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Empirical Testing of Purchasing Power Parity Validity in Selected European Union Countries

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Abstract

In this article, the authors carried out an empirical analysis of the validity of purchasing power parity (PPP) in Slovenia, Croatia, the Czech Republic, Slovakia and Austria. The results provide mixed support for PPP, which is typical for ex-transition economies. In the first phase of the empirical part of the research, the authors tested the stationarity of the real exchange rate in a logarithm, while in the second phase, the cointegration of nominal exchange rate, domestic and foreign price levels was tested. The Vector Error Correction Model (VECM) was used in the third phase to test if the signs of variables are in accordance with economics and econometrics theories, while in the final phase, restrictions were imposed for the symmetry and proportionality of coefficients. Slovenia is subject to limitations on the symmetry and proportionality of coefficients, which means the validity of both the absolute and relative versions of the PPP theory. Croatia is subject to a limitation on symmetry, but not to a limit on the proportionality of coefficients, which means the validity of the relative version of the PPP theory. In the case of the Czech Republic, Slovakia and Austria, restrictions on the symmetry and proportionality of the coefficients do not apply, which consequently constitutes an invalidity of both versions. However, to the authors' knowledge, and taking into account Liu (1992), who states that it is more important to check the presence of co-integration than to check the symmetry and proportionality of the coefficients, since there is a co-integratation between the nominal exchange rate, foreign prices and domestic prices, the theory of PPP is valid for all the selected countries. The empirical results suggest that all the real exchange rate time series are stationary, additionally, cointegration exists among all the variables for all countries, and the signs of coefficients are statistically significant for all variables in all countries, however, the coefficient restrictions are only statistically significant in Slovenia and Croatia.

Keywords: PPP, stationarity, cointegration, ADF test, Johansen test

Introduction

The importance of international trade has increased since the Second World War. During this period, economies have increasingly acted outwardly and merged into different forms of integration, which represents the onset of accelerated globalisation. A shift from closed to open economies has increased the global trade volume, resulting in more and more countries integrating into the world trading system, which has led to increased trade between countries. As countries mainly have their own national currencies, apart from the euro area countries, the exchange rate represents an important factor in foreign trade for each individual country.

Modern exchange rate theories include the monetary theory, the portfolio theory, and the balance of payment approach. The focus of this article is on the long-term exchange rate theory, i.e. purchasing power parity (PPP). The earliest records of the PPP theory date back to the 16th century and were written by scholars at Salamanca University. At that time, the development of the PPP theory was under the influence of three factors: the Salamanca University was then one of the leading educational institutions; the period called the Spanish Price Revolution, caused by the import of precious metals in Spain as the result of Spain expanding its territory to South America and leading to deterioration of the balance of payments; and prohibition by the Catholic church to charge interest. After this period, no significant progress in the field of the PPP theory was made until the First World War.

In 1918, during the First World War, the Swedish economist Gustav Cassel further developed the PPP theory (Taylor, 2002, 2006). In his work, he wrote about his attempt to develop a theory during the time of war, presuming that the trade rate between two countries is defined by a quotient ratio of the purchasing power of money in one country and the purchasing power in another. He reported that the inflation rate during wartime decreased the purchasing power in all countries to a different level, therefore the conversion rates would be expected to deviate from the old parities proportional to the inflation in an individual country. According to Cassel, the exchange rate could not deviate much from the PPP until a considerable trade between countries and free movement of goods existed. Even if a trade restriction had been applied, deviations from the PPP would not have occurred if they were the same for both parties. If trade restrictions had been more drastic for one party, larger deviations from the PPP would occur (Cassel, 1918).

After the Second World War, with the rise of Keynesian economics, the analysis of international economics was performed inside models with fixed prices, therefore no emphasis was placed on studying the PPP theory. The theory started gaining momentum among monetarists in the 1960s. Since then, the PPP theory – in different forms of strictness – has become one of the most important theories among economists dealing with international economics and finances (Taylor, 2006).

Modern studies conducted from the year 2000 onwards have presented mixed results in terms of the validity of the PPP theory for certain countries only, but not all the analysed countries; it especially depends on the countries selected, price indices and time period, thus meaning that the PPP theory in general has still not been completely empirically confirmed.

The objective of this article is to provide a detailed description of the PPP theory, including its shortcomings and limitations, as well as to provide the foundation for its empirical evaluation by using the econometrics stationarity test and cointegration test. The validity of the PPP theory will be studied for five countries – Slovenia, Croatia, the Czech Republic, Slovakia and Austria – all of which are EU member states.

Overview of Literature

The long-term theory of PPP is one of the most controversial topics in international economics. The validity of the PPP theory carries important implications for policy makers, central banks, multinational enterprises and players in foreign exchange markets. PPP is important for policy makers for two reasons. First, it can be used in predicting whether a currency is over or undervalued, which is especially important for less developed countries and those countries with significant differences in domestic and foreign inflation rates. Second, the PPP theory represents the foundation for many theories that aim at determining the exchange rate (Holmes 2002, 2001).

Sideris (2006) divided the studies on the PPP theory into four groups. The first group are early correlation studies, which were not reliable, and their results demonstrated weak or no support for the validity of the PPP theory. The second group are studies testing the presence of a unit root or stationarity of the real exchange rate. The third group of studies verifies cointegration between prices and the exchange rate. The results of early cointegration tests in relation to the validity of PPP theories vary and indicate a weak presence of the exchange rate returning to PPP during a transitional period towards flexible exchange rates (Taylor & McMahon, 1988; Mark, 1990), whereas for the period between the first and second world wars, as well as for those countries with a high inflation rate, the studies confirmed the return of the

exchange rate to the PPP level (Taylor & McMahon, 1988). The results of subsequent studies have demonstrated support for PPP for more countries, even during the transition towards flexible exchange rates (Kim, 1990; Kugler & Lenz, 1993), whereas for the transition countries, the studies using the cointegration tests do not demonstrate strong support for PPP theories (Sideris, 2006). Today, a combination of tests verifying the stationarity and cointegration is used, however, the time series are too short, and in order to deal with this issue, it is suggested that a longer time period should be used and the analysis should be performed on a larger number of countries by means of panel tests. Due to the weak statistical power of the initial tests, which provided mixed results on the validity of the PPP theory, it is recommended that the latest studies should use advanced econometric tests, including a unit root test with improved power, which can also allow for structural breaks. The second option is to use unit root panel tests and cointegration tests with improved power, while the third option is tests with the autoregression parameter allowing for non-linear adjustment of the real exchange rate (Sideris, 2006).

Generally, three important facts on the long-term PPP apply in terms of the results of cointegration studies: the support of the validity of PPP is greater in a fixed exchange rate than in a flexible exchange rate; the presence of cointegration is greater if the Wholesale Price Index (WPI) is used instead of the Consumer Price Index (CPI); and the evidence of PPP invalidity will, in principle, be greater if multivariate cointegration is employed instead of bivariate cointegration (Taylor, 2006; Froot & Rogoff, 1995).

Bahmani-Oskoee and Chang (2015) pointed out that the latest studies use a unit root test to check whether the real exchange rate is returning to its average rate. They also determined that standard unit root tests assumed that the adjustment of the real exchange rate was a linear process, whereas the latest studies have shown that this process can also be non-linear. The studies assuming the non-linear adjustment of the real exchange rate largely confirm the validity of the PPP theory. Foreign exchange market interventions, transaction costs, the different adjustment pace of the commodity prices following changes in the exchange rate, and structural breaks are among the main factors that cause non-linear exchange rate developments. The last option is the use of multivariate cointegration techniques, namely the Johansen test.

Kasman, Kasman and Ayhan (2010) reported that in the 1990s, the transition countries experienced drastic institutional and structural changes to create market-driven/oriented economies. Through economic transformation, these countries liberalised their markets, introduced trade reforms, created competition and privatisation, adopted new currency exchange regimes, established financial institutions and led an even more open economy to attract direct foreign investments. There are two characteristic facts for these countries; the first is the transition process which led to real production shocks and caused a permanent deviation from the PPP theory, while the second is that these countries faced massive monetary shocks as the result of inflation expectations, which caused temporary deviations from the PPP theory.

Sideris (2006) analysed the validity of the long-term PPP theory in 17 former transition countries and included four

Table 1. Review of existing/available studies

Author	Countries	Period	Base currency	Price index	Tests	Study results
Sideris (2006)	17 countries of Eastern and Central Europe, including Slovenia, Croatia, the Czech Republic, Slovakia	Slovenia: 1992 (M1) – 2004 (M1), Others: 1993 (M1) – 2004 (M1)	USD	CPI	Johansen and Larsson cointegration test	Weak support of the PPP theory
Cuestas and Regis (2009)	8 countries of Eastern and Central Europe, including Croatia, the Czech Republic, Slovakia	1993 (M12) – 2006 (M10)	EUR, USD, REER (currency basket of main trade partners)	CPI, HICP	Unit root test: Bierens test, Kapetanios test	PPP validity
Telatar and Husanov (2009)	12 countries of Eastern and Central Europe, including Slovenia, Croatia, the Czech Republic, Slovakia	Slovenia: 1993 (M7) – 2007 (M12) Croatia: 1992 (M1) – 2007 (M11) The Czech Republic, Slovakia: 1990 (M1) – 2008 (M3)	REER (currency basket of main trade partners)	CPI	ADF, KPSS, KSS, ST-TAR	Following the gradual structural changes and asymmetric adjustments of PPP applicable for all the selected countries.

Table 1. Review of existing/available studies (cont.)

Author	Countries	Period	Base currency	Price index	Tests	Study results
Christidou and Panagiotidis (2010)	15 EU member states, including Austria.	1973 (M1) – 2009 (M4)	USD	CPI	ADF, non-linear KSS, unit root panel test	No validity of PPP theory, except for Great Britain.
Giannellis and Papadopoulos (2010)	10 countries that joined the EU after 2004 and 12 countries that were already member states by the year 2004	1990 (M1) – 2006 (M7) Slovenija: 1992 (M1) – 2006 (M7), The Czech Republic, Slovakia 1993 (M1) – 2006 (M7)	EUR	CPI, TPI	ADF, SETAR	Confirmed convergence to a balanced real exchange rate.
Kasman, Kasman, Ayhan (2010)	11 countries of Eastern and Central Europe and Cyprus, Malta and Turkey	1990 (M1) – 2006 (M9) Slovenia: 1991 (M12) – 2006 (M9) Croatia: 1992 (M12) – 2006 (M9) The Czech Republic: 1994 (M1) – 2006 (M9) USD 1993 (M6) – 2006 (M9) DEM Slovakia: 1993 (M1) – 2006 (M9)	USD, DEM	CPI	Lagrange multiplier (LM) unit root test	Considering the structural breaks, weak support of PPP in case of the USD, support of PPP in 8 countries in the case of DEM.
Chang and Tzeng (2011)	9 countries of Eastern Europe.	1995 (M1) – 2008 (M12)	USD	CPI	Univariate unit root test (ADF, PP) KPSS), panel test and SURKSS	PPP validity in only two cases.
Su and Chang (2011)	7 countries of Eastern Europe, including the Czech Republic, Slovakia.	1993 (M1) – 2008 (M12)	USD	CPI	Breitung cointegration test	PPP validity
Boršič, Bekő and Baharumshah (2012)	12 countries of Eastern and Central Europe, including Slovenia, Croatia, the Czech Republic, Slovakia	1994 (M1)–2008 (M12)	USD, EUR	CPI	SURADF	PPP applicable in the case of EUR for Croatia, Poland, and Bulgaria; in the case of USD applicable for Bulgaria, Poland and Romania.
Bahmani – Oskooee and Chang (2015)	14 countries of Eastern and Central Europe, including Slovenia, Croatia, the Czech Republic, Slovakia anf Austria.	1994 (M1)–2012 (M6)	REER (currency basket of the main trade partners)	/	Caner and Hansen TAR unit root test, ADF, KPSS, PP	PPP validity in five countries, including Slovenia. Adjustment to PPP is non-linear.

ADF: Augmented Dickey Fuller Test, KPSS: Kwiatkowski–Phillips–Schmidt–Shin Test, KSS: Kapetanios, Shin and Shell Test, ST-TAR: Smooth Transition Threshold AutoRegressive test, PP: Phillips Perron Test, SURADF: Seemingly Unrelated Regressions Augmented Dickey–Fuller Test, SURKSS: The seemingly unrelated regressions Kapetanios, Shin, Snell test, SETAR; Self-Exciting Threshold AutoRegressive model, TAR: Caner and Hansen TAR unit root test, MW: Mann-Whitney Test, IPS Test: Im-Pesaran-Shin Test.
HICP: harmonised consumer price index, TPI: traded good price index, REER: real effective exchange rate, CPI: consumer price index, PPP: purchasing power parity.

countries in the sample that are important from the perspective of this analysis – Slovenia, Croatia, the Czech Republic and Slovakia. The time period ranged from January 1990 to January 2004, whereby this time period differed for certain countries in terms of the onset of transition reforms. Sideris chose the US dollar as the base currency and the CPI for the price index. The validity of the PPP theory was verified using the Johansen cointegration test and the Larsson panel cointegration test.

The results of the Johansen test provide support for the long-term PPP theory, however, the cointegration vectors violate the principle of symmetry and proportionality. For Slovenia and the Czech Republic, two of the countries analysed in this paper, the Johansen cointegration test rejected the null hypothesis at 5% risk and concluded that cointegration exists. In the case of Croatia and Slovakia, the test could not reject the null hypothesis and confirmed the existence of cointegration. In the Larsson test, the time period is uniform, specifically from January 1995 onwards. In six countries, which included Slovakia, the Larsson test could not reject the null hypothesis, showing there is no cointegration. In the study, the author concluded that the results are compliant with the studies relating to the validity of the PPP theory for transition countries. According to the author, the factors causing a deviation from long-term PPP are productivity shocks, managed exchange regimes requiring frequent interventions in foreign exchange markets, and the existence of non-exchangeable goods and services.

Cuestas (2009) analysed the validity of PPP theory in eight Eastern Europe countries, including Croatia and Slovakia. The analysis covered the period from December 1993 to October 2006. He used the CPI for the US dollar as the base currency and the Harmonised Index of Consumer Prices (HICP) for the euro as the base currency. He used the real effective exchange rate (REER). In his analysis, he pointed out that many previous studies did not consider the existence of non-linearity, therefore he included it. He provided three arguments to support his decision. First, if limitations in international trade exist and there is absence of arbitrage, this leads to non-linear exchange rate movement. Second, foreign exchange intervention operations can lead to non-linear movement of the real exchange rate. The third argument refers to the existence of structural changes leading to a non-linear deterministic trend. Due to the existence of non-linearity, he used two unit root tests, specifically the Bierens and Kapetanios tests.

Considering the non-linear deterministic trend, the results speaking in favour of PPP are more powerful because this trend encompasses structural changes during the transition period which strongly influenced the movement of exchange rates in these countries. For Slovakia, none of the tests

confirmed the validity of PPP for any of the exchange rates. In the case of Croatia, the KSS test confirmed the validity of PPP in the REER and the real exchange rate with the euro as the base currency, whereas the Bierens test could not confirm the validity of the PPP theory for euro as the base currency. In the Czech Republic, the KSS test rejected the validity of the PPP theory regardless of the selected exchange rate and the Bierens test only confirmed the validity of PPP in the REER.

Telatar and Husanov (2009) examined the validity of the PPP theory based on 12 countries in Eastern and Central Europe including Slovenia, Croatia, the Czech Republic and Slovakia. They used a commercially balanced REER. The time period differed for individual countries, depending on the available data. Their analysis shows that major structural changes in selected countries occurring during the transition period could result in non-linear adjustment of the exchange rate, which is why they used the stationarity tests enabling non-linearity and moderate structural changes in addition to classic tests such as ADF and KPSS.

When the analysis did not include linearity and structural changes, the results of the ADF and KPSS tests only confirmed the PPP theory in five countries, including Slovenia, Croatia and the Czech Republic. Considering the data non-linearity, the KSS test confirmed the validity of PPP in seven countries, including Slovenia, Croatia, the Czech Republic and Slovakia. When taking into account the structural changes and asymmetric adjustment by applying the ST-TAR test, the PPP theory was confirmed in all the countries.

Giannellis and Papadopoulos (2010) analysed the validity of the long-term PPP theory for 10 countries that joined the EU in 2004, including Slovenia, the Czech Republic and Slovakia. In addition to these ten countries, they also analysed 12 member states that joined the EU prior to 2004, including Austria. They used the CPI and TPI, which represent the weighted average of import and export prices. The ADF test confirmed stationarity for the CPI in all ten countries that became an EU member state in 2004 and thereafter. Among the other 12 countries, the ADF test only confirmed stationarity for France at 10% risk and the Netherlands at 5% risk. The TPI was only used for those member states that joined the EU before 2004. The ADF test only confirmed stationarity for Germany, whereas for Austria, calculation of the TPI was not possible due to the lack of sufficient data. As only one case of stationarity was confirmed, the authors checked whether the TPI reflects a non-linear movement. They established that linearity was rejected for all 12 countries, therefore they used the SETAR model which confirmed stationarity in six of the eight countries with enough data to

calculate the TPI. They concluded that in most cases the real exchange rate converges to PPP.

Kasman, Kasman and Ayhan (2010) wrote in their study that, unlike other authors, they used the Lagrange multiplier unit root test, thus enabling no more than two endogenous structural breaks for testing the stationarity of currencies against the US dollar and the DEM. The CPI was used, while the time period differed among the countries due to different data availability – it starts after 1990 and lasts until September 2006 for all countries.

In an analysis not employing structural breaks, it is not possible to confirm the stationarity of the exchange rate in any of the countries except Romania and Slovakia. If the analysis considers one structural break, the stationarity of the exchange rate can be confirmed in Romania and Turkey for the US dollar as well as for the DEM. Exchange rate stationarity could only be confirmed for the DEM in Slovenia, Cyprus, Croatia, and Slovakia. In the analysis taking into account two structural breaks, exchange rate stationarity can only be confirmed in Romania and Turkey for both the USD and the DEM, whereas in Slovenia, Bulgaria, Croatia, Cyprus, Estonia and Slovakia, it can only be confirmed for the DEM.

Christidou and Panagiotidis (2010) studied the validity of the PPP theory for 15 EU member states between January 1974 and April 2009; all data were monthly and seasonally adjusted. The authors chose two breakpoints (December 1991 and December 1998) to establish whether the Maastricht Treaty had an impact on these relations. They used the USD as the base currency and the CPI. Their analysis included the ADF test, the KSS test and four panel tests, such as the IM test, Pesaran test, Hadri and Kurozumi test, and the Hadri test which, unlike the other three panel tests, does not apply the assumption on the heterogeneity of the parameters. The ADF test confirmed stationarity in Great Britain for the entire period and in Sweden only for the period following the Maastricht Treaty. The KSS test showed that PPP only applies for the entire period in Great Britain. In Sweden and Italy, the KSS test showed stationarity only for the period between 1973 and 1998 for the former state, and between 1992 and 2009 for the latter. As far as all the other countries are concerned, the PPP theory does not apply in any time period. However, the authors established that the half-life of the exchange rate following the introduction of the euro decreased only in Sweden. In all the countries except Austria, Greece and Ireland, the half-life decreased in the period following the Maastricht Treaty.

Panel unit root tests provided results confirming the validity of PPP for the entire period. The results of the IM test, taking into account the Maastricht Treaty in 1992, indicate the rejection of the PPP validity. The Pesaran test only confirmed the validity of the PPP theory after the introduction of the Maastricht Treaty when considering all fifteen countries and not just the twelve countries with the euro as their currency. After the introduction of the euro, none of the tests provide results confirming the PPP theory.

Su and Chang (2011) analysed the validity of the PPP theory for seven Central and Eastern Europe countries, including Slovakia and the Czech Republic. They used monthly data from 1993 to 2008, the CPI and the nominal exchange rate at the end of a monthly period, and the US dollar as the base currency. Using the Breitung nonparametric test, they first verified the existence of cointegration between variables and then determined the linearity of cointegration. Asymmetric price adjustment and non-proportional price and exchange rate movement were allowed in the long-term PPP. The result of the Breitung test showed the existence of cointegration between all countries included in the sample. The existence of bivariate linear cointegration was rejected in all cases except in Slovakia, and the existence of multivariate cointegration was rejected in the case of Slovakia and Russia. The study provided robust results confirming the PPP theory in the selected countries and indicated the existence of nonlinear cointegration.

Chang and Tzeng (2011) included nine East European countries in their analysis, including the Czech Republic. The period under observation was between January 1995 and December 2008. The year 2000 was chosen as the base year for the CPI. The US dollar was selected as the base currency. Prior to the analysis, they converted all data into natural algorithms. The choice of the US dollar as the base currency is justified by the fact that the internal exchange market is mainly dominated by the US dollar. Using the Jarque-Bera test, they determined that, with the exception of the Bulgarian Lev/USD exchange rate, the bilateral real exchanges rates are not normally distributed, and the graphic analysis demonstrated considerable upward and downward movements, showing non-linear adjustment of the real exchange rate.

The authors first performed the ADF, PP and KPSS tests confirming the stationarity of a time series only after using them on the first differentiation of the time series. The Im-Pesaran-Shin, Hadri, MW, Choi and Chang panel tests showed the same results as the unit root test, which is non-stationarity of time series of the real exchange rate. The SURKSS panel test, which is a combination of the SURADF and KSS tests, can identify how many and which time series are stationary. The SURKSS test confirmed the validity of PPP in two countries, the Czech Republic not being one of them. They concluded that the support for PPP validity is low in

transition countries, which is why PPP validity remains a questionable and inconclusive issue.

Boršič, Baharumshah and Bekő (2012) analysed the validity of the PPP theory in twelve Eastern and Central European countries. The real exchange rates used in the study were monthly-based, the base currency was the US dollar in the first case and the euro in the second. The time period extended from January 1994 to December 2008. When verifying the validity of PPP, they used the SURADF panel unit root test, which, unlike the Levin, IM, Fisher ADF and Fisher SURADF PP tests, enables the identification of how many and which countries from the panel include the unit root. The test is specific as it contains non-standard distributions, therefore critical values are to be calculated by means of the Monte Carlo simulation. In addition to this test, they also used the aforementioned tests. In the case of the US dollar as the base currency, only the Levin test rejected the null hypothesis of non-stationarity, by considering the constant and trend. When the euro is selected as the base currency, all the listed tests rejected the null hypothesis of non-stationarity.

The results of the SURADF test showed that the validity of the PPP theory can be confirmed for certain countries in the panel, however, the validity depends on the base currency. The validity of the PPP theory with the US dollar as the base currency could be confirmed for seven countries, whereby Slovenia, Croatia, the Czech Republic and Slovakia were not among them. When the euro was used as the base currency, the validity of the PPP theory was confirmed for five countries, including Croatia and Slovenia. The first study finding was that the validity of PPP cannot be generalised for a group of countries but can be applied only for individual countries. The second finding refers to the validity of PPP and its dependence on the selected base currency.

Bahmani-Oskooee et al. (2014, 2015) analysed the PPP and real exchange rate in Central and Eastern European countries and verified the validity of PPP theory for fourteen transition countries, including all the five countries that are the subject of this analysis. They used monthly data for the REER for the period from 1994 to mid-2012. The validity was verified by using the Caner-Hansen TAR test examining non-stationarity and non-linearity. The authors wanted to demonstrate the difference between the Carner and Hansen test and the standard ADF, KPSS and PP unit root tests. The standard unit root tests showed weak support for the PPP theory. The KPSS test showed that no time series is stationary, which is similar to the results of the ADF test establishing a stationary time series for three countries, including Slovenia. The PP test displayed a stationary time series for four countries, including Slovenia. When the authors used the first time series differentiation, all the tests provided the same results, i.e. that the time series is stationary. The KPSS

test was an exception showing a non-linear time series for three countries.

They further performed the Caner and Hansen test consisting of two steps. The first step is verifying linearity by means of the Wald test WT and bootstrap p-value. Once they merged the results, the results rejected the null hypothesis verifying linearity and concluded that a simple linear model is inappropriate. In the second step, they studied the characteristics of the threshold unit root of the real exchange rate. They rejected the unit root hypothesis at a 10% risk level in five countries, including Slovenia, but could not reject the null hypothesis for the remaining nine countries.

Koukouritakis (2009) examined the validity of PPP between the twelve new EU countries vis-à-vis the Eurozone by using the Johansen cointegration methodology. The evidence also suggests that the PPP vector enters the cointegration space for Bulgaria, Cyprus, Romania and Slovenia, which means that the long-run PPP vis-à-vis the Eurozone was only verified for these countries. The study of Boršič et al. (2011) found support for the validity of PPP in some reforming European economies, and special attention was devoted to individual country-specific factors that cause PPP deviations. Yang-Cheng et al. (2012) applied the newly developed Autoregressive Distributed Lag (ADL) test for threshold cointegration to test the validity of long-run PPP for a sample of transition countries (i.e. Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Russia) over the period from January 1995 to December 2008. The empirical results indicate that PPP only holds true for five of these transition countries. The Cuestas and Regis (2013) study points to the fact that the PPP theory holds true in a greater number of countries. Together with Chang (2013), they proved that PPP holds true for most of the transition countries studied.

Arize et al. (2015) explored the symmetry and proportionality conditions in the PPP and the results of a long-run cointegration analysis and short-run dynamics, all of which provide evidence for long-run PPP. Huang and Yang (2015) analysed the PPP by applying the Pesaran panel unit root test to real exchange rate data of eleven euro countries for the sample period of January 1957 to May 2013. They proved that the evidence for the mean-reverting in real exchange rates is much weaker in the post-1998 euro period than in the pre-euro period, and that for the four countries not using the euro – Norway, Sweden, Switzerland and the UK – the evidence for the mean-reverting in real exchange rates is strong in both the pre- and post-euro (post-1998) periods.

Chun et al. (2016) applied in their a non-linear threshold unit-root test to test the validity of PPP to assess the non-stationary properties of the convergence of RERs based on the

Taylor rules for the ten Central Eastern European countries. In the Su et al. (2014) article, the Monte Carlo simulation was used with the wildbootstrapped KSS test for the period from 1994 to 2012, which included a number of crises, such as the Asian financial crisis, the Russian crisis, and global financial crises, therefore, the study provided strong evidence against PPP.

Nazlioglu et al. (2021) proved that PPP is valid for Greece, Italy, Ireland, Portugal and Spain, considering that structural breaks in the non-linear framework play a crucial role. Bekő and Kavkler (2019) analysed the PPP theory for a class of ten Central Eastern European economies covering the period from January 2001 to December 2016. The results of the unit root tests imply that the null hypothesis of non-stationarity of real exchange rates cannot be rejected for the whole period. The weak evidence on PPP found in this study suggests that the process of real integration of Central and Eastern European economies, as well as the subsequent price convergence among European markets, remains incomplete.

Bahmani-Oskooee (2017) analysed the PPP in 27 emerging markets by using the new Fourier non-linear quantile unit root test. Conventional unit root tests support PPP in half of the countries at most. The Fourier non-linear quantile unit root test reinforces PPP in 26 out of 27 countries in the case of emerging markets. Mladenović and Bodor (2020) analysed the sustainability of PPP within the quantile autoregression model in the economies of the Czech Republic, Hungary, Poland, Romania, Serbia and Turkey. To some extent, the empirical results support the PPP theory for the euro and US dollar-based real exchange rate in Romania, Serbia and Turkey. The euro-based real exchange rate in Hungary and Poland is also identified to confirm the PPP theory. The dynamics of the real exchange rate in the Czech Republic cannot be associated with validity of the PPP. The persistence of the euro-based real exchange rate is estimated to be more prominent after the depreciation shocks.

Pažický (2020) proved the existence of the long-run relationship by the vector error correction model (VECM); no cointegrating vector in the case of the Slovak Republic and the Czech Republic was proved, which rejects the existence of a persistent long-run equilibrium between the exchange rate, domestic prices (i.e. in the Slovak Republic) and foreign prices (i.e. in the Czech Republic). Yoon and Jei (2020) proved that, by applying a time-varying cointegration model, the PPP varies over time for the United States, Canada and Mexico. The PPP elasticity based on the CPI is particiularly more volatile than the PPI.

Seshaiah and Tripathy (2018) proved the co-integration of a positive relationship between GDP PPP per capita and the real exchange rate, real interest rate, and money supply,

and a negative relationship between GDP, PPP and CPI in Brazil, Russia, India, China, and South Africa. Prabheesh and Garg (2020) used a structural break unit root test and structural break cointegration technique to test the presence of economic relationships between nominal exchange rates and each of the price and interest rate differentials in Brazil, Russia, India, China and South Africa. The study examines the validity of two cointegrating vectors representing PPP conditions.

General conclusions of the literature on PPP

Among the ten studies analysed in Table 1 in detail, the stationarity test is used, while the cointegration and panel tests were used additionally. The conclusions of the studies showed relatively mixed results. Only three studies showed the validity of the long-term PPP theory for all or most of the analysed countries, with one considering the structural breaks. In addition to these three studies, one demonstrated convergence with the real exchange rate. The other studies only showed support for the PPP theory for certain countries.

The selected studies are among the more recent ones, therefore six of them use tests for non-linear adjustment of the real exchange rate. The results of the studies taking into account the existence of non-linearity – Cuestas (2009), Telatar and Husanov (2009), Giannellis and Papadopoulos (2010), Christidou and Panagiotidis (2010), Su and Chang (2011), and Bahmani-Oskooee and Chang (2015) – show strong evidence of validity of the PPP theory, or, in other words, the validity of the PPP theory was proved for a larger number of the analysed countries than in studies that have used linear adjustment of the real exchange rate.

The most frequently used currency in the analysis is the USD (in seven studies), while the EUR is used in three instances, the REER in two, and the DEM in one. From the perspective of international trade, the use of the USD and EUR is compliant with the theory relating to international trade, as those countries using the USD and EUR are the largest external trading partners among the analysed countries. Bahmani-Oskooee and Chang (2015), as well as Telatar and Husanov (2009), established in their studies that it is better to consider the REER rather than the bilateral exchange rates when analysing the validity of the PPP theory. The REER was used because the rate movement is the key for international trade flows. Bahmani-Oskooee and Chang (2015) argue that the PPP theory is not only valid for a bilateral trading partner but also for the majority of their trading partners if the REER is stationary.

All the studies used the CPI as the price deflator. The HICP was only used in one study by Cuestas (2009).

Giannellis and Papadopoulos (2010) point out that many studies state that the choice of the price index, in addition to the inadequate econometric test, are the reason for the rejection of the PPP theory. The analyses of the validity of the PPP theory have shown that the evidence speaking in favour of validity of the PPP theory is stronger if the PPI is used instead of the CPI, as it includes proportionally more exchange goods than the CPI, which is why the authors used the TPI in their analysis. They also highlighted the results of previous studies which concluded that the real exchange rate returns to its average level faster if the PPI is used instead of the CPI.

Review of the Periods Important for the Development of Macroeconomic Conditions in Selected Countries

During the last thirty years there has been intensive transformation of the former transition economies from the 1990s, which have reintegrated into the global economy and, in most of these countries, the standard of living has improved considerably. The transformation towards a market economy was difficult and long-lasting. Liberalisation of trade and prices was implemented very rapidly, while the institutional changes in the field of governing, competition, the labour market, privatisation and restructuring often faced opposition from different interests. In terms of macroeconomic policies, the period of the countries' transformation process can be further categorised into four different subperiods (IMF, 2014).

Four of the selected countries belong to this group, whereas Austria belongs to the developed economies and therefore the same characteristics do not apply. When the four countries faced transformation of their economy, Austria had positive economic growth, low inflation, a low unemployment rate and stable public debt. It was not until after 2009 that a similar movement of macroeconomic indicators was noticeable, as in the other analysed countries (IMF, 2019).

Initial programs of stabilisation and reform

This covers the period from 1990 to 1993 and the common features of this period are a drastic decline in GDP in all countries included in this study, interruption of trade links and high inflation rates. Those countries with better initial conditions and a more aggressive approach towards reforms stabilised their economies faster (IMF, 2014). The cumulative GDP decline during this period was 21% in Slovenia, 35% in Croatia, 18% in the Czech Republic, and 22% in Slovakia (Havrylyshyn, Izvorski, & van Rooden, 1998).

The surveyed countries adopted two approaches during their reforms, one being the 'shock therapy' and the other the 'gradual change' approach. The former was adopted in Poland and later also in the then Czechoslovakia, whereas the latter was adopted in the then Yugoslavia, of which Slovenia and Croatia were a part. This process officially started in Yugoslavia in 1989 and included the elimination of social ownership of enterprises and liberalisation of exchange rate regimes and imports. The objective was to correct the economic, structural and institutional shortcomings in terms of fixed exchange rates. The initial results of the gradual approach brought a significant decline in inflation with a relatively low shortfall in BDP, however, it ended with the secession of individual Yugoslavian states (IMF, 2014).

Market reforms

From 1994 to 1996 the regional economic changes continued despite political uncertainties and different paces of macroeconomic stabilisation. Globally, this was a period of integration, in 1994 the NAFTA agreement came into force, and in 1995 the World Trade Organization was established. Market reform in Central and Eastern European countries enabled integration into the global economy and the increase of market and capital flows; during this period, the surveyed countries began to record economic growth and disinflation and achieve fiscal stability. There were five main objectives of the reforms in this period – macroeconomic stability, liberalisation of prices and convertibility of currencies, reforms relating to enterprises (privatisation), establishing and strengthening of social security, and the development of institutional and legal frameworks. It was also important to improve the labour market which had a common characteristic in all Central and Eastern European countries: a high employment rate, but with rather unproductive work (IMF, 2014).

Economic shocks and recovery

Major crises were globally present from 1997 and 2001 in the developing countries, for example, the crisis in Mexico from 1994 to 1995, the Asian crisis in 1997, and the crisis in Argentina in 2001. The developing countries in Europe were highly vulnerable under these conditions as they had not yet achieved complete macroeconomic stability, market institutions were in the process of being developed and financial systems were still fragile. Many countries that had not established a robust market-oriented framework were the first to succumb to internal crises and afterwards also the Russian crisis in 1998, which resulted from the Asian crisis and most affected the former Soviet Union States. At first, the Russian crisis spread to the developing countries in Latin America and then back to Asia, and even to Europe. Recovery took

place in 1999 when regional GDP increased by 4% and in 2000 when it increased by 7%. By the year 2001, most countries in the region had their current account balance, budget deficits and inflation under control (IMF, 2014).

Economic boom

The period between 2002 and 2007 was characterised by fast regional economic growth, encouraged by favourable global conditions and increasing trust in the process of converging towards the European Union. Economic growth in the region was on average 6% on an annual basis, meaning that GDP would double every twelve years. However, the main driver of economic growth was external borrowing for consumption and construction. With the highly increased domestic demand and credit boom generating increased consumption and investments in construction and real estate, external imbalances started to occur, and production capacities could not keep up with demand, which was not sustainable and led to overheating tendencies in the economy. The entire region faced increased deficits in their current account balance and increased credit-to-GDP ratio. There was also no proper feedback from the fiscal and monetary policies to decrease the overheating economies, partially due to the assessment of the output gap at the time, indicating an inflation gap of between 1% and 2%, however, subsequent revised data have shown that the output gaps for Slovenia, the Czech Republic and Slovakia were significantly higher, i.e. between 5% and 7% (IMF, 2014).

Global crisis

The onset of the global financial crisis in the developed economies was recorded in the summer of 2007 and spread to former transition countries with a delay. During this period of delay, economic growth, credit growth and foreign capital inflow was still present in these countries, therefore it was argued that the developments in these countries are separate from those in the developed economies. The economic boom ended in 2008 and the former transition economies were very vulnerable due to imbalances stemming from this period. The combination of accumulated imbalances and external shocks, such as the collapse of Lehman Brothers in 2008 and the euro crisis between 2010 and 2012, led to the worst consequences for the former transition countries. The effects manifested themselves in economic growth, which was below the potential level, high unemployment rates and fragile financial markets, and this also hindered accession to the EU. Due to decreased capital inflows, these countries faced a deep recession. It was not until 2010 that weak economic growth returned, however, during the years of the euro crisis, an economic downturn was recorded once again (IMF, 2014).

The period after 2015

In Table 2, the observations stating that economic growth began after 2014 are confirmed. All the surveyed countries recorded strong economic growth; the lowest economic growth was in Austria, which may be attributed to the fact that the global crisis and the euro crisis did not have such a great impact in Austria as in the other four countries. This may be the reason why Austria recorded somewhat slower economic growth. In the other four countries, the global crisis and the euro crisis left their mark, hence these countries recorded high economic growth rates when economic recovery took place. Differences were noted during the time when the selected countries reached the level of GDP they were at prior to the global crisis in 2008. Austria reached this level of GDP in 2011, Slovakia in 2010, the Czech Republic in 2014, Slovenia in 2017, and Croatia not until after 2019. The economies in some of the surveyed countries have somewhat transformed, and imports started taking on much greater importance.

Slovenia has shifted towards an export-oriented economy and has been recording a positive current account balance since 2010. As seen in Table 2, the current account balance has been marked by a high percentage of GDP since 2015, which continued to rise until 2019. A similar situation can be seen also in Croatia, which started to record a positive current account balance in 2014. The Czech Republic also started to focus on exports, however, the current account recorded since 2015 shows negative and positive results, and the percentage of the current account balance in this period was between -0.4% and 0.4% of GDP. Since 2015, Slovakia has recorded a negative current account balance and consequently also a negative percentage of the current account balance ranging between -2% and -3% of GDP. Austria has recorded a positive current account balance since 2000.

The Purchasing Power Theory and Empirical Analysis

Law of one price

The law of one price provides that in competitive markets, in the absence of transport costs and official barriers to trade, identical goods sold in different countries must be sold for the same price if their prices are expressed in the same currency (Krugman, Obstfeld, & Melitz, 2012). This is written using the equation:

$$P_i = E \times P_i^* \tag{1}$$

Table 2. Selected macroeconomic conditions after 2014

		Slovenia	Croatia	The Czech Republic	Slovakia	Austria
2015	GDP (growth in %)	2.2	2.4	5.3	4.8	1.0
	CA (% of GDP)	3.8	3.3	0.3	-2.1	1.7
2016	GDP (growth in %)	3.1	3.5	2.5	2.1	2.1
	CA (% of GDP)	4.8	2.1	-0.3	-2.7	2.7
2017	GDP (growth in %)	4.8	3.1	4.4	3.0	2.5
	CA (% of GDP)	6.2	3.4	0.1	-1.9	1.5
2018	GDP (growth in %)	4.1	2.7	2.8	4.0	2.4
	CA (% of GDP)	6.1	1.9	0.4	-2.6	2.3
2019	GDP (growth in %)	2.4	2.9	2.4	2.3	1.6
		6.6		-0.4	-2.9	2.6

CA: current account, GDP: gross domestic product
Sources: Eurostat, 2020 a, b; BS, 2020a, b; HNB, 2020, a, b; ČNB, 2020, a, b; NBS, 2020 a, b, OeNB, 2020, a, b.

where P_i is the price of an i good in the country of origin and P_i^* is the price of an i good abroad, and E is the nominal exchange rate (Taylor & Sarno, 2002). The basic argument for why the law of one price is generally true is arbitration, which means buying something in countries where the price is low and selling in countries where the price is high, thus eliminating the price differences in the medium run (Lan, 2001). The assumptions on which the law of one price is based are (Krugman, Obstfeld, & Melitz, 2012):

- absence of transport costs
- economic operators have complete information on the prices of goods and services at home and abroad
- there are no barriers to international trade and international financial markets
- the quality of the same goods is the same everywhere and the basket of goods is universal

If the law of one price is not the case for a particular commodity, some economists argue that prices and exchange rates should not deviate too much from the ratio envisaged by the PPP theory. When goods and services become temporarily more expensive in one country than in another, demand for the currency and its products declines in the country where products and services are more expensive, causing the exchange rate and home prices to return to PPP (Krugman, Obstfeld, & Melitz, 2012).

Absolute purchasing power parity

The absolute parity of purchasing power states that the exchange rate between two currencies is equal to the price ratio between the two countries (Krugman, Obstfeld, & Melitz, 2012,). This is written using the equation:

$$E_t = \frac{P_t}{P_t^*} \tag{2}$$

where P_t is the price of a good in the country of origin and P_t^* is the price of a good abroad and E is the nominal exchange rate.

Relative purchasing power parity

The relative parity of purchasing power states that the percentage change in the exchange rate between two currencies over any time period is equal to the difference in percentage changes between the price levels of two countries (Krugman, Obstfeld, & Melitz, 2012. This is written using the equation:

$$\frac{E_t - E_{t-1}}{E_{t-1}} = \pi_t - \pi_t^* \tag{3}$$

where E is the nominal exchange rate, the π in the country of origin and π^* is the price index in a foreign country.

The relative version of PPP is also important because it may also apply when the absolute version of PPP does not apply. If the factors that lead to deviations from the absolute version of PPP are stable over time, the percentage changes in relative prices may roughly illustrate those in the exchange rates (Krugman, Obstfeld, & Melitz, 2012).

As can be seen in equation 3, if the expected rate of domestic price inflation (π) is higher than foreign prices (π^*), the foreign currency will appreciate against the domestic currency and the domestic currency will depreciate against the foreign currency. If the nominal foreign exchange rate of the in the country of origin depreciates exactly enough to compensate for the difference in inflation, the real exchange rate in the country of origin will remain unchanged.

Purchasing Power Parity Limitations

There are many problems with the validity of the theory of PPP, as there are many economic and specific factors in reality that cause deviations from PPP. These factors include the existence of transport costs, tariffs and non-tariff restrictions, price discrimination, various consumables, government consumption, cumulative current account deficit, and Dutch disease. There are also specific restrictions in the case of transition countries – the initial undervaluation of exchange rates, trend appreciation, the Balassa-Samuelson hypothesis, and the Bhagwati-Kravis-Lipsey theory (more in Krugman, Obstfeld & Melitz, 2012).

Definition of the real exchange rate

The real exchange rate is the nominal rate between the currencies of two countries, taking into account the price developments in the two countries. The equation by which the real exchange rate is calculated is:

$$RE_t = NE \times \frac{P^*}{P} \tag{4}$$

where RE_t is the real exchange rate, NE is the nominal exchange rate, P^* represents the price index in a foreign country, and P represents the price index in the country of origin.

If the value of the real exchange rate increases, this refers to real depreciation and improving a country's international competitiveness, however, if the value of the real exchange rate decreases, this refers to real appreciation that exacerbates a country's international competitiveness.

Models for testing purchasing power parity

The model for testing the absolute version of PPP can be recorded in the form (Cheung & Lai, 1993):

$$e_t = \alpha_0 + \alpha_1 p_t + \alpha_2 p_t^* + \xi_t \tag{5}$$

All the variables are in the logarithmic form, with et the nominal exchange rate, pt the prices of domestic goods and p_t^* the prices of foreign goods, and it shows deviations from PPP. In the strictest form of the absolute version of PPP, $\alpha_0 = 0$, $\alpha_1 = 1$ and $\alpha_2 = -1$ is assumed. The proportionality assumption ($\alpha_1 = \alpha_2$) and symmetry($\alpha_1 = -\alpha_2$) of the coefficients must be met (Froot & Rogoff, 1995).

Since the studies that checked the validity of the PPP theory were rejected in the short term, econometric techniques began to be developed to verify whether the nominal exchange rate and relative prices stabilised at PPP levels. In the long term, the validity of PPP can be checked through the characteristics of the real exchange rate, because regardless of the level at which the real exchange rate stabilises, it must return to its average (Taylor, 2006). The real exchange rate (ret) is recorded using the formula:

$$re_t = ne_t - p_t + p_t^* \tag{6}$$

where all the variables are in logarithms, net represents the nominal exchange rate, pt the domestic price level and p_t^* the foreign price level. Under the assumption of PPP, the real exchange rate should be 0, i.e. the real exchange rate movement is equal to the deviation from PPP (Taylor, 2006).

In the first phase, the stationarity of the real exchange rate was checked. A stochastic process is stationary, when the average value and variance are constant over time, and the covariance between two time periods depends only on the distance between two time periods and not the actual time during which the covariance is calculated. Such a time series will tend to average, and the fluctuations around this average will mainly have a constant amplitude (Davidson & MacKinnon, 2003).

To check the stationarity of the real exchange rate time series, the Augmented Dickey-Fuller test (ADF) derived from the Dickey-Fuller test, was used, which assumes the unreliability of the ut errors. In order to allow the correlation of the ut errors, the ADF test also includes deferred variables of the dependent variable ΔY_t. The ADF was carried out on the basis of an evaluation of the regression formula of the form (Gujarati & Porter, 2009):

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-1} + \varepsilon_t \tag{7}$$

where ε_t is error, $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$ and m is the number of deferrals determined in such a way that ε_t is not correlated.

The zero and alternative ADF test hypothesis are as follows:

H0: the time series contains a unit root; (H0: δ = 0)

H1: the time series is stationary; (H1: δ< 0)

When validating or rejecting a zero hypothesis instead of classical t statistics, τ statistics were used. The ADF test for rejecting the null hypothesis requires that τ statistics must take up greater negative values than usual (Gujarati & Porter, 2009).

In the second phase, the authors looked for a stationary linear combination of three variables. The problem arises if the time series of variables are integrated into different orders, but MacDonald (1993) argues that even if time series are integrated into different orders, the volatility of variables can lead to a stationary linear combination between them. To check co-synthesisation, the Johansen co-integration test was used, which is based on vector authored aggression (VAR) and is written in a shorter form (Johansen, 1991):

$$Y_t = A_1 Y_{t-1} + \cdots + A_m Y_{t-m} + BX_t + \eta_t \tag{8}$$

where A_1, A_m and B are arrays, Y_t is a vector to non-stationary variables I(1), X_t is a vector of deterministic variables and η_t vector of innovation. The equation (10) can also be recorded as:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{m-1} \Gamma_i \Delta Y_{t-1} + BX_t + \eta_t \tag{9}$$

where:

$$\Pi = \sum_{i=1}^{m} A_i + I \qquad \Gamma = -\sum_{J=i+1}^{m} A_j \tag{10}$$

Matrix Π contains information on long-term changes to the time series. Granger's representative theorem states that matrix Π can be divided into two, $t_o \times r$ matrix ρ and α of order r ($r \leq k_{-1}$) so that $\Pi = \rho\text{-}\alpha$, if matrix Π also has the reduced order $r < k$. The α contains r linear co-integrative vectors, and the ρ array represents the adjustment parameters in the 'vector error correction' (VEC) model (Boršič & Bekő, 2007).

The number of integrated vectors is checked using two statistics: 'Trace Statistics' (LR_{tr}) and 'The Maximum Eigen Value Statistic' (LR_{max}).

The null hypothesis and the alternative hypothesis in Trace Statistics are:

H0: the number of co-integrated vectors is less than or equal to r

H1: the number of co-integrated vectors is the same as k, where the number of endogenous variables for r = 0, 1, ... k-1

'Trace Statistics' are written in the form:

$$LR_{tr}(r \mid k) = -T \sum_{i=r+1}^{k} \log(1 + \lambda_i) \tag{11}$$

where λ_i is the maximum own value of the A_i matrix in the equation (12).

The null hypothesis and the alternative hypothesis in 'The Maximum Eigen Value Statistic' (LRmax) are:

H0: the number of co-integrated vectors equals r

H1: the number of co-integrated vectors is $r+1$

'The Maximum Eigen Value Statistic' (LRmax) can be calculated by equation (12):

$$LR_{max}(r \mid r+1) = -Tlog(1 - \lambda_{r+1})$$
$$= LR_{tr}(r \mid k) - LR_{tr}(r+1 \mid k) \tag{12}$$
$$r = 0, 1, \cdots, k-1$$

where the markings are the same as in the equation 10 and 11.

The Johansen test also allows the limits to be checked, thus two limits were checked for the purposes of this study, namely the symmetry of the coefficients, $\beta = (1, -\beta_1, \beta_1)$, which confirms the validity of the relative version of the PPP theory and the second limit of the proportionality of the coefficients, $\beta = (1, -1, 1)$, which confirms the absolute version of the PPP theory (Sideris, 2006). The first place in brackets is the nominal exchange rate, the second is the domestic price level and the third is the foreign price level. Liu (1992) states in his study that it is more important to check the presence of co-integration between the nominal exchange rate and the level of domestic and foreign prices than to check the symmetry and proportionality of the coefficients, therefore,

if there is co-integration between these three variables, the theory of PPP holds true.

Empirical Analysis

Data on the bilateral nominal exchange rate and the CPI were obtained from the databases of the Institute for Economic Diagnosis and Prognosis of the Faculty of Economics and Business of the University of Maribor, while for Austria the CPI data were obtained from OECD databases and the exchange rate was obtained from the Eurostat database. The period considered is from January 1993 to December 2019.

The stationarity verification of real exchange rates was carried out graphically as well as using the ADF test. Figure 1, which shows the dynamics of the logarithms of the real exchange rates of all the selected countries in the period from 1993 to the end of 2019, provides some characteristics that apply in four countries, with the exception of Austria. The real exchange rate of the Austrian shilling was in a trend of appreciation until April 1995, and a trend of depreciation until 1999. Austria adopted the euro in January 1999 and since then the real exchange rate movement with the base currency of the euro has only depended on a change in the price level in Austria and the European Union. It is evident that the real exchange rate has stabilised at a constant level, which may be an indicator of the stationarity stability of the real exchange rate, which is a precondition of the validity of PPP in the long term.

While the other observed countries, which were still transition countries at the beginning of the observed period, are subject to characteristics different from those applicable to Austria, overall, the dynamics of all the four real exchange rates of these countries showed significant depreciation. The real exchange rate of the Slovenian tolar depreciated from the beginning of the observed period up to its entry into the ERM II in 2004. The depreciation of the real exchange rate of the Croatian kuna was rapid, with the exchange rate depreciating from a ratio of one Croatian kuna to one euro to a ratio of around seven kunas to one euro within just 10 months. While the Czech koruna depreciated until 1997, the Czech Republic chose a managed flexible exchange rate regime as a result of the currency crisis that has led to speculative attacks on the Czech crown, and since 1997 the Czech koruna has been appreciating towards the euro, other than during the economic crisis after 2008 and the European debt crisis in 2013 when it depreciated against the euro. In terms of speculative attacks, the same applies to the Slovak crown, which depreciated until 2000, and then appreciated until the introduction of the euro in 2009. Figure 1 illustrates that the real exchange rates of the Slovenian tolar and the Croatian

kuna moved similarly and stabilised at a constant level, which may indicate the stationarity of the real exchange rate, which is a prerequisite for the long-term validity of the PPP theory. The Czech koruna and Slovak crown demonstrated a similar real exchange rate trend until Slovakia adopted the euro, and the dynamics of the movements of these two currencies may indicate the non-stationarity of the real exchange rate time series, which in turn constitutes weak support for PPP or even its invalidity.

Existing literature explains this pattern of real exchange rate developments as being the result of various factors, including the inherited macroeconomic instability of the transition countries, the mixed success of the performance of selected exchange rate regimes, monetary problems that originate from rising capital inflows, inflationary wage pressures and price adjustments, and real appreciation as a result of the catching-up process of developed countries (Halpern & Wyplosz, 1997; Brada, 1998).

Figure 1. Evolution of the logarithms of real exchange rates of countries for the period 1993-2019
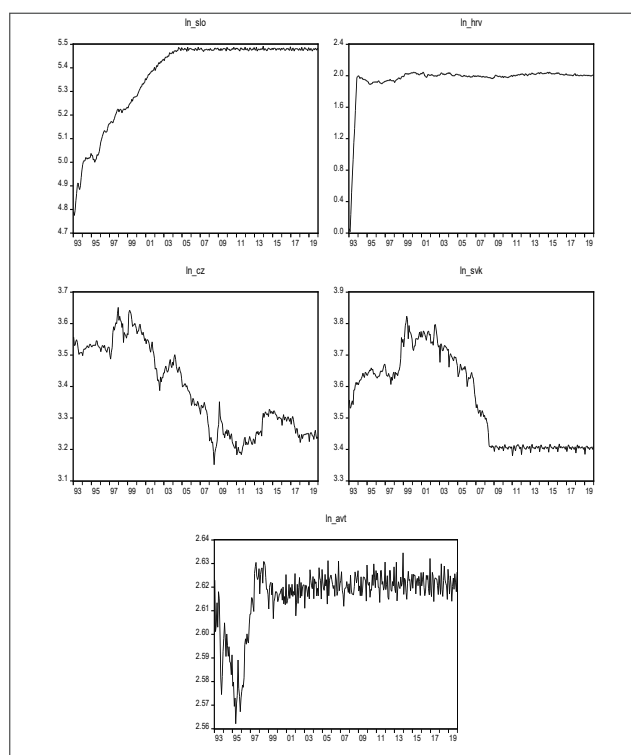
Symbols: Slo = Slovenia, Hrv = Croatia, Cz = the Czech Republic, Svk = Slovakia, Avt = Austria
Source: 2020. The Institute for Economic Diagnosis and Prognosis; calculation of the real exchange rate and the figures in Eviews 10.

On the basis of the results presented in Table 3, it is evident that the ADF test rejected the zero hypothesis for Slovenia and Croatia at 1% risk, taking into account both the constant and the trend and constant. In the case of Austria, however,

the zero hypothesis was rejected at 5% risk, taking into account both the constant and the constant and the trend. For these three countries, the ADF test provided results showing the stationarity of the real exchange rates of these three countries, which is a precondition for the validity of the PPP theory in the long term.

While for the Czech Republic and Slovakia, the ADF could not reject the zero hypothesis either by taking into account the constant or the constant and trend at any level of risk. The ADF test result for these countries indicates that the real exchange rates of these two countries proved non-stationarity, which may indicate the invalidity of the PPP theory in the long term.

Bekő and Kavkler (2019) analysed the PPP theory for a class of ten Central Eastern European economies and the unit root tests imply that the null hypothesis of the non-stationarity of the real exchange rates cannot be rejected for the whole period. The weak evidence on PPP found in this study suggests that the process of the real integration of Central and Eastern European economies and the subsequent price convergence among European markets remains incomplete.

Due to the difficulties of rejecting the zero hypothesis of the ADF test, and consequently non-stationarity of the real exchange rates of the Czech Republic and Slovakia, the

authors of this study also decided to carry out the ADF test at the levels of the first differentiation of the real exchange rate of each country. When introducing the first real exchange rate differentials, the results of the ADF test in Table 4 reject the zero hypothesis in all countries, taking into account both the constant and the trend at a 1% risk. By introducing the first differentiation, all the time series of the real exchange rates become stationarity, which is a prerequisite for the validity of the PPP theory in the long term. The authors also found that by introducing the first differentials, the time series of the real exchange rate of the Czech Republic and Slovakia were integrated to the order of 1.

Bahmani-Oskooee (2017) analysed the PPP in 27 emerging markets by using the new Fourier non-linear quantile unit root test. Conventional unit root tests support PPP in half of the countries at most. The Fourier non-linear quantile unit root test reinforces PPP in 26 out of 27 countries in the case of emerging markets.

To check the co-integration between the nominal exchange rate and foreign and domestic price levels, the Johansen test was used to assess the long-term equilibrium ratio between the nominal exchange rate and the foreign and domestic price levels. A two-step verification of the presence of co-integration was carried out, which included first checking whether co-integration exists and what is the rank of cointegration.

Table 3. Results of the ADF test for logarithm of the real exchange rate

Country	Constant	Constant and trend	Confirmation and rejection of the hypothesis H_0
Slovenia	-7,6023*** (1) (0,0000)	-4,8049*** (1) (0,0005)	-***
Croatia	-13,2948*** (2) (0,0000)	-13,5662*** (2) (0,0000)	-***
The Czech Republic	-1,1472 (0) (0,6978)	-2,0582 (0) (0,5666)	+
Slovakia	-0,4733 (1) (0,8930)	-2,4386 (1) (0,3589)	+
Austria	-2,9868** (12) (0,0372)	-3,6224** (14) (0,0295)	-**

Notes: *** shows the statistical significance of the test at a 1% significance level, ** shows the statistical significance of the test at a 5% significance level, and * shows the statistical significance of the test at a 10% significance level.
The numbers in smaller brackets represent the number of deferrals (time-lags), while, the larger numbers in brackets represent the p-value of the test. The critical values for the constant are: -3.4505 (1%), -2.8703 (5%) and -2.5715 (10%). The critical values for the constant and the trend are: -3.9868 (1%), -3.4238 (5%) and -3.1349 (10%). The minus sign shows the H0 rejection, plus indicates its confirmation.
Source: 2020. The Institute for Economic Diagnosis and Prognosis; calculation of the real exchange rate and analysis in Eviews 10.

Table 4. Results of the ADF test for the first difference of the real exchange rate

Country	Constant	Constant and trend	Confirmation and rejection of the hypothesis H_0
Slovenia	-10.5951*** (1) (0.0000)	-12.0007*** (1) (0.0000)	-***
Croatia	-5.9205*** (1) (0.0000)	-5.8436*** (1) (0.0000)	-***
The Czech Republic	-19.3963*** (0) (0.0000)	-19.3656*** (0) (0.0000)	-***
Slovakia	-20.7351*** (0) (0.0000)	-20.7919*** (0) (0.0000)	-***
Austria	-14.6668*** (2) (0.0000)	-14,64339** (2) (0.0000)	-***

Notes: *** shows the statistical significance of the test at a 1% significance level, ** shows the statistical significance of the test at a 5% significance level, and * shows the statistical significance of the test at a 10% significance level.
The numbers in smaller brackets represent the number of deferrals (time-lags), while the larger numbers in brackets represent the p-value of the test. The critical values for the constant are: -3.4505 (1%), -2.8703 (5%) and -2.5715 (10%). The critical values for the constant and the trend are: -3.9868 (1 %), -3.4238 (5 %) and -3.1349 (10%). The minus sign shows the H0 rejection, plus indicates its confirmation.
Data source: 2020. The Institute for Economic Diagnosis and Prognosis; calculation of the real exchange rate and the analysis in Eviews 10.

The Johansen test for co-integration rank is summarised in Table 5. The first step in the analysis is the assessment of the estimated five VARs of the third order in equation 9; the time period is the same for all the estimated VARs and all the systems of the deterministic variable Xt contain a constant; the number of deferrals (time-lags) was selected on the basis of the Akaike Information Criterion.

The results of the 'Maximal Eigenvalue' and 'Trace Statistics' (Table 5) reject both zero hypotheses at 5% risk and indicate the existence of three co-integrated vectors in all the selected countries.

In the second step, by using the vector error correction model (VEC), a check of whether the nominal exchange rate coefficients and foreign and domestic price levels have the appropriate signs, was carried out, and also whether they are statistically significant. From equation 6, it is evident that the sign of the nominal exchange rate coefficient and the sign of the foreign price coefficient must be positive and that of the domestic price coefficient must be negative. The results in Table 6 indicate that all the coefficients in all countries have signs according to the econometric and economic theory, as are t − statistics of all coefficients are statistically significant.

When checking the hypotheses about the symmetry and proportionality of the coefficients, test statistics were used, which are asymptotically distributed by χ2 − distribution

by degrees of freedom equal to the number of limits. The results in Table 6 show that, in the case of Slovenia, they adhere to the limits on the symmetry and proportionality of the coefficients, which means that both the absolute and the relative version of the PPP theory are considered and proved. A limitation on the symmetry of coefficients applies only to Croatia, indicating the validity of the relative version of the PPP theory, while for the Czech Republic, Slovakia and Austria, both hypotheses were rejected, which means that, consequently, no version of the PPP theory is valid for these countries. However, as previously stated, Liu (1992) states that it is more important to check the presence of co-integration than to check the symmetry and proportionality of coefficients, therefore if there is a correlation between the variables, and the PPP theory is valid, in so far as this conclusion is taken into account, the PPP theory holds true for all the selected countries.

Mladenović and Bodor (2020) analysed the sustainability of PPP within the quantile autoregression model in the economies of the Czech Republic, Hungary, Poland, Romania, Serbia and Turkey. The empirical results support to some extent the PPP theory for the euro and US dollar-based real exchange rate in Romania, Serbia and Turkey. The euro-based real exchange rate in Hungary and Poland is also identified to confirm the PPP theory. The dynamics of the real exchange rate in the Czech Republic cannot be associated with the validity of the PPP. The persistence of the

Table 5. The Johansen test and the cointegration rank

	Maximal Eigenvalue			Trace Statistics		
Country	r = 0	r = 1	r = 2	r = 0	r = 1	r = 2
Slovenia (6)	62.28*	47.14*	15.97*	125.39*	63.11*	15.98*
Croatia (7)	139.33*	59.96*	51.32*	250.63*	111.29*	51.32*
The Czech Republic (8)	53.78*	40.41*	11.81*	106.01*	52.23*	11.82*
Slovakia (4)	141.61*	57.68*	33.59*	232.89*	91.28*	33.59*
Austria (4)	112.98*	75.99*	17.23*	206.41*	93.42*	17.43*
Critical values at 95% significance level	21.13	14.26	3.84	29.79	15.49	3.84

Note: * indicates the rejection of the zero hypothesis at 5% risk

Table 6. The Johansen test – testing of limitations

		Estimated vectors		$H_1\ (\beta_1 = -\beta_2)$	$H_2\ (\beta_1 = -1, \beta_2 = 1)$
Country	S	p	p*	x^2 (1 level of freedom)	x^2 (2 levels of freedom)
Slovenia	1	-0.84 (-9.4638)	1.12 (3.5267)	0.5112 (0.4746)	4.0446 (0.1323)
Croatia	1	-0.75 (-39.9072)	1.57 (3.6512)	1.4377 (0.2305)	25.9118*** (0.0000)
The Czech Republic	1	-0.99 (-2.7079)	8.00 (7.8874)	22.4360*** (0.0000)	24.9000*** (0.0000)
Slovakia	1	-3.69 (-5.4754)	25.03 (14.8063)	86.4549*** (0.0000)	88.6886*** (0.0000)
Austria	1	-1.33 (-3.2673)	13.81 (12.4442)	64.0013*** (0.0000)	132.3929*** (0.0000)

Notes: *** indicates the rejection of hypotheses at 1% risk, x^2_c at 1 degree of freedom and α = 0.05 equals 3.8415, at α = 0.01 equals 6.6349, x^2_c at 2 degrees of freedom and α = 0.05 equals 5.9975, at α = 0.01 equals 9.2703.

euro-based real exchange rate is estimated to be more prominent following depreciation shocks.

Conclusion

The results of the empirical studies, which checked the validity of PPP in selected countries, indicated invalidity or weak support for the PPP theory. Only taking into account structural breaks and non-linear exchange rate adjustments improved the results in terms of the validity of PPP.

It can therefore be concluded that adherence to a linear deterministic trend generates results that indicate the existence of co-integration, which is a prerequisite for the validity of PPP. 'VECM' also provided statistically significant coefficients with corresponding signs for all selected countries, while testing the hypotheses relating to limitations on symmetry and proportionality gives mixed results. Slovenia

is subject to limitations on the symmetry and proportionality of coefficients, which means the validity of both the absolute and relative versions of the PPP theory. Croatia is subject to a limitation on symmetry, but not to a limit on the proportionality of coefficients, which means the validity of the relative version of the PPP theory, while in the case of the Czech Republic, Slovakia and Austria, restrictions on the symmetry and proportionality of the coefficients do not apply, this consequently constitutes an invalidity of both versions. However, by taking into account Liu (1992), who states that it is more important to check the presence of co-integration than to check the symmetry and proportionality of the coefficients – since there is co-integration between the nominal exchange rate, foreign prices and domestic prices – the PPP theory is true for all the selected countries.

In this analysis, the validity of PPP was checked in five countries – Slovenia, Croatia, the Czech Republic, Slovakia and Austria. Austria was already one of the developed economies at that time, while the remaining four countries were

going through the process of transition of their economies. Therefore, the macroeconomic picture among the four former transition countries is the same and differs from the macroeconomic picture in Austria; a similar macroeconomic picture was shared by these five countries after the onset of the global financial and economic crisis. By focusing on the selected countries, which have undergone many changes in a short period of time, five important periods can be highlighted, namely the period of initial stabilisation and reform during which exchange rate regimes were selected, which these countries also changed several times, and they recorded high falls in GDP and high inflation rates. In the following period, countries began implementing market reforms that underpinned convergence towards developed European countries. A period of economic turmoil following economic crises in certain countries around the world

followed, but there was also a rapid recovery of economies; this period was followed by a period of economic boom, which was on a shaky base, as economies were overheating, and even during the global financial and economic crises, these countries recorded sharp falls in GDP, and many systemic problems were revealed, which subsequently became apparent in the debt crisis.

In the verification itself, there are dilemmas in the use of econometric tests, namely the problem of the statistical strength of tests, difficulties in the results of panel studies, the enormity of short-term volatility of exchange rates, non-linear adjustment of exchange rates and compliance with a sufficiently long time period, which could be the subject of further research.

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Empirično preverjanje veljavnosti paritete kupne moči v izbranih državah Evropske unije

Izvleček

V tem članku empirično analiziramo veljavnost paritete kupne moči v Sloveniji, na Hrvaškem, Češkem, Slovaškem in v Avstriji. Rezultati kažejo mešano podporo paritete kupne moči, kar je značilno za nekdanje tranzicijske države. V prvem koraku empiričnega dela smo preverili stacionarnost realnega deviznega tečaja v logaritmu, v drugem koraku smo preizkusili kointegracijo med nominalnim deviznim tečajem in domačo ter tujo ravnjo cen, v tretjem koraku pa smo uporabili model za vektorsko popravljanje napak (VECM), da bi preverili, ali so predznaki spremenljivk v skladu z ekonomsko in ekonometrično teorijo. V zadnjem koraku smo uvedli omejitve simetričnosti in sorazmernosti koeficientov. Za Slovenijo veljajo omejitve simetričnosti in sorazmernosti koeficientov, kar pomeni veljavnost tako absolutne kot relativne različice teorije paritete kupne moči. Za Hrvaško velja omejitev simetričnosti, ne pa tudi omejitev sorazmernosti koeficientov, kar pomeni veljavnost relativne različice teorije paritete kupne moči. V primeru Češke, Slovaške in Avstrije pa omejitve simetričnosti in sorazmernosti koeficientov ne veljajo, kar posledično pomeni, da sta obe različici neveljavni. Če upoštevamo Liuja (1992), pa ta navaja, da je pomembneje preveriti prisotnost kointegracije kot simetričnost in sorazmernost koeficientov, saj obstaja kointegracija med nominalnim deviznim tečajem in tujimi ter domačimi cenami, torej teorija paritete kupne moči velja za vse izbrane države. Empirični rezultati kažejo, da so vse časovne vrste realnih deviznih tečajev stacionarne, poleg tega obstaja kointegracija med vsemi spremenljivkami za vse države, znaki koeficientov so statistično pomembni za vse spremenljivke v vseh državah, omejitve koeficientov pa so statistično pomembne le v Sloveniji in na Hrvaškem.

Ključne besede: pariteta kupne moči, stacionarnost, kointegracija, test ADF, Johansenov test