The Purchasing Power Parity in Emerging Europe: Empirical Results Based on Unit Root Tests with Two Breaks

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Summary: The purpose of the paper is to evaluate the validity of purchasing power parity (PPP) for eight countries from the Emerging Europe: Hungary, Czech Republic, Poland, Romania, Lithuania, Latvia, Serbia and Turkey. Monthly data for euro and U.S. dollar based real exchange rate time series are considered covering the period: January, 2000-August, 2011. Given significant changes in these economies in this sample it seems plausible to assume that real exchange time series are characterized by more than one time structural break. In order to endogenously determine the number and type of breaks while testing for the presence of unit roots we applied the Lee-Strazicich approach. The validity of the PPP has been accepted only for two euro based real exchange rate time series (in Hungary and Turkey). The PPP hypothesis has been accepted for the U.S. dollar based real exchange rate time series in Poland, Romania and Turkey. To assess the adjustment dynamics of real exchange rates, the impulse response function is calculated. In addition, half-life is estimated, however the corresponding confidence intervals appear to be considerably wide. Having in mind the available empirical results on this topic we may conclude that the persistence of real exchange rate in Emerging Europe is still substantially high. The lack of strong empirical support for PPP suggests that careful policy actions are needed in this region to prevent serious exchange rate misalignment.

Key words: Purchasing power parity, Real exchange rate, Unit root test, Structural breaks, Emerging economies.

1. Introduction

It is widely accepted in the literature that changes in the real exchange rate during a period of time can be seen from the viewpoint of the purchasing power parity (PPP) theory. This theory suggests that the exchange rate is adjusted in the direction of neutralizing the differential inflation rate among the countries acting as trading partners, so any change in the real exchange rate can be interpreted in relation to the equilibrium level, in terms of deviations from the equilibrium. It is clear that adjusting exchange rate actually reflects macroeconomic imbalances in the observed economies, as well as certain monetary failures, creating significant impact on the level of inflation and manufacturing. The absolute version of the PPP theory implies the equality of prices of identical baskets of goods denominated in national currencies. Therefore, the key principle this approach rests upon is based on the law of one price, i.e. the equality of currency purchasing power

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in all countries. On the other hand, the relative version of this theory endorses the view that the percentage change in the value of one currency for the purpose of equalizing the value of the selected basket of goods should respect the differences in the inflation rates between those two countries. The sustainability of the PPP theory can be observed from the short-term and the long-term aspect. The most important determinants of the exchange rate deviations in short-term are: differences in consumption patterns and transaction costs, the implemented model of monetary policy, as well as the dynamics of adjustments to the price changes.

From the viewpoint of the trend regime applied, the selected European emerging economies can be classified into three groups. The first group includes the Czech Republic, Poland and Hungary, i.e. countries which favoured a gradual approach in changing the implemented regime, considering the fact that they practiced central arrangements during the transition from fixed to flexible currency policy. The second group are the EU member states which have remained consistent in the implementation of the selected regime, where on one hand we single out Latvia and Lithuania, which have favoured rigid regimes, while Romania has focused on higher and lower levels of flexibility. Countries which are not part of the European Union, Serbia and Turkey, belong to the third group and their orientation focused on flexible currency forms, while preserving the sequential approach. It is evident that the managed float in the regime of inflation targeting is the dominant currency strategy in the selected economies. Looking at the correlation between monetary and exchange rate regimes, Kosta Josifidis, Jean-Pierre Allegret, and Emilija Beker Pucar (2009a) emphasize that the inflation changes, the degree of economic openness and the level of foreign reserves are the most important determinants of the exchange rate in the period from 2000-2009.

In the process of abandoning the fixed and moving to more flexible currency regimes, the selected European economies are specific in certain aspects, while bearing in mind the numerous institutional and structural changes during the 1990s events. At the very beginning of the transition period, all countries were characterized by macroeconomic distortions, which were mostly manifested in high rates of inflation and the enormous decrease in production. Fixing the exchange rate was considered to be suitable in the initial years of the stabilization program, since tight macroeconomic policies had a positive impact on the reduction of the inflation expectations. However, when the direction of reforms was clearly determined, followed by the price and trade liberalization, stabilization of inflation and net capital inflows, some countries changed their orientation regarding the choice of exchange arrangements. In other words, as opposed to the role of the exchange rate as a psychological anchor, the priority was given to more liberal currency strategies.

The aim of this paper is to analyze the validity of the PPP theory for the following eight European emerging economies: the Czech Republic, Latvia, Lithuania, Hungary, Poland, Romania, Serbia and Turkey. Our analysis covers monthly data for the period from January 2001 to August 2011. The uniqueness of this research is primarily reflected in the selected sample and the observation period in terms of strong economic turbulence, monetary and real shocks during the transition period, as well as in focusing on countries with different currency strategies in the process of evaluation of the sustainability of the PPP theory. Furthermore, the three-dimensional importance of structural breaks, which can be divided into: i) tendency of the movement of the time series in the long run; ii) increasing the degree of accuracy assessment; iii) the credibility of the results, has also influenced the choice of an appropriate econometric research technique. Tests which are designed for the analysis with the existence of one and (or) two structural breaks, are used in order to test the stationarity of the euro and U.S. dollar based time series of the real exchange rate. In order to additionally verify the obtained results, we also calculated the period of time that needs to pass so the deviations from the equilibrium decrease in half.

The paper is divided into five sections. After the introduction, section 2, “Literature Survey“, describes the dominant attitudes in the sources about the sustainability of the PPP theory. The third section, "Data and Methodology", presents the sample and the period of observation, a brief overview of the most important tests in this area, and a description of the econometric techniques applied in the research. The fourth section, “Empirical Results“, contains the most important results of the implemented tests, while the last part presents concluding remarks and final findings about the validity of the PPP theory in the selected economies.

2. Literature Survey

Different approaches to testing the validity of the PPP theory can be classified into two groups, depending on the tests used: 1) testing the stationarity of time series of the real exchange rate; 2) identifying the cointegration relationship between the nominal exchange rate and the relative prices. Variations in the results are often based on the application of the appropriate econometric methodology, the characteristics of the selected sample, the length of the observation period and the frequency of the data used.

Saadet Kasman, Adnan Kasman, and Duygu Ayhan (2010) test the validity of the PPP theory on a sample of eleven countries of Central and Eastern Europe and three market economies, for the period from the early 1990s until September 2006. The results of the LM unit root tests that include one and two structural breaks in the analysis of the U.S. dollar based real exchange rate indicate the acceptance of the alternative hypothesis only in the cases of Romania and Turkey. On the other hand, observing the time series of Deutsche mark based real exchange rate, stationarity was found in seven of the fourteen countries. In the second part, the half-life test was applied, where the estimated parameters indicated that on average, 1.9 years need to pass for the deviations from long-term balance to be diminished by 50%. Similar findings were obtained in research of Ali Acaravci and Ilhan Ozturk (2010), where the validity of the PPP theory was disproved in six out of eight transition countries in the period from January 1992 - January 2009. The results of applying the tests which take into account the presence of structural breaks in the analysis indicate that only the time series of Romania and Bulgaria accepted the alternative hypothesis and long-term accordance with purchasing power parity, while the theory itself remains a controversial issue. The paper Minoas Koukouritakis (2009) analyzed the long-term equilibrium relationship between the nominal exchange rate, the domestic and foreign prices for ten countries that joined the European Union during the historic enlargement in 2004, as well as for Bulgaria and Romania. The results of the application of the Johansen cointegration methodology in the presence of a structural break in the analysis indicate the viability of the PPP hypothesis only for Romania, Bulgaria, Slovenia and Cyprus. Marked non-stationarity of time series real exchange rate in the Czech Republic, Hungary and Slovenia in the period 1992-2006 is featured in the work of Jani Beko and Darja Boršić (2007), and further analysis revealed the unsustainability of the PPP theory for the above economies. On the other hand, Ebru G. Solakogu (2006) supports the PPP theory on a selected sample of 21 countries using a panel approach, from the beginning of the 1990s to 2003. Noting that the half-life parameters for all time series related to the period of about one year, he came to the conclusion that the convergence is prominent in more than in less open economies.

The results of the research in the work of Dimitrios Sideris (2005) support the PPP theory in the long run on a sample of seventeen transition countries during the period from the early 1990s to the end of 2004. However, the calculated cointegration vector suggests a change in symmetry and proportionality, where the main causes of deviations from the long-term stand-level are considered to be frequent interventions in the foreign exchange market. Similarly, Atanas Christev and Abbas Noorbakhsh (2000), in a sample of six countries in Central and Eastern Europe, using the cointegration method, support the PPP hypothesis and point out that the cointegration vector indicates a certain degree of distortion of symmetry and proportionality. Despite the short-term dynamics, they conclude that there is a long-term equilibrium adjustment between cointegrated series of exchange rate and price level. The empirical results of the application of unit root tests in the work Athanasios Papadopoulos and Nikolaos Giannellis (2006) indicate the acceptance of the PPP theory in four selected economies (Hungary, Poland, Czech Republic and Slovakia). The determined stationarity of euro based time series exchange rate is interpreted in terms of the developed trade relations and removing trade barriers in the exchange in the Euro area.

What is specific in the research work of David Barlow (2003) is the analysis of sustainability of the PPP theory between two transition countries (Poland and the Czech Republic) and Romania, as examples of economies with reforms which were implemented later. The conclusion is interesting as it supports the viability of the hypothesis by looking at two more advanced transition countries, but it also justifies the analysis that involves Poland and the Czech Republic on one side and Romania on the other. This finding is explained by the fact that the exchange rate played a central role in the strategy of reducing the inflation in Poland and the Czech Republic, unlike Romania, which in the beginning of the transition period has remained consistent in implementing the fluctuating currency arrangement.

Verification of the application of unit root tests which include structural breaks in the analysis is featured in the work of Štefan Lyocsa, Eduard Baumöhl, and Tomáš Vyrost (2011). Looking at the key macroeconomic indicators of the Czech Republic, Poland, Hungary and Slovakia in the period 1990-2009, there was a significantly higher level of stationarity after the implementation of tests with one and two structural breaks, while emphasizing the validity of the model which involves changes in the level and trend (Model C).

Rajmund Mirdala (2009) points out the non-stationarity of time series that depict the movement of selected macroeconomic indicators of Poland, the Czech Republic, Hungary and Slovakia in the period 1998-2008, and additionally, he presents the reactions to monetary shocks in these countries with the impulse response function. Selahattin Diboogly and Ali M. Kutan (2001) present similar empirical results, in the sense that nominal shocks had a dominant influence on the movement of the real exchange rate in Poland, while for Hungary the real changes had more prominent effect.

3. Data and Methodology

We estimated the acceptability and viability of the PPP theory for the following countries: the Czech Republic, Latvia, Lithuania, Hungary, Poland, Romania, Serbia and Turkey. We used monthly, log data about: euro based nominal exchange rate, U.S. dollar based nominal exchange rate, the harmonised consumer price index (CPI) in individual countries, the CPI index in the Euro area and the CPI index in the U.S. market, for the period January 2000 - August 2012. Taking into account the theoretical knowledge about nominal and real dimensions in economics, real exchange rate series are formed by adjusting the nominal price level of a country and a per se CPI index:

$$rer = e_t - p_t^* + p_t,$$

where *rer* is the real exchange rate, e_t is the logarithm of the nominal exchange rate, while p_t^* and p_t denote logarithm of the data about the CPI index within individual countries and in the Euro area or the U.S. market, respectively. In order to obtain the initial insights into the movement of time series in terms of stationarity, we applied traditional ADF, KPSS and DF-GLS tests at the beginning, and after that, we implemented Lee-Strazicich tests with structural breaks in the analysis. Then, based on the modified forms of autoregressive model, we calculated half-life parameters and formed the corresponding confidence intervals. Finally, impulse response function is estimated for each real exchange rate time series that is derived from adequate ARIMA representation. The data in this paper are taken from the website of the Vienna Institute for International Economic Studies and analyzed using the software package E-Views 6.0 and RATS 6.20. The data about the euro and U.S. dollar based real exchange rate by individual countries are presented in Graph 1.

3.1 Unit Root Tests and Structural Break

The traditional standpoint related to unit root tests was based on the assumption that the shocks only have a momentary effect and that they do not correlate with long-term time-series movement tendency. On the other hand, Pierre Perron (1989) points to the limited power of the standard ADF test, advocating the view that the series are adjusted to the deterministic trend after small and frequent shocks, while the persistence of the unit root increases with the presence of fewer and unexpected external variations.

Namely, when taking into account the approach which upon the inherent unpredictability of shocks and their impact on the path of macroeconomic series in the long run, the main goal of modelling structural breaks refers to the examination of their statistical significance and the exact date when they appear.

From the point of the historical genesis of the unit root tests with one structural break, Perron (1989) developed a modified version of the Dickey-Fuller test, with test procedure which involves the presence of a break in both hypotheses, while the period of the break is fixed and is determined independently of the data. Recognising criticism and conflicting opinions regarding the *a priori* determination of the point of the break, Perron (1990) developed a variant of the test where the period of the break is not predefined. Skepticism regarding the exogenous inclusion of the break into the analysis is also reflected in the work of Eric Zivot and Donald W. K. Andrews (1992), who developed a procedure of unit-root testing under the null, while the inclusion of the break in the trend function was observed under the alternative hypothesis. It is evident that the rejection of H_0 does not necessarily mean the absence of unit roots, but it certainly suggests the exclusion of the prediction of the existence of a unit root without a break. In the unit root tests with endogenous implementation of structural breaks in the analysis, the date of the break was determined on the basis of t-statistics test of the unit root, with respect to the criteria of minimum values. The results of research work in Luis C. Nunes, Paul Newbold, and Ching-Ming Kuan (1997) basically provided the justification of the previous ideas and attitudes of 1992, by introducing some modifications in terms of including the break in both hypotheses and the application of sequential testing process.

In order to further improve and increase the level of implementation of unit root tests, Robin L. Lumsdaine and David H. Papell (1997) point to their sensitivity with respect to the number of structural breaks that are included into the analysis. Considering the limitations when including only one break, they promoted an approach in which two structural breaks are included in the process of testing the stationarity of time series. In relation to the findings of Perron (1989, 1990) and Zivot and Andrews (1992), there is noticeably more frequent rejection of the null hypothesis on the existence of unit roots, as well as less sensitivity in determining the date of the occurrence of shocks in relation to the presumption on their number.

3.2 Lee and Strazicich Unit Root Tests

Taking into account the affirmations and defectiveness of unit root tests we have mentioned above, Junsoo Lee and Mark C. Strazicich (2003) promote two testing procedures, related to the number of structural breaks included in analysis. The first one, which is related to the testing of unit roots in the presence of one structural break in time series y_t, is represented by the model:

$$y_t = \delta' Z_t + e_t$$

where $e_t = \beta e_{t-1} + \varepsilon_t$ ($\varepsilon_t \sim N(0,\sigma^2)$). In this equation, Z_t is a vector of exogenous variables which varies depending on whether the model is tested with the changes in the level or, at the same time, changes in both the level and trend. In this context, Z_t for the model A is $[1, t, D_t]$, while the nature of the model C implies the extension of the vector for changes of movement in the trend, and $Z_t = [1, t, D_t, DT_t]$. The values of D_t and DT_t can be represented as follows:

$$D_t = \begin{pmatrix} 1 & t \geq T_b + 1 \\ 0 & otherwise \end{pmatrix} \quad DT_t = \begin{pmatrix} t - T_b & t \geq T_b + 1 \\ 0 & otherwise \end{pmatrix},$$

where T_b refers to the timing of the break. Taking into account the assumption that the data generating process in this test includes the break of both tested hypotheses, we can start from the values $\beta = 1$ and $\beta < 1$ for the null and the alternative hypothesis, respectively. If we consider the model with changes in the level, the hypotheses can be presented as follows:

H_0: $y_t = \mu_0 + d_1B_t + y_{t-1} + v_{1t}$
H_1: $y_t = \mu_1 + \gamma_t + d_1D_t + v_{2t}$

and v_{1t} and v_{2t} are stationary error terms. Impulse variable B_t takes a value equal to the one for $t = T_b + 1$, while it equals zero in other cases, and v_{1t} i v_{2t} are new error terms. Consequently, the hypotheses that characterize the model with changes in the level and trend are:

H_0: $y_t = \mu_0 + d_1B_t + d_2D_t + y_{t-1}+v_{1t}$
H_1: $y_t = \mu_1 + \gamma_t + d_1D_t + d_2DT_t + v_{2t}$

On the other hand, the LS test, which involves the analysis of two structural breaks, retains the key features and characteristics of a single break test, with a modification of the hypotheses. The main characteristic of this test is to include breaks under the null and an alternative hypothesis, while rejecting the null hypothesis unambiguously indicates trend-stationary time series. The vector of exogenous variables is extended and for the model with the changes in the level $Z_t = [1, t, D_{1t}, D_{2t}]$, while the model C is described by $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]$. Dummy variables which are introduced take the following values:

$$D_{jt} = \begin{pmatrix} 1 & t \geq T_{bj} + 1, \ j = 1,2 \\ 0 & \text{otherwise} \end{pmatrix} \qquad DT_{jt} = \begin{pmatrix} t - T_{bj} & t \geq T_{bj} + 1 \\ 0 & \text{otherwise} \end{pmatrix},$$

where T_{bj} denotes the date when the break appeared. Now for the model A, the next set of hypotheses is valid:
H_0: $y_t = \mu_0 + d_1B_{1t} + d_2B_{2t} + y_{t-1} + v_{1t}$
H_1: $y_t = \mu_1 + \gamma_t + d_1D_{1t} + d_2D_{2t} + v_{2t}$
Similarly, the hypotheses in the model C are expanded with D_{jt} and DT_{jt} components:
H_0: $y_t = \mu_0 + d_1B_{1t} + d_2B_{2t} + d_3D_{1t} + d_4D_{2t} + y_{t-1} + v_{1t}$
H_1: $y_t = \mu_1 + \gamma_t + d_1D_{1t} + d_2D_{2t} + d_3DT_{1t} + d_4DT_{2t} + v_{2t}$

The test statistics of LM unit root test can be represented by the following regression:

$$\Delta y_t = \delta'\Delta Z_t + \Phi \tilde{S}_{t-1} + u_t, \quad \tilde{S}_t = y_t - \tilde{\psi}_x - Z_t\tilde{\delta}, \ t = 2,...,T$$

$\tilde{\delta}$ - coefficients in the regression of Δy_t on ΔZ_t

$\tilde{\psi}_x$ – is given by y_1 - $Z_1\delta$ (y_1 and Z_1 denote the first observations of od y_t and Z_t, respectively).[4] LM t-test statistics of unit root null hypothesis when $\Phi = 0$ is denoted by τ, while LM unit root test is defined as: $LM_\tau = \inf_{\lambda} \tau(\lambda)$, where λ denotes the location of the break ($\lambda = T_b / T$), which is determined on the basis of the minimum t-statistics of the unit root test for any potential breaks in the time series, with excluding the top and bottom 10% of observation. Table 1 presents the critical values for the models A and C for both versions of the LS test, as guidelines in the acceptance or rejection of the null and alternative hypotheses. These values refer to the sample T = 100 and they are derived by the authors of the test.

Table 1 Critical Values of LS Tests for Models A and C

Level of significance	One break		Two breaks	
	C (model A)	C/T (model C)	C (model A)	C/T (model C)
5%	-3.57	From -4.45 to -4.51	-3.84	-5.29
10%	-3.21	From -4.17 to -4.21	-3.50	-4.99

Source: Lee and Strazicich (2003, 2004).

3.3 Half-Life Estimation

Unlike the previous research in this area, Barbara Rossi (2005) developed a methodology for the half-life test which is acceptable for the AR(p) processes in general, as well as an appropriate approach for calculating the corresponding confidence interval. The estimated parameters are interpreted through the number of periods which are required for the real exchange rate deviations from equilibrium levels, which occur as a response to shocks to the unit-level time series, to be reduced by 50%.

Kenneth S. Rogoff (1996) proposes a consensus on the adoption of a period of three to five years for the alleviation of the imbalances and return to a level suggested by the theory of purchasing power parity. In further research on this issue, Yin-Wong Cheung and Kon S. Lai (2000) conclude that in the model without real rigidities this period is decreased and reduced to the length of one or two years. According to the formula for calculating the half-life:

$$\hat{h} = \frac{\ln(0.5)}{\ln \hat{\beta}}$$

[4] The point is, therefore, in the *a priori* exclusion of deterministic components from the model (constant and trend, $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t\tilde{\delta}$) with the idea that the test becomes robust to the size of the breaks. We can notice the use of ΔZ_t, which for the model A includes $[1, B_t]$, while in the model C, it is expanded for the component D_t, where $B_t = \Delta D_t$ i $D_t = \Delta DT_t$ (Lee and Strazicich 2004). It is clear that the extended version of the test which includes two structural breaks in the analysis must be taken into account in determining the test statistics, so the first difference of the vector of exogenous variables in the model A refers to $\Delta Z_t = [1, B_{1t}, B_{2t}]$, and for the model C, $\Delta Z_t = [1, B_{1t}, B_{2t}, D_{1t}, D_{2t}]$.

corresponding confidence interval with probability of 95% is:

$$\hat{h} \pm 1.96 \hat{\sigma}_{\hat{\beta}} (\ln(0.5)/\hat{\beta}) [\ln \hat{\beta}]^{-2}$$

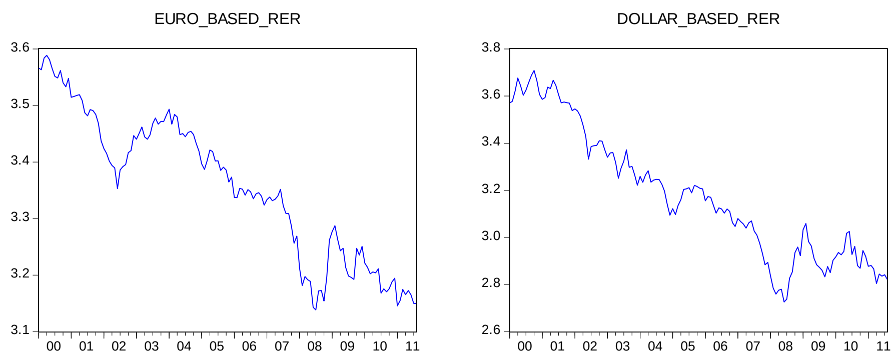
where $\hat{\sigma}_{\hat{\beta}}$ is an estimate of the standard deviation of $\hat{\beta}$ (Rossi 2005). $\hat{\beta}$ denotes the estimation of an autoregressive parameter defined earlier but from the model that is used to derive DF-GLS unit-root test statistics (Kasman, Kasman, and Ayhan 2010).

4. Empirical Results

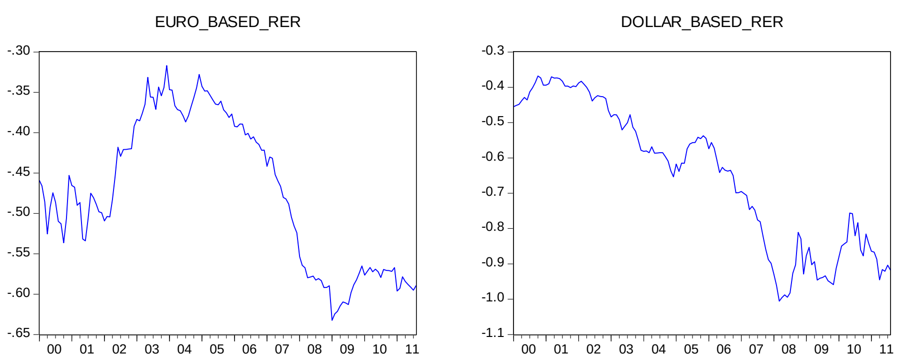
The first part of this section presents euro and U.S. dollar based time series of real exchange rates, after which we outlined the results of unit root tests that do not involve structural breaks in the analysis.

Graph 1 Movement of Real Exchange Rates in Selected Economies over the Observed Period

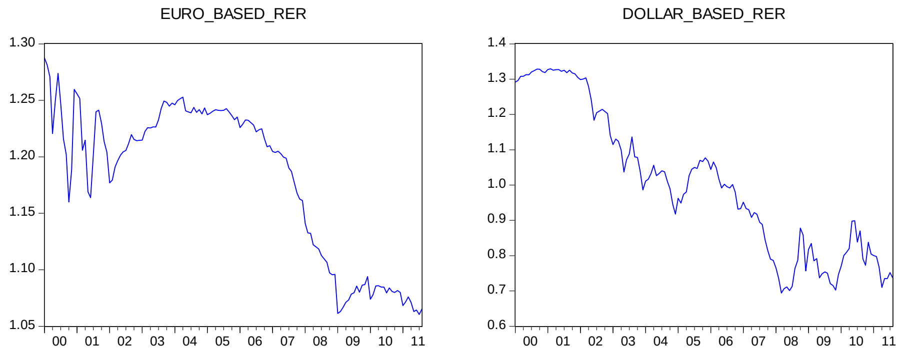
Czech Republic



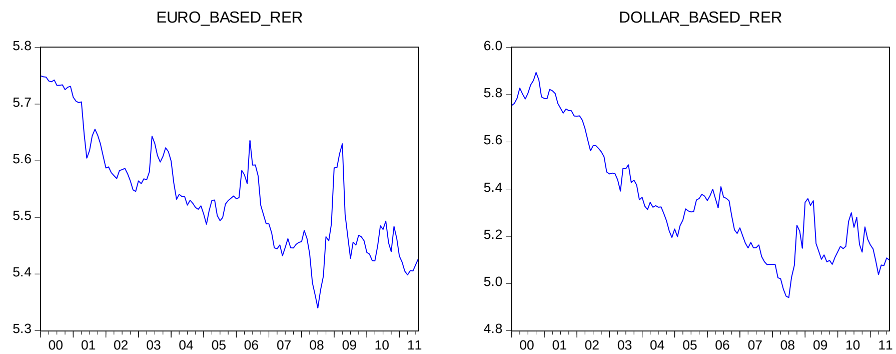
Latvia



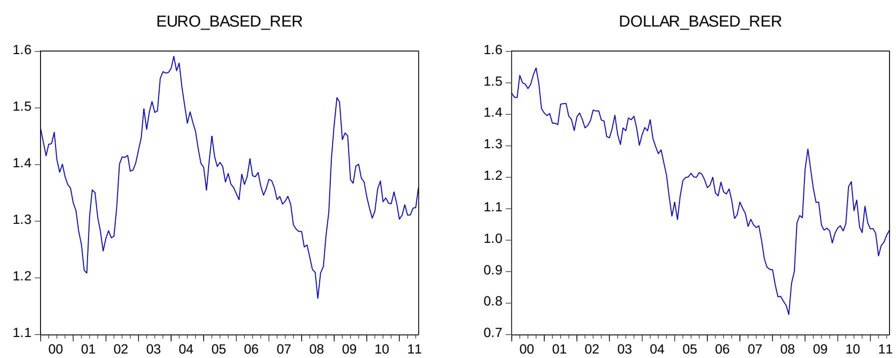
Lithuania



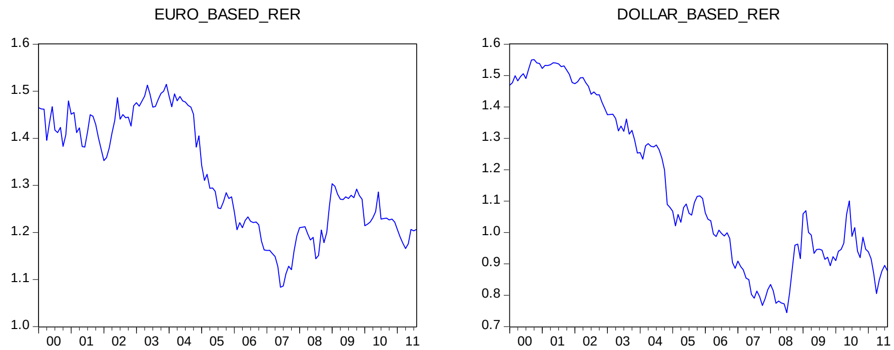
Hungary



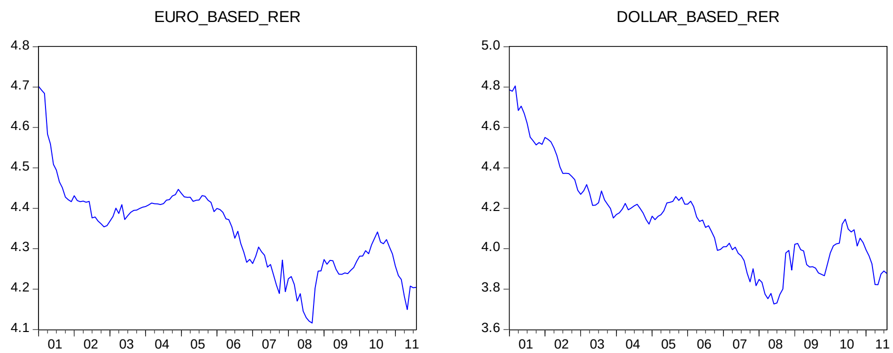
Poland



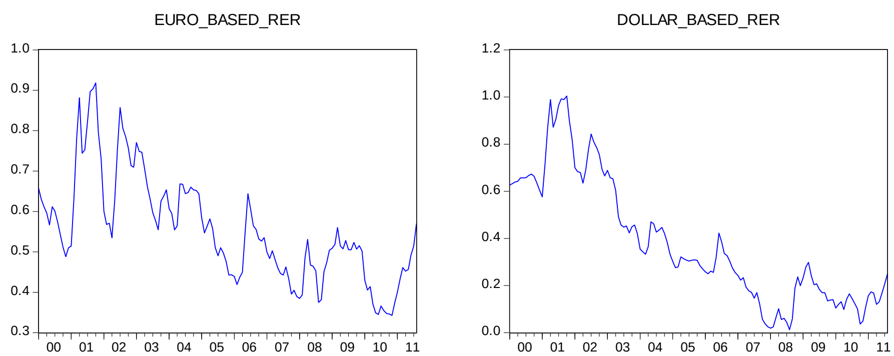
Romania



Serbia



Turkey



In tabular representations of results which ensue, the number of lags (k) which aim is eliminating autocorrelation in residuals in ADF test is switched on in accordance with the strategy of "specific to general", which implies gradual extension of the baseline model. On the other hand, the automatic Newey-West correction, which in most series includes nine extensions, was applied to the KPSS test, while with the ERS test, the number of additional lags follows the ADF test. Mark τ_t refers to the model that includes both deterministic components, while τ_μ refers to the model that contains only one constant.

Table 2 Unit Root Tests without Structural Break

euro based real exchange rate

Selected economies:	*k*	*DF-ADF*	*KPSS*	*DF-GLS*
Czech Republic	0	-2.58 (τ_t)	0.09	-2.59
Latvia	1	-0.65 (τ_μ)	0.65	-0.61
Lithuania	7 7	-1.34 (τ_t) 0.22 (τ_μ)	0.30 1.14	-0.59 1.25
Hungary	9	-2.14 (τ_μ)	1.24	0.33
Poland	1	-2.64 (τ_μ)	0.24	-2.07
Romania	5	-1.08 (τ_μ)	1.07	-0.08
Turkey	1	-2.98 (τ_μ)	1.07	-2.57
Serbia	11	-2.25 (τ_t)	0.10	-2.08

Note: In the analysis of the model which includes both deterministic components, the critical values are: -3.44, 0.146, -2.99 for the ADF, KPSS and DF-GLS tests respectively, while the determination of stationarity about nonzero mean values is calculated by using the following values: -2.88, 0.46 and -1.94. These critical values are available from the EViews output.

Source: Authors calculations.

Table 3 Unit Root Tests without Structural Break

U.S. dollar based real exchange rate

Selected economies:	*k*	*DF*	*KPSS*	*DF-GLS*
Czech Republic	0	-2.46 (τ_t)	0.20	-2.43
Latvia	7	-0.85 (τ_μ)	1.25	0.02
Lithuania	0	-2.45 (τ_t)	0.13	-2.40
Hungary	8	-1.87 (τ_μ)	1.26	0.08
Poland	0	-1.56 (τ_μ)	1.26	-0.49
Romania	0	-0.96 (τ_μ)	1.20	0.23
Turkey	2	-1.34 (τ_μ)	1.26	-0.79
Serbia	7	-2.09 (τ_t)	0.20	-1.23

Source: Authors calculations.

In Tables 2 and 3 we can notice that most of time series are characterized by the presence of the unit root. Focusing on the U.S. dollar based real exchange rate, the alternative hypothesis on stationarity is rejected for all of the observed economies. A similar interpretation is found in euro based real exchange rates, where Turkey deserves special attention, due to the stationarity determined over the observed period. It is important to point out that in some countries there is a discrepancy between the results of the tests applied, but the final attitude about the presence of unit roots is formed on the basis of graphic representation correlogram of the observed series of the real exchange rate. Taking into account the number of additional lags involved, it is evident that in most countries initially there was an autocorrelation in the residuals, which was gradually eliminated. From the standpoint of the presence of deterministic components, the empirical findings indicate a greater incidence of models which exclude the presence of a linear trend.

After getting acquainted with the nature of euro and U.S. dollar based time series of the real exchange rate during the period, the LS tests with one and two structural breaks were applied for the models A and C. Numerical results for the selected economies indicated greater validity of LS test with two structural breaks and changes in slope and intercept. Tables 4 and 5 show the results for the euro and U.S. dollar real exchange rate, respectively.

Table 4 LS Test with Two Structural Breaks in Level and Slope of the Trend Function for the Euro Based Real Exchange Rate

Selected economies:	*K*	*Dates of breaks*	*LM test statistics*
Czech Republic	5	2003:05 2007:11	-4.60
Latvia	12	2004:02 2007:08	-4.14
Lithuania	12	2002:03 2007:07	-3.83
Hungary	3	2003:03 (-0.63, 2.24) 2009:07 (2.94, -0.27)	-5.32*
Poland	11	2003:03 2007:06	-4.52
Romania	1	2004:11 2008:01	-3.45
Turkey	8	2005:10 (-1.21, -2.98) 2010:02 (1.19, -3.31)	-6.38*
Serbia	11	2003:06 2008:06	-2.94

Note: * indicates the value of the test-statistics that is less than the critical value of 5% significance level. Values in brackets present t-ratios of dummy variables estimates, where the first value refers to change in level, and second denotes change in level and slope of the trend function. These t-ratios are indicated only in terms of accepting the hypothesis of stationarity.

Source: Authors calculations.

Table 5 LS Test with Two Structural Breaks in Level and Slope of the Trend Function for the U.S. Dollar Based Real Exchange Rate

Selected economies:	*k*	*Dates of breaks*		*LM test statistics*
Czech Republic	6	2002:02 2009:05		-4.75
Latvia	6	2007:07 2009:05		-4.85
Lithuania	6	2002:10 2008:11		-4.16
Hungary	6	2002:02 2008:11		-4.74
Poland	4	2007:08 2008:11	(-0.08, -3.73) (-1.57, 3.42)	-5.96*
Romania	9	2002:04 2008:07	(0.33, -3.60) (-0.12, 5.63)	-5.35*
Turkey	8	2003:07 2007:07	(1.10, -5.10) (1.87, -2.97)	-5.81*
Serbia	6	2005:01 2008:06	(-1.27, 4.44) (-1.21, 3.37)	-4.99**

Note: * and ** respectively denote the values of the test-statistics that are less than the critical values for the significance level of 5% and 10%. Values in brackets present t-ratios of estimated dummy variables, where the first value refers to change in level while the second indicates change in level and slope of the trend function. Like in the previous table, t-ratios are shown only for countries with established stationarity.

Source: Authors calculations.

In tables 4 and 5 the optimal number of lags is presented with k, t-ratios of dummy variables are shown in brackets and they are related with changes in level or in level and slope of the trend function. In the case of stationary time series, these values refer to the period when the break appeared. The critical values are based on the LS tests (Lee and Strazicih 2003, 2004) and they are presented on page eight, where * and ** indicate statistical significance for rejecting the null hypothesis at 5% and 10%, respectively.

The results which are presented in Table 4 indicate trend-stationary euro based time series of real exchange rate in Hungary and Turkey, while in other countries, we adhere to the decision on the existence of stochastic components. On the other hand, the numerical values in Table 5 indicate a higher level of stationarity for U.S. dollar based real exchange rate with respect to euro, given that on the 5% level of statistical significance, the alternative hypothesis of stationarity is adopted in Poland, Romania and Turkey. Results for Serbia also suggest stationarity around a deterministic trend, but only for the 10% level of significance. Detected break points are presented in Appendix 1 with a short explanation of its key causes in the selected economies.

Table 6 summarizes the results of applying the estimation of half-life for time series of real exchange rate in which, after inclusion of structural breaks in the analysis, we decided on the stationarity.

Table 6 Estimation of Half-Life Parameters for Euro and U.S. Dollar Based Real Exchange Rates

Selected economies:	*Estimation*	*Confidence interval with a probability of 95%*
Hungary	*euro based real exchange rate* 4.98	(1.84, 8.12)
Turkey	*euro based real exchange rate* 4.14	(1.96, 6.32)
	dollar based real exchange rate 6.51	(1.45, 11.57)
Poland	*dollar based real exchange rate* 7.43	(1.25, 13.60)
Romania	*dollar based real exchange rate* 17.42	(-4.02, 38.86)

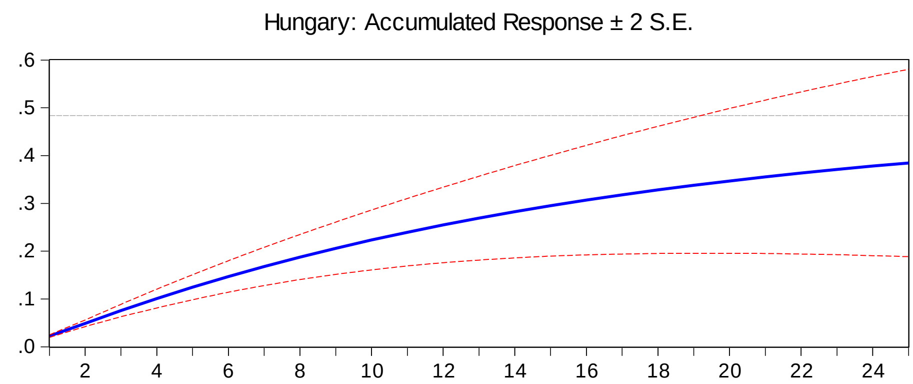
Note: Estimation for $\hat{\beta}$ is derived based on DF-GLS test with constant and trend.

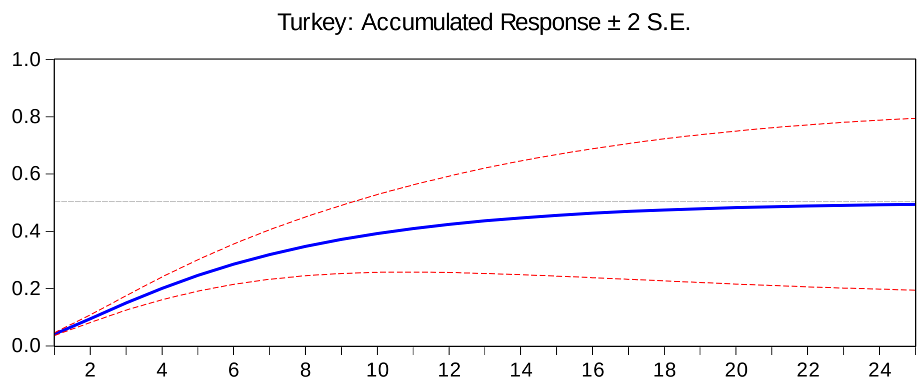
Source: Authors calculations.

Focusing on the euro based real exchange rate, we conclude that Hungary needs 4.98 months to reduce deviations, whereas Turkey requires a period of 4.14 months. Thus, on average, 4.55 months need to pass for the variations due to structural breaks to be reduced in half. On the other hand, looking at the U.S. dollar based real exchange rate, we can notice a relatively wide range of estimated half-life parameters, from 6.51 months in Turkey, over 7.43 in Poland, to 17.42 months in Romania, which gives the average of 10.45. Unacceptably wide confidence intervals for 95% probability necessarily pose a question on the determined stationarity of time series real exchange rates, especially in Romania and Poland.

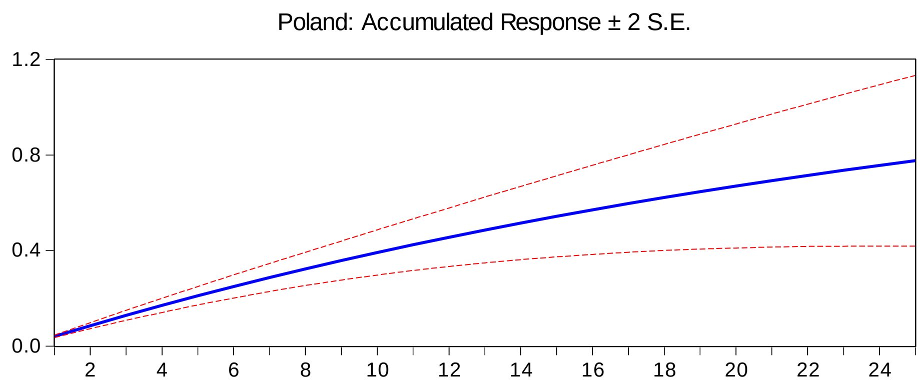
Finally, for five stationary time series we have calculated accumulated impulse response functions derived from corresponding ARMA specifications for the impulse size of one standard deviation. The results are depicted in Graph 2 and Graph 3. Our results suggest a relatively high persistence of real exchange rates to accumulated unexpected random shocks. Nevertheless, persistence to random shocks is of smaller magnitude for the euro based real exchange rates. Among the U.S. dollar real exchange rates persistence appears to be extremely strong for Romania and then for Poland. This finding is in accordance with half-life point and interval estimates.

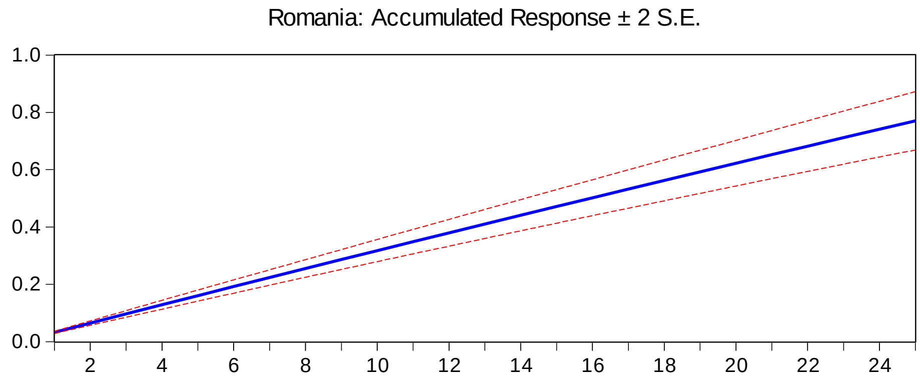
Graph 2 Accumulated Impulse Response Functions for Stationary Euro Based Real Exchange Rates

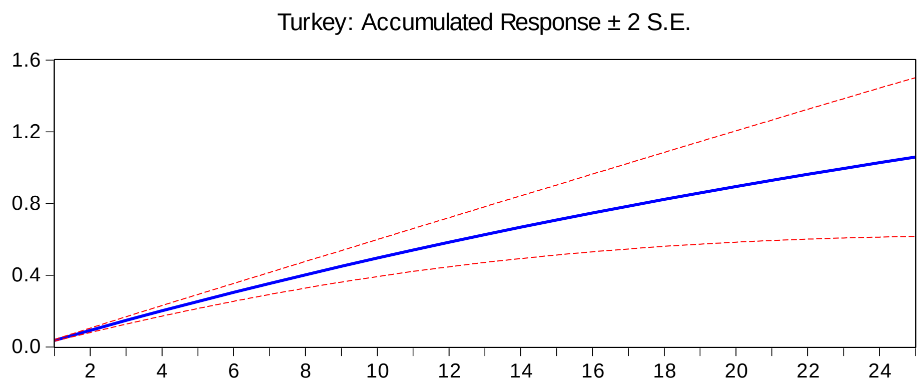




Graph 3 Accumulated Impulse Response Functions for Stationary U.S. Dollar Based Real Exchange Rates







5. Concluding Remarks

This paper investigates the sustainability and validity of PPP theory in the Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Serbia and Turkey in the period from early 2000 to August 2011. It is important to note that the observed period was also a period of great turbulence and adverse developments in the international economic scene, which through spillover effects had a significant impact on the macro environment in the selected economies.

The empirical results obtained by standard unit root tests (ADF, KPSS and DF-GLS) indicate a very high level of persistence in time series of real exchange rates in the observed countries, with the exception of the established stationarity of euro based real exchange rate in the case of the Turkish economy. Implementation of LS unit root test is in the function to achieve reliable results and evaluations, and bearing in mind the different variants of this test, the greatest ponder is given to modelling with two structural breaks and changes in the level and slope of the trend. Studying the dynamics of the euro based real exchange rate, we conclude that the alternative hypothesis of stationarity is adopted in the case of Hungary and Turkey. Empirical results for the U.S. dollar based real exchange rates indicate prominent disparity in the results of standard tests and the rejection of the presumption of non-stationarity in Poland, Romania and Turkey. In contrast, the application of numerical data of the half-life test suggests that these periods are relatively long, and confidence intervals are unacceptably wide, which altogether implies that the evaluation is inaccurate and unreliable.

Having in mind the rethinking of the implemented test results, the sensitivity of the observation period in terms of strong distortions as well as the existence of negative dimensions of the impact of exogenous shocks in the long run, we can conclude that PPP theory is unsustainable in selected European economies.

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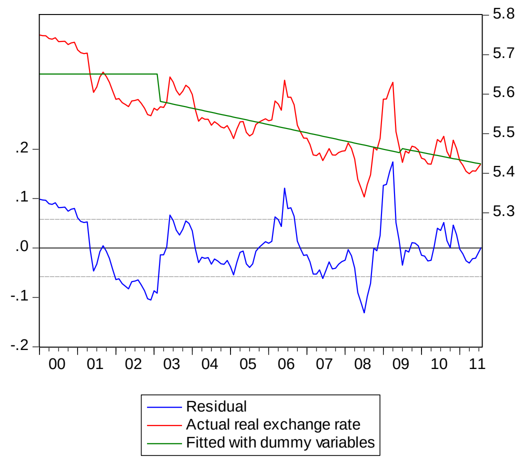
Appendix 1

Graph 4 Determined Points of Structural Breaks in Euro and U.S. Dollar Based Real Exchange Rates in Selected Economies

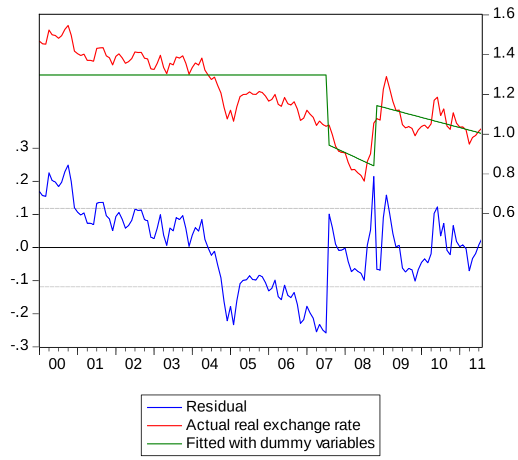
Hungary



Observing at the euro based real exchange rate, the structural break which occurred in March 2003, can be brought in correlation with falling growth rates of GDP and the worsening of the current account deficit, since the mentioned negative trends were expressed at the end of 2002 and early 2003. On the other hand, unfavourable distortions in macroeconomic environment that occur as a consequence of global economic crisis, were manifested by the break in 2009.

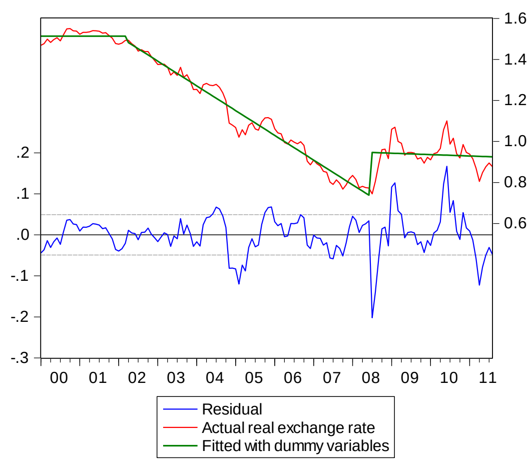
After the determination and exclusion of identified breaks from analysis, the LS test at the level of 5% reject the null hypothesis for euro based real exchange rate, while in the case of the U.S. dollar based real exchange rate confirms the presence of stochastic component.

Poland



When we analyze the U.S. dollar based real exchange rate, we can conclude that the breaks in 2007 and 2008 that occurred after the outbreak of the global economic recession did not have a long-term impact on the movement of the series, because the LS test at the level of 5% adopted an alternative hypothesis of stationarity around a trend with a break. Focused on the euro based real exchange rate, results of the implemented methodology, which include structural breaks in the analysis, confirmed the findings obtained by the traditional tests about the existence of unit root.

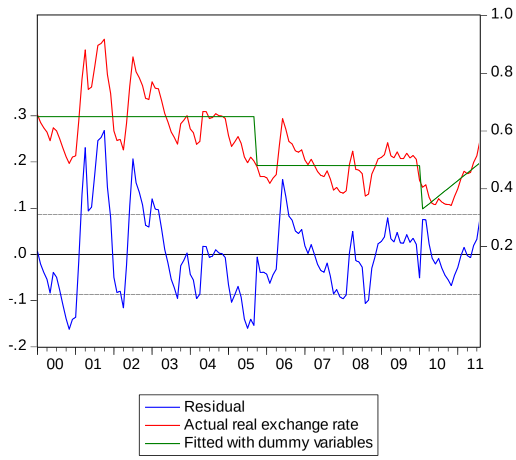
Romania



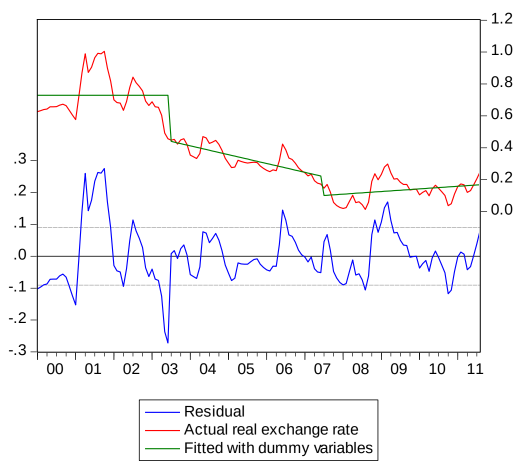
Negative trends of the U.S. dollar based real exchange rate, which were more prominent in April 2002 can be related to the changing currency strategies and the economic system. Looking at the economic performance of this economy, it is important to point out that 2001 and 2002 were periods of significant fluctuations of the key macroeconomic indicators. Together with other countries, the global economic crisis has had an adverse impact on the developments in Romania, which is reflected in the significant break in 2008.

Investigating the stationarity of the U.S. dollar based real exchange rate, empirical findings of LS test at the level of 5% statistical significance reject the hypothesis of the existence of unit root, which implies that the mentioned breaks did not have a long-term impact on the movement of the series, while the euro based real exchange previous decision on the presence of unit root remains the same.

Turkey



The tendency of growth of the current account imbalance and significant fluctuations in the import and export had a destabilizing effect on the euro based real exchange rate, which was manifested in the appearance of the break in February, 2005.



Changes in international trade relations and the increase of the current account deficit caused the occurrence of the break in a series of U.S. dollar based real exchange rate in

2003. On the other hand, the decline in GDP growth and the spillover effects of the global recession, are manifested in breaks in 2007 and 2010.

These findings of applied LS tests suggest that neither the previous two, or breaks caused by the global economic crisis did not affect the movement of time series in the long run. The derived conclusion is reflected in the rejection of the hypothesis of non-stationarity at the level of 5% significance in the time series of euro and U.S. dollar based real exchange rate.