^* + \varepsilon_t^* \quad (0 < c_0 < 1) \tag{2}$$

where

s_t^* – a log nominal exchange rate,

$\bar{s}_t^*$ – a target for the exchange rate.

We shall assume that monetary authorities target the PPP level of the exchange rate

$$\bar{s}_t^* = p_t^* - p_t \tag{3}$$

Because s_t is measured in US dollars per unit of foreign currency, the rule indicates that ceteris paribus, the foreign country lowers interest rates when its currency depreciates relative to the target.

As the next equation makes clear, our argument still holds if the United States was to target exchange rates. We omit the exchange rate target in Equation (1) on the interpretation that United States monetary policy has virtually ignored exchange rates except as an indicator.

Subtracting the foreign from the home monetary rule, we obtain

$$i_t^* - i_t = -c_0(s_t^* - \bar{s}_t^*) + c_1(y_t^{*g} - y_t^g) + c_2(\pi_t^* - \pi_t) + (\varepsilon_t^* - \varepsilon_t) \qquad (4)$$

RER can be expressed as the summation of the nominal exchange rate and price difference of the two countries, that is

$$q_t^* = s_t^* + p_t - p_t^* \qquad (5)$$

Perhaps the most pertinent reference is Vasicek (2010), who finds that a term in the real exchange rate (RER) is statistically significant in Taylor rules estimated for the Euro Area, with $c_0 = 0.1$.

Using Equations (3), (4) and (5), we obtain the real exchange rate expression as

$$q_t^* = \frac{1}{c_0}[(i_t - i_t^*) - c_1(y_t^g - y_t^{*g}) - c_2(\pi_t - \pi_t^*)] + \eta_t \qquad (6)$$

In Equation (6), $\eta_t = \frac{1}{c_0}(\varepsilon_t^* - \varepsilon_t)$. This equation implies that the real exchange rate could be affected by interest rate differentials, output gap differentials and inflation differentials.

3. Enders and Lee's (2012) Fourier Unit Root Test

In fact, Eng, Wong and Habibullah (2012) and Byrne and Nagayasu (2008) prove that inflation differentials and/or interest rate differentials are the sources of structural breaks in the mechanism that characterizes the nonstationary real exchange rate. Wu, Tsai and Chen (2004), Shibamoto and Kitano (2012), and Chowdhury (2010) also investigate structural changes in RERs of different countries, which motivate us to involve structural breaks in testing unit roots. For this consideration, we apply the method of Enders and Lee (2012) to implement a variant of the flexible Fourier transform (Gallant, 1981) to control for the unknown nature of breaks. One advantage of this Fourier function is that it is able to capture the essential characteristics of one or more structural breaks using only a small number of low-frequency components. This is true because a break tends to shift the spectral density function towards a frequency of zero. In particular, this test works best in the presence of breaks that are gradual and have good power to detect U-shaped and smooth breaks.

Enders and Lee (2012) develop their unit root test using the LM principle. As indicated by Pascalau (2010), the LM has increased power over the DF approach. Following the Enders and Lee (2012), we consider the following data-generating process (DGP):

$$q_t^* = \alpha_0 + \theta t + \gamma_1 \sin(2\pi kt/T) + \gamma_2 \cos(2\pi kt/T) + \varepsilon_t \quad (7)$$

$$\varepsilon_t = \beta\varepsilon_{t-1} + u_t \quad (8)$$

The rational for selecting $[\sin(2\pi kt/T),\ \cos(2\pi kt/T)]$ is based on the fact that a Fourier expression is capable of approximating absolutely integrable functions to any desired degree of accuracy where *k* represents the frequency selected for the approximation and $\gamma = [\gamma_1,\ \gamma_2]'$ measures the amplitude and displacement of the frequency component. A desired feature of Equation (7) is that the standard linear specification emerges as a special case by setting $\gamma_1 = \gamma_2 = 0$. It also follows that at least one frequency component must be present if there is a structural break. Here, if it is possible to reject the null hypothesis $\gamma_1 = \gamma_2 = 0$, the real exchange rates must have a nonlinear component. Enders and Lee (2012) use this property of Equation (7) to develop a test that has a greater power to detect breaks of an unknown form than the standard Bai and Perron (1998) test under the null hypothesis of a unit root $\beta = 1$ and under the alternative hypothesis of $\beta < 1$. Enders and Lee (2012) employ the LM methodology of Schmidt and Phillips (1992) and Amsler and Lee (1995) by imposing the null restriction and estimating the following regression in terms of first differences

$$\Delta q_t^* = \delta_0 + \delta_1 \Delta \sin(2\pi kt/T) + \delta_2 \Delta \cos(2\pi kt/T) + v_t \quad (9)$$

The estimated coefficients $\tilde{\delta}_0$, $\tilde{\delta}_1$ and $\tilde{\delta}_2$ are then used to construct the following detrended series

$$\tilde{S}_t = q_t^* - \tilde{\psi} - \tilde{\delta}_0 t - \tilde{\delta}_1 \sin(2\pi kt/T) - \tilde{\delta}_2 \cos(2\pi kt/T),\ t = 2\ ...,\ T \quad (10)$$

where

$$\tilde{\psi} = q_1 - \tilde{\delta}_0 t - \tilde{\delta}_1 \sin(2\pi kt/T) - \tilde{\delta}_2 \cos(2\pi kt/T)$$

q_1 – the first observation of q_t.

The testing regression based on the detrended series has the following expression

$$\Delta q_t^* = \theta \tilde{S}_{t-1} + d_0 + d_1 \Delta \sin(2\pi kt/T) + d_2 \Delta \cos(2\pi kt/T) + \varepsilon_t \quad (11)$$

If q_t^* has a unit root, then $\theta = 0$, and the LM test statistic (denoted τ_{LM}) is the t-test for the null hypothesis of $\theta = 0$. The innovation process ε_t is assumed to satisfy Phillips and Perron (1988)'s serial correlation and heterogeneity conditions. Equation (11) can be augmented with the lag values of $\Delta\tilde{S}_{t-j}$, $j = 1, 2, \ldots p$, to dispose of the remaining serial correlation (Ng and Perron, 2001). Enders and Lee (2012) derive the properties of the asymptotic distribution of the τ_{LM} statistic and demonstrate that it depends only on the frequency k and is invariant to all other parameters in the DGP. Enders and Lee (2012) suggest that the frequencies in Equation (11) should be obtained via the minimization of the sum of squared residuals. However, their Monte Carlo experiments suggest that no more than one or two frequencies should be used because of the loss of power associated with a larger number of frequencies.

4. Data and Empirical Findings

We use monthly data that cover the years from 2000 to 2013 to apply a stationary test with a Fourier function proposed by Enders and Lee (2012) to test the validity of Taylor rules. During this period, CEECs started their liberalization programs and transitioned to market economies. This empirical study covers ten CEECs: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and the Slovak Republic versus United States. For the selection of interest rates, there has been some discussion about what is the correct short-term interest rate. For CEECs, the interest rate is usually measured by the Euro Overnight Index Average (EONIA) lending rate on the money market because it is the benchmark European interest rate. Nevertheless, Pérez Quirós and Sicilia (2002), Hamilton (1996), Moschitz (2004), Würtz (2003) and Kempa (2008) raise objections to this approach because of the relatively high volatility when examining a daily frequency due to short-term liquidity needs. For other studies (e.g., Ullrich, 2003; Siklos, Werner and Bohl, 2004; Gerdesmeier and Roffia, 2004; Bouvet and King, 2011; Boeckx, 2011), this does not appear to be relevant because the monthly averages smooth out such movements. Some studies find that the conclusions are unaffected when they replaced the overnight rate with the 3-month EURIBOR (Carstensen and Colavecchio, 2004; Belke and Klose, 2011). Consequently, it is possible to interchange the two rates in the reaction function of the central bank. Because the different measures of interest rates are often found to be highly correlated, we consider the choice of the interest rate measure robust to our estimates and base our choice on the availability of the data. Thus, our short-term interest rate is measured by the 3-month interest rate from the Statistical Office of the European Union, EUROSTAT. We have chosen this databank for two main reasons: first, it is the source employed by

European Central Bank (ECB); second, it offers homogeneous data for all European countries. For the Slovak Republic we choose 3-month interest rate from the Organization of Economic Co-operation and Development (OECD). While for Croatia, we use the discount rate as our short-term interest rate from the Central Bank of Croatia due to its longer availability than other variables (McGettigan et al., 2013).

Furthermore, the output is measured by the seasonally adjusted Industrial Production Index (IPI). Generally, the way to calculate the potential output is a difficult task and affects the results. However, most studies use a filter to calculate the potential output and output gap. If we assume the original series to exhibit a deterministic trend, we can measure the potential output by the Hodrick-Prescott filter of the IPI. The output gap is then computed as the deviation of the logarithm of the actual industrial production from its HP trend. Inflation is measured by the annual percentage change in the seasonally adjusted Harmonized Consumer Price Index (HCPI). Judd and Rudebusch (1998) base their inflation rates on different price indices and conclude that the estimation is not very sensitive to different measures of inflation. Kozichi (1999), Bodenstein, Erceg and Guerrieri (2008), Mehra and Sawhney (2010), Airaudo and Zanna (2012) come to the opposite conclusion that the recommendations given by the Taylor rule are not robust to the inflation measures. We will base our estimates on the choice of only one index, HICP, from EUROSTAT.

The descriptive statistics of RERs for CEECs can be seen in Table 1. We have 163 observations for each country from January 2000 to July 2013. From the first column, the variance of the ten CEECs are not small, from the highest mean of 32.825 for Hungary to the lowest mean of –49.311 for Croatia. However, the standard deviation of each country is similar and they are around 36.52. From the probability of Jarque-Bera test we can see that for Croatia, Estonia, Hungary, Latvia and Romania, the distribution of real exchange rates are not normal distribution, while for Bulgaria, Czech Republic, Lithuania, Poland and Slovak Republic the real exchange rate can be treated as normal distribution.

For comparison, the univariate unit root tests are first employed to examine the null of a unit root in bilateral RERs based on Taylor rules for the ten CEECs that we study. Based on the results from Table 2, there is no question that three univariate unit root tests – the ADF, PP, and KPSS tests – all fail to reject the null of non-stationary RERs among these ten CEECs except for Latvia and Lithuania. Our results signify that the determination of RER is a random process. In other words, Taylor rules do not hold among these eight CEEC countries under study. This finding is consistent with the RER unit root literature and is due to the low power of the ADF, PP, and KPSS tests when the RER is highly persistent and fails to incorporate the structural breaks in the model. Therefore, we proceed to test the RER using the unit root test with a Fourier function, proposed by Enders and Lee (2012).

Table 1

Descriptive Statistics of Real Exchange Rates

	Bulgaria	Croatia	Czech Republic	Estonia	Hungary	Latvia	Lithua-nia	Poland	Roma-nia	Slovak Republic
Mean	18.113	–49.311	4.046	27.257	32.825	–21.222	–6.403	–6.893	–10.940	–23.506
Median	12.305	–44.549	2.984	34.272	18.871	–20.384	–6.843	–4.205	–10.872	–23.983
Maximum	98.902	14.734	76.961	135.320	145.351	48.853	82.116	91.172	189.350	43.588
Minimum	–73.282	–123.931	–64.052	–154.931	–78.159	–161.498	–111.396	–91.146	–133.021	–71.592
Std. Dev.	33.237	35.499	27.636	54.341	52.527	25.264	31.916	37.908	45.702	21.172
Skewness	0.153	–0.315	–0.071	–1.002	0.601	–0.700	–0.081	0.105	0.835	0.165
Kurtosis	2.607	2.251	2.702	4.524	2.521	8.214	3.146	2.663	5.516	2.849
Jarque-Bera	1.691	6.508	0.742	43.031	11.369	197.929	0.324	1.071	61.933	0.897
Probability	0.429	0.039	0.690	0.000	0.003	0.000	0.851	0.585	0.000	0.639

Source: Raw data are from OECD Statistics.

Table 2

Univariate Unit Root Test for Real Exchange Rates (based on the United States)

Country	Levels			First Differences		
	ADF	PP	KPSS	ADF	PP	KPSS
Bulgaria	–1.060[1]	–1.299[2]	0.987[1]***	–12.831[1]***	–22.427[1]***	0.113[1]
Croatia	–1.638[1]	–1.627[1]***	0.818[1]***	–18.872[0]***	–31.426[2]***	0.165[0]
Czech Republic	–1.299[1]	–1.629[3]	0.912[1]***	–18.313[0]***	–19.202[3]***	0.051[1]
Estonia	–1.152[0]	–1.089[2]	0.857[1]***	–13.208[0]***	–13.364[2]***	0.046[1]
Hungary	–1.553[1]	–1.088[4]	0.963[1]***	–13.854[0]***	–13.845[3]***	0.051[2]
Latvia	–3.412[3]***	–3.422[3]***	0.153[3]	–11.069[2]***	–39.398[4]***	0.198[4]
Lithuania	–3.221[0]***	–2.599[1]**	0.290[0]	–16.870[0]***	–42.055[3]***	0.270[0]
Poland	–1.742[0]	–1.753[2]	0.707[1]**	–16.078[0]***	–16.019[1]***	0.118[2]
Romania	–1.620[1]	–1.672[3]	0.627[3]*	–12.528[0]***	–12.644[4]***	0.211[4]
Slovak Republic	–1.841[2]	–1.413[2]	0.654[1]**	–13.894[1]***	–22.053[1]***	0.058[1]

Note: *** and ** indicate significance at the 1% and 5% levels, respectively. The numbers in parenthesis indicate the lag orders selected based on the recursive *t*-statistic, as suggested by Perron (1989). The numbers in the brackets indicate the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987).

Source: Raw data are from OECD Statistics and processed in Eviews 8.0.

First, a grid search is performed to find the best frequency because there is no prior knowledge concerning the shape of the breaks in the data. We estimate Equation (11) for each integer k = 1, 2, ..., 5, following the recommendations of Enders and Lee (2012) that a single frequency can capture a wide variety of breaks.

The second column in Table 3 displays the residual sum of squares (RSSs) and indicates that a single frequency works best for all of the series. The significant $F(\hat{k})$ statistic shown in the fourth column of Table 3 also indicate that both sine and cosine terms should be included in the estimated model.

Table 3

Unit Root Test with a Nonlinear Fourier Function

Countries	**Residual sum of squares (RSSs)**	$\hat{k}$	$F(\hat{k})$	**N of lags of** ΔS_t	$\tau_{LM}(\hat{k})$
Bulgaria	5 471.86	1	52.107***	10	–11.310***
Croatia	2 119.067	1	79.689***	6	–7.975***
Czech Republic	378.916	1	91.852***	3	–3.861**
Estonia	353.559	1	120.079***	1	–2.401
Hungary	516.668	1	121.189***	1	–2.629*
Latvia	347.072	1	124.691***	2	–1.325
Lithuania	8.640	1	354.864***	2	–0.420
Poland	1 434.922	1	61.915***	2	–3.591**
Romania	47 689.804	1	5.796**	8	–31.082***
Slovak Republic	1 827.801	1	79.429***	9	–5.352**

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. Critical values for the $\tau_{LM}(\hat{k})$ statistic are bootstrapped with 10,000 replications.

Source: Raw data are from OECD Statistics and processed in Gauss 10.

We use a 10% significance level and select the lag order of the test on the basis of the recursive *t*-statistic, as suggested by Perron (1989). The fifth column in Table 2 shows the number of lags of ΔS_t that are needed to remove the serial correlation in residuals. The last column in Table 3 shows the results of the $\tau_{LM}(\hat{k})$ statistic based on the estimated frequencies and its critical values are bootstrapped with 10,000 replications. We are able to reject the unit root null hypothesis for seven CEECs at the 1% significance level: they are Bulgaria, Croatia, Romania; Czech Republic, Poland and Slovakia at the 5% significance level and Hungary at the 10% significance level. As RER is found to be stationary using a unit root test with structural break(s) means the effects of shocks such as real and monetary shocks that cause deviations around a mean value or deterministic trend are only temporary. Then, Taylor rules are valid in the long-run. Therefore, the stationary test with the Fourier function employed by Enders and Lee (2012) provides some evidence that favor the long-run validity of Taylor rules for the CEECs under study relative to the United States. Taken together, our results provide strong support for Taylor rules for seven CEECs and indicate that these countries are non-linear stationary, implying that deviations in the exchange rate are mean-reverting towards the Taylor rule equilibrium. As mentioned earlier, discretionary monetary policy by the central bank as well as interventions in monetary markets could determine this nonlinear behavior.

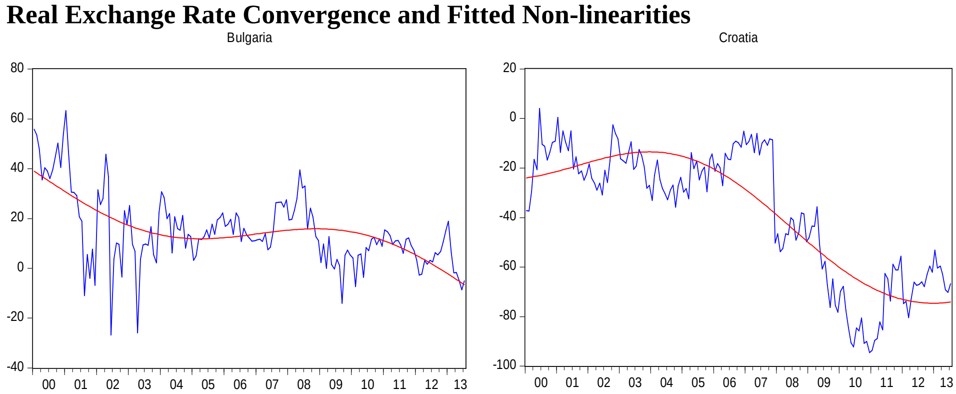
These results therefore focus on new EU member countries and EU accession and candidate countries in CEE that have either moved from fixed to more flexible exchange rate regimes (the Visegrad Group) or have already pursued a fairly flexible exchange rate regime since the early stages of transition. We investigate the role of the exchange rate by examining the interest rate-setting behavior of the central bank and the extent to which the interest rate-setting behavior has accounted for exchange rate developments. When estimating monetary policy rules one must explicitly consider shifts in exchange rate regimes. The influence of the exchange rate on the interest rate-setting behavior of CEE central banks can differ strongly between periods with different exchange rate arrangements. Most countries follow their officially announced policy settings, i.e., the importance of the exchange rate for the interest rates declined substantially after the introduction of floating exchange rates. For example, Croatia exhibits float exchange rate during sample period, and the Czech Republic, Hungary, Poland and Slovakia switched from fixed to flexible exchange rate regimes during the sample period and then chose inflation targeting as a monetary strategy. Hungary and the Czech Republic have shifted the role of the exchange rate in their interest rate setting behavior in line with their official policy shifts from fixed to flexible exchange rate regimes. Poland gives the strongest results for pure inflation targeting, which are also in line with the official announcements, while the results for Slovakia may reflect the discretionary stance of the central bank as observed by central bank members themselves. Bulgaria and Romania – followed no specific way, staying on the rigid exchange rate form or performing more flexible regimes with different nominal anchors. In the aftermath of the failure of pegging in January 1991, Bulgaria chose an independently floating regime. Under the pressure of a currency crisis in July 1997, due to a dramatic increase in inflation, Bulgaria changed direction toward hard peg by adopting a currency board. Romania officially declared managed floating exchange rate regimes during the entire sample period but Romania never officially declared any monetary policy strategy and pursued different forms of monetary targeting, later moving to a two-pillar strategy akin to the strategy of the ECB. These seven CEECs have successively moved from rather fixed to more flexible exchange rate regimes by widening the exchange rate bands over time. Thus, officially, the role of the exchange rate has declined over time or has never played a significant role in the monetary policy strategies of the respective countries. Nevertheless, the exchange rate may still have been of implicit significance in monetary policy strategies.

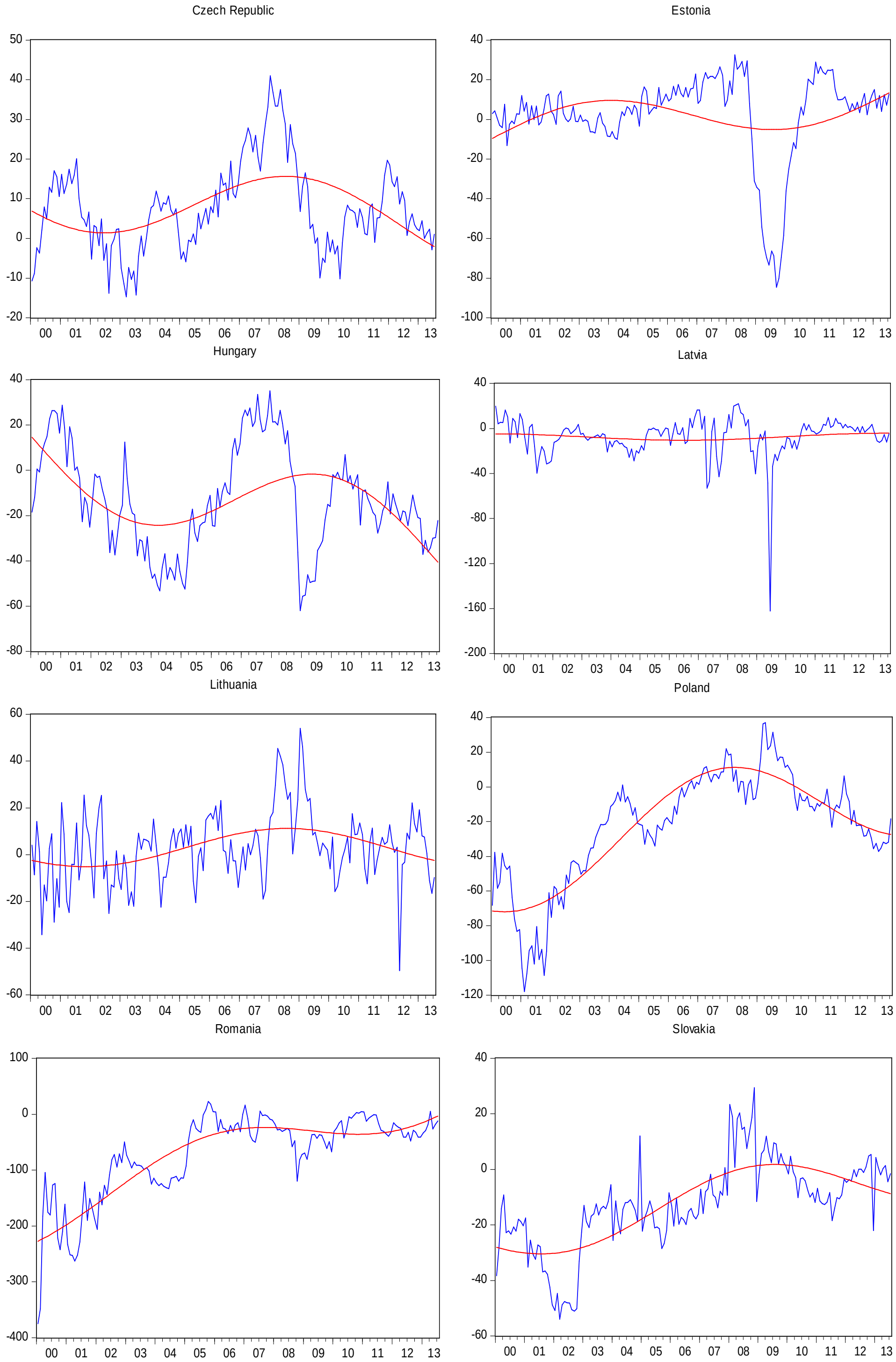
We cannot reject the null hypothesis for Estonia, Latvia and Lithuania because these countries still had significant restrictions on foreign exchange transactions and faced high inflation. The interest rate-setting behavior of their central banks reacted strongly to US dollar exchange rate changes, although shifts in monetary regimes make it difficult to assess the relative importance placed by countries in terms of inflation control and external equilibrium. For example, Estonia has adopted a monetary policy regime of inflation targeting, which allowed the country to fight inflation. Additionally, the existing managed floating exchange rate regime is compatible with 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 Latvia to improve its living standards and economic efficiency have reduced its fiscal and monetary discipline and have led to persistent current account deficits. As a result, higher demand and unit labor costs together with higher food and energy prices have contributed to higher inflation rates. The process of CEEC economic transition began with the liberalization of foreign exchange markets and the provision of currency convertibility. These drastic steps resulted in the initial deep undervaluation of national currencies. At the same time, price liberalization was accompanied by very high inflation rates. The result of this policy is that central banks in these three CEECs tend to look beyond inflation and focus on other objectives as well, most prominently on exchange rate changes.

Figure 1 displays the time paths of the RER in which a positive change in the RER indicates real depreciation. 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 stationarity). The estimated time paths of the time-varying intercepts are also shown in Figure 1.

A further examination of the figures indicates that the all Fourier approximations seem reasonable and support the notion of long swings in RER. As mentioned earlier, trade barriers as well as interventions in the exchange markets could motivate this nonlinear behavior.

Figure 1
Real Exchange Rate Convergence and Fitted Non-linearities





Source: Data are from the fourier unit root results and dotted in Eviews 8.0.

Apparently, the stationary test with a Fourier function employed in our study provided evidence favoring the long-run validity of Taylor rules for the seven CEECs under study. The major policy implication that emerges from this study is that Taylor rules can be used to determine the equilibrium US dollar exchange rate for these seven CEECs. They have strict inflation targeting (when stabilizing inflation around the inflation target is the only objective for monetary policy) with flexible inflation targeting (when there are additional objectives for monetary policy). Our results also indicate that strict inflation targeting implies a vigorous use of the direct exchange rate channel for stabilizing inflation on a short horizon. In contrast, flexible inflation targeting ends up stabilizing inflation on a longer horizon, and thereby also stabilizes RERs and other variables to a significant extent. In comparison with the Taylor rule, the reaction function under inflation targeting in an open economy responds to more information, particularly to foreign disturbances. Our findings indicate that we can use Taylor rules to predict exchange rates and to determine whether a currency is over- or undervalued and experiences a difference between domestic and foreign inflation rates. Nevertheless, reaping unbounded gains from arbitrage in traded goods is not possible in these seven countries.

Conclusions

Using models that do not assume a linear adjustment, this study implements a stationary test with a Fourier function proposed by Enders and Lee (2012) to test the validity of long-run Taylor rules for a sample of CEECs. Standard linear ADF, PP, and KPSS statistics show that the data are essentially non-stationary for these countries. In contrast, when we adopt a Fourier unit root test, which has a higher power than a standard univariate and non-linear unit root statistic to reject a false null hypothesis of unit root behavior, the empirical evidence suggests that the real exchange rates based on Taylor rules are well characterized in CEECs by a non-linear mean-reverting process which exhibits periods of structural breaks.

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