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UDK 339.743:330.43(497.5)
JEL Classification F31, C52, E20
Izvorni znanstveni rad

LONG SPAN UNIT ROOT TEST OF PURCHASING POWER PARITY: THE CASE OF CROATIA

Using unit root test, hypothesis of purchasing power parity in Croatia is tested with the data spanning from 1952 to 2003. Although "the power problem" suggests that at least 75 annual observations of the real exchange rate is required to reject the null hypothesis with 50% probability, unit root test technique with only 51 annual observation for Croatia has rejected unit root hypothesis. Furthermore, using simple, autoregressive models estimated on the data, we show that univariate equations explain 20-55 percent of the in-sample variation in real exchange rates, although the degree of short-run persistence was high in certain periods. The econometric estimates imply a half-life of shocks to the real exchange rate of about 0.9 years for mark-kuna, 2.2 years for dollar-kuna and 1.2 years for lira-kuna.

Key words: real exchange rate, purchasing power parity, the power problem, unit root, long span test.

1. Introduction

In this paper the long run mean reverting properties of real exchange rates are investigated. To do so, we have assembled what to our knowledge is the longest currently available exchange rate and price level data set for the Croatia, a data set that continuously spans 51 years in length, beginning in 1952 and ending in 2003.

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The motivation for this investigation centers around two related issues: the concern in the literature over the low power of statistical tests of nonstationarity applied to real exchange rates during float (Frankel 1986), and the potential problems that arise in attempting to increase test power by incorporating pretransition observation in the data set.

1.1. Purchasing power assumption and the power problem

Issues related with the purchasing power parity (PPP) assumption can perhaps be best understood in the context of the shifts in professional consensus over past three and a half decades on the subject of real exchange rate stability between the currencies of the mayor industrialized countries. While most prefloat studies supported the existence of a fairly stable real exchange rate over long run (Friedman and Schwartz 1993), the prevailing orthodoxy of the early 1970s, largely associated with the monetary approach to the exchange rate, went even further by adopting the much stronger proposition of PPP on continuous basis (Frenkel 1976; Lothian and Taylor 1996).

First shift in professional consensus occurred after the apparent "collapse" of PPP under the float period. Observed high variance of real exchange rate was motivating force for development of the sticky price overshooting model (Dornbusch 1976). Subsequently, largely as a result of studies published mostly in the 1980s that could not reject the hypothesis of random walk behavior in real exchange rates (Meese and Rogoff 1983), sentiment shifted again, to a position broadly diametrically opposite to that of the belief in PPP on continuous basis, of a decade before. At this point of time, it was considered that PPP was of little use empirically over any time horizon and that movements in real exchange rates are either permanent or highly persistent (Stockman 1987).

That view has been called into question after Frankel (1986) noticed and proved that power of nonstationarity tests increase with the number of the observations – "The Power problem". Monte Carlo simulations have shown that it is required to have at least 75 years of stationary data on real exchange rates in order for the unit root test to be powerful enough to reject null hypothesis with 50% of probability. Following Frankel's approach, a number of studies employing long-term data have presented evidence of real exchange rate mean reversion (Frankel 1986; Edison 1987; Diebold, Husted and Rush 1991; Glen 1992; Lothian and Taylor 1996). Lothian and Taylor (1996) have even managed to outperform random walk model during float period with the univariate autoregression model estimated on the prefloat data.

Overall, arguably the main conclusion emerging from the recent relevant literature appears to be that PPP might be viewed as a valid long-run international parity condition when applied to bilateral exchange rates obtaining among major industrial countries (Taylor and Sarno 2002).

Unfortunately, "the power problem" (Frankel 1986) and latest shift in professional understanding of purchasing power parity remained unexplored in Croatia. Pufnik (2002) is probably the only study in which purchasing power parity assumption was tested at all. Engel-Granger methodology was used in order to test for the cointegration of relative price levels and nominal exchange rates between December 1991 and September 1996. As it might have been expected - due to "the power problem" - in such a small sample (5 years), the null hypothesis of random walk has not been rejected.

Having in mind that it is not possible to increase the test power without incorporating pretransition and preindependence observation in the data set, it is necessary to analyze in which way the change in sample homogeneity affects reliability of results.

1.2. Long Span Purchasing Power Parity Data and New Countries

Applicability of purchasing power parity assumption in a newly independent and transitional country such as Croatia definitely presents a problem. During observed period, Croatia has been part of a much larger monetary and custom union and labor market as well. It is quite difficult to predict effects of all upper mentioned changes on the real exchange rate, but on the other side it is quite easy to find other researchers that have tested purchasing power parity assumption on the set of countries that have changed various monetary, custom and labor market integrations.

Probably the most famous work that has faced issues related to the integration and disintegration of countries is Diebold, Husted and Rush (1991). In the paper stationarity of real exchange rates of US, UK, Germany, Belgium, France and Sweden was tested on the data set that stretches during 19th century[1]. The data set for the real exchange rate of the countries that would become Germany during 1764-1857 was continued with data for the unified Germany during 1857-1913. Furthermore, Belgian and French data set is even more complicated. During 1851-1859 Belgium didn't coin money and French money was in common circulation.

[1] Time series data for CPI/WPI are available for US during 1791-1913; UK during 1798-1913; Sweden during 1830-1913; Germany during 1792-1913 and France during 1806-1913.

In 1960, France and Belgium together with Italy and Switzerland formed Latin monetary union which made each countries coinage legal tender in the others. Diebold, Husted and Rush (1991) ignored upper mentioned changes and proved mean reverting properties of the real exchange rates constructed for Germany during 1792-1913, France during 1806-1913 and Belgium during 1832-1913.

1.3. Planned Economy and Purchasing Power Parity

The issue of the validity of purchasing power parity assumption in the former communist country should also be addressed. It is generally known fact that PPP assumption[2] was ignored by central planners in former Yugoslavia in the early post WWII years (Pertot 1971, p. 107)[3], but the planning system was abandoned by the end of 1950-ies, and the last institutional remains (such as multilateral exchange rates) of the planning system were eliminated during 1965 reform. Compared to centrally planned economies, economic system of former country's self-management had several differences: market determined consumer prices for the majority of consumer products, existence of financial sector and price adjustment instead of quantity adjustment of market disequilibrium (Anušić et al. 1995, p. 6). Throughout most of the analyzed period, the economy of the former Yugoslavia was open economy and economic policy was conducted in that regard (Pertot 1971, p. 108; Babić 1982). Probably the best empirical proof of the strength of international linkages in former Yugoslavia is price level in Croatia and Slovenia, that was at the beginning of transition - after adjusting for productivity - comparable with price levels in market economies and much higher than in any other transition country (Heston Summers and Aten 2002; Nestić 2004; Egert, Halpern and MacDonald 2006).

2. Purchasing Power Parity

Purchasing power parity assumption relates to the Cassel's (1918) assumption that nominal exchange rates should cover price differentials among countries and it is one of the basic building blocks of economic theory and economic mod-

[2] Pertot refers to PPP asumption as Poincaré's update ("Poincaréova nijansa") due to the fact that Raymond Poincaré (President 1913-1920 and primeminister 1912-13, 1922-24, 1926-29 of France) avoided famous Winston Churchill's mistake during restorations of international monetary system after the WWI.

[3] Coricelli and Jazbec (2001) have constructed the model that explains why it is not possible to expect factor price equalisation and HBS effect in planned economies.

els. Probably the most famous researcher of PPP in Croatia is Vinski (1967, p. 169-198; 1976), who was one of the pioneers in interpreting and researching the concept domestically as well as globally (UN).

Under PPP assumption, the nominal exchange rate e is proportional to a ratio of foreign p^* and domestic price levels p:[4]

$$e_t = p_t^* - p_t \tag{1}$$

Therefore, the logarithm of the real exchange rate q is defined as:

$$q_t \equiv e_t + p_t^* - p_t \tag{2}$$

If PPP held continuously, q would be constant reflecting differences in units of measurements. However, the sample variance of major real exchange rates over floating period is very large, providing strong and clear evidence against continuous PPP. Therefore, the goal of this research is to prove that in the long run (51 years of data), real exchange rate has mean reverting properties.

3. The data set

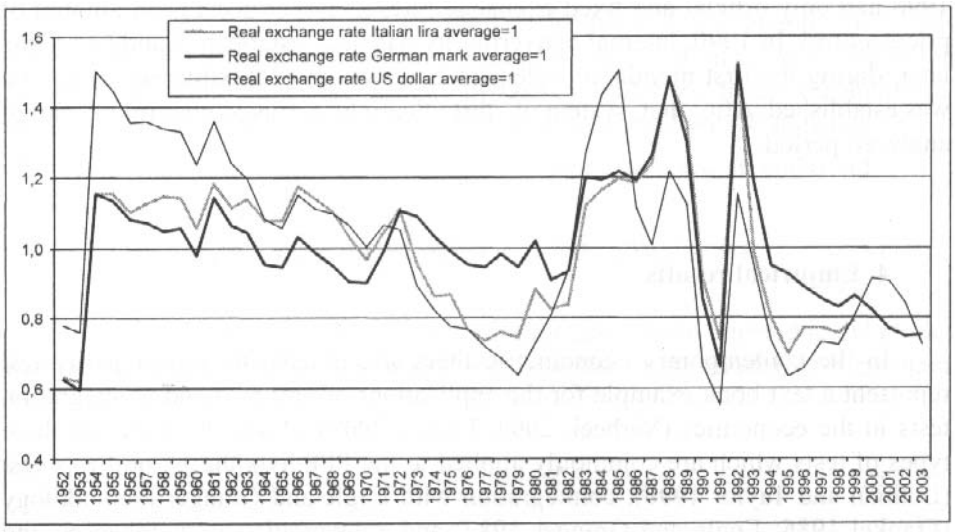
The data set consists of annual observation of mark-kuna, dollar-kuna and lira-kuna exchange rates and consumer price indexes of Croatia, Germany, USA and Italy.[5] Nominal exchange rates were deflated in order to obtain mark-kuna, dollar-kuna and lira-kuna real exchange rates (Figure 1).

[4] Small letters denote logarithms. Therefore ratio of two variables can be denoted as difference of their logarithms.

[5] Prior to 1998, alternative price indices were used as a proxy for CPI in Croatia.

Figure 1

REAL EXCHANGE RATE GERMAN MARK (EURO) - KUNA, US DOLLAR – KUNA, ITALIAN LIRA - KUNA 1952-2003 (INCREASE OF INDEX REPRESENTS DEPRECIATION)



Note: During the period of fixed exchange rate, from 24 May 1949 through 13 July 1973, official nominal exchange rate of former Yugoslav dinar was devaluated four times against dollar, once against gold, and in 1965 dinar was denominated 1:100. Nevertheless, prior to reform of 1965, majority of international trade was undertaken via internal exchange rates, which was between 0.5 and 4 times the official nominal exchange rate. At the beginning, system of the multilateral internal exchange rates was internal system, but in summer of 1954, instead of devaluation, former Yugoslavia has registered internal exchange rate as "invoice/bottom line" nominal exchange rate (obračunski tečaj). At the moment of registration, the internal exchange rate was twice bigger (devaluated) than official nominal exchange rate. Therefore, between 1954 and 1965, internal nominal exchange rate has been used for calculation of real exchange rate.

In the 1990 the former Yugoslav dinar was denominated 1:10000 and in 1994, during exchange of Croatian dinar with Croatian kuna, another denomination occurred 1:1000.

After the introduction of Euro, real exchange rate of German mark is calculated with nominal exchange rate of Euro multiplied with 1.95583, which is the last recorded nominal exchange rate of German mark per Euro. Inflation data are for corresponding countries throughout the entire period.

Source: Data Appendix. Statistical Appendix available at (jtica@efzg.hr)

The sample offers uniquely rich body of data for studying exchange rate behavior. For the four countries analyzed in this study, exchange rate arrangements varied considerably over these 51 years ranging from fixed exchange rates prior to 1974, to flexible exchange rates all the way to the establishment of EMS in Germany and Italy, and throughout the entire post 1974 period in the USA. In Croatia, a period prior to 1965 was characterized by fixed internal multilateral exchange rates and high level of control over prices. Period between reform of 1965 and 1990 had only official and fixed exchange rates and ever decreasing amount of price control. In 1990, internal convertibility has been established and two years later, during the first months of independence, system of flexible exchange rate was established. After that, system of "dirty floating" survived up until the end of analyzed period.

4. Empirical results

In the contemporary econometric literature, purchasing power parity test represent a text book example for the applications of unit root and cointegration tests in the economics (Verbeek 2004, Enders 2003). Basically, there are three types of tests which are commonly applied to the PPP hypothesis: unit root test (Lothian and Taylor 1996), cointegration with Engle and Granger methodology (Frankel 1986; Engle and Granger 1987) and cointegration with Johansen and Juselius methodology (Johansen and Juselius 1990).

In this paper, only the simplest one, unit root test methodology will be used in order to reject null hypothesis of the unit root process for the bilateral real exchange rate movements. The reason for the selection of the unit root test is the fact that it is transparent and easily verifiable methodology, while Engle Granger's (1987) methodology is sensitive to selection of regressors in small samples[6] and Johansen and Juselius methodology is much more reliable and sophisticated, but in the same time not very intuitive.

"The power problem" suggests that it is required at least 75 years of data in order to be able to reject the null hypothesis with more than 50% probability (Frankel 1986). Therefore it is obvious that unit root test is going to be biased towards non-rejection of null hypothesis in our test on the 51 years long sample. In other words, even with stationary data, probability of rejection of null hypothesis of unit root is going to be smaller than 50%.

[6] "In practice it is possible to find that one regression indicates that the variables are cointegrated, whereas reversing the order indicates no cointegration" (Enders 2004, p. 347).

4.1. Unit root test

Augmented Dickey Fuller coefficient (Dickey Fuller 1979), Phillips-Perron coefficient (Phillips Perron 1988) and Fuller's (1976 (Enders 2004, p. 439)) critical values were used for the unit root test. Lags length for the ADF unit root test was selected according to Sims, Stocks and Watson (1990) methodology and Akaike and Schwarz criteria (Verbeek 2004; Enders 2004). The choice of all three upper mentioned methodologies for the lags length selection enabled us to address widest possible set of problems or controversies that might arise due to the autocorrelation and heteroskedasticity of Dickey-Fuller residuals.[7] Furthermore, various restricted and unrestricted models were compared with F statistics.

At first, unit root test was tested in the model with constant and trend:

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_1 t + \delta_1 \Delta y_{t-1} + ... + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t \ . \qquad (1)$$

In the case that null hypothesis of unit root hasn't been rejected in the model with constant and tend, unit root test was repeated in the model with constant only:

$$\Delta y_t = a_0 + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + ... + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t \ . \qquad (2)$$

At the end, in the case that null hypothesis of unit root has not been rejected in the model with constant only, unit root test was repeated in the model without constant and trend:

$$\Delta y_t = \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + ... + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t \ . \qquad (3)$$

The null hypothesis of the model with constant and trend was H_0:(a_0,γ,a_1)=(0,0,0), the null hypothesis for the model with constant only was H_0:(a_0,γ)=(0,0) and the null hypothesis for the model without constant and trend was H_0:(γ)=(0). Phillips-Perron coefficient was estimated also for the above mentioned models.

It is obvious that graphical analysis of data implies that most probably all three real exchange rates are stationary and without any deterministic trend, which

[7] Augmented Dickey Fuller test upgrades original Dickey Fuller test with appropriate lag lengths in order to solve for autoregressive and moving average terms in the original data generating process (Enders 2004, p. 190; Pufnik 2002, p. 42).

implies that it is quite logical to skip unit root test with deterministic trend and proceed with the model with drift. Nevertheless, testing was undertaken quite rigorously following Enders (2004, p. 213) methodology starting with unit root tests with weakest power to reject null hypothesis to the one with strongest power to reject null hypothesis.

Unit root test for the bilateral real exchange rate of the mark-kuna has rejected the null hypothesis of unit root. Phillips-Perron coefficient has rejected null hypothesis in three tested models with 1% significance. Since Augmented Dickey Fuller coefficient depends on lags lengths, three different methodologies, Akaike, Schwarz and *t* statistics, were used in order to estimate lag lengths for the ADF test.

In the model with trend and constant for the real exchange rate of German mark (euro)[8], t methodology has indicated that the best model is with no lags at all and the Akaike and Schwarz methodology has shown that the best model is with two lags. Unit root test of the model with constant, trend and no lags has rejected null hypothesis of unit root at 1% significance. But, in the model with constant and trend that was selected with the Akaike and Schwarz methodology, it wasn't possible to reject null hypothesis even at 10% significance.

Since the results were ambiguous, model was tested in restricted version without trend in order to increase the power of unit root test. The Akaike and Schwarz methodology have identified the model with constant and two legs. Again, it wasn't possible to reject unit root hypothesis even at 10% significance.

Therefore, the model without trend and constant was constructed. Once more, the Akaike and Schwarz methodology have indicated the model with two lags. Unit root test of the model without trend and constant and with 2 lags has rejected unit root hypothesis at 5% significance level. Due to ambiguity of the results, F statistics was also used in order to compare restricted and unrestricted models and according to it the restricted model without constant and trend was most representative.

[8] It should be highlighted one more time that price levels of Germany were used in order to calculate real exchange rates of kune/euro even after the 1999. Therefore, the real exchange rate of German mark (euro) does not represent relative prices of Croatia vis à vis Euroland, but vis à vis Germany during the entire analysed period.

Table 1

UNIT ROOT TEST FOR THE GERMAN MARK (EURO)-KUNA REAL EXCHANGE RATE

DM (Euro)								
Unit root test with constant and trend								
p	Akaike info criterion	Schwarz criterion	lag's p t statistic	γ	Augmented Dickey-Fuller t statistic	SSR	Φ2	Φ3
0	-0,81	-0,70	n.a.	-0,54	-4,52*	1,18	0,56	0,84
2	-0,98	-0,79	-1,56***	-0,46	-2,63	0,88	0,65	1,06
3	Phillips-Perron (Newey-West)				-4,38*			
Unit root test with constant only								
p	Akaike info criterion	Schwarz criterion	lag's p t statistic	γ	Augmented Dickey-Fuller t statistic	SSR	Φ1	
0	-0,82	-0,74	n.a.	-0,53	-4,45*	1,22	0,01	
2	-0,98	-0,83	-1,46***	-0,42	-2,41	0,91	0,03	
2	Phillips-Perron (Newey-West)				-4,38*			
Unit root test without constant								
P	Akaike info criterion	Schwarz criterion	lag's p t statistic	γ	Augmented Dickey-Fuller t statistic	SSR		
0	-0,86	-0,82	n.a.	-0,53	-4,49*	1,22		
2	-1,02	-0,90	-1,48***	-0,53	-2,44**	0,92		
2	Phillips-Perron (Newey-West)				-4,41*			

Note: Augmented Dickey-Fuller t statistics is tested using Fuller's (1976 (table A in Enders 2004, p. 439) theoretical values, Lag's p t statistic is tested using standard t-test, Φ statistic is tested using Dickey, David and Fuller's (1981 (table B in Enders 2004, p. 440) theoretical F values; * denotes significance at 1%; ** denoted significance at 5%; *** denotes significance at 10%.

Source: Data Appendix. Statistical Appendix available at (jtica@efzg.hr)

Unit root test for the bilateral real exchange rate of the dollar-kuna has rejected the null hypothesis of the unit root at higher significance level than unit root test of mark-kuna. Phillips-Perron coefficient has rejected null hypothesis in the model with trend and constant at the 5% significance, in the model with constant at 10% significance and in the model without exogenous variables at 1% significance level. Augmented Dickey Fuller was also estimated with three different methodologies for lag length selection.

In the model with trend and constant for the real exchange rate of US dollar, t methodology has indicated that the best model is with one lag and the Akaike and Schwarz methodology has shown that the best model is with two lags. Unit root test of the model with constant, trend and one lag has rejected null hypothesis of unit root at 1% significance. But, in the model with constant and trend that was selected with the Akaike and Schwarz methodology, it wasn't possible to reject null hypothesis even at significance level of 10%.

Having in mind ambiguity of results, model was tested in restricted version without trend in order to increase the power of unit root test. The Akaike and Schwarz methodology have identified the model with constant and two legs. Again, it wasn't possible to reject unit root hypothesis even at 10% significance level.

At the end, the model without trend and constant was constructed. Once more, the Akaike and Schwarz methodology have indicated the model with two lags. Unit root test of the model without trend and constant and with 2 lags has rejected unit root hypothesis at 10% significance level. Due to ambiguity of the results, F statistics was also used in order to compare restricted and unrestricted models and according to it the restricted model without constant and trend was most representative.

Table 2

UNIT ROOT TEST FOR THE US DOLLAR-KUNA REAL EXCHANGE RATE

USD								
Unit root test with constant and trend								
p	Akaike info criterion	Schwarz criterion	lag's p t statistic	γ	Augmented Dickey-Fuller t statistic	SSR	Φ2	Φ3
1	-0,63	-0,48	1,81**	-0,52	-4,44*	1,32	-2,45	-3,40
2	-0,79	-0,60	-1,62***	-0,31	-2,44	1,06	0,82	1,59
2	Phillips-Perron (Newey-West)				-3,69**			
Unit root test with constant only								
p	Akaike info criterion	Schwarz criterion	lag's p t statistic	γ	Augmented Dickey-Fuller t statistic	SSR	Φ1	
2	-0,78	-0,63	-2,06**	-0,19	-1,87	1,12	0,33	
2	Phillips-Perron (Newey-West)				-2,72***			
Unit root test without constant								
p	Akaike info criterion	Schwarz criterion	lag's p t statistic	γ	Augmented Dickey-Fuller t statistic	SSR		
2	-0,81	-0,69	-2,11**	-0,18	-1,81***	1,13		
2	Phillips-Perron (Newey-West)				-2,72*			

Note: Augmented Dickey-Fuller t statistics is tested using Fuller's (1976 (table A in Enders 2004, p. 439) theoretical values, Lag's p t statistic is tested using standard t-test, Φ statistic is tested using Dickey, David and Fuller's (1981 (table B in Enders 2004, p. 440) theoretical F values; * denotes significance at 1%; ** denoted significance at 5%; *** denotes significance at 10%.

Source: Data Appendix. Statistical Appendix available at (jtica@efzg.hr)

Unit root test for the bilateral real exchange rate of the lira-kuna has rejected the null hypothesis of unit root at even higher significance level than unit root test of dollar-kuna and mark-kuna. Phillips-Perron coefficient has rejected null hypothesis in the model with trend and constant at the 5% significance, and in the models with constant only and without constant and trend, null hypothesis was rejected at 1% significance. As in the case with German mark and US dollar, augmented Dickey Fuller was estimated with three different methodologies for lag length selection.

In the model with trend and constant for the real exchange rate of Italian lira, t methodology has indicated that the best model is with five lags and the Akaike and Schwarz methodology has shown that the best model is with two lags. Unit root test of the model with constant, trend and five lags, as well as in the model with two lags, hasn't rejected null hypothesis of unit root.

Therefore, the model was tested in restricted version without trend in order to increase the power of unit root test. The Akaike and Schwarz methodology have again identified the model with two lags, and t methodology has identified model with five lags. Again, it wasn't possible to reject unit root hypothesis even at 10% significance level.

Since both previous models haven't rejected null hypothesis of unit root, the model was tested without constant and trend. Once more, the Akaike and Schwarz methodology have indicated the model with two lags and t methodology has pointed to five lags. In both models, the null hypothesis was rejected, in the model with two lags at 10% significance level and in the model with five legs at 5% significance. Since there was not any ambiguity in this model, F statistics has, as it was expected confirmed the restricted models.

Table 3

UNIT ROOT TEST FOR THE ITALIAN LIRA-KUNA REAL EXCHANGE RATE

Lira								
Unit root test with constant and trend								
p	Akaike info criterion	Schwarz criterion	lag's p t statistic	γ	Augmented Dickey-Fuller t statistic	SSR	Φ2	Φ3
2	-0,80	-0,60	-1,41***	-0,34	-2,26	0,95	-1,92	1,09
5	-0,72	-0,39	1,73**	-0,45	-2,41	0,82	0,13	4,27
1	Phillips-Perron (Newey-West)				-3,84**			
Unit root test with constant only								
p	Akaike info criterion	Schwarz criterion	lag's p t statistic	γ	Augmented Dickey-Fuller t statistic	SSR	Φ1	
2	-0,80	-0,64	n.a.	-0,28	-1,92	0,99	0,05	
5	-0,76	-0,47	1,83**	-0,42	-2,36	0,83	4,78	
2	Phillips-Perron (Newey-West)				-3,57*			
Unit root test without constant								
p	Akaike info criterion	Schwarz criterion	lag's p t statistic	γ	Augmented Dickey-Fuller t statistic	SSR		
2	-0,84	-0,72	n.a.	-0,28	-1,94***	1,00		
5	-0,80	-0,55	1,86**	-0,43	-2,43**	0,83		
2	Phillips-Perron (Newey-West)				-3,61*			

Note: Augmented Dickey-Fuller t statistics is tested using Fuller's (1976 (table A in Enders 2004, p. 439) theoretical values, Lag's p t statistic is tested using standard t-test, Φ statistic is tested using Dickey, David and Fuller's (1981 (table B in Enders 2004, p. 440) theoretical F values; * denotes significance at 1%; ** denoted significance at 5%; *** denotes significance at 10%.

Source: Data Appendix. Statistical Appendix available at (jtica@efzg.hr)

The analysis has shown that it is possible to reject unit root test for all three real exchange rates despite the fact that our data spans only over 51 years. According to ADF, the null hypothesis of unit root for the real exchange rate of German mark and US dollar was rejected in all free models selected via t methodology, and in the case of Italian lira, null hypothesis was rejected only in the model without trend and constant. The null hypothesis of unit root for all three exchange rates was rejected in all the models without constant and trend regardless of the lags selection methodology. The null hypothesis was rejected for the German mark at 1

and 5%, for the US dollar at 10% and for the Italian lira at 10 and 5% significance level.

According to Phillips-Peron the null hypothesis was rejected in all three models for all currencies. The level of significance varied across models and exchange rates. Null hypothesis was rejected at smallest level of significance for German mark (1% in all three models), and slightly bigger level of significance for US dollar (1% in the last model, 5% in the first and 10% in the model with an intercept) and Italian lira (5% in the model with trend and intercept and 1% in other two models).

The fact that null hypothesis of unit root for the bilateral real exchange rates in Croatia during 1952-2003 was rejected is obvious proof of the validity of purchasing power parity assumption for the explanation of the real exchange rate in the long run. Furthermore, the fact that the model without trend and constant rejected unit root in all cases and that F statistics has always pointed to the most restricted model, can be interpreted as a proof of pure Casselian (1918) version of purchasing power parity in the long run.

4.2. Harrod Balassa Samuelson effect

The fact that purchasing power parity wasn't productivity biased (model with trend was not significant) during the analyzed period can be attributed to either lack of Harrod-Balassa-Samuelson (HBS) effect in Croatia and/or lack of convergence of relative productivity of Croatia.

Egert et al. (2003) and Mihaljek and Klau (2003) provide evidence for existence of the HBS effect in Croatia during post-stabilization period, but there is not any theoretical or empirical evidence about cointegration between relative sector prices and relative sector productivity in the era of self-management. On the other side, Stipetić (2002), Tica (2004) and Družić (2006) proved that there was not any significant convergence of GDP per capita in 2003 relative to 1950.[9] According to Tica (2004), GDP per capita in Croatia compared to US was 19% in 1950, 20% at nadir in 1993 and 24% in 2000. Stipetić estimated 19% for 1950 and 23% for 2000. Družić (2006) offers similar estimate of convergence but at lower level of GDP: 13% in 1950, 12% in 1993 and 14% in 2000.[10] Therefore, if relative GDP

[9] GDP per capita can be a proxy for the relative productivity of tradable and nontradable sector although average productivity and relative sector productivity does not have to be correlated (Asea and Mendoza 1994).

[10] Družić (2006) compared GDP in Croatia and US at current 1990 US dollars, while Tica's (2004) and Stipetić's (2002) comparison was done in 1990 Geary-Khamis PPP dollars.

per capita of Croatia was mean-reverting during 1950-2000, it is quite obvious that even productivity biased real exchange rate is going to be stationary and not trend stationary. In other words HBS effect might be present, but if there is no convergence of productivity (GDP per capita) there is not any significant trend (appreciation) in real exchange rates.

Although deterministic trend was insignificant in the pre-transitional period, it is reasonable to expect productivity biased purchasing power parity in the post-transitional period. In 2000 compared to 1993 the development gap was 5% smaller according to Stipetić (2002) and Tica (2004). Therefore, structural break is reasonable assumption for the early nineties. Unfortunately, data spans for post transitional period are to short. According to that, the share of post transitional data in the sample is too small to influence results and/or to be tested independently in time series tests.[11]

4.3. Simple dynamics of real exchange rate

The dynamics of the real exchange rate was estimated with simple univariate autoregressive model. The methodology developed by Lothian and Taylor (1996) was used in order to estimate AR(1) model of bilateral real exchange rates movements in Croatia.

Autoregressive univariate model for real exchange rate of German mark-kuna has resulted with statistically significant AR(1) coefficient of 0.46. Therefore, according to the model, 54% of deviation dies out in one time period, or in other words, half-life of shocks to the real exchange rate is less than a year (0.9) for the mark-kuna exchange rate.

[11] According to Enders (2004, p.200): "When there are structural brakes, the various Dickey-Fuller test statistics are biased towards the nonrejection of a unit root." In other words, the fact that null hypothesis of unit root is rejected is the best proof that there is not any structural brake in our sample. Of course, this does not mean that in the future, after the share of post transitional years in sample increases, there is not going to be any structural breaks.

Table 4

AR(1) MODEL FOR MARK-KUNA REAL EXCHANGE RATE

Dependent Variable: LREER_DM
Method: Least Squares
Date: 06/09/05 Time: 17:04
Sample(adjusted): 1953 2003
Included observations: 51 after adjusting endpoints
Convergence achieved after 3 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.005134	0.041379	-0.124063	0.9018
AR(1)	**0.465890**	0.120145	3.877716	0.0003
R-squared	0.234814	Mean dependent var		-0.008199
Adjusted R-squared	0.219197	S.D. dependent var		0.178502
S.E. of regression	0.157730	Akaike info criterion		-0.817440
Sum squared resid	1.219057	Schwarz criterion		-0.741682
Log likelihood	22.84471	F-statistic		15.03668
Durbin-Watson stat	1.906381	Prob(F-statistic)		0.000314
Inverted AR Roots	.47			

Source: Data Appendix. Statistical Appendix available at (jtica@efzg.hr)

Autoregressive univariate model for real exchange rate of US dollar-kuna has resulted with statistically significant AR(1) coefficient of 0.73. Therefore, according to the model, 27% of deviation dies out in one time period, or in other words, half-life of shocks to the real exchange rate is 2.2 years for the US dollar-kuna exchange rate.

Table 5

UNIVARIATE AR(1) MODEL FOR US DOLAR

Dependent Variable: LREER_USD
Method: Least Squares
Date: 06/09/05 Time: 17:01
Sample(adjusted): 1953 2003
Included observations: 51 after adjusting endpoints
Convergence achieved after 3 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.034489	0.097583	-0.353436	0.7253
AR(1)	**0.735626**	0.097987	7.507412	0.0000
R-squared	0.534933	Mean dependent var		-0.030135
Adjusted R-squared	0.525442	S.D. dependent var		0.267377
S.E. of regression	0.184191	Akaike info criterion		-0.507258
Sum squared resid	1.662395	Schwarz criterion		-0.431500
Log likelihood	14.93508	F-statistic		56.36123
Durbin-Watson stat	1.734336	Prob(F-statistic)		0.000000
Inverted AR Roots	.74			

Source: Data Appendix. Statistical Appendix available at (jtica@efzg.hr)

Autoregressive univariate model for real exchange rate of Italian lira-kuna has resulted with statistically significant AR(1) coefficient of 0.58. Therefore, according to the model, 42% of deviation dies out in one time period, or in other words, half-life of shocks to the real exchange rate is 1.2 years for the Italian lira-kuna exchange rate.

Table 6

UNIVARIATE AR(1) MODEL FOR ITALIAN LIRA

Dependent Variable: LREER_L
Method: Least Squares
Date: 06/09/05 Time: 17:04
Sample(adjusted): 1953 1999
Included observations: 47 after adjusting endpoints
Convergence achieved after 3 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.006550	0.059052	-0.110924	0.9122
AR(1)	**0.584811**	0.114519	5.106670	0.0000
R-squared	0.366893	Mean dependent var		-0.013246
Adjusted R-squared	0.352824	S.D. dependent var		0.208638
S.E. of regression	0.167844	Akaike info criterion		-0.689944
Sum squared resid	1.267720	Schwarz criterion		-0.611215
Log likelihood	18.21369	F-statistic		26.07808
Durbin-Watson stat	1.983818	Prob(F-statistic)		0.000006
Inverted AR Roots	.58			

Source: Data Appendix. Statistical Appendix available at (jtica@efzg.hr)

5. Conclusion

Using data that span 51 years, it is shown that three real exchange rates that we examine over the 1952-2003 are significantly mean reverting. Even stationary, first-order autoregressive, univariate models are capable of explaining 23% of variation for German mark, 53% of variation for US dollar and 37% of the variation for Italian lira real exchange rate.

In line with other studies it is shown that mean reverting process in Croatia was much faster compared to other industrial countries. It is estimated that average half-life of adjustment during 1952-2003 was 0.9 years for German mark, 2.2 years for US dollar and 1.2 years for Italian lira. Only speed of adjustments of US dollar is approximately within the range estimated for industrial countries (2.8-7.3 years)[12], while speeds of adjustments for German mark and Italian lira are much faster.[13]

[12] Edison 1987; Diebold, Husted and Rush 1991

[13] Faster speed of adjustment for countries with a history of growth and hyperinflationary problems is quite common stylized fact and in the case of Croatia was already documented in previous research (Cota and Erjavec 2005).

Foremost among the economic implications of these purely statistical findings is what they tell us about purchasing power parity as an equilibrium condition. Translated to the level of economic policy, these findings reinforce the idea of purchasing power parity as a long-run constraint even in the case of Croatia. In the context of EMU enlargement it should be stated that any economic policy that ignores some version[14] of purchasing power parity as a long run constraint of economic policy in Croatia should be regarded as an irrational.

[14] FEER, NATREX, HBS and NOEM are definitely promising modifications for the future work on the long run PPP in Croatia, while PEER, BEER and CHEER are obviously going to imply convergence toward long run equilibrium levels if data samples are long enough (Tica 2006; Egert, Halpern and MacDonald 2006).

Data appendix

REAL EXCHANGE RATE GERMAN MARK (EURO) - KUNA, US DOLLAR – KUNA, ITALIAN LIRA - KUNA 1952-2003 (INCREASE REPRESENTS DEPRECIATION)

Year	Real exchange rate lira 1973=1	Real exchange rate mark 1973=1	Real exchange rate dollar 1973=1	Real exchange rate lira average=1	Real exchange rate mark average=1	Real exchange rate dollar average=1
1952	0,66588310	0,57738446	0,87551174	0,63542694	0,62926963	0,78152875
1953	0,65187171	0,54665186	0,85202734	0,62205640	0,59577532	0,76056530
1954	1,20902111	1,06025700	1,68422415	1,15372291	1,15553427	1,50342882
1955	1,21000013	1,04117041	1,61834749	1,15465715	1,13473252	1,44462378
1956	1,15121245	0,98933432	1,51758329	1,09855830	1,07823831	1,35467625
1957	1,18030733	0,98289576	1,52258685	1,12632244	1,07122117	1,35914270
1958	1,20005774	0,96209472	1,49893743	1,14516951	1,04855089	1,33803196
1959	1,19577794	0,96743157	1,49142193	1,14108545	1,05436733	1,33132321
1960	1,10555386	0,89625598	1,38360156	1,05498805	0,97679572	1,23507697
1961	1,23772219	1,04885531	1,52155951	1,18111126	1,14310800	1,35822564
1962	1,16472264	0,97617074	1,38939525	1,11145056	1,06389182	1,24024873
1963	1,19046883	0,95555401	1,33708452	1,13601917	1,04142242	1,19355336
1964	1,12541821	0,87330812	1,20910643	1,07394384	0,95178571	1,07931325
1965	1,12860295	0,86512987	1,18060102	1,07698291	0,94287254	1,05386780
1966	1,22885676	0,94599594	1,28709328	1,17265131	1,03100544	1,14892850
1967	1,19218122	0,90467572	1,24044314	1,13765324	0,98597209	1,10728609
1968	1,15396928	0,87215907	1,22787628	1,10118904	0,95053340	1,09606823
1969	1,08147375	0,82998358	1,19227081	1,03200931	0,90456793	1,06428488
1970	1,01046230	0,82387520	1,12333740	0,96424578	0,89791063	1,00275122
1971	1,09152569	0,90726133	1,19052184	1,04160149	0,98879005	1,06272365
1972	1,15987953	1,01376551	1,17719489	1,10682897	1,10486495	1,05082731
1973	1,00000000	1,00000000	1,00000000	0,95426201	1,08986243	0,89265364
1974	0,90356953	0,94754566	0,92076515	0,86224207	1,03269441	0,82192436
1975	0,91009363	0,90880182	0,86946339	0,86846777	0,99046896	0,77612966
1976	0,80634443	0,87520588	0,86141721	0,76946385	0,95385401	0,76894721
1977	0,77191411	0,86575647	0,80626400	0,73660830	0,94355546	0,71971450
1978	0,79772128	0,90027867	0,76863503	0,76123511	0,98117990	0,68612486
1979	0,77974775	0,86751315	0,71499209	0,74408365	0,94546999	0,63824029
1980	0,92746642	0,93399055	0,81356195	0,88504596	1,01792122	0,72622904
1981	0,86497867	0,83180002	0,90783553	0,82541628	0,90654760	0,81038269
1982	0,87966742	0,85693544	1,05123589	0,83943320	0,93394175	0,93838955
1983	1,17149761	1,09843064	1,42283273	1,11791566	1,19713829	1,27009682
1984	1,21824399	1,09348207	1,60570488	1,16252395	1,19174503	1,43333831
1985	1,25317991	1,11312498	1,68060195	1,19586197	1,21315310	1,50019545
1986	1,23681632	1,09174833	1,24663431	1,18024682	1,18985549	1,11281266
1987	1,29841454	1,15632434	1,12832454	1,23902767	1,26023446	1,00720301

Year	Real exchange rate lira 1973=1	Real exchange rate mark 1973=1	Real exchange rate dollar 1973=1	Real exchange rate lira average=1	Real exchange rate mark average=1	Real exchange rate dollar average=1
1988	1,54892338	1,35937774	1,36107877	1,47807873	1,48153473	1,21497192
1989	1,41533436	1,18903957	1,25663697	1,35059980	1,29588956	1,12174157
1990	0,95634637	0,78281114	0,74850368	0,91260500	0,85315646	0,66815453
1991	0,77099814	0,60831219	0,61768466	0,73573423	0,66297661	0,55137846
1992	1,59478418	1,39210199	1,28739397	1,52184195	1,51719966	1,14919691
1993	1,03909955	1,08950437	1,06841905	0,99157322	1,18740988	0,95372815
1994	0,84024590	0,87234520	0,82333778	0,80181474	0,95073626	0,73495547
1995	0,73414587	0,84644940	0,71156231	0,70056751	0,92251341	0,63517869
1996	0,80949220	0,81447720	0,73536858	0,77246765	0,88766810	0,65642944
1997	0,81178591	0,78445732	0,82150424	0,77465645	0,85495057	0,73331875
1998	0,79228486	0,76013713	0,81039044	0,75604734	0,82844490	0,72339798
1999	0,83258588	0,79310488	0,90400806	0,79450507	0,86437521	0,80696608
2000		0,75493751	1,02295766		0,82277803	0,91314688
2001		0,70630324	1,01364145		0,76977336	0,90483073
2002		0,68719524	0,94344726		0,74894827	0,84217164
2003		0,69074106	0,80834751		0,75281274	0,72157435

Source: SGJ 1965, p. 285; SGH 1974, p. 161; SGH 1982, p. 206.; SGH 1991, p. 141; SLJH 1999, p. 159; SLJH 2003, p. 175; HNB 2005; Gartner 2000; SBD 2005; US Department of Labor 2005; Tecajevi i tecajne liste 1945.-1993., 1993; BSI 2005

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LIST OF ABBREVIATIONS

PPP – Purchasing Power Parity
HBS – Harrod Balassa Samuelson
ADF – Augmented Dickey Fuller
FEER – Fundamental Equilibrium Exchange Rate
NATREX – Natural Real Exchange Rate
NOEM – New Open Economy Macroeconomics Real Exchange Rate
PEER – Permanent Equilibrium Exchange Rate
BEER – Behavioural Equilibrium Exchange Rate
CHEER – Capital Enhanced Measured of Equilibrium Exchange Rate
SGH – Statistical Yearbook of Croatia
SLJH – Statistical Yearbook of Croatia
SGJ – Statistical Yearbook of Yugoslavia

TESTIRANJE PARITETA KUPOVNE MOĆI TESTOM JEDINIČNOG KORIJENA NAD DUŽIM VREMENSKIM RAZDOBLJEM: SLUČAJ HRVATSKE

Sažetak

U ovom radu je testirana hipoteza pariteta kupovne moći na godišnjim podacima za Hrvatsku u razdoblju od 1952. do 2003. Iako problem snage ukazuje na činjenicu da je potrebno imati niz od 75 godina kako bi se sa 50% šanse mogla odbaciti nulta hipoteza u slučaju kada je realni tečaj uistinu stacionaran, unit root test je uspio odbaciti nultu hipotezu na podacima za Hrvatsku na nizu dugom 51 godinu. Povrh toga, upotrebom jednostavnog autoregresivnog modela uspješno je objašnjeno 20 do 55% varijacija realnog tečaja u promatranom razdoblju, iako je stupanj postojanosti devijacija u nekim razdobljima bio visok. Ekonometrijske procjene su ukazale na činjenicu da pola devijacije od ravnoteže za realni tečaj kune i njemačke marke nestaje nakon 0,9 godina, za realni tečaj dolara i kune nakon 2,2 godine i za realni tečaj kune i talijanske lire 1,2 godine.

Ključne riječi: realni tečaj, paritet kupovne moći, problem snage, unit root test, testiranje dugog razdoblja.