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Examination of Purchasing Power Parity Hypothesis: Evidence from Unit Root and Cointegration analysis of dinar-euro and dinar-dollar exchange rates[2]

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Abstract: *The paper shows the results of an empirical analysis of the relative variant of purchasing power parity (PPP) for dinar-euro and dinar-dollar exchange rates. The study was conducted for the period January 2007 – August 2013 and involved testing of the empirical foundation of strong and weak PPP forms. The first part of the strong PPP form testing comes down to examination of non-stationarity of dinar-euro and dinar-dollar real exchange rates by use of standard unit root tests (ADF, PP, KPSS, DF-GLS). Considering that the results obtained by different tests differ, the final conclusion about the non-stationarity of the series has been reached on the basis of their correlogram and ordinary and partial autocorrelation functions. Having in mind reduced power and bias of standard unit root tests in the presence of structural breaks, the initial findings have been checked by use of the LS (Lee and Strazicich) unit root test for models A and C with one and two structural breaks. The findings confirm the non-stationarity of the real exchange rates. Johansen and Engle-Granger cointegration tests have been used to test weak PPP form, so as to examine the presence of a long-run equilibrium relationship between the nominal exchange rates and inflation differentials, i.e. the corresponding price indices. The test results show that the series are not cointegrated. The non-stationarity of the real exchange rates and the lack of cointegration between the series indicate that PPP, regardless of the form, has no empirical support. Such results do not come as surprise considering that the*

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analysis refers to a relatively short period of time, and the fact that even the strongest supporters of PPP have acknowledged that PPP is not a short-run relationship.

Key words: *Purchasing power parity, real exchange rate, nominal exchange rate, unit root tests, cointegration.*

Ispitivanje hipoteze pariteta kupovnih snaga: rezultati testova jediničnog korena i kointegracione analize na dinar/evro i dinar/dolar deviznom kursu

Apstrakt: *U radu smo prikazali rezultate empirijske analize relativne varijante pariteta kupovnih snaga (PKS) za dinar-evro i dinar-dolar devizni kurs. Istraživanje je sprovedeno za period januar 2007-avgust 2013. i obuhvata testiranje empirijske zasnovanosti snažne i slabe forme PKS. Prvi deo testiranja snažne forme PKS svodi se na ispitivanje nestacionarnosti vremenskih serija realnog deviznog kursa dinara prema evru i dolaru primenom standardnih testova jediničnog korena (ADF, PP, KPSS, DF-GLS). Budući da se dobijeni rezultati razlikuju od testa do testa, konačan zaključak o nestacionarnosti pomenutih serija izveden je na osnovu njihovog korelograma i običnih i parcijalnih autokorelacionih funkcija. Imajući u vidu smanjenu moć i pristrasnost standardnih testova jediničnog korena u prisustvu strukturnih lomova, prethodne nalaze proverili smo upotrebom LS (Lee and Strazicich) testa jediničnog korena za modele A i C sa jednim i dva strukturna loma. Nalazi do kojih smo došli potvrdili su nestacionarnost realnih deviznih kurseva. Testiranje slabe forme PKS sprovedeno je primenom Johansenovog i Engl-Grejndžerovog testa kointegracije s ciljem da se ispita prisustvo dugoročne ravnotežne relacije između nominalnih deviznih kurseva i inflacionih diferencijala, odnosno odgovarajućih indeksa cena. Rezultati testiranja pokazuju da pomenute serije nisu kointegrisane. Nestacionarnost realnih kurseva i odsustvo kointegracije između pomenutih serija pokazuju da PKS, bez obzira na formu, nema empirijsku podršku. Ovakvi rezultati ne iznenađuju, budući da se analiza odnosi na prilično kratak period, a da su i najtvrdokorniji zagovornici PKS prihvatili da PKS nije kratkoročna relacija.*

Ključne reči: *paritet kupovnih snaga, realni devizni kurs, nominalni devizni kurs, testovi jediničnog korena, kointegracija.*

1. Introduction

One of the essential elements of the exchange rate theory is Purchasing Power Parity (PPP), being a benchmark used in evaluation of exchange rates in policy discussions (one of the essential theoretical concepts in determina-

tion of long-run real exchange rates), and a leading topic in widely conducted economics-related discussions and researches. Although the PPP theory is one of the most extensively tested hypotheses in the international finance literature, dating as far back as the time of John Stuart Mill, Viscount Goschen, Alfred Marshall and Ludwig von Mises, more recent history of PPP is linked to a debate on how to restore the world financial system after its collapse during the World War I (Rogoff, 1996, p. 648). Before the World War I, national currencies had been convertible to gold at fixed rate (gold standard), meaning that one currency was exchanged for another at an exchange rate simply derived from the current gold standard. The break out of the World War I led to abandoning of the gold standard due to the fact that many countries endeavored to gain seigniorage revenues, implicitly leading to devaluation of their currencies. The end of the war re-raised the question of re-establishing an exchange rate system in such a way to minimise distortion of prices and government finances (Rogoff, 1996, p. 648). A simple return to the pre-war exchange rate system was not possible considering that the countries experienced highly different inflation rates. The first attempts to treat PPP as a practical empirical theory were made by the famous Swedish economist Gustav Cassel as far back as in 1921 and 1922 (Rogoff, 1996, pp. 648-649). In particular, Cassel suggested calculating cumulative CPI from the beginning of 1914 and then determining exchange rates in such a way to cover inflation differentials, therefore assuring maintenance of PPP. The PPP hypothesis may be used in multiple ways, from determining the initial value of a nominal exchange rate for a newly created country to long-term predictions of real exchange rate and GDP comparison between countries.

This research aims to evaluate the empirical sustainability of the relative variant of the PPP theory in relation to the European Monetary Union (EMU) and the United States of America (USA) as benchmark countries. The initial hypothesis that was tested was that there is no proof of empirical sustainability of the PPP theory during the period between January 2007 and August 2013.

The paper consists of seven parts. The introduction provides a short history and explanation of relevance of the PPP hypothesis. The second part represents an overview of the most important papers dealing with the observed phenomenon. Methodological framework for the research is found in the third part, while the fourth one provides for basic information about data used during the analysis. The results of the empirical research are presented in the fifth part, with the sixth one left for the most important conclusions. At the end of the paper is the seventh part which contains the reference list.

2. Literature review

With implementation of floating exchange rates, interest in examination of the PPP theory grew enormously. As previously mentioned, that made the PPP theory one of the most extensively tested hypotheses in international finance literature. Acaravci and Ozturk (2010) investigated the empirical foundation of the PPP for 8 transition countries (Bulgaria, Croatia, Czech Republic, Hungary, Macedonia (FYR), Poland, Romania and Slovak Republic) during the period between January 1992 and January 2009, using four unit root tests (ADF, KPSS, Lee and Strazicich with one and two structural breaks). The results of testing non-stationarity of real exchange rate obtained by using unit root tests without structural breaks (ADF and KPSS) show that real exchange rate is a non-stationary time series, therefore fairly effectively disputing the PPP hypothesis. When using unit root tests with structural breaks (Lee – Strazicich model A and C) the findings show that the PPP hypothesis can only be acceptable for Bulgaria and Romania. In other words, testing non-stationarity of real exchange rate by use of four types of unit root tests brings us to the conclusion that the real exchange rate is a non-stationary time series for 6 transition countries, i.e. that the PPP hypothesis is not sustainable, not even in the long run. Having in mind that the results presented provide very little evidence of the PPP theory sustainability in the long run, we can conclude that the PPP hypothesis remains a fairly controversial subject. Real exchange rate is generally a non-stationary series and, in the long run, it does not converge towards a long run equilibrium set by the PPP theory. As possible explanations for the observed deviations from the PPP theory, Acaravci and Ozturk mention foreign exchange market interventions, productivity shocks, imbalances in public finances, existence of non-tradable goods and services, etc.

Kasman, Kasman, and Ayhan (2010) examined validity of the PPP theory on a sample of 14 countries, 11 of which belong to the group of Central and East European transition countries, while the remaining three (Cyprus, Malta, and Turkey) are, in fact, market economies. The analysis used the Lagrange multiplier (LM) unit root test without structural breaks (Schmidt-Phillips Test) and with one and two structural breaks (Lee – Strazicich model C). The studies conducted on USD and DM based real exchange rate time series, by use of the LM unit root test without structural breaks, show that, in most of the cases, the sustainability of the PPP hypothesis cannot be proven, except for Romania in case of USD-based real exchange rates and for Romania and Slovakia in case of DM-based real exchange rates. Still, use of the LM unit root test with one and two structural breaks reveals that the PPP hypothesis is sustainable for Romania and Turkey in case of USD−based real exchange rates, and for Bulgaria, Croatia, Cyprus, Estonia, Romania, Slovakia, Slovenia and Turkey in case of DM−based real exchange rates. Estimated half-life of a

shock to the real exchange rate ranges from 1.25 to 2.72 years (1.9 years on average). Therefore, the evidence supporting the PPP theory is quite strong for 8, out of 14 countries in total, in case of DM-based real exchange rates.

While examining the PPP theory for 12 new EU member states using the Johansen cointegration methodology, in the presence of a structural break, in May 2004, for 10 countries that had just joined the EU, Koukouritakis (2009) discovered the presence of a long-run equilibrium relationship between the nominal exchange rate and harmonised consumer price indices, but only for Bulgaria, Cyprus, Romania and Slovenia. For the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland and Slovakia, the PPP hypothesis is not sustainable even in the long run. As a possible explanation for the results, Koukouritakis mentions fixed exchange rate between national currencies and euro that prevents the nominal exchange rate to cover inflation differential in relation to the eurozone.

Baharumshah, Tze-Haw and Fountas (2008) analysed the dynamics of real exchange rate for six East-Asian countries in relation to the United States and Japan. All countries within the sample, except Singapore, experienced financial crisis in the autumn of 1997. Following the ARDL cointegration procedure, using time series with monthly frequency for the period from 1976 to 2002, they tested long term empirical foundation of the PPP theory. The research results provided no evidence for the weak form of PPP in the pre-crisis period, but they provided very strong evidence for the post-crisis period. Estimated persistence of PPP deviations (half-lives) for the post-crisis period is less than 7 months, with very narrow confidence intervals and an upper bound of 1 year or less in most countries.

Testing the PPP hypothesis for the Czech Republic, Hungary and Slovenia in comparison with Austria, Germany, France and Italy, based on time series from January 1992 to December 2006, failed to reveal evidence of empirical sustainability of the PPP theory for any of the three analysed countries (Beko & Boršič, 2007). Although the Johansen test of cointegration confirmed the presence of a long-run equilibrium relationship between the nominal exchange rate and relevant consumer price indices, signs and statistical insignificance of estimated cointegrating coefficients contradict the assumptions of the weak version of PPP.

Lopez and Papell (2007) tested validity of the PPP within the eurozone and between the eurozone and its main partners using econometric techniques for panel data analysis. The aim of the research was to provide answers to two main questions: (a) whether the evidence of the PPP hypothesis validity are stronger within the eurozone or between the eurozone and other countries, (b) whether the process of convergence towards PPP has started by creation of the eurozone in 1999 or perhaps earlier. The findings reached by Lopez and Papell revealed that the convergence within the eurozone is stronger than

between it and other partners. The convergence intensity within the eurozone greatly varies with change of reference currency, with more convincing evidence in case of big countries such as France, Germany, and Italy. When USD is used as reference currency, strong evidence supporting the PPP hypothesis are typical only for the panel of eurozone member states. On the other hand, the authors make a sharp distinction between the start of the PPP convergence process and the results confirming it. In fact, in both cases, within the eurozone and between it and other countries, an absolute rejection of unit-root null hypothesis generally starts between 1996 and 1999. However, the process of PPP convergence started earlier, generally in 1992 or 1993, with the EMS currency crisis, signing the Maastricht Treaty and official creation of a common European market.

Furthermore, Bahmani-Oskooee and Brooks (n.d.) tested sustainability of the PPP hypothesis on a sample of 20 developing countries using a method proposed by Perron (1994) that enables modelling of structural breaks, i.e. use of a model where both the slope and intercept are allowed to change. The authors have managed to find evidence of a modified version of PPP (quasi PPP) in nine countries.

Villeneuve and Handa (2006) used cointegration and fractional cointegration techniques in order to test empirical foundation of the PPP theory between the Canadian and the US currencies during the floating exchange rate period from 1974 to 2001. The authors attempted to answer the question whether residual of cointegrating equations (deviations from the cointegrating relationship) possess long memory, as well as whether they can be well described by a fractionally cointegrated process. The Johansen cointegration test has shown that nominal exchange rate and relevant price indices are cointegrated, i.e. that there is evidence of empirical foundation of the PPP in the long run. However, Villeneuve and Handa's findings indicate the fact that deviations from the cointegrating relationship do not follow a fractionally cointegrated stationary process, meaning that the PPP hypothesis, even in the long run, is poorly sustainable, at best.

Giannellis and Papadopoulos (2006) analysed validity of the PPP hypothesis for 4 selected CEEC (Czech Republic, Hungary, Poland and Slovak Republic) in relation to euro and USD as reference currencies. Using univariate unit root tests as well as a multivariate cointegration test, the authors have discovered a pretty strong empirical evidence of the PPP theory. Furthermore, any impossibility to accept the PPP hypothesis cannot be attributed to the presence of structural breaks, except in case of the Czech Republic/EUR. Reviewing complete results, Giannellis and Papadopoulos found evidence of strong-form PPP in 6 out of the 8 cases, while for the remaining two they managed to find a weak-form PPP.

Researching the PPP hypothesis on a sample of 17 European economies in transition, in relation to USD, by use of the Johansen cointegration test and Larsson, Lyhagen and Lothgren (2001) panel cointegration technique, Sideris (2006) discovered the presence of long run equilibrium relations but the coefficients of the estimated cointegrating vectors violate the symmetry and proportionality.

Solakoglu (2006) also tested the PPP hypothesis for transition economies using econometric techniques for panel data analysis. The results obtained indicate empirical sustainability of PPP for selected transition economies suggesting a half-life of about one year. Furthermore, the analysis shows that the rate of convergence towards PPP is higher for 'more open' than for 'less open' transition economies.

Testing empirical validity of PPP for the German mark–Turkish lira real exchange rate, by use of threshold autoregression with a unit root (TAR) methodology that provides the possibility to simultaneously consider non-stationarity and non-linearity, has shown that PPP holds in one threshold regime but not in another, with stronger support in the most recent years (Alba & Park, 2005).

Payne, Lee and Hofler (2005) analysed sustainability of the PPP theory for Croatia. By testing non-stationarity of real effective exchange rates on a monthly basis, constructed using the producer price index and the retail price index, implementing the Lee-Strazicich (LS) LM unit root tests with one and two structural breaks, the authors have failed to find evidence supporting validity of PPP.

Koedijk, Tims and van Dijk (2004) investigated the relevance of the PPP hypothesis in two dimensions: (a) within the eurozone over the period 1973–2003 and (b) between euro and several other major currencies over the period 1979–2003, using univariate ADF and SUR ADF unit root tests with homogeneous and heterogeneous mean reversion coefficients. The first segment of the analysis, when restriction of homogeneity of mean reversion coefficient is imposed, provides evidence in favor of PPP. Leaving the assumption of homogeneousness of the mean reversion coefficient out, enables rejection of the null unit root hypothesis for Finland, France, and Spain, but evidence for PPP is weak for other countries. In the second part of the analysis, with the assumption of the homogeneous mean reversion coefficient, the authors find support for the PPP hypothesis. However, without the assumption, the unit root hypothesis is rejected only for the euro-Swiss franc rate.

Barlow and Radulescu (2002) tested strong-form PPP in respect to Romanian leu - US dollar using the Johansen, Engle-Granger, Philips-Hansen fully modified OLS and Autoregressive Distributed Lag (ARDL) methods to analyse cointegration. The results obtained provide evidence of the PPP hypothesis

sustainability. Having such findings in mind, appreciation of the leu-dollar real exchange rate during the transition period may be explained by the fact that, at the beginning of the transition process, leu was devalued beyond the equilibrium level and then it gradually appreciated converging towards its constant equilibrium level.

Estimating half-life of PPP deviations Murray and Papell (2002) explicitly account for serial correlation, sampling uncertainty and small sample bias. Calculating confidence intervals as well as point estimates for long-run and after 1973 time periods data they revealed that univariate methods provide virtually no information regarding the size of the half-lives.

3. Theoretical Methodology

Explaining the analytical framework relied on during the testing of empirical foundation of the PPP hypothesis must start with the essence and simple mathematical formulation of the PPP theory. A key building block of the theory is the "law of one price" (LOP) that basically boils down to the equation (Rogoff, 1996, p. 649):

$$P_i = EP_i^*, \tag{1}$$

where P_i, P_i^* and E respectively represent the price of good i in the home and foreign country and the nominal exchange rate defined as the home-currency price of foreign currency. In other words, according to the LOP, when prices are converted into the same currency, the same product should cost the same in different countries, i.e. the nominal exchange rate should be equal to relative price of good i. It is completely clear that the LOP is a theoretical fiction which, for various reasons (tariff and non tariff barriers, transport costs, insurance costs, existence of nontradable goods, different efficiency of intermediaries in distribution channels, different competition intensity, different consumption tax rates, etc.) is not sustainable in actual circumstances. However, there is evidence that, for some highly traded commodities, the law of one price does hold very well (Rogoff, 1996, p. 650).

Purchasing power parity theory requires a wider inflation differential indicator, not based on the difference in prices of one good, no matter which good is taken into consideration, but on the difference between selected baskets of goods, most often those used to calculate national consumer price indices (CPI). Therefore, the so called *absolute (CPI) purchasing power parity* can be expressed as (Rogoff, 1996, p. 650):

$$\sum P_i = E\sum P_i^*, \tag{2}$$

where the summation is done for goods and services covered by the CPI. There are several issues related to the *absolute (CPI) purchasing power parity* (Rogoff, 1996, p. 650). The first issue concerns the fact that even if the LOP was perfectly applicable, the equation (2) would not necessarily be applicable, unless if the baskets of goods used to calculate the national CPIs were identical. The second issue, particularly significant in time series analysis, is related to the question of how to handle the introduction of new goods into the market basket. The third issue is related to scarce availability of data necessary for empirical testing of the PPP hypothesis. In particular, data on prices are most often available as index numbers and not in the form of price levels nor market basket prices. Although CPIs indicate nothing about whether the relation (2) is valid for the base period, we can assume the dynamic character of the equation, i.e. that the relation (2) is valid for the average between the base and current period, which represents a *relative (CPI) PPP* presented by the following equation (Rogoff, 1996, p. 650):

$$\sum P_{it} / \sum P_{it-1} = \left(E_t / E_{t-1}\right)\left(\sum P_{it}^* / \sum P_{it-1}^*\right), \tag{3}$$

or:

$$\left(\sum P_{it} / \sum P_{it-1}\right) / \left(\sum P_{it}^* / \sum P_{it-1}^*\right) = \left(E_t / E_{t-1}\right). \tag{4}$$

Relative PPP, in accordance with the relation (4), requires equal nominal exchange rate index and inflation differential. From the equation (3) real exchange rate index may be expressed as:

$$R = \frac{\left(E_t / E_{t-1}\right)\left(\sum P_{it}^* / \sum P_{it-1}^*\right)}{\sum P_{it} / \sum P_{it-1}}. \tag{5}$$

Log-linearisation of equation (5) gives:

$$r = e - p + p^*, \tag{6}$$

where e, p and p^* represent natural logarithms of nominal exchange rate index, home CPI and foreign CPI, respectively.

Methods of testing the PPP hypothesis have evolved through the literature. Froot and Rogoff (1994, pp. 6-23) distinguish three different stages of PPP tests: (a) simple PPP as the null hypothesis, (b) the real exchange rate as a random walk and (c) cointegration of nominal exchange rate and price indices. Considering that the studies relying on the first approach did not show much interest in the properties of the error term, as in whether the slope coefficient was one, the techniques have, with the progress of econometric tests, been eliminated, so all of the approaches to PPP analysis come down to two basic ones: (a) applying a test for the non-stationarity of time series referring

to the real exchange rate and (b) identifying the long-term relationship between the nominal exchange rate and the relative prices.

Testing the non-stationarity of the real exchange rate is an approach based on applying unit root tests on a time series derived by the equation (6). The stationarity of the real exchange rates supports the PPP proposition and shows convergence of real exchange rates toward the long-run equilibrium level determined by PPP. Assuming the rejection of the hypothesis of a unit root, the real exchange rate will be mean-reverting, thus tending to revert real exchange rates to their PPP level in the long term (Koedijk et al., 2004, p. 1084). Such approach relates to testing the so called *strong form* of the PPP hypothesis (Acaravci & Ozturk, 2010, p. 192; Beko & Boršič, 2007, p. 423; Giannellis & Papadopoulos, 2006, p. 10; Sideris, 2006, pp. 137-138). In the first part of our research, standard unit root tests were used: augmented Dickey–Fuller (ADF), Phillips–Perron (PP), Kwiatkowski–Phillips–Schmidt–Shin (KPSS) and Ellioth-Rothenberg-Stock (DF-GLS). However, having in mind the defectiveness of standard unit root tests, due to the fact that, in the presence of a structural break, conventional testing procedures may erroneously fail to reject the unit root hypothesis, we have also used the endogenous one and two-break LM Lee and Strazicich (LS) unit root tests (Lee & Strazicich, 2003, 2004).

Identifying the cointegration relationship between the nominal exchange rate and the relative prices is based on testing stationarity of linear combination:

$$r = e - \alpha p + \alpha^{*} p^{*}, \tag{7}$$

for any constants α and α^{*}. Such methodological framework may be compatible with testing non-stationarity of the real exchange rate index (using the first approach). When the restriction of proportionality ($\alpha=\alpha^{*}=1$) is imposed to the equation (7), the testing of non-stationarity of linear combination (7) is identical to testing non-stationarity of the real exchange rate index (the strong form of the PPP).

Relaxing the model (7) from proportionality restrictions brings us to analysis of the *weak form of the* PPP hypothesis. That may be done in two ways. The first one means implementing symmetry restrictions ($\alpha=\alpha^{*}$) instead of proportionality restrictions. In this case, we are testing the existence of a cointegration between the nominal exchange rate index (e) and inflation differential (p/p^{*}), also known as bivariate tests (Froot & Rogoff, 1994, p. 18). The other way implies applying trivariate tests that place no restrictions on the coefficients in the equation (7). No matter which test is used (bivariate or trivariate) if the series are cointegrated, it is of essential importance to pay attention to signs/statistical significance of estimated cointegrating coefficients. This part of the research was performed using the Engle-Granger (EG) and the Johansen cointegration tests.

The possibility to exclude the proportionality restriction, i.e. why α and α^* do not have to be equal to one, can most simply be shown with the following model (Froot & Rogoff, 1994, pp. 18-19). Let us assume that the PPP hypothesis is sustainable for traded goods, i.e. that the following applies:

$$e = p^T - p^{*T} \tag{8}$$

where the superscript T is used to denote price indices for tradables, while * still has the same meaning. Furthermore, CPI is calculated as weighted average of traded and nontraded goods prices:

$$p = \gamma p^T + (1-\gamma) p^N, \tag{9}$$

$$p^* = \gamma^* p^{*T} + (1-\gamma^*) p^{*N}, \tag{10}$$

where the superscript N is used to denote price indices for nontraded goods to which PPP does not necessarily have to apply. Besides, it is assumed that there is a linear relationship between prices of nontraded and traded goods (Froot & Rogoff, 1994, p. 18):

$$p^N = \mu_0 + \phi p^T + \varepsilon \tag{11}$$

$$p^{*N} = \mu_0^* + \phi^* p^{*T} + \varepsilon^*, \tag{12}$$

where ε and ε^* are stationary processes. When the equations (11) and (12) are replaced in the equations (9) and (10) we get:

$$p = \gamma p^T + (1-\gamma)(\mu_0 + \phi p^T), \tag{13}$$

$$p^* = \gamma^* p^{*T} + (1-\gamma^*)(\mu_0^* + \phi^* p^{*T}), \tag{14}$$

which, after rearranging gives:

$$p = p^T[\gamma + \phi(1-\gamma)] + \mu_0 - \gamma\mu_0, \tag{15}$$

$$p^* = p^{*T}[\gamma^* + \phi^*(1-\gamma^*)] + \mu_0^* - \gamma^*\mu_0^*. \tag{16}$$

When, in the cointegration equation of the relation (7):

$$e = \alpha p - \alpha^* p^*, \tag{17}$$

we replace the equations (15) and (16) we will get:

$$e = \alpha\left\{p^T\left[\gamma + \phi(1-\gamma)\right] + \mu_0 - \gamma\mu_0\right\} - \\ - \alpha^*\left\{p^{*T}\left[\gamma^* + \phi^*\left(1-\gamma^*\right)\right] + \mu_0^* - \gamma^*\mu_0^*\right\}. \quad (18)$$

Having in mind that the sustainability of the PPP hypothesis for traded goods is a starting assumption of the model (eq. 8), equation (18) implies:

$$\alpha = 1/\left[\gamma + \phi(1-\gamma)\right], \quad (19)$$

$$\alpha^* = 1/\left[\gamma^* + \phi^*\left(1-\gamma^*\right)\right]. \quad (20)$$

The explanation as to why it is reasonable to reject the proportionality restriction ($\Phi = \Phi^* = 1$) comes down to the fact that there is a trend in the relative prices of traded and nontraded goods and errors in measuring nontraded goods prices (Froot & Rogoff, 1994, p. 19).

Finally, the algorithm of testing the PPP hypothesis incorporates several steps. The first step is to analyse the strong form of PPP and it involves testing the non-stationarity of the real exchange rate (eq. 6) by use of the aforementioned unit root tests. Should no evidence be found for the strong version of PPP, sustainability of the first variant of weak PPP (bivariate tests-symmetry restrictions) is tested, which comes down to testing the cointegration between the nominal exchange rate index (e) and inflation differential (p/p^*) using the Engl-Granger and Johansen test, provided that the estimated cointegration coefficient must be positive and statistically significant. If the series are not cointegrated, we move to the last step which involves analysing the weakest form of PPP, i.e. leaving out any restriction and testing cointegration between the nominal exchange rate index and relevant CPI (eq. 7), on condition that the elements of the estimated cointegration vector are statistically significant and with appropriate sign. The non-stationarity of the real exchange rate and the absence of cointegration between the series indicate that PPP has no empirical support. The testing was conducted using software packages EViews 5.1 and RATS 8.0.

4. Data

The empirical research used time series with monthly frequency for the period from January 2007 to August 2013. In particular, the basic time series used for calculating the rest of the series are the logarithm of the nominal dinar-euro and dinar-dollar exchange rate index (LNNEUR and LNNUSD) and the logarithm of the consumer price index in Serbia, EMU and USA (LNCPIS, LNHICPE and LNCPIUSA). All the time series have been created using January 2007 as the base period. On the basis of the above mentioned time series, series of real exchange rate indices in relation to both currencies have

been created (LNREUR and LNRUSD) in such a way that a value greater than one (i.e. greater than zero, when it comes to logarithmic transformations) corresponds to real exchange rate depreciation and vice versa. Finally, the inflation differential time series (LNDEUR and LNDUSA) were calculated by dividing Serbia's consumer price index by corresponding indices in EMU and USA.

The following table shows a list of variables and data sources while detailed information about the methods used in constructing the variables are available upon request.

Table 1. Variables used in the empirical research

Variable	Label	Source
The natural logarithm of the real dinar-euro exchange rate index	LNREUR	Author's calculation based on data downloaded from http://webrzs.stat.gov.rs/WebSite/public/ReportView.aspx; http://www.nbs.rs/internet/cirilica/index.html and http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes
Natural logarithm of the real dinar-USA dollar exchange rate index	LNRUSD	Author's calculation based on data downloaded from http://webrzs.stat.gov.rs/WebSite/public/ReportView.aspx; http://www.nbs.rs/internet/cirilica/index.html and http://www.bls.gov/cpi/data.htm
Natural logarithm of the nominal dinar-euro exchange rate index	LNNEUR	Author's calculation based on data downloaded from http://www.nbs.rs/internet/cirilica/index.html
Inflation differential between Serbia and EMU	LNDEUR	Author's calculation based on data downloaded from http://webrzs.stat.gov.rs/WebSite/public/ReportView.aspx and http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes
Natural logarithm of consumer price index in Serbia	LNCPIS	Author's calculation based on data downloaded from http://webrzs.stat.gov.rs/WebSite/public/ReportView.aspx
Natural logarithm of harmonised consumer price index in EMU	LNHICPE	Author's calculation based on data downloaded from http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes
The natural logarithm of the nominal dinar-USA dollar exchange rate index	LNNUSD	Author's calculation based on data downloaded from http://www.nbs.rs/internet/cirilica/index.html
Inflation differential between Serbia and USA	LNDUSA	Author's calculation based on data downloaded from http://webrzs.stat.gov.rs/WebSite/public/ReportView.aspx and http://www.bls.gov/cpi/data.htm
Natural logarithm of consumer price index in USA	LNCPIUSA	Author's calculation based on data downloaded from http://www.bls.gov/cpi/data.htm

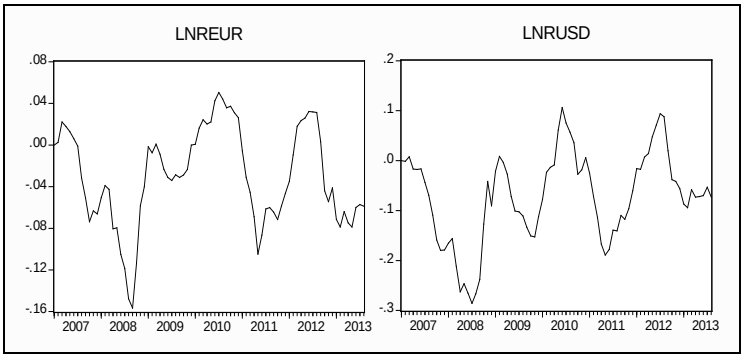
Source: Author

5. Results of the empirical Research

5.1 Testing for random walk real exchange rates

As previously mentioned, the first step in testing empirical support for the PPP theory is based on testing the non-stationarity of the real exchange rate. A visual presentation of relevant time series (Fig. 1) brings us to the conclusion of their non-stationarity.

Figure 1. Real dinar-euro and dinar-dollar exchange rates



Source: Author

When using standard unit root tests, the number of lags in the ADF test necessary to eliminate autocorrelation was determined following the "specific to general" approach. Also, in the DF-GLS test, the number of additional lags follows the ADF test. On the other hand, when using the PP and KPSS tests, the Newey-West correction using Bartlett kernel was applied. The test results (Table 2) show that the euro based real exchange rate, according to the DF-GLS and KPSS tests, is a stationary series, i.e. non-stationary and at a verge of non-stationarity according to the PP and ADF tests, respectively. Furthermore, the difference in results obtained by different tests also occurs in case of dollar based real exchange rate. In particular, according to the ADF and PP tests, the time series is non-stationary, while, according to the DF-GLS and KPSS tests, it is stationary. Taking into account the graphic representation correlogram of the observed series, as well as their visual form, we can conclude that the real exchange rate series are, in fact, non-stationary.

Table 2 Unit Root Tests without Structural Break

Real exchange rates	k	Deterministic components	ADF	DF-GLS	PP	KPSS
LNREUR	1	c	-2.91 (-2.90)	-2.67 (-1.95)	-2.48 (-2.90)	0.09 (0.46)
LNRUSD	1	c	-2.80 (-2.90)	-2.45 (-1.95)	-2.46 (-2.90)	0.23 (0.46)

Note: k represents the number of lags which aim to eliminate autocorrelation in residuals in ADF. Critical values at 5% significance level are shown in the parentheses.

Source: Author

After applying standard unit root tests, the testing was conducted using one and two-break LM Lee and Strazicich (LS) unit root tests for A and C models. The test results (Table 3) show that the real exchange rate series are non-stationary in both variants of the models. Such results undoubtedly do not support the PPP proposition.

Table 3 LS Test with One and Two Structural Breaks

Series	Model	No. of breaks	k	T_B	Test statistics	Critical values (5%)
LNREUR	A	1	3	2008:10	-3.50	-3.57
		2	1	2008:12 2012:12	-3.20	-3.84
	C	1	3	2009:05	-4.02	From -4.45 to -4.51
		2	3	2008:07 2011:02	-4.57	-5.29
LNRUSD	A	1	3	2008:11	-3.19	-3.57
		2	1	2008:11 2012:09	-2.93	-3.84
	C	1	5	2009:06	-4.39	From -4.45 to -4.51
		2	5	2008:08 2011:03	-5.19	-5.29

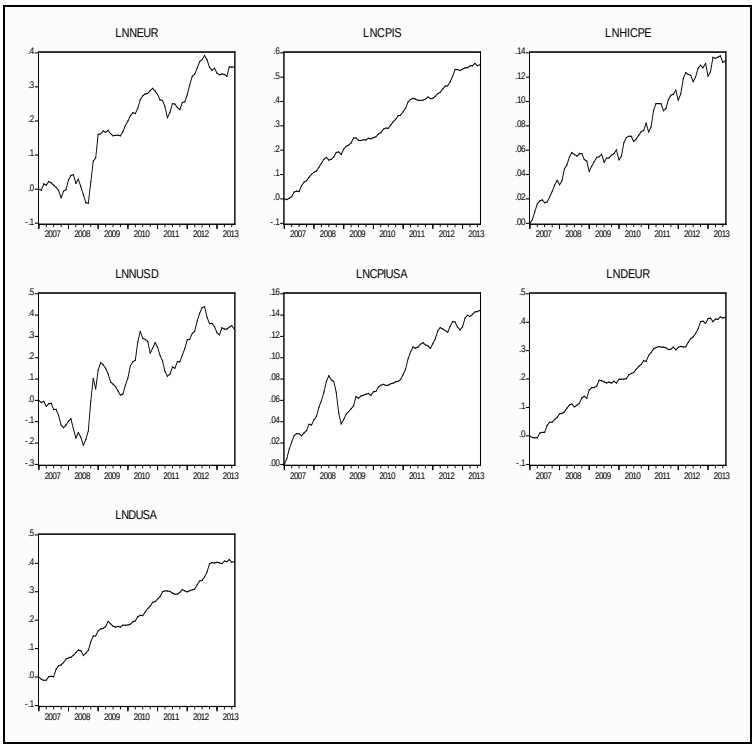
Note: k represents the number of lags and T_B timing of the break. Critical values are taken from Lee and Strazicich (2003, p. 1084; 2004, p. 12).

Source: Author

5.2 Cointegration analysis

The second part of the analysis actually involves testing whether the nominal exchange rate and relevant price indices are cointegrated series. Formal testing of non-stationarity of all time series relevant for testing empirical foundation of the *weak form* of the PPP hypothesis shows that they are I(1) processes, which is also indicated by their dynamics (Fig. 2). All non-stationarity test results are available upon request.

Figure 2. Movement of Nominal Exchange Rates, Inflation Differentials and Consumer Price Indices



Source: Author

By utilising the Engle-Granger two-step procedure (Table 4) we arrive at the conclusion that the nominal exchange rate series are not cointegrated either with inflation differential series or with the corresponding price indices.

Table 4. Engle-Granger cointegration test results

	LNDEUR	LNCPIS	LNHICPE	C	Trend	EG test statistics	Critical values (5%)
LNNEUR	0.99 (0.042)	-	-	-0.03 (0.011)	-	-2.92	-3.42
	-0.02 (0.305)	-	-	-0.02 (0.010)	0.01 (0.002)	-3.17	-3.91
	-	1.42 (0.168)	-2.92 (0.721)	-0.01 (0.012)	-	-2.06	-3.86
	-	0.01 (0.248)	-3.28 (0.576)	0.01 (0.010)	0.01 (0.002)	-4.13	-4.29
	LNDUSA	LNCPIS	LNCPIUSA	C	Trend	EG test statistics	Critical values (5%)
LNNUSD	1.19 (0.077)	-	-	-0.11 (0.019)	-	-3.09	-3.42
	0.24 (0.550)	-	-	-0.12 (0.019)	0.01 (0.003)	-3.86	-3.91
	-	2.07 (0.202)	-5.15 (0.862)	-0.05 (0.022)	-	-3.15	-3.85
	-	-0.69 (0.385)	-5.31 (0.647)	-0.005 (0.018)	0.02 (0.003)	-3.53	-4.28

Note: Standard errors are provided in brackets below the coefficients. Critical values of the EG test are attained according to James. G. MacKinnon (2010).

Source: Author

Testing with the use of Johansen test gives very similar results (Table 5). Euro based nominal exchange rate is not cointegrated with the corresponding

Table 5. Johansen cointegrationtest results

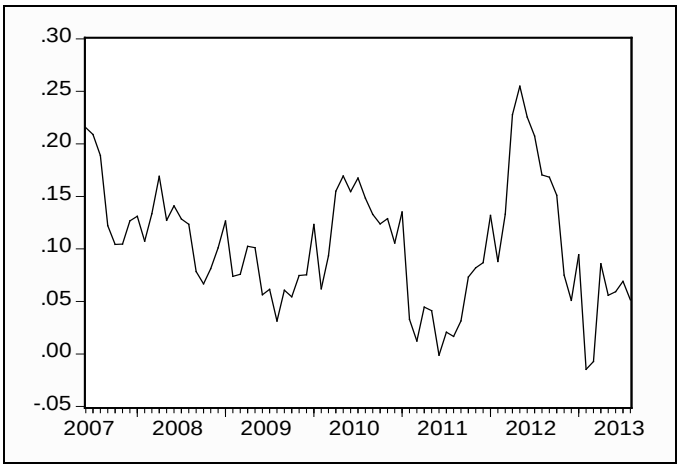
	LNDEUR	LNCPIS	LNHICPE	C	Trend	Trace test	Critical values (5%)- Trace	Max-eigenvalue test	Critical values (5%)- Max-eigen.
LNNEUR	0.99 (0.1314)	-	-	0.02 (0.0418)	-	8.69 (1)	9.16	12.82 (0)	15.89
	-	2.64 (0.3709)	-7.64 (1.5980)	-0.13 (0.0299)	-	3.14 (2)	9.16	3.14 (2)	9.16
	LNDUSA	LNCPIS	LNCPIUSA	C	Trend	Trace test	Critical values (5%)- Trace	Max-eigenvalue test	Critical values (5%)- Max-eigen.
LNNUSD	1.37 (0.1671)	-	-	-0.16	-	15.34 (0)	15.49	13.24 (0)	14.26
	-	0.89 (0.8231)	-7.29 (1.3672)	-0.03	0.01 (0.0054)	40.85 (0)	42.92	19.40 (0)	25.82

Note: Standard errors are given in parentheses below the coefficients. The values given in parentheses next to the Trace test statistics and Max-eigenvalue test statistics refer to cointegration rank.

Source: Author

inflation differential, but the test shows the presence of two cointegration equations, when it comes to price indices. Taking into account the dynamics of the residual series of the cointegration equation, (Fig. 3), as well as its correlogram, it seems as though the series is non-stationary after all.

Figure 3. The residual of the cointegration equation between euro based exchange rate and price indices



Source: Author

On the other hand, dollar based nominal exchange rate is cointegrated neither with inflation differential nor with price indices, clearly indicating that there is almost no empirical evidence to support the weak form of the PPP hypothesis.

Having in mind all the results obtained during the analysis, we can conclude that we did not manage to find any reliable and convincing empirical evidence to support any variant of the PPP hypothesis. To a large extent, the conclusion is coinciding with the findings of Mladenovic, Josifidis and Srdic (2013), and, in the same time, very different from the results shown by Tica and Sonora (2010). The difference in relation to the last mentioned research may be resulting from the fact that it was conducted for the time period between January 1994 and December 2006 for dinar-German mark exchange rate.

6. Conclusion

Based on the research results, we accept the initial hypothesis on the lack of empirical evidence to support the PPP theory. Such conclusion was reached following both available methodical approaches: (a) testing non-stationarity of

the real bilateral exchange rate and (b) testing cointegration of the nominal exchange rate and relevant price indices, i.e. inflation differential. The first approach concerns analysis of the strong form of the PPP hypothesis conducted using standard unit root tests (ADF, DF-GLS, PP, KPSS) and one and two-break LM Lee and Strazicich (LS) unit root tests for A and C models. The findings undoubtedly show that the dinar-euro and dinar-dollar exchange rate series are non-stationary, which, empirically, refutes the strong form of PPP. The second part of the research involved testing two variants of the weak form of the PPP hypothesis and it was conducted by using the Engle-Granger and the Johansen cointegration tests. The results obtained show that the time series of the nominal exchange rate of dinar for euro and dollar do not form a long-run equilibrium relationship with the inflation differential and the corresponding price indices series. The lack of cointegration between the nominal exchange rate and inflation differential series eliminates the possibility of empirical support for the first and more demanding weak form of PPP which imposes the symmetry restriction. Furthermore, the lack of cointegration between the nominal exchange rates and relevant price indices shows that there is no evidence for the second (less restrictive) weak form of the PPP theory, which does not impose either the proportionality restriction or the symmetry restriction. The only hint of a situation deviating from the foregoing conclusion lies within the finding of the presence of two cointegrating vectors between the nominal dinar-euro exchange rate and corresponding price indices. However, having in mind that the dynamics and the correlogram of the residuals of their cointegrating equation indicate that it is most likely a non-stationary linear combination, as well as that the result obtained by the EG test shows that the series are not cointegrated, we can conclude that the series are most likely not cointegrated. Such a result is no surprise at all and it was completely expected, considering that the presence of the floating exchange rates has convinced even the strongest supporters of the PPP theory that PPP is not a short-run relationship (Froot & Rogoff, 1994, p. 2), and having in mind that the testing was, due to data availability, based on rather short time series. A research of a long-run empirical foundation of the PPP hypothesis requires much longer CPI time series that are only available as of January 2007.

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