Journal of Applied Economics and Business Research
JAEBR, 5(1): 20-37 (2015)

Is Real Exchange Rates Nonlinear with A Unit Root? A Note on Romania's Experience

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The study examines the validity of Purchasing Power Parity (PPP) in Romanian context, by checking the presence of linear and nonlinear unit root in real exchange rate of Romanian Leu with US Dollar and Euro for the period 1991:01 to 2011:02. Since the Wald test results indicate the presence of nonlinearity in the data, we employed the Caner and Hanson (2001) nonlinear unit root test based on TAR model and KSS (2003) nonlinear unit root test based on ESTAR model to examine the unit root properties. We find the presence of mean reversion in the full sample Leu-Dollar real exchange rate and the Leu-Euro real exchange rates. The series of Leu-Dollar exchange rates has a unit root in the first period, while it is mean reverting in the second period. By the contrary, the Leu-Euro real exchange rates are mean reverting in the first regime, while in the second regime it has a unit root.

***Key words**: Real exchange, Unit root, Tests, Nonlinearity, Implications*

1. Introduction

In recent years, purchasing power parity (PPP), a concept introduced by Cassel in 1918 attracted the attention of many researchers. PPP is a theory of long-term equilibrium of exchange rates based on relative price levels of two countries. The theory says that the nominal exchange rate between the currencies of two countries should be equal to the ratio of the two relevant national aggregate price levels or the prices in different countries should be equal when measured in a common currency.

According to Sideris (2006), the empirical analyses on PPP can be grouped in (based on the different types of the tests they apply) three categories; (a) The early "correlation" studies, which apply naive static PPP tests, (b) the unit root testing studies, which test for stationarity of the real exchange rates and (c) the cointegration - based studies, which test for

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cointegration between relative prices and exchange rates. These studies tested the validity of PPP using different time periods, country-groups and a large spectrum of econometric techniques.

In unit root studies of real exchange rate, PPP hypothesis is valid when the real exchange rate is stationary. So, if the real exchange rate is stationary, then the shocks do not have permanent effects and the variable returning to its long run equilibrium, which is achieved aftershocks, occurred. In this case, the real exchange rate is a mean-reverting process. On the contrary, if the real exchange rate has a unit root, then the shocks have permanent effects and the variable is not returning to its long run equilibrium. However, PPP does not hold on the short run because the prices level is inelastic in respect to the changes in the nominal exchange rate. The obtained results are not very conclusive. Moreover, Wu and Lee (2009) observed that different findings on the validity of long-run PPP depend on the numeraire currency, the length of data span, and econometric methods. In the empirical literature, the initial papers tested the PPP hypothesis using the conventional Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests, while the new approach is focused on the panel and nonlinear unit root tests. The choice for nonlinear modeling type is argued by Taylor and Peel (2000). As the exchange rate becomes increasingly misaligned with the economic fundamentals, however, one might expect that the pressure from the market to the exchange rate to return to the neighborhood of fundamental equilibrium would become increasingly strong". Based on this argument, our paper studies the stationarity of real exchange rates in Romania's case, in the presence of nonlinearity, using TAR model of Caner and Hansen (2001). We choose Romania because this country registered strong fluctuation in the real exchange rate, especially after 1990. More, this country gave up the communism and centralized economy in 1989 and since 2007 was accepted as a new UE member. The dataset cover the period January 1991 - February 2011, and the monthly real exchange rates represent the official values provided by National Bank of Romania (Euro was utilized in UE starting 1999). As Figure 1 shows, the Leu illustrates a lent depreciation in respect to Euro and US Dollar. Starting 2002, there is a strong currency fluctuation. This volatility was caused by full consumption of foreign reserves and balance of payments imbalances. Romania's National Bank (BNR) intervened to temper national currency Leu's depreciation and to discourage the speculators.

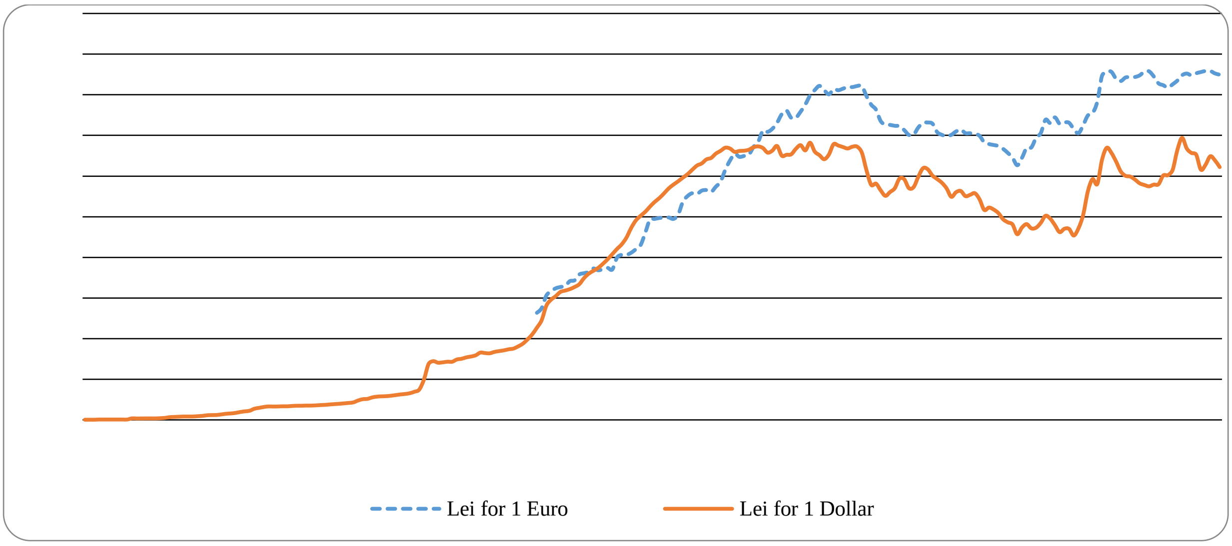

Figure 1: Leu-Euro and Leu-US Dollar real exchange rates

Our approach has two particularities: on the one hand, treats the case of an ex-emergent economy, with strong volatility in the level of real exchange rate, and on the other hand, performs a nonlinear model for testing the validity of PPP hypothesis. There are some authors who have focused their PPP studies on the East-European economies, but with different results regarding the Romanian's case: Choudhry (1999), Christev and Noorbakhsh (2000), Barlow (2003), Sideris (2006), Beirne (2007), Cuestas (2009), Baharumshah and Borsic (2008), Telatar and Hasanov (2009), Acaravci and Ozturk (2010) or, recently, Aslan and Kula (2011).

Excepting the Section 1, the rest of the paper is structured as follows: Section 2 contains the literature review. Section 3 presents methodology, variables' description and data. Section 4 shows estimation and empirical results. Section 5 concludes.

2. Literature Review

In the Romanian context, the PPP hypothesis has been tested by several researchers over years, using both linear and nonlinear approach. Some of them claim the existence of the unit root of the real exchange rate, while other found mean reversion (absence of unit root) in real exchange rate. Choudhry (1999) investigated the validity of PPP hypothesis in the case of USA, Poland, Romania, Russia and Slovenia, by using Harris-Inder test for cointegration & Fractional cointegration. The author finds that only Slovenia's and Russia's real exchange rate is stationary. Weak support for PPP has been obtained by Christev and Noorbakhsh (2000), for the period of 1990:1-1998:11, in the case of Bulgaria, Czech Republic, Hungary, Poland, Romania and Slovak Republic. Barlow (2003) investigated the PPP validity for a set of two advanced transition economies (Poland and the Czech Republic) and also for a lagging similar economy (Romania). He used a cointegration analysis, by using a monthly data over April 1994-December 2000, and found different outputs. The author validated the PPP hypothesis between lagging reformer and developed market economies and rejected for advanced reformed and developed countries.

Sideris (2006) tested the PPP hypothesis for seventeen economies of the former Soviet bloc: the Baltic countries (Estonia, Latvia, and Lithuania), a set of nine Central and Eastern Europe (CEE) countries (Bulgaria, Croatia, the Czech Republic, Hungary, Macedonia, Poland, Romania, the Slovak Republic, and Slovenia) and five economies; members of the Commonwealth of Independent States (CIS) (Belarus, Georgia, Moldova, Russia, and Ukraine). The main results showed that, under long-run equilibrium, the hypotheses of symmetry and proportionality are not validated by the coefficients of cointegrating vectors, giving the weak and strong PPP terms, respectively.

Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovak Republic, and Slovenia are targeted countries for Beirne (2007). The author examined PPP and found the same results: weak evidence in favour of PPP hypothesis.

By taking into account of any source of nonlinearity, Cuestas (2009) analyzed the empirical fulfilment of PPP in a number of Central and Eastern European countries and finds stronger evidence in favour of PPP for this set of countries. Baharumshah and Boršič (2008) investigate the validity of the PPP hypothesis for 13 Central and Eastern European countries (CEEC) in transition. The authors find that the long-run PPP relationship holds for Bulgaria, Croatia, Latvia, Lithuania, Russia and Slovenia. PPP fails to hold for transition countries with higher inflation rates and volatile exchange rates regimes. Telatar and Hasanov (2009) focused on Bulgaria, Croatia, the Czech Republic, Hungary, Macedonia, Poland, Romania,

 ISSN 1927-033X

and Slovakia. Their finding indicates that the, reforms and efforts aimed at preparation for EU membership might have shifted equilibrium real exchange rates in relatively small economies, such as: Estonia, Latvia, Lithuania, Slovakia, and Slovenia. The PPP hypothesis is not valid in the Romania's case. Acaravci and Ozturk (2010) examined the validity of the PPP in 8 transition countries, for monthly data from January 1992 to January 2009. The results of unit root test indicate that PPP does not hold for Bulgaria, Croatia, Czech Republic, Hungary, Macedonia (FYR), Poland, Romania, and Slovak Republic. More, in the presence of structural breaks, PPP holds only for Bulgaria and Romania. Recently, Aslan and Kula (2011) applied, as first step, the univariate unit root tests, and as second step, panel Lagrange Multiplier (LM) unit root tests. They used one and two structural breaks of real exchange rates, in the case of six Eastern European countries (Bulgaria, Czech Republic, Hungary, Poland, Romania, and Russia). Both set of tests validated the PPP hypothesis for investigated area.

In this context, we find some new evidence regarding the PPP hypothesis, in the Romania's case, using TAR model of Caner and Hansen (2001), which simultaneously tests the nonlinearity and unit root of data series. The dataset cover the period January 1991 - February 2011.

3. Emprical Methodology

3.1. Linear and nonlinear unit root tests

Results from two improved versions of Dickey-Fuller type unit root tests, namely, the DF-GLS test of Elliott et al. (1996) and Kapetanios et al. (2003) - a nonlinear unit root (KSS test) - are utilized. Elliott et al. (1996) proposed to extract the constant and trend effects from the series of interest using the general least squares (GLS) method, prior to the estimation of the Dickey and Fuller (1979) test, yielding the so-called DF-GLS test. It has been shown that the DF-GLS is better than the ordinary Dickey-Fuller test, in terms of small-sample size and also power (Baum et al., 2001; Vougas, 2007). Vougas (2008) further demonstrated that the DF-GLS test has good size even when there is a neglected level or trend break under the null hypothesis. The DF-GLS test is applied on the real exchange rate series. Further, to cater for nonlinearity, Kapetanios et al. (2003) extended the DF and ADF unit root tests by allowing for nonlinear adjustment. Therefore, we used this test also in our analysis because conventional univariate unit root tests such as the ADF test have comparatively low power to reject a false null hypothesis of unit roots (see for example, Campbell and Perron, 1991; Lothian and Taylor, 1996 and 1997) and are sensitive to the choice of lag length (see for example, Cuddington and Liang 2000). Kapetanios et al.'s (2003) proposed test is based on the following exponential smooth transition autoregressive (ESTAR) specification:

$$\Delta y_t = \gamma y_{t-1}[1-\exp(-\theta y_{t-1}^2)] + \varepsilon_t \qquad \theta \geq 0 (1) \tag{1}$$

where y_t is the de-meaned or de-trended series of interest, ε_t is an i.i.d. error with zero mean and constant variance, and $[1-\exp(-\theta y_{t-1}^2)]$ is the exponential transition function adopted in the test to present the nonlinear adjustment. The null hypothesis of a unit root in y_t (i.e., $\Delta y_t = \varepsilon_t$) implies that θ = 0 (thus $[1-\exp(-\theta y_{t-1}^2)]$ = 0). If θ is positive, it effectively determines the speed of mean reversion. The Kapetanios et al.'s (2003) test directly focuses on the θ parameter by testing the null hypothesis of nonstationarity H_0: θ = 0 against the mean-reverting nonlinear alternative hypothesis H_1: θ > 0. Because y_t in (1) is unidentified

 ISSN 1927-033X

under the null, we cannot directly test H_0: θ = 0. To deal with this issue, Kapetanios et al. (2003) reparameterize (1) by computing a first-order Taylor series approximation to specification (1) to obtain the auxiliary regression expressed by (2) below:

$$\Delta y_t = \delta y_{t-1}^3 + error \ . \quad (2)$$

Assuming a more general case where the errors in (2) are serially correlated, regression (2) is extended to

$$\Delta y_t = \sum_{j=1}^{p} \rho_j y_{t-j} + \delta y_{t-1}^3 + error \ , \quad (3)$$

with the p augmentations, which are used to correct for serially correlated errors. The null hypothesis of nonstationarity to be tested with either (2) or (3) is H_0: δ = 0 against the alternative of H_1: δ < 0. Kapetanios et al. (2003) show that the t-statistic for δ = 0 against δ < 0, i.e., t_{NL}, does not have an asymptotic standard normal distribution. They tabulate the asymptotic critical values of the t_{NL} statistics via stochastic simulations. In this paper, we estimate the t_{NL} statistics using regression (3) but for de-meaned and de-trended data series and refer to them as t_{NL1} and t_{NL2}, respectively. To obtain the de-meaned or de-trended data, we first regress each series on a constant or on both a constant and a time trend, respectively, and then we save the residuals.

Thereafter, with saved residuals we estimated equation (3) and to avoid problem of serial correlation we choose appropriate lag-length. Further, to select the lag length (k), in order to avoid serial correlation, we use the'‘t-sig’ approach[2] proposed by Hall (1994). This involves starting with a predetermined upper bound k. If the last included lag is significant, k is chosen. However, if k is insignificant[3], it is reduced by one lag until the last lag becomes significant. If no lags are significant k is set equal to zero.

3.2. The Caner and Hansen (2001) Threshold Autoregressive (TAR) Unit Root Test

Traditional unit root tests, such as the Augmented Dickey Fuller (1979), the Phillips-Perron (1988), and the KPSS (1992), provides evidence of non-stationarity if it is due to nonlinearity of the data due to their low power. Caner and Hansen (2001) is the first attempt at developing a rigorous asymptotic theory which simultaneously tests for nonlinearity and unit root in the data series, without assuming stationarity *a priori*. Therefore, in order to jointly test for non-stationarity and non-linearity, TAR model proposed by Caner and Hansen (2001) is utilized. A two-regime TAR model, with an autoregressive unit root, can be described by the following data generating process:

$$\Delta r_t = \theta'_1 x_{t-1} I_{\{Z_t < \lambda\}} + \theta'_2 x_{t-1} I_{\{Z_t \geq \lambda\}} + e_t , \quad (4)$$

[2] The'‘t-sig’ approach has been shown to produce test statistics which have better properties in terms of size and power than information-based methods such as the Akaike Information Criterion or Schwartz Bayesian Criterion (see for example, Hall 1994, Ng and Perron, 1995).
[3] We used conventional level of significance that is 5% level of significance as a benchmark and fixed k_{max}= 12.

where $t = 1,...,T, r_t$ is the variables measuring real exchange rate for $t = 1,2,...,T, X_{t-1} = (r_{t-1}, v_t^{'}, \Delta r_{t-1},..., \Delta r_{t-k})', I_{\{\bullet\}}$ is the indicator function, e_t is an i.i.d. disturbance, $Z_{t-1} = \Delta r_{t-1} - \Delta r_{t-m}$ is the threshold variable, m represents the delay parameter, and $1 \le m \le k, v_t$ is a vector of exogenous variables including and intercept and possibly a liner time trend. The threshold value, λ, is unknown and takes the value in the compact interval $\lambda \in \Lambda = [\lambda_1, \lambda_2]$, where λ_1 and λ_2 are selected according to $P(Z_t \le \lambda_1) = 0.15$ and $P(Z_t \le \lambda_2) = 0.85$[4]. The component of θ_1 and θ_2 can be portioned as follows:

$$\theta_1 = \begin{pmatrix} \rho_1 \\ \beta_1 \\ \alpha_1 \end{pmatrix}, \quad \theta_2 = \begin{pmatrix} \rho_2 \\ \beta_2 \\ \alpha_2 \end{pmatrix}, \tag{5}$$

where ρ_1 and ρ_2 are scalar terms, β_1 and β_2 have the same dimensions as v_t, and α_1 and α_2 are k-vectors. Thus (ρ_1, ρ_2) are the slope cofficients on r_{t-1}, (β_1,β_2) are the slope on determinstec componetn s, and (α_1, α_2) are the slope coefficients on (Δr_{t-1},…, Δr_{t-k}) into two regimes. The threshold effect in equation (4) has the null hypothesis of $H_\circ : \theta_1 = \theta_2$, which is tested using the familiar Wald statistic: $W_T = W_T(\hat{\lambda}) = \sup_{\lambda \in \Lambda} W_T(\lambda) = T\left(\dfrac{\hat{\sigma}_0^2}{\hat{\sigma}^2(\lambda)} - 1\right)$, where $\hat{\sigma}_0^2$ and $\hat{\sigma}^2$ are residual variance from least squires estimation of the null liner and TAR models, respectively.

The stationarity of the process r_t can be established in two ways. The first is when there is a unit root in both regimes (that is a complete unit root). Here the null hypothesis is of the form $H_\circ : \rho_1 = \rho_2 = 0$, which is tested against the unrestricted alternative $\rho_1 \ne 0 \; or \rho_2 \ne 0$ using Wald statistic. The parameter of ρ_1 and ρ_2 from equation (4) will control the regime dependent unit root process of the real exchange rate. If $\rho_1 = \rho_2 = 0$ holds, real exchange rate has a unit root can be described as the evidence of support for PPP hypothesis. This statistics is:

$$R_{2T} = t_1^2 + t_2^2, \tag{6}$$

where t_1 and t_2 are the two ratios for $\hat{\rho}_1$ and $\hat{\rho}_2$ from the ordinary least squire estimation. However, Caner and Hansen (2001) claim that this two sided Wald statistic may have less power that one-side version of the test hence, they proposed to use one sided Wald statistic which is as follows:

$$R_{1T} = t_1^2 I_{\{\beta_1 < 0\}} + t_2^2 I_{\{\beta_2 < 0\}} \tag{7}$$

To distinguish between the stationary case given as H_1 and the partial unit root case given as H_2, Caner and Hansen (2001) suggest using individual t statistic t_1 and t_2. If only one of $-t_1$

[4] According to Andrews (1993), this division provides the optimal tradeoff between various relevant factors which includes the power of the test and the ability of the test to detect the presence of a threshold effect.

 ISSN 1927-033X

and $-t_2$ is statistically significant, this will be consistent with the partial unit root case H_2. This means that our interest variables behaves like a nonstationary process in one regime; but exhibits a stationary process in the other regime, vice versa. Caner and Hansen (2001) show that both tests, R_{1T} and $R_{2T,}$ will have power against both alternatives.[5] To obtain maximum power form these tests, we have generated critical values using bootstrap simulations with 10,000 replications, following Caner and Hansen (2001).

[5] Caner and Hansen (2001) have pointed out that R_{1T} has more power than that of R_{2T}.

 ISSN 1927-033X

4. Empirical Results

First of all we utilized a linear unit root test, an improvised version of DF test, DF-GLS test of Elliott et al. (1996), and present the results in Table 1.

Table 1: Results of linear unit root analysis

Exchange Rate	Constant	Constant and trend
1991.1-2011.02		
USDMEDIU	0.495867 (1)	-1.281742 (1)
1999.1-2011.02		
USDMEDIU	-0.087676 (2)	-0.977003 (2)
EUROMEDIU	0.713871 (3)	-0.996574 (3)

Note: (1) Critical values -2.574714, -1.942164 and -1.615810 at 1%, 5% and 10% level of significance for constant, and critical values are
-3.463800, -2.922400 and -2.626700 at 1%, 5% and 10% level of significance for constant and trend model.
(2) Critical values -2.581120, -1.943058 and -1.6158241 at 1%, 5% and 10% level of significance for constant, and critical values are
-3.527200, -2.986000 and -2.696000 at 1%, 5% and 10% level of significance for constant and trend model.
(3) Critical values -2.581120, -1.943058 and -1.615241 at 1%, 5% and 10% level of significance for constant, and critical values are
-3.527200, -2.986000 and -2.696000 at 1%, 5% and 10% level of significance for constant and trend model.
(4) "k" denotes lag length and selection is based on SIC.

Source: Author's calculation

Table 1 shows that none of the series is stationary based on this test. Furthermore, we examined the PPP-hypothesis using nonlinear unit root test proposed by Kapetanios et al. (2003). Results of Kapetanios et al.'s (2003) test are reported in Table 2 for de-meaned and de-meaned and de-trended data series.

Table 2: Results of nonlinear unit root analysis

Country	De-meaned (k)	De-meaned and De-trended (k)
1991.1-2011.2		
USDMEDIU	-0.002268868 (7)	-0.025735408 (8)
1999.1-2011.2		
USDMEDIU	-0.008382158 (9)	-0.421911955 (9)
EUROMEDIU	-0.014006190 (7)	-0.228810851 (7)

Note: (1) Critical values are -3.48, -2.93 and -2.66 for de-meaned data series. (2) Critical values are -3.93, -3.40 and -3.13 for de-meaned and de-trended data series at 1%, 5% and 10% level of significance respectively. (3) "k" denotes lag length and selection is based on SIC.

Source: Author's calculation

It is evident from the Table 2 that when we did analysis with de-meaned data series and de-meaned and de-trended data series we do not find evidence for the support of PPP-hypothesis in any case. Next, we analyzed TAR unit root test proposed by Caner and Hansen (2001).

To test for the presence of nonlinearities and unit root hypothesis jointly in the bilateral real exchange rate, we have proceeded to test this joint hypothesis by using Caner and Hansen's (2001) nonlinear TAR unit root tests. The results from the Caner and Hansen (2001) test are presented in Tables 3–6. Tables 3 present the Wald test for the presence of non-linearity in the real exchange rate. We present the bootstrap critical values at conventional significance levels and bootstrap p-values are generated with 10,000 bootstrap replications for threshold variables (that is real exchange rate) of the form $Z_{t-1}= r_{t-1}- r_{t-m}$ for delay parameters *m* which varies from 1 to 12.[6] Since the parameters *m* is generally unknown, we have made *m* endogenous by selecting the least squares estimate of *m* that minimizes the residual variance following Caner and Hansen (2001). This means that we have selected level of *m* at which the value of W_t statistic is maximized. It is clear from table 1a that the W_t statistic is maximized for bilateral real exchange rate of dollar for the full period (1991 January to 2011 February) when $m = 9$. At this level results imply strong statistical evidence against the null hypothesis of linearity for the full period bilateral real exchange rate of Leu with US Dollar at the 2% significance level. Table 3b provides the Wald test results for the bilateral real exchange rate of Leu with Euro. In this case we find that the W_t statistic is maximized when m is 4 and the null hypothesis of linearity can be rejected at 2% level of significance. But in the sub sample of Leu-US dollar real exchange rate the W_t statistic is maximized when m=2 and we are able to reject the linearity null at 5% level of significance. The rejection of null linearity in all the three cases indicate that simple linear models are inappropriate, and therefore, for testing the PPP hypothesis in real exchange rate the TAR model is used.

Table 3: Wald tests for the presence of non-linearity in the real exchange rate

a: Wald test for threshold effect using fixed delay parameter

M	Wald statistics	Bootstrap critical values			Bootstrap p-value
		10%	5%	1%	
1	44.595540	36.319419	41.889784	55.476653	0.035900
2	41.388748	35.818122	41.714285	54.436628	0.050900
3	38.415509	35.584333	41.158710	55.904304	0.071000
4	35.260555	35.493320	41.166353	55.763322	0.102600
5	32.584798	35.702150	41.398657	54.652806	0.146400
6	38.677752	35.540388	41.403629	54.438463	0.069000
7	35.384525	35.884067	41.233403	54.571651	0.105300
8	31.474210	36.096984	41.254486	56.436384	0.177200
9	55.679117	36.359197	42.031991	57.652726	0.012700
10	54.351866	36.452053	42.465898	57.606411	0.013400
11	53.517241	36.277816	43.068178	57.629175	0.016000
12	54.483005	36.547001	42.342782	57.654987	0.013600

b: Wald test for threshold effect using fixed delay parameter

M	Wald statistics	Bootstrap critical values			Bootstrap p-value
		10%	5%	1%	
1	23.424463	25.990996	29.028058	36.301232	0.176600
2	27.380381	25.926821	28.818813	35.939401	0.071700
3	28.887457	25.895787	29.066847	36.340430	0.052300
4	35.067697	25.929809	28.976809	36.429076	0.013100
5	33.103060	26.109759	29.384880	36.064401	0.021000
6	34.216029	26.068531	29.153666	35.556336	0.013800
7	33.480580	26.036078	29.089001	36.172063	0.018400
8	31.243106	25.791797	29.010696	35.639764	0.031300

c: Wald test for threshold effect using fixed delay parameter

M	Wald statistics	Bootstrap critical values			Bootstrap p-value
		10%	5%	1%	
1	21.552671	25.234474	28.227341	34.220789	0.225300
2	29.709637	25.668814	28.595162	34.838252	0.038700
3	27.542444	25.848419	28.728831	34.798828	0.068200
4	29.016162	25.491871	28.474414	35.018501	0.043400
5	27.324366	25.427986	28.150604	33.677697	0.062000
6	20.501313	25.370666	28.204725	34.345439	0.288900
7	20.480425	25.265997	28.082668	34.292340	0.289200
8	17.745285	25.247998	27.926654	34.242460	0.474300

[6] Lag length i.e., m has been chosen 12 for full sample (period spanning from January 1991 to February 2011) and m = 8 has been chosen for the sub sample (period spanning from January 1999 to February 2011). Figures of Thresh hold regime plot are presented in the Appendix.

 ISSN 1927-033X

Where m denotes optimal delay Parameter. We set a maximum lag of 12 and base all our bootstrap tests on 10,000 replications.

In the next step we have attempted to explore the threshold unit root properties of the real exchange rate based on the R1T and R2T statistics for each delay parameter m, ranging from 1 to 12, paying particular attention to the results obtained for our preferred model. The R1T and R2T tests results, together with the bootstrap critical value at the conventional levels of significance and the bootstrap p-value, are reported in Tables 4. "Section a" in Table 4 provides the unit root results for Leu-Dollar real exchange rate for the full sample. Here we are able to reject the unit root null at 1% significance on the preferred model (i.e., for the model when m = 9). For the models from m = 5 to 12, we are able to reject the unit root null either at 5% or at 10% level of significance.

Table 4: One and two sided unit root test results for Leu-Dollar and Leu-Euro

a: One and two sided unit root test results for Leu-Dollar real exchange rate

m	R_{1T}					R_{2T}				
	Wald statistics	**Bootstrap values**		**critical**	**Bootstrap p-value**	**Wald statistics**	**Bootstrap values**		**critical**	**Bootstrap p-value**
		10%	**5%**	**1%**			**10%**	**5%**	**1%**	
1	6.94	10.52	13.43	20.14	0.25	6.94	10.91	13.81	20.69	0.27
2	9.09	10.51	13.34	20.54	0.14	9.09	10.96	13.76	20.73	0.16
3	5.81	10.55	13.41	19.94	0.33	5.81	10.99	13.78	20.13	0.36
4	9.23	10.84	13.59	20.60	0.14	9.23	11.25	13.86	20.90	0.15
5	10.88	10.55	13.38	20.31	0.09	10.88	11.00	13.75	20.63	0.10
6	15.15	10.82	13.88	20.98	0.03	15.15	11.21	14.10	21.16	0.03
7	14.54	11.03	14.02	21.80	0.04	14.54	11.40	14.29	21.96	0.04
8	13.73	10.94	13.97	22.01	0.05	13.73	11.33	14.19	22.22	0.05
9	20.68	11.22	14.31	22.62	0.01	20.68	11.52	14.49	22.62	0.01
10	18.77	11.10	14.17	22.58	0.02	18.77	11.45	14.55	22.61	0.02
11	18.75	11.21	14.20	23.49	0.02	18.75	11.52	14.36	23.57	0.02
12	22.55	11.52	14.79	23.24	0.01	22.55	11.82	14.98	23.40	0.01

Table 4b: One and two sided unit root tests for Leu-Euro real exchange rate

m	R_{1T}					R_{2T}				
	Wald statistics	**Bootstrap values**		**critical**	**Bootstrap p-value**	**Wald statistics**	**Bootstrap values**		**critical**	**Bootstrap p-value**
		10%	**5%**	**1%**			**10%**	**5%**	**1%**	
1	5.12	9.69	11.95	17.44	0.35	5.13	10.20	12.49	18.08	0.39
2	11.09	9.88	12.02	17.77	0.07	11.72	10.31	12.57	18.44	0.06
3	10.15	9.84	12.42	17.64	0.09	10.15	10.40	12.88	18.44	0.10
4	10.71	10.08	12.70	18.04	0.08	10.71	10.65	13.14	18.44	0.09
5	21.61	10.26	12.92	18.51	0.00	21.61	10.82	13.28	18.70	0.00
6	18.38	10.45	12.96	18.66	0.01	18.38	10.92	13.35	18.90	0.01
7	19.53	10.64	13.23	19.185	0.00	19.53	11.07	13.61	19.52	0.01
8	22.77	10.66	13.16	18.71	0.00	22.77	11.00	13.58	19.09	0.00

Table 4c: One and two sided unit root test result for Leu-Dollar (sub-period) real exchange rate

m	R_{1T}					R_{2T}				
	Wald statistics	**Bootstrap values**		**critical**	**Bootstrap p-value**	**Wald statistics**	**Bootstrap values**		**critical**	Bootstrap p-value
		10%	5%	1%			10%	5%	1%	
1	6.77	9.52	11.89	17.43	0.23	6.77	9.99	12.51	17.95	0.25
2	8.04	9.72	12.05	17.31	0.16	8.04	10.15	12.49	18.15	0.18
3	12.15	9.79	12.25	17.73	0.05	12.15	10.44	12.74	18.34	0.06
4	3.63	10.02	12.58	18.03	0.53	3.63	10.70	13.04	18.59	0.58
5	3.685	10.18	12.75	18.47	0.53	3.68	10.77	13.28	18.93	0.57
6	5.27	10.30	12.66	17.98	0.37	5.27	10.77	13.17	18.42	0.41
7	10.31	10.31	12.67	18.08	0.10	10.31	10.77	13.16	18.58	0.11
8	4.95	10.48	12.89	18.61	0.40	4.95	10.86	13.22	19.03	0.44

 ISSN 1927-033X

Where m denotes optimal delay Parameter. We set a maximum lag of 12 and base all our bootstrap tests on 10,000 replications.

The unit root null can be rejected at 10% level of significance for the Leu-Euro real exchange rate variable for the preferred model when m = 4, as shown in "Section b" in Table 4. For the model with m = 2 and 3 also we are able to reject the unit root null at 10%, but when we use m more than 5, 6, 7 and 8, we are getting more powerful evidence against the unit root i.e., we can reject the unit root null at 1% level of significance. On the contrary, for the Leu-Dollar sub-period, we are unable to reject the unit root null for the preferred model when m = 2. The null hypothesis of unit root is rejected in the case of model with m = 3 at 5% level of significance. To sum up, our results provide evidences of stationarity property of Leu-Euro and Leu-Dollar real exchange rates. Furthermore, since the one-sided test statistic of R1T and R2T are unable to distinguish the complete and partial unit root in real exchange rate; we examine evidence on the unit root hypothesis through partial unit root by examining the individual t-statistics, t1 and t2.

The results are reported in Table 5. It is clear from "Section a" in Table 5 that the Leu-Dollar real exchange rate has a unit root in the first regime since we are unable to reject the unit root null in preferred model when m = 9. But in regime two, we are able to reject the unit root null at 5% level of significance. However, for the Leu-Euro real exchange rate the null can be rejected for first regime at 5% level, but for the second regime we are unable to reject the null. For the sub-period Leu-Dollar real exchange rate in the first regime the variable posses a unit root. In the second regime the unit root hypothesis can be rejected at 10% level.

Sections a, b, and c in Table 6 provide the least squire estimate of the threshold model and the point estimate of the threshold $\hat{\lambda}$ for the preferred value of the delay parameter *m*. For the Leu-Dollar full sample case the preferred m is 9 and the $\hat{\lambda}$ is 0.580655.[7] It can be interpreted as the TAR model splits the regression in to two regimes depending on whether the 9 month change in real exchange rate lies below or above the $\hat{\lambda}$ 0.580655.

The first regime occurs when $Z_{t-1}<0.580655$, i.e., the change in real exchange rate of Leu with US Dollar is less than 84.72% for a period of 9 months. The threshold value, $\hat{\lambda}$, for the Leu-Euro real exchange rate and the Leu-Dollar real exchange rate for our preferred models (i.e., model 4 and model 2) for the sub period are 0.069851 and -0.015967 respectively. The first regime in case of Leu-Euro real exchange rate occurs when $Z_{t-1}<0.069851$, i.e., the change in real exchange rate of Leu with Euro is less than 74.45% for a period of 4 months. The first regime occurs when $Z_{t-1}<-0.015967$, i.e., the change in real exchange rate of Leu with US Dollar is less than 32.116% for a period of 2 months.

[7] Figures of Thresh hold regime plot are presented in the Appendix for better understanding.

 ISSN 1927-033X

Table 5: Partial unit root results for the full sample Leu-Dollar, Leu-Euro and Leu-Dollar sub sample

a: Partial unit root results for the full sample Leu-Dollar exchange rate

m	t_1^2 Statistic					t_2^2 Statistic				
	***t*-Statistic**	**Bootstrap values**		**critical**	**Bootstrap p-value**	***t*-Statistic**	**Bootstrap values**		**critical**	**Bootstrap p-value**
		10 %	5%	1%			10 %	5%	1%	
1	2.29	2.59	3.02	3.87	0.15	1.29	2.61	3.08	3.99	0.44
2	2.15	2.56	2.97	3.82	0.18	2.11	2.63	3.09	4.12	0.19
3	2.23	2.58	2.99	3.77	0.16	0.92	2.63	3.09	4.16	0.56
4	2.31	2.60	3.02	3.85	0.15	1.97	2.65	3.12	4.10	0.23
5	2.13	2.59	3.03	3.85	0.19	2.52	2.63	3.09	4.07	0.11
6	1.71	2.58	3.05	3.87	0.29	3.49	2.64	3.14	4.16	0.02
7	2.59	2.63	3.07	3.87	0.10	2.79	2.65	3.16	4.24	0.08
8	2.23	2.61	3.07	3.93	0.17	2.96	2.64	3.15	4.28	0.06
9	2.61	2.62	3.09	3.93	0.10	3.72	2.65	3.21	4.23	0.02
10	2.58	2.66	3.06	3.94	0.10	3.48	2.66	3.20	4.34	0.03
11	2.87	2.67	3.09	3.94	0.07	3.24	2.63	3.19	4.42	0.04
12	2.30	2.68	3.09	3.97	0.169	4.15	2.71	3.28	4.42	0.01

b: Partial unit root results for the Leu-Euro exchange rate

m	t_1^2 Statistic					t_2^2 Statistic				
	***t*-Statistic**	**Bootstrap values**		**critical**	**Bootstrap p-value**	***t*-Statistic**	**Bootstrap values**		**critical**	**Bootstrap p-value**
		10 %	**5%**	**1%**			**10 %**	**5%**	**1%**	
1	2.24	2.52	2.93	3.69	0.15	0.31	2.52	2.93	3.73	0.72
2	3.33	2.55	2.96	3.70	0.02	-0.79	2.51	2.96	3.73	0.92
3	2.30	2.58	2.95	3.69	0.15	2.21	2.51	2.93	3.75	0.15
4	3.09	2.58	3.01	3.76	0.04	1.08	2.52	2.94	3.82	0.48
5	4.53	2.59	3.01	3.79	0.00	1.03	2.56	2.99	3.82	0.51
6	3.68	2.61	3.03	3.77	0.01	2.20	2.55	2.99	3.82	0.17
7	4.14	2.64	3.07	3.85	0.00	1.54	2.60	3.02	3.88	0.35
8	4.41	2.67	3.08	3.82	0.00	1.82	2.58	2.99	3.87	0.26

We set a maximum lag of 12 and base all our bootstrap tests on 10,000 replications.

c: Partial unit root results for the Leu-Dollar sub sample

m	t_1^2 Statistic					t_2^2 Statistic				
	***t*-Statistic**	**Bootstrap values**		**critical**	**Bootstrap p-value**	***t*-Statistic**	**Bootstrap values**		**critical**	**Bootstrap p-value**
		10 %	**5%**	**1%**			**10 %**	**5%**	**1%**	
1	0.95	2.52	2.92	3.68	0.53	2.42	2.50	2.88	3.64	0.11
2	1.08	2.56	2.97	3.70	0.49	2.62	2.52	2.90	3.69	0.08
3	1.58	2.55	2.94	3.66	0.33	3.10	2.54	2.95	3.76	0.03
4	0.82	2.61	3.00	3.78	0.57	1.71	2.55	2.96	3.74	0.29
5	0.40	2.63	3.03	3.83	0.70	1.87	2.53	2.97	3.71	0.24
6	0.18	2.62	3.02	3.74	0.75	2.28	2.56	2.97	3.74	0.14
7	0.38	2.64	3.03	3.76	0.71	3.18	2.57	2.99	3.78	0.03
8	2.03	2.67	3.09	3.84	0.22	0.91	2.55	2.96	3.64	0.56

We set a maximum lag of 12 and base all our bootstrap tests on 10,000 replications.

Table 6: Partial unit root results

a: Partial unit root results-complete data points

Regressors	*Estimates, m=9,* $\hat{\lambda}$ **= 0.580655**				Test for equality of individual coefficients	
	$Z_{t-1} < \hat{\lambda}$		$Z_{t-1} > \hat{\lambda}$		Wald statistics	Bootstrap p-value
	Estimates	S E	*Estimates*	S E		
Constant	**0.01**	**0.00**	**-0.00**	**0.02**	**0.23**	**0.83**
Y(t-1)	-0.01	0.00	-0.02	0.01	5.05	0.28
DY(t-1)	0.81	0.08	0.19	0.11	20.80	0.00
DY(t-02)	-0.27	0.10	0.01	0.09	4.19	0.16
DY(t-03)	0.37	0.10	-0.04	0.04	13.88	0.01
DY(t-04)	-0.16	0.11	-0.06	0.04	0.75	0.58
DY(t-05)	0.19	0.11	-0.05	0.04	4.34	0.18
DY(t-06)	-0.30\	0.11	0.02	0.04	7.67	0.09
DY(t-07)	0.13	0.10	0.03	0.04	0.67	0.59
DY(t-08)	-0.03	0.10	0.13	0.04	4.54	0.16
DY(t-09)	0.08	0.09	-0.05	0.04	1.94	0.33
DY(t-10)	-0.10	0.08	-0.02	0.03	1.05	0.49
DY(t-11)	0.12	0.07	-0.01	0.03	2.39	0.30
DY(t-12)	-0.06	0.06	-0.04	0.03	0.16	0.79

b: Partial unit root results

Regressors	*Estimates, m=4,* $\hat{\lambda}$ **= 0.069851**				Test for equality of individual coefficients	
	$Z_{t-1} < \hat{\lambda}$		$Z_{t-1} > \hat{\lambda}$		Wald statistics	Bootstrap p-value
	Estimates	S E	*Estimates*	SE		
Constant	**0.04**	**0.01**	**0.03**	**0.02**	**0.09**	**0.89**
Y(t-1)	-0.03	0.01	-0.01	0.01	0.84	0.64
DY(t-1)	0.51	0.12	0.22	0.15	2.16	0.36
DY(t-02)	0.00	0.13	-0.02	0.14	0.02	0.94
DY(t-03)	0.17	0.13	-0.12	0.15	2.26	0.36
DY(t-04)	-0.12	0.12	0.03	0.18	0.49	0.67
DY(t-05)	-0.01	0.10	-0.26	0.17	1.58	0.45
DY(t-06)	0.08	0.10	-0.43	0.18	5.96	0.12
DY(t-07)	-0.03	0.09	0.16	0.16	1.01	0.52
DY(t-08)	0.21	0.10	-0.26	0.13	8.73	0.05

c: Partial unit root results

Regressors	*Estimates, m=2,* $\hat{\lambda}$ **= -0.015967**				Test for equality of individual coefficients	
	$Z_{t-1} < \hat{\lambda}$		$Z_{t-1} > \hat{\lambda}$		Wald statistics	Bootstrap p-value
	Estimates	SE	*Estimates*	SE		
Constant	**0.02**	**0.04**	**0.04**	**0.01**	**0.20**	**0.86**
Y(t-1)	-0.03	0.03	-0.04	0.01	0.00	0.98
DY(t-1)	-0.01	0.18	0.48	0.11	5.18	0.14
DY(t-02)	-0.46	0.22	-0.35	0.12	0.21	0.77
DY(t-03)	0.19	0.17	0.36	0.11	0.66	0.61
DY(t-04)	-0.07	0.14	-0.02	0.13	0.08	0.86
DY(t-05)	-0.10	0.14	0.45	0.12	8.32	0.05
DY(t-06)	0.01	0.15	-0.54	0.12	8.09	0.07
DY(t-07)	0.05	0.13	0.07	0.13	0.01	0.96
DY(t-08)	-0.15	0.13	0.03	0.10	1.06	0.53

Where m denotes optimal delay Parameter. We set a maximum lag of 12 and base all our bootstrap tests on 10,000 replications.

5. Discussions and conclusions

We have examined the relevance of PPP in Romanian context by checking the nonlinearity and mean reversion in the data generating process of Leu-US Dollar real exchange rate for the period 1991 January to 2011 February, Leu-Euro real exchange rate, and Leu-Dollar real exchange rate for the 1999 January to 2011 February period. The Wald test results confirmed the presence of nonlinearity in the bilateral real exchange rates of Romanian Leu. The KSS (2003) test result indicated presence of unit root and hence provide the evidence against the PPP hypothesis for Romania. This output confirm the results of Choudhry (1999), Barlow (2003), Sideris (2006), and Telatar and Hasanov (2009), which validate the hypothesis of PPP in the case of Romania. By contrast, Christev and Noorbakhsh (2000), Beirne (2007), Acaravci and Ozturk (2010), and Aslan and Kula (2011) obtained different finding as results of the investigated period (until 2009, only), type of assumption (linear/nonlinear) and/or structural break approach followed.

However, the second set of main test (i.e., the Caner and Hanson test) indicates the presence of mean reversion in the full sample Leu-Dollar real exchange rate and the Leu-Euro real exchange rates. The series of Leu-Dollar exchange rates has a unit root in the first period, while it is mean reverting in the second period. Differently, the Leu-Euro real exchange rates are mean reverting in the first regime, while in the second regime it has a unit root.

Such a mixed results partially confirm the findings of the literature, which claim or not the evidence of mean reversion hypothesis. This partial confirmation has the origins in the Caner and Hanson's (2001) tool, which tests the presence of both nonlinearities and unit root hypothesis in the bilateral real exchange rate. Additionally, in the case of Romania, our analysis covers a long period of time, from January 1991 to February 2011, with monthly frequency.

Regarding the policy implications, our paper reinforces the importance of both trade and exchange rate policies. These implications suppose that the Romanian government should be very careful in the areas of trade and monetary policies, as the PPP hypothesis hold better during the period when the trade is more open and the country partners are much closed. These happen because the trade barriers and increase of transportation costs put a pressure on transaction and real exchange rates. Moreover, the nonlinearity should be also carefully treated. On the real exchange area, the governmental interventions should follow prudential adjustments, because the exchange market can have an aggressive reaction in such conditions.

Given this policy implications, our investigation can represent a very good starting point for further analyses related to the concrete type of governmental policies should be made for adjusting the amplitude of real exchange rates' processes under nonlinearity conditions.

 ISSN 1927-033X

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 ISSN 1927-033X

Appendix

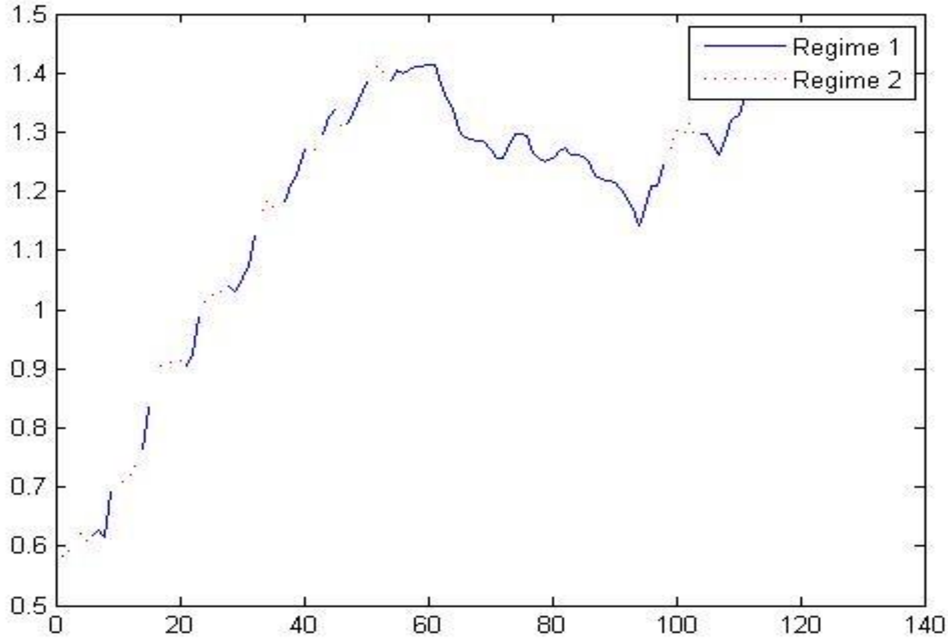

Figure A1: Thresh hold regime plot for full sample Leu-Dollar real exchange rates

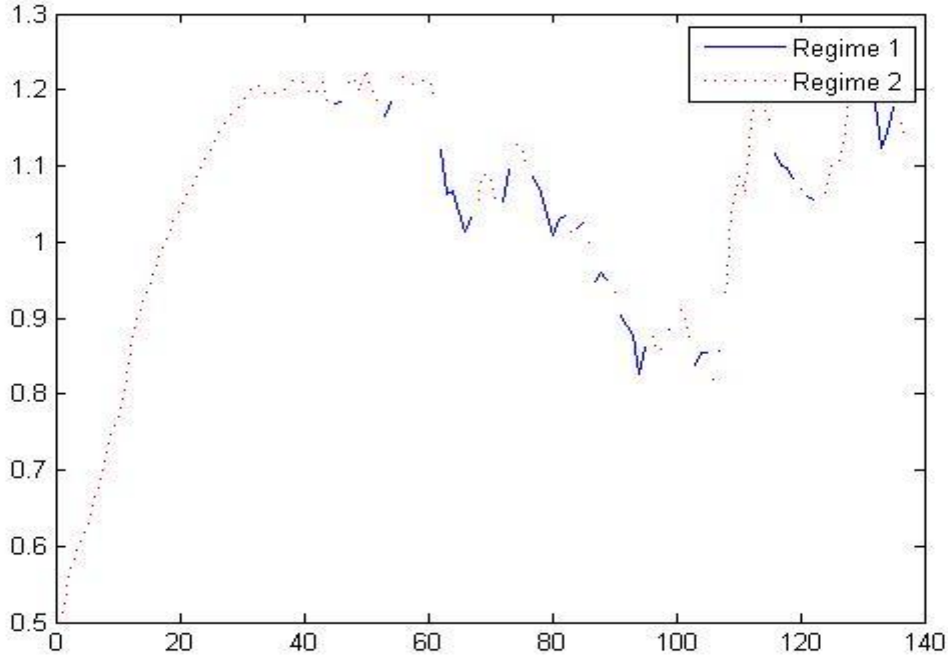

Figure A2: Thresh hold regime plot for full sample Leu-Euro real exchange rates

 ISSN 1927-033X

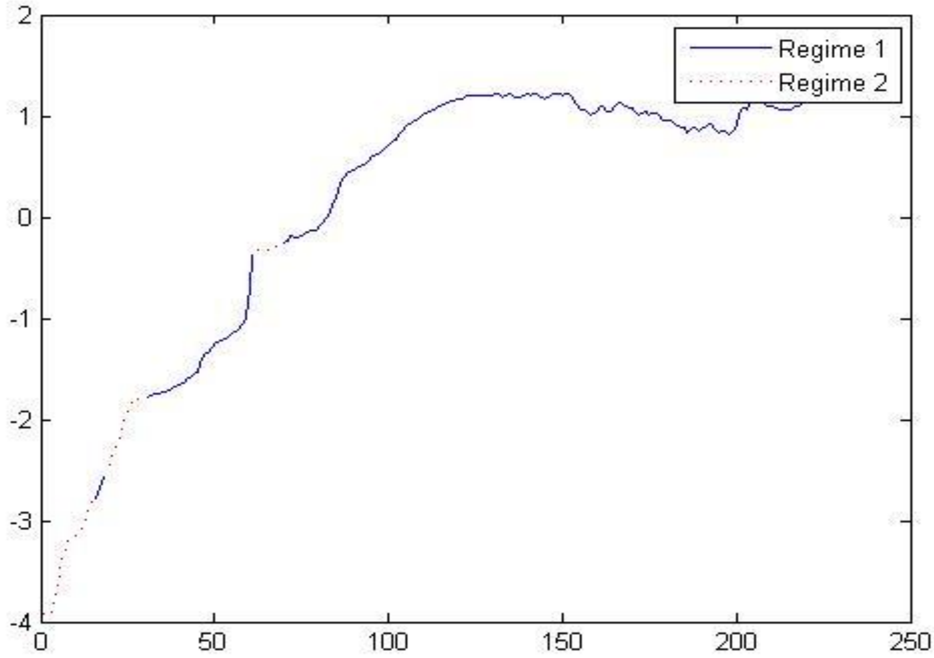

Figure A3: Thresh hold regime plot for sub sample Leu-Dollar real exchange rates

 ISSN 1927-033X