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Should the CNB Devaluate the Exchange Rate? Evidence from Purchasing Power Parity

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TREBA LI HNB DEVALVIRATI TEČAJ KUNE?
PRIMJER PARITETA KUPOVNE MOĆI

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U članku se ispituje valjanost hipoteze o paritetu kupovne moći u slučaju Hrvatske. Koristi se bilateralni tečaj kune prema euru kojeg se zajedno s razinom cijena u Hrvatskoj i Eurozoni testira na postojanje pariteta kupovne moći. S obzirom da literatura sugerira da je paritet kupovne moći valjan dugoročni paritetni odnos kojeg karakteriziraju asimetrična obilježja, u radu se koriste dvije metode; Johansenova kointegracija koja pretpostavlja simetriju u kratkom i dugom roku te kointegracija s uključenim pragom koja dopušta mogućnost nesimetrične prilagodbe na devijaciju od pariteta u kratkom roku. Rezultati Johansenove kointegracije upućuju na zaključak da je u Hrvatskoj prisutan apsolutni paritet kupovne moći. U kratkom roku jedino se tečaj kune prema euru prilagođava na devijacije od pariteta, dok su cijene u Hrvatskoj i Eurozoni slabo egzogene. Model korekcije odstupanja ne upućuje na postojanje prijenosa promjena tečaja kune prema euru na potrošačke cijene. Rezultati kointegracije s uključenim pragom sugeriraju da prilagodba na odstupanje od pariteta kupovne moći nije asimetrična.

JEL klasifikacija: C22, F31, P22

Ključne riječi: paritet kupovne moći, kointegracija, nelinearna prilagodba, Hrvatska

SHOULD THE CNB DEVALUATE THE EXCHANGE RATE?
EVIDENCE FROM PURCHASING POWER PARITY

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In this paper we explore the validity of the purchasing power parity hypothesis in the case of Croatia. We use bilateral HRK/EUR exchange rate and test it jointly with Croatian and eurozone price level for the purchasing power parity. Because the literature suggests that the purchasing power parity is a valid long-run international parity condition which incorporates asymmetric properties, we use two cointegration methods; Johansen cointegration that assumes symmetry in both, short and long run and threshold cointegration which allows for asymmetric adjustment in the short run. The results of Johansen cointegration suggests that in the long run the absolute purchasing power parity condition holds. In the short run, only the exchange rate adjusts to deviations from the parity while Croatian and eurozone price level are weakly exogenous. Error correction model does not confirm the existence of exchange rate pass-trough to domestic consumer prices. The results of threshold cointegration suggest that adjustment of deviations from the purchasing power parity is not asymmetric.

JEL classification: C22, F31, P22

Key words: purchasing power parity, cointegration, threshold adjustment, Croatia

1. INTRODUCTION

As Sarno and Taylor (2001) state, Purchasing Power Parity (PPP) is the exchange rate that equates domestic and foreign price levels, so that the purchasing power of a unit of one currency would be the same in both economies. The starting point for PPP is the *law of one price* that says unshackled trade in goods ensures identical prices across countries when we abstract tariffs and transportation costs (Froot and Rogoff, 1995).

If one reviews the empirical literature devoted to testing the validity of PPP, one can conclude that PPP is probably one of the most extensively tested theoretical propositions. The motivation behind testing PPP is often a practical one; PPP can indicate the degree of misalignment of the nominal exchange rate and the appropriate policy response. Although PPP owes its attractiveness both to its intuitive appeal and simplicity, empirical models often have often been unable to prove conclusively this core principle of international finance. Development of new econometric models in the last two decades, notably unit root tests, cointegration and nonlinear models, gave rise to new wave of empirical studies. Nonlinear techniques in particular have performed somewhat better, than linear counterparts, but still have not conclusively validated the PPP hypothesis in developed and developing countries (Sarno and Taylor, 2001; Bahmani-Oskooee and Hegerty, 2009).

The aim of this paper is to test whether PPP holds in Croatia. Given the fact that debates about the overvaluation of the nominal HRK/EUR exchange rate are quite common in Croatia, we feel it is very important to establish whether the exchange rate is aligned with fundamentals suggested by a particular theory. In this case, we use PPP hypothesis in order to model the long run behaviour of the exchange rate in Croatia. We use multivariate approach and model bilateral HRK/EUR exchange rate as a function of Croatian and eurozone price level. In order to test the PPP, we use two cointegration methods. The first method, Johansen cointegration (Johansen, 1988), assumes that both long run and the short run behaviour of exchange rate and price levels are symmetric. We also specify vector error correction models in order to detect whether exchange rate pass-through is present. The second method, the threshold cointegration, assumes symmetry in the long run, but allows for non-linear adjustment in the short run (Enders and Siklos, 2001). We apply both the linear and the non-linear method because the literature (Sarno and Taylor, 2001; Bahmani-Oskooee and Hegerty, 2009) shows nonlinear methods are more successful at detecting PPP. To the best of our knowledge, this is the first paper that applies nonlinear methodology on testing the PPP for the Croatian exchange rate.

The remainder of the paper is organized as follows. Section two reviews the empirical literature on PPP, entailing both the linear and the nonlinear studies. A special attention is then given to the results for transition economies and Croatia. The third section presents the applied methodology, data and detailed results of the empirical analysis, while section four concludes the paper.

2. LITERATURE REVIEW

Sarno and Taylor (2001) provide an extensive overview of PPP tests for developed countries. The authors conclude that consensus concerning the validity of PPP between the currencies of the major industrialized countries, in both the short and long run, appears to have shifted several times in the post-war period. In recent years the prevailing view is that long-run PPP does have some validity, at least for the major exchange rates, although a number of puzzles have yet to be resolved conclusively. Authors also point out that investigating the role of non-linearities in real exchange rate adjustment toward long-run equilibrium is a promising strand of research which can reconcile the persistence of real exchange rates with their observed high volatility. Several other authors also concluded that nonlinear methods are more appropriate for testing PPP in developed countries. Using a theoretical model, Dumas (1992) showed that the speed of adjustment towards the equilibrium varies with the magnitude of the deviation from PPP. Accordingly, deviations then follow a nonlinear process. Taylor, Peel and Sarno (2001) showed that four major real bilateral US dollar exchange rates are characterized by a nonlinear mean reverting process. Thereby the real exchange rates behave more like unit root processes the closer they are to long run equilibrium. They become more mean reverting the further they are from equilibrium.

The results from empirical studies seem even less conclusive for developing countries. Using a residual-based test Thacker (1995) concluded that PPP does not hold for two European transition economies, Poland and Hungary. Choudhry (1999) reported mixed results using fractional cointegration on Polish, Russian, Romanian and Slovenian exchange rates, while Christev and Noorbakhsh (2000) showed there is little evidence of PPP in Bulgaria, Czech Republic, Hungary, Poland, Romania and Slovakia when Johansen cointegration is applied. Using the same technique, Barrow (2003) got mixed results for Poland, Czech Republic and Romania. Bahmani-Oskooee and Hegerty (2009) list different explanations for the apparent absence of PPP in transition economies. While some of the reasons can be attributed to both developed and less-developed economies (like the choice of price indices or black-market exchange rates), other stem from characteristics of transition economies. Some of the characteristics are small number of observations, administratively controlled prices and exchange rates, Samuelson-Ballasa effect, massive increase in capital inflows and foreign investment, etc.

Frequent rejections of PPP in developing countries when using linear methods argue in favour of nonlinear PPP tests. The logic behind using nonlinear methods is that exchange rates can exhibit nonlinear properties due to transaction costs, government policy and price rigidity (Bahmani-Oskooee and Hegerty, 2009). Moreover, having in mind that most of transition economies suffered external and internal shocks, high inflation and/or major exchange rate shifts, one should expect nonlinearity in the adjustment process. After reviewing the literature, Bahmani-Oskooee and Hegerty (2009) concluded that nonlinear tests indeed provide more support for PPP than linear tests do. Thus Bahmani-Oskooee, Kutan and Zhou (2008) confronted linear with nonlinear unit root tests using the data for developing countries. They showed that nonlinear tests are two times more successful in detecting PPP. Telatar and Hasanov (2009) tested for PPP across twelve Central and Eastern European countries using linear and nonlinear unit root tests and found more evidence in favor of PPP when applying nonlinear tests. Moreover, after allowing for structural breaks and asymmetric adjustment they found that PPP holds for all twelve countries in the sample. Authors reach the same conclusion using the same methods on data for CIS countries (Telatar and Hasanov, 2009a).

Existing literature exploring the validity of PPP in Croatia deals with linear approach only, which comprises unit root, cointegration and panel data tests. Payne et al. (2005), using unit root tests with two endogenous structural breaks, failed to find evidence of PPP in Croatia. Pufnik (1996) and Egert (2005) find no evidence of cointegration when testing PPP for Croatia. In his cointegration study on 17 European transition economies, Sideris (2006), who used both Johansen cointegration and panel cointegration, concluded that PPP does not hold for a number of countries including Croatia. Nevertheless, there are results in favour of PPP in Croatia. Tica (2006) used unit root test on a 51 years long data set and concluded that the bilateral exchange rates are mean reverting. Further on, Sonora and Tica (2008) use panel unit root tests with structural breaks and show that real exchange rates in Croatia are stationary. Moreover, their results imply that the deviations from the long-run PPP are adjusted rather quickly.

3. EMPIRICAL ANALYSIS

3.1. DATA AND METHODOLOGY

To test for PPP in Croatia we needed data for the Croatian exchange rate and prices for Croatia and 12 European Monetary Union member states. Therefore, we collected monthly observations of average nominal HRK/EUR exchange rate, Croatian consumer price index and harmonized index of consumer prices for European Monetary Union. We have chosen to test the bilateral HRK/EUR rate because this exchange rate is of particular importance for the Croatian economy. Besides the fact that countries from Eurozone account for 52.4 percent of Croatian exports and 50.9 percent of Croatian imports,[1] this exchange rate is an implicit target of the Croatian National Bank, whose exchange rate policy, though formally defined as a managed float, can also be characterized as a “quasi currency board“ or “floating with a life jacket“ (Billmeier i Bonato, 2002; Reinhart i Rogoff, 2002). Further on, since Croatia is a highly euroized economy whose currency has not completely assumed store of value and unit of account functions, establishing whether HRK/EUR exchange rate is aligned with the fundamentals is extremely relevant for policy formulation.
The base year for the consumer price indices is 2005. The source for the Croatian data set (exchange rate and prices) is the Croatian National Bank and Croatian Bureau of Statistics, while for the EMU consumer prices the source is Eurostat. We chose 2000 as a starting year because we wanted to avoid several major structural breaks that occurred in Croatia before 2000.[2] All series range from January 2000 to December 2009, i.e. providing 10 years long series or 120 monthly observations. All series were seasonally adjusted and transformed to logarithms.

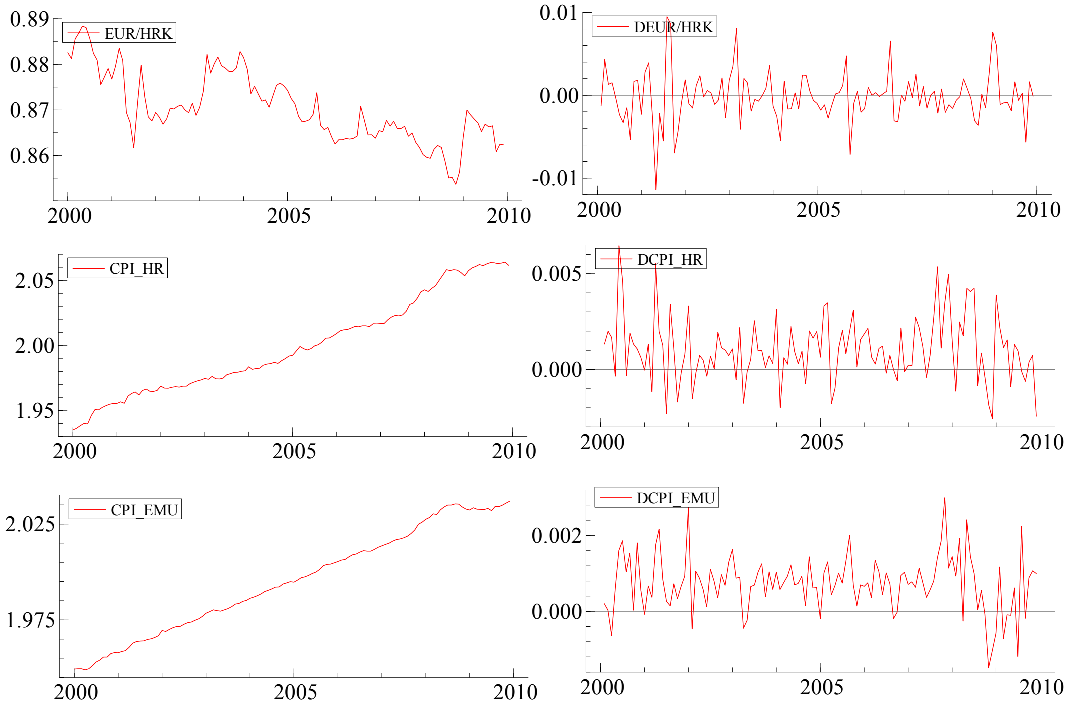
Before exploring cointegration and asymmetric adjustment between variables, one should always determine the order of integration of time series. Graphical representations of the variables of interest (nominal exchange rate, domestic and foreign prices) suggest all three series in levels do not revert to their means (left side of Picture 1.). However, series in first differences seem to be mean reverting (right side of Picture 1.)
Nevertheless, to detect the level of integration formally, we used an augmented Dickey-Fuller unit root test (which we will abbreviate by ADF) (Dickey and Fuller, 1981). Besides ADF, we can also use results of Johansen cointegration procedure as an implicit unit root test. Namely, if one or more variables in Johansen model are I(0), then Trace and Max test statistics will indicate that matrix Π in cointegrating VAR has full rank.

After confirming that the series we are analysing are integrated of the same order we turn to modelling the long run relationship between HRK/EUR exchange rate, domestic and EMU price levels. In order to test for cointegration we use both Engle-Granger (Engle and Granger, 1987) and Johansen cointegration model (Johansen, 1988; Johansen, 1991). We use the

[1] Last available data the Central Bureau of Statistics provides are for 2009.
[2] We must, however, note that we also repeated the same econometric exercise using data span ranging from January 1996 to December 2009 The main results remained the same.

Johansen results in order to capture symmetric properties of PPP both in the short and long run, while the estimates of Engle-Granger model are used in order to test for threshold cointegration and asymmetric adjustment of PPP in the short run.

Picture 1. Series in levels and first differences



Source: Eurostat, Croatian Bureau of Statistics and Croatian National Bank.

As the literature suggests, two test statistics, Trace test and Max test are used to detect the number of cointegrating vectors in Johansen procedure. The trace statistic tests the hypothesis that the number of cointegrating vectors is less than c while the max statistic tests that the number of cointegrating vectors is equal to c against c + 1. Johansen's tests are biased when the constant term is included in the model and tend to detect cointegration more often in finite samples when compared to asymptotic cases (Cheung and Lai, 1993). Thus, we use finite sample correction of trace and max statistics proposed by Reimers (Reimers, 1992) that takes into account the number of parameters and degrees of freedom. Adjusted test statistics are denoted by Trace test (T-nm) and Max test (T-nm).

As discussed in the literature review, PPP seems to exhibit asymmetric properties when adjusting the deviations from the long run equilibrium. If the adjustment is indeed asymmetric, then Johansen test or any other cointegration test that assumes symmetric adjustment is misspecified. Enders and Chumrusphonlert (2004) give reasons for nonlinearities inherent to PPP. According to them, nonlinearities are justified by the existence of transaction costs, stickiness of national price levels but also by asymmetric nominal exchange rate movements. In fact, if the official intervention in the foreign exchange market is in accordance with a managed float regime, monetary authorities might be more willing to tolerate currency appreciation than depreciation which leads to asymmetric behaviour of the exchange rate. This inference indicates one could expect asymmetries in the Croatian exchange rate (since it is managed by the central bank) and it gives us a motivation for pursuing this kind of modelling strategy.

In order to detect nonlinearities of PPP in Croatia, we use a threshold cointegration method developed by Enders and Siklos (2001). As against Engle-Granger or Johansen method that assume symmetric behaviour in the long and short run, this method allows for asymmetric adjustment in the short run while maintaining symmetry in the long run. Enders and Siklos (2001) developed a test for threshold cointegration based on generalized threshold autoregressive (TAR) and momentum-TAR (M-TAR) tests for unit roots.[3]

In order to estimate the long run equilibrium relationship one starts with the Engle-Granger type of cointegration model that will be the basis for threshold cointegration tests:

$$e_t = \beta_0 + \beta_1 p_t + \beta_2 p_t^* + \mu_t \qquad (1)$$

Here e_t is the exchange rate, p_t domestic prices and p_t^* foreign prices; all integrated of degree one while μ_t is the disturbance term that may be serially correlated. In presence of cointegration, equation (1) implies the existence of an error-correction representation of the variables.[4] Hence, Enders and Siklos (2001) suggest an alternative specification of error-correction model:

$$\Delta\mu_t = I_{jt}\rho_1\mu_{t-1} + (1 - I_{jt})\rho_2\mu_{t-1} + \varepsilon_t, \qquad j = 1,2 \qquad (2)$$

where I_{1t} and I_{2t} are the Heaviside indicator functions for the TAR and the M-TAR model respectively, such that

$$I_{1t} = \begin{cases} 1 & \text{if} \quad \mu_{t-1} \geq \tau_1 \\ 0 & \text{if} \quad \mu_{t-1} < \tau_1 \end{cases}$$

in the TAR case, and

$$I_{2t} = \begin{cases} 1 & \text{if} \quad \Delta\mu_{t-1} \geq \tau_2 \\ 0 & \text{if} \quad \Delta\mu_{t-1} < \tau_2 \end{cases}$$

in the M-TAR case. τ_1 and τ_2 are the values of the threshold and (ε_t) is a sequence of independent and identically distributed random variables with mean zero and a constant variance. The residuals from equation (1) are used to estimate equation (2) and ε_t is independent of μ_s, for $s < t$.

Since the least squares estimates of ρ_1 and ρ_2 have an asymptotic multivariate normal distribution (Tong (1983, 1990)) and given the existence of a single cointegrating vector in the form of (1), the error-correcting model for any variable x_{it} can be written in the form:

$$\Delta x_{it} = \rho_{1,t} I_{jt}\mu_{t-1} + \rho_{2,i}(1 - I_{jt})\mu_{t-1} + \ldots + v_{i,t} \qquad j = 1,2 \quad (3)$$

where $\rho_{1,i}$ and $\rho_{2,i}$ are the speed of adjustment coefficients of Δx_{it}.

[3] More details about TAR and M-TAR models can be found in Tong (1983), Caner and Hansen (1998), and Enders and Siklos (2001).
[4] Guaranteed by the Granger representation theorem.

First we test for threshold cointegration using TAR and M-TAR model setting the value of the threshold τ to zero. Moreover, we also test for threshold cointegration using TAR and M-TAR model with unknown threshold. In other words, when the value of the threshold τ is unknown, it needs to be estimated along with the parameters ρ_1 and ρ_2. We estimated the threshold τ using Chan (1993) algorithm. In each of the four cases, depending on the type of asymmetry under consideration $(I_{1t}$ or $I_{2t})$, we estimated regression equation (2) and tested the null hypotheses $\rho_i = 0$ and $\rho_1 = \rho_2 = 0$, which are direct tests of the existence of cointegration.[5] After that, we compared the sample statistics with the critical values suggested by Enders and Chumrusphonlert (2004). Eventually, if the test statistics suggest the existence of cointegration, one uses the Wald test to detect the existence of asymmetric adjustment. The null hypothesis of the Wald test is symmetric adjustment (i.e., $\rho_1 = \rho_2$).[6]

3.2. RESULTS

The results of ADF unit root tests confirm our graphical analysis (Tables 1 and 2). In levels, we cannot reject the null hypotheses about the existence of unit root. However, after differencing the data, ADF test suggests that all three series are integrated of order one.

Table 1. ADF test – in levels

Name of the variable	Period	Chosen time lag	t-value (ADF)	Beta	Sigma	t- value (lag)	AIC
HRK/EUR exchange rate	2001(8) - 2009(12)	3	-1.537	0.92804	0.002726	-1.786	-11.76
Domestic prices	2001(8) - 2009(12)	11	-0.1591	0.99912	0.001537	-2.435	-12.84
EMU prices	2001(8) - 2009(12)	12	-0.8106	0.99759	0.0006667	-3.178	-14.50

Note: ADF - Augmented Dickey-Fuller; constant included; optimal time lag chosen according to AIC; all series are seasonally adjusted and in logarithms; * null hypothesis about existence of unit root rejected on 1 percent level of significance; ** hypothesis about existence of unit root rejected on 5 percent level of significance.
Source: calculation of the authors.

Table 2. ADF test – in first differences

Name of the variable	Period	Chosen time lag	t-value (ADF)	Beta	Sigma	t- value (lag)	AIC
HRK/EUR exchange rate	2001(9) - 2009(12)	1	-8.644*	-0.10643	0.002639	2.296	-11.85
Domestic prices	2001(9) - 2009(12)	0	-8.303*	0.16227	0.001581	-	-12.88
EMU prices	2001(9) - 2009(12)	11	-3.890*	0.10819	0.0006634	3.151	-14.52

Note: ADF - Augmented Dickey-Fuller; constant included; optimal time lag chosen according to AIC; all series are seasonally adjusted and in logarithms; * null hypothesis about existence of unit root rejected on 1 percent level of significance; ** hypothesis about existence of unit root rejected on 5 percent level of significance.
Source: calculation of the authors.

After confirming our series are stationary in first differences, we can continue with cointegration analysis. The first step of our modelling strategy is to estimate Engle-Granger cointegration equation with the exchange rate as a dependent variable and domestic and EMU prices as the explanatory variables. The residuals from this equation will later be used for threshold cointegration test of PPP. The results of Engle-Granger cointegration equation are displayed in Table 3. One can notice that both coefficients (for domestic and EMU price

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[5] For the tests, we used the larger of the *t* values and *F* statistics that were later denoted by Tmax and Φ both in the text and in the corresponding tables.

[6] For the tests, we used *F* statistics that was denoted by W both in the text and in the corresponding tables.

level) have incorrect sign and are also larger than one in absolute terms. Besides wrongly signed coefficients, the ADF test of residuals from the cointegration equation (when compared against Davidson i MacKinnon (1993) critical values) suggests that residuals are not stationary. Therefore Engle-Granger cointegration estimates suggests that PPP hypothesis is not valid for Croatia.

Table 3. Engle-Granger cointegration

Dependant variable: HRK/EUR exchange rate	Coefficient	Standard error	t-value and p-value
Domestic prices	-1.357	0.087	-15.5 (0.00)
EMU prices	1.795	0.085	20.5 (0.00)
RSS=0.01319		AR test	F(7,111) = 102.2 (0.00)
LL=376.64		ARCH test	F(7,104) = 24.3 (0.00)
N=120		Normality test	Chi^2(2) = 27.0 (0.00)

Note: p-value is presented in parenthesis.
Source: calculation of the authors.

Given the fact that Engle-Granger cointegration test has low power in presence of multiple cointegration vectors, we continue our analysis with Johansen cointegration. Table 4 presents trace and max test statistics along with their finite sample corrections. All four test statistics indicate the presence of two cointegration relationships.
Long run coefficients and adjustment parameters are reported in Table 5. Since there are two cointegration vectors, we need at least four restrictions to identify long run coefficients and adjustment parameters for both vectors. We assume that the first cointegration vector reflects absolute purchasing power parity condition, while the second vector entails the long run relationship between domestic and EMU price level. Hence, for the first vector we impose weak exogeneity of EMU prices jointly with the restrictions derived from absolute PPP condition:

- long run coefficients for the exchange rate should be equal to 1,
- long run coefficients for EMU prices should be equal to 1,
- long run coefficient for domestic prices should be equal to -1,
- EMU prices are weakly exogenous in the short run.

For the second vector, we impose the following restrictions:

- long run coefficients for the exchange rate should be 0,
- long run coefficient for domestic prices should be equal to 1.[7]

LR test results suggest that all six restrictions are jointly accepted (Chi^2 test statistics is equal to 0.89, corresponding p-value is 0.63). This in turn indicates that absolute version of PPP hypothesis holds for HRK/EUR exchange rate. Moreover, Johansen tests conducted on sample dating back to 1996 also indicated the presence of absolute PPP for the HRK/EUR exchange rate. This finding suggests that HRK/EUR exchange rate reflects well the fundamentals and that there is no need for its devaluation or depreciation. Moreover, the long run coefficients for the second vector suggest that consumer prices in Croatia move closely together with EMU consumer prices.

[7] Please note that restrictions relate to long run coefficient written in vector notation.

Table 4. Johansen cointegration

Rank	Eigenvalue	Trace test	Max test	Trace test (T-nm)	Max test (T-nm)
0	-	62.42 [0.000]*	42.15 [0.000]*	59.25 [0.000]*	40.01 [0.000]*
1	0.3004	20.27 [0.048]**	18.61 [0.016]**	19.24 [0.068]	17.67 [0.024]**
2	0.1459	1.66 [0.836]	1.66 [0.835]	1.57 [0.850]	1.57 [0.849]
3	0.0139	-	-	-	-

Note: p-values presented in brackets; * - null hypothesis rejected at 1 percent significance level; ** - null hypothesis rejected at 5 percent significance level. VAR includes 2 lags and a restricted constant. Lag length chosen according to SBIC. VAR residuals satisfy all diagnostic tests except test for heteroscedasticity.
Source: Calculation of the authors.

Table 5. Johansen cointegration – restricted cointegrating space

Variables	Long run (1. vector)	Short-run (1. vector)	Long run (2. vector)	Short-run (2. vector)
	β coefficients	α coefficients	β coefficients	α coefficients
Exchange rate	1.0	-0.236	-	-0.286
Domestic prices	-1.0	0.0235	1.0	0.0168
EMU prices	1.0	0	-0.871	-0.0076
Constant	-0.7717	-	-0.340	-

Note: β coefficients are written in vector notation.
Source: Calculation of the authors.

After defining two cointegration vectors, we proceed by formulating vector error correction models for HRK/EUR exchange rate, domestic and EMU prices. The estimation results are presented in Table 6. Three error correction models satisfy all diagnostic tests except tests for heteroscedasticity. Namely, residuals from error correction models for the exchange rate and EMU prices are heteroscedastic, which necessitated the application of heteroscedasticity consistent standard errors. When analysing the results one notices that error correction models of domestic and EMU prices have small explanatory power. Moreover, both domestic and EMU prices are weakly exogenous, which means that only HRK/EUR exchange rate adjusts to deviations from both equilibria in the short run. This suggests that the exchange rate adjusts the deviations from long run PPP, but it also corrects the short run Croatian – EMU inflation differential. Error correction model for HRK/EUR exchange rate also suggests that the exchange rate is in the short run responding to changes in EMU prices. Namely, higher inflation in Eurozone leads to appreciation of nominal HRK/EUR exchange rate. Error correction model for domestic prices indicates that there is no pass-trough from nominal exchange rate to domestic prices.

Table 6. Vector error correction models

Dependant variable	Δ Exchange rate	Δ Domestic prices	Δ EMU prices
Constant	9.98252e-5 (0.066)	0.00013 (0.066)	-8.6e-6 (-0.015)
Δ Exchange rate(-1)	0.192 (1.52)	0.0175 (0.32)	-0.029 (-1.38)
Δ Domestic prices(-1)	-0.055 (-0.251)	0.038 (0.34)	0.069 (1.43)
Δ EMU prices(-1)	-0.884*	0.187	0.062

	(-2.205)	(0.74)	(0.44)
ECT_PPP(-1)	-0.236* (-3.84)	0.023 (0.68)	0.0004 (0.031)
ECT_INFLATION DIFFERENTIAL(-1)	-0.2853* (-3.70)	0.0189 (0.44)	-0.007 (-0.36)
sigma	0.0027	0.0017	0.0007
R^2	0.198	0.025	0.0702
AR test	1.22 [0.296]	1.05 [0.40]	1.4240 [0.20]
ARCH test	2.85 [0.009]	1.16 [0.33]	2.2763 [0.03]
RESET test	1.40 [0.239]	0.012 [0.91]	0.42656 [0.51]

Note: ECT_PPP – error correction term from the first restricted cointegration vector; ECT_ INFLATION DIFFERENTIAL – error correction term from the second restricted cointegration vector; t-values in parenthesis, p-values in brackets; in the models with the exchange rate and EMU prices as dependant variables, heteroscedasticity consistent standard errors are applied.
Source: Calculation of the authors.

Though Johansen cointegration results provide evidence in support of absolute PPP in the case of Croatia, we still wanted to verify are there any asymmetries in the adjustment process. Namely, if adjustment process is characterised by threshold effects then any cointegration test that assumes symmetric adjustment (including Johansen cointegration) is misspecified (Enders and Siklos, 2001). As suggested in the methodology description, firstly we estimated the cointegration equation with exchange rate as a dependent variable and domestic and foreign prices as explanatory variables (Table 3). Residuals from cointegration equation were then used for testing threshold cointegration. We tested for both, TAR and M-TAR threshold cointegration using two thresholds: zero and a consistent estimate of the threshold as suggested in Chan's algorithm (1993).

Table 9. Threshold cointegration

TAR		M-TAR		TAR		M-TAR	
Threshold = 0		Threshold = 0		Threshold = 0.0131		Threshold = 0.00018	
Parameters and tests	values	Parameters and tests	values	Parameters and tests	values	Parameters and tests	values
$\rho_1 =$	-0.071	$\rho_1 =$	-0.121	$\rho_1 =$	-0.086	$\rho_1 =$	-0.128
$\rho_2 =$	-0.067	$\rho_2 =$	-0.018	$\rho_2 =$	-0.056	$\rho_2 =$	-0.012
Tmax	-1.24	Tmax	-0.36	Tmax	-1.14	Tmax	-0.247
$\Phi(\rho_1 = \rho_2 = 0)$	2.10	$\Phi(\rho_1 = \rho_2 = 0)$	3.45	$\Phi(\rho_1 = \rho_2 = 0)$	2.35	$\Phi(\rho_1 = \rho_2 = 0)$	3.78
$W(\rho_1 = \rho_2)$	0.003 (0.96)	$W(\rho_1 = \rho_2)$	2.31 (0.12)	$W(\rho_1 = \rho_2)$	0.19 (0.66)	$W(\rho_1 = \rho_2)$	2.95 (0.09)
AR test	0.96 (0.46)	AR test	0.83 (0.56)	AR test	0.85 (0.55)	AR test	0.84 (0.55)

Note: ρ_1 and ρ_2 denote adjustment parameters; p-value in parenthesis.
Source: calculation of the authors.

Table 9 displays the results of TAR and M-TAR tests with the known and unknown threshold. All four models satisfy diagnostic tests. Comparing the test statistics for Tmax and Φ, which are direct tests of threshold cointegration, with the critical values tabulated in Enders and Chumrusphonlert (2004), we conclude that there is no threshold cointegration, i.e. the adjustment to deviations from PPP in Croatia is not asymmetric.[8] This in turn suggests that conducted Johansen cointegration tests and corresponding vector error correction models are

[8] Tmax has to be equal to or less than -1.8, while the value of Φ statistics has to be equal to or larger than 8.

not misspecified and their results are correct. In other words, since no evidence of threshold cointegration is found, we can conclude that absolute PPP holds in Croatia.

4. CONCLUDING REMARKS

The aim of this paper was to test whether PPP theory holds for the case of Croatia and to determine whether the adjustment of deviations from PPP is symmetric or asymmetric. Using HRK/EUR exchange rate, domestic and EMU prices and applying Johansen cointegration we demonstrated that there are two long run relationships between selected variables. Upon imposing restrictions to the cointegration space, we conclude that one long run relationship is an absolute PPP condition, while the other relationship suggests that domestic price level is in the long run a function of EMU price level. Vector error correction models indicate that domestic and EMU prices are weakly exogenous. Hence in the short run only HRK/EUR exchange rate adjusts to deviations from long run absolute PPP. Moreover, HRK/EUR exchange rate also corrects the discrepancy from long run equilibrium relationship between Croatian and EMU prices, while domestic prices remain sticky in the short run. Error correction model for HRK/EUR exchange rate suggests that in the short run higher inflation in Eurozone leads to appreciation of nominal HRK/EUR exchange rate. Error correction model for domestic prices indicates that there is no pass-trough from nominal exchange rate to domestic prices. Finally, we find no evidence of nonlinearities in PPP in Croatia.

Our empirical results provide evidence about validity of absolute purchasing power parity in Croatia. In other words, nominal exchange rate of Kuna against Euro is aligned with the fundamentals, i.e. in the long run it is a function of domestic and EMU price levels. Given the fact that HRK/EUR exchange rate depreciation or devaluation is often perceived as a panacea for Croatian unsatisfactory growth performance and the lack of competitiveness, results of this study suggest that the increasing cost competitiveness and not exchange rate depreciation should be perused as an appropriate policy response.
Finally, since no evidence of pass-trough from exchange rate to domestic consumer price inflation was found, one might be tempted to recommend monetary policy makers to allow for more nominal exchange rate variability. However, such recommendation has to be weighted against the fact that this study pursued a partial equilibrium approach that did not control for the adverse impact of nominal exchange rate changes on the level of liability dollarization and the import dependence of Croatian production. If one would take these structural characteristics into account, one may end up recommending just the opposite.

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