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Stationarity of Real Exchange Rates in the "Fragile Five": Analysis with Structural Breaks

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Abstract

In this study the stationarity of monthly real exchange rate data for the "fragile five" countries which are among the emerging market economies, is analyzed for the period of 2003:01-2015:10, using traditional unit root tests and unit root tests with structural breaks. According to the results of traditional Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root test results, it has been determined that the real exchange rate series of the fragile five countries had a unit root and therefore the Purchasing Power Parity (PPP) hypothesis does not hold true in these countries. The results of a Zivot-Andrews unit root test, which allows for a single structural break, show that real exchange rate series were stationary for Brazil and India, and hence the PPP hypothesis is valid in these countries. According to the results of a Lee-Strazicich unit root test, which allows for two structural breaks, it has been concluded that the hypothesis is valid only for India. Likewise, using the Carrion-i-Silvestre (CS) unit root test, which allows for five structural breaks in the time series, it has been determined that only South Africa's and India's real exchange rate series are not stationary, and therefore the PPP hypothesis is not valid for these countries. In line with the results of the CS unit root test it can be claimed that, due to the fact that South African and Indian central banks are not under the pressure of establishing exchange rate stability, they have the possibility of implementing an independent monetary policy.

Keywords: Fragile five, purchasing power parity, real exchange rate, structural break, unit root tests

1. Introduction

Real exchange rate is one of the most important macroeconomic indicators used in determining economic activities. Determining real exchange rates gained importance after structural transformations were experienced globally in the way of liberalization of foreign trade and capital movements, starting from the 1970s, and after the Bretton-Woods system was abandoned in 1973. On the other hand, due to the fact that real exchange rate has an important role in portfolio investments and in measuring international competition, many studies have been conducted to analyze the divergence of real exchange rates from their equilibrium values. The most commonly used approach utilized by researchers in analyzing divergences and determining equilibrium in real exchange rates is the Purchasing Power Parity (PPP) hypothesis, which was developed by Gustav Cassel (1918).

The PPP hypothesis stipulates that for a basket of fixed goods and services the exchange rates in two countries are equal to the price levels rate of these countries. In other words, this hypothesis requires that the real exchange rate of two countries be in equilibrium in the long term (Chang, Lee, & Liu, 2012).

The basic premise of the PPP hypothesis is that real exchange rates will converge to a constant equilibrium value. This proposition is especially important from the perspective of the effectiveness of monetary policies implemented by central banks. In the case of PPP theory not being valid the monetary policy implemented by a central bank will not be as effective, and in order to make PPP valid the central bank will shape its policy recommendations towards exchange rates. The PPP hypothesis is important for economists and policy makers from two different perspectives. The first is that, whether over- or under-valued, national currency is a determining criterion in estimating exchange rate models. The second is that the PPP hypothesis constitutes the foundation of models determining exchange rates, and is taken as a basic concept when determining exchange rates (Holmes, Otero, & Panagiotidis, 2012, p. 768).

In order for the PPP hypothesis to hold true, real exchange rates should be stationary in the long term. In other

words, they should not have a unit root. If a real exchange rate is not stationary, divergences in the exchange rate will be permanent and the PPP hypothesis will not hold true. The results obtained when the PPP hypothesis is determined with respect to the permanency of divergences in real exchange rates explain which shocks the exchange rates are exposed to. In fact, Rogoff (2006) states that aggregate demand shocks such as monetary policy changes do not have a permanent effect on real exchange rates, whereas a real economy-related shock such as a technology shock can have a permanent effect on real exchange rates. In addition, in order to be able to make an international comparison of countries' national income levels, the PPP hypothesis should be valid.

In this study, the validity of the PPP hypothesis for the countries which are among the emerging market countries, and which were called the "Fragile Five" in 2003, has been analyzed using monthly data from the period 2003:01-2015:10, and employing traditional unit root tests and unit root tests with structural breaks. The primary contribution of this study to the literature is to analyze the validity of the PPP hypothesis for the countries in question. Secondly, the analysis has been made by taking into account the structural breaks that arose due to macroeconomic policy changes implemented in the time series of these countries during the analysis period. In the following section of the study an overview of the fragile five countries is presented. Section three explores the empirical literature in this area, section four presents the econometric methodology and empirical findings, and the last section concludes the study.

2. Fragile Five Countries

In a report published in 2001 by Jim O'Neill, former CEO of international investment bank Goldman Sachs, the concept of the BRIC countries (Brazil, Russia, India and China), which with their high growth rates rank among emerging countries, was added to the literature. In his report O'Neill envisioned that in the following decade the weight of the BRIC countries, and particularly of China, in world GDP would increase, due to the global effect of the financial and monetary policies of the BRIC countries. In a report conducted by Wilson and Purushothaman (2003) and published by Goldman Sachs, it was projected that by 2050 the total national income of the BRIC countries would exceed the total national income of the G6 countries (USA, Japan, UK, Germany, France and Italy). After the announcement made by the US Central Bank (FED) in May 2013 that it would decrease its amount of bond buying, global markets experienced severe volatilities and some of the emerging market countries were affected by these fluctuations more seriously than others. After this announcement capital outflow took place in these countries, and the national currencies of these countries lost a significant amount of their value. In response to these developments, Morgan Stanley published a report in August 2013 offering a new grouping called the "fragile five", which consisted of Brazil, India, Indonesia, Turkey and South Africa (BIITS). Table 1 presents the responses of the fragile five countries' national currencies to the US dollar after the FED's 2013 announcement that it would decrease its amount of bond buying.

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Table 1. The nominal exchange rate of the fragile five countries

Countries	National Currency/USD Dollar			Change (2013-2014 %)
	2012	2013	2014	
Brazil	1.95	2.16	2.35	9.13
India	53.44	58.60	61.03	4.15
Indonesia	9386.63	10461.24	11865.21	13.42
Turkey	1.80	1.90	2.19	14.96
South Africa	8.21	9.66	10.85	12.40

Source. International Financial Statistics.

In Table 1 it is observed that after the FED's announcement, the national currencies of BIITS countries lost value against the US dollar. Starting in 2013 the highest depreciation was observed in Turkey's national currency (Turkish lira), followed by the Indonesian rupee and South Africa's rand. Common characteristics of fragile five countries, and hence reasons behind their fragility, are high foreign deficits and relatively high inflation, a decline in their growth rate, foreign source dependency, and political conditions within the country. Table 2 presents the values of some selected macroeconomic indicators belonging to fragile five countries in the period 2007-2014.

Table 2. Critical macro-economic indicators of fragile five countries

Countries	2007	2008	2009	2010	2011	2012	2013	2014
				Rate of Growth (%)				
Brazil	6.01	5.02	-0.24	7.57	3.92	1.76	2.74	0.14
India	9.80	3.89	8.48	10.26	6.64	5.08	6.90	7.29
Indonesia	6.35	6.01	4.63	6.22	6.17	6.03	5.58	5.02
Turkey	4.67	0.66	-4.83	9.16	8.77	2.13	4.19	2.91
South Africa	5.36	3.19	-1.54	3.04	3.21	2.22	2.21	1.52
				Current Account Balance/GDP (%)				
Brazil	0.11	-1.66	-1.46	-2.14	-2.01	-2.25	-3.39	-4.43
India	-0.65	-2.53	-1.92	-3.19	-3.41	-4.99	-2.64	-1.53
Indonesia	2.43	0.02	1.97	0.68	0.19	-2.66	-3.20	-2.86
Turkey	-5.70	-5.40	-1.90	-6.10	-9.60	-6.10	-7.90	-5.80
South Africa	-5.40	- 5.50	- 2.70	-1.50	-2.20	-5.00	-5.80	-5.40
				Budget Balance/GDP (%)				
Brazil	-2.74	-1.53	-3.19	-2.72	-2.47	-2.57	-3.05	-6.23
India	-4.41	-9.96	-9.75	-8.4	-8.12	-7.48	-7.23	-7.15
Indonesia	-0.95	0.05	-1.64	-1.24	-0.6	-1.59	3.3	-2.16
Turkey	-1.52	-2.35	-6.51	-2.92	-0.8	-1.6	-2.2	-1.3
South Africa	-0.58	-1.44	-5.5	-4.83	-4.48	-5.9	-5.86	-3.8
				Unemployment Rate (%)				
Brazil	8.1	7.1	8.3	7.9	6.7	6.1	6.5	6.8
India	3.7	4.1	3.9	3.5	3.5	3.6	3.6	3.6
Indonesia	9.1	8.4	7.9	7.1	6.6	6.1	6.3	6.2
Turkey	10.3	11	14	11.9	9.8	9.2	8.7	9.2
South Africa	22.3	22.7	23.7	24.7	24.7	25	24.6	25.1
				Consumer Price Index Inflation Rate(%)				
Brazil	3.6	5.7	4.9	5	6.6	5.4	6.2	6.3
India	6.4	8.3	10.9	12	8.9	9.3	10.9	6.4
Indonesia	6.4	10.2	4.4	5.1	5.4	4.3	6.4	6.4
Turkey	8.8	10.4	6.3	8.6	6.5	8.9	7.5	8.9
South Africa	6.2	10	7.2	4.1	5	5.7	5.8	6.1

Source. OECD. Stat, World Data Bank.

Table 2 shows that, except for the global crisis period, there was a current account deficit and that this deficit was growing during high growth periods in the fragile five countries. This situation emerged in these countries because growth rates were high, and national currencies were overvalued, which led to an increase in imports. In addition, the fact that these countries had high budget deficits along with high current account deficits (twin deficits) shows that they have consumption-oriented economies. Within this context, it is also observed that in these countries inflation rates and unemployment rates are also high.

3. Empirical Literature

Starting from the early 1980s, the validity of the PPP hypothesis in developed and developing countries has been analyzed by many researchers using different data sets and methods of analysis. In these studies researchers have used unit root tests, co-integration tests and non-linear models as their analysis methods. Corboe and Ouliaris (1988) used the Engle-Granger co-integration test for Canada, France, Italy, the UK and Japan, and reached the conclusion that absolute PPP was not valid in these countries. Kim (1990), who used co-integration test results in economic data for Canada, France, Italy, and Japan, determined that the PPP hypothesis was valid in general for these countries.

Fisher and Park (1991) worked on the G10 countries (Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland and the USA) and employed the Engle-Granger co-integration test, concluding that the PPP hypothesis did not hold true in these countries. Cheung and Lai (1993), who used a fractional co-integration test for Canada, France, Italy and Japan, found that PPP was a long term phenomenon and that there were some divergences in PPP in the short term. Cooper (1994) analyzed the validity of the PPP hypothesis in the economies of Australia, New Zealand and Singapore, using the Engle-Granger co-integration

test and generalized unit root test (ADF). Based on the co-integration and ADF unit root test results, he found that PPP was not valid in the countries in question. For 18 OECD countries, and based on production price index (PPI) and consumer price index (CPI), Wu (1996) analyzed the stationarity of real exchange rate series using the ADF, Phillips-Perron and panel unit root tests. He stated that according to his test results the process of real exchange rates arriving at an equilibrium value is a slow one and that therefore PPP was valid in the long term. Oh (1996), who used a panel unit root test for 150 countries, reached the conclusion that in G6 and OECD countries PPP was valid when the flexible exchange rate regime was in use.

Papell (1997) analyzed the stationarity of the real exchange rates, which he calculated based on the US dollar and German mark, for developed countries that adopted a flexible exchange rate system. He used ADF and panel unit root tests for his analysis. His results showed that when the US dollar was taken as the basic currency and monthly data were used, PPP was valid in all developed countries in the long term. However, he obtained stronger results showing that when the German mark was taken as the basic currency and three-monthly data were used, PPP was valid in all countries. Diboglu (1997), who analyzed the validity of PPP for Germany, Italy and Japan in the post Bretton-Woods period using co-integration and the Vector Error Correction Model (VECM), reached the conclusion that the PPP hypothesis was valid in these countries. Coakley and Fuertes (1997) analyzed the validity of the PPP hypothesis for G10 countries and for Switzerland using ADF unit root, panel unit root and Johansen co-integration test methods. In the panel unit root test results they found stronger results than in ADF unit root test results, and concluded that the PPP hypothesis was valid in these countries. Paul and O'Connel (1998), who used unit root tests to analyse stationarity and cross sectional dependency of real exchange rates using data from 64 countries (of which 20 were from Europe, 13 from Asia, 13 from South America and 13 from Africa), determined that the PPP hypothesis was not valid. Boyd and Smith (1999) analyzed PPP for 31 developing countries using both time series and panel data analysis methods. The panel data analysis results obtained by the ADF unit root and Johansen co-integration tests, which are time series methods, show that PPP was valid in all countries. Cheng (1999), who used the Johansen co-integration and VECM methods for Japan, reached the conclusion that PPP was valid in the long term. In their study, in which they employed both unit root and co-integration test methods using data for 21 countries, Culver and Papell (1999) found that, according to the results of both methods, the PPP was valid. Heimonen (1999) analyzed the stationarity of real effective exchange rates for 13 European Union (EU) member countries using a panel unit root test, and found that PPP was valid in those countries. Islam and Ahmed (1999), who analyzed the validity of PPP in Korea using the Johansen co-integration test, state that that PPP was valid according to the results they obtained from their research. Ramirez and Khan (1999) analyzed the PPP hypothesis employing the Johansen co-integration and VECM methods, using data for five developed countries. The Johansen co-integration test results showed that PPP was valid in all countries in the long term.

Cuddington and Liang (2000) analyzed the stationarity of the dollar-sterling real exchange rate using the ADF and Phillips-Perron (PP) unit root tests. The results of their analysis show that the dollar-sterling real exchange rate had a unit root, and therefore the authors concluded that in the long term PPP was not valid. Fleissig and Strauss (2000), who analyzed the stationarity of the real exchange rate for OECD countries using six price indices and employing a panel unit root test, reached the conclusion that in general PPP was valid. Alves, Cati and Fava (2001) researched the validity of the PPP hypothesis for Brazil, employing a fractional co-integration test. The test results show that absolute PPP was not valid in Brazil and that relative PPP was valid in the long term. Kua and Mikkola (2001), who tested the stationarity of real exchange rates for 24 developed countries using panel data analysis, found that the PPP hypothesis was valid in the long term. Luintel (2001) used real exchange rate data for 20 OECD countries and employed a heterogeneous panel unit root test to analyze PPP. The results of this analysis show that PPP was valid in those countries. Pedroni (2001), who used the Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) methods for 20 developing and developed countries, reached the conclusion that the PPP hypothesis did not hold true.

Nagayasu (2002) analyzed the validity of the PPP hypothesis in 17 African countries using the panel co-integration technique, and found that in the long term PPP was valid in weak form. Kargbo (2003), who used the Johansen co-integration test and VECM methods for Africa, reached the conclusion that PPP was valid. Khim and Liew (2003) analyzed the stationarity of real exchange rates in Indonesia, Malaysia, Singapore, the Philippines and Thailand, using traditional ADF and Exponential Smooth Transition (ESTAR), which is based on the non-linear time series technique. They determined that in the unit root test results, which were based on the ESTAR model, real exchange rates reached an equilibrium value in the long term, and therefore the PPP hypothesis was valid. Moon and Perron (2003) analyzed the stationarity of real exchange rates in 17 developed countries using a panel unit root test under cross-sectional dependency, and found that real exchange rates had a

unit root. Nusair (2003) researched the stationarity of real exchange rates for Indonesia, the Philippines, Malaysia, Thailand, Korea and Singapore, using ADF, PP and KPSS unit root tests. Unit root test results show that PPP was valid for Indonesia, Korea, Malaysia and the Philippines.

Basher and Mohsin (2004), in a study in which they used the panel co-integration technique for 10 developing Asian countries, found that PPP was not valid. Enders and Chumrusphonlert (2004), who used the threshold co-integration test for Pacific countries, found that in general the PPP hypothesis was not valid in the long term. Using a non-linear time series models-based unit root test for Turkey, Erlat (2004) analyzed the validity of PPP. Erlat's results revealed that when the US dollar and consumer price index (CPI) were used to obtain real exchange rates, the validity of the PPP hypothesis was stronger. Liew, Baharumshah and Chong (2004) analyzed the stationarity of real exchange rate data, which they obtained based on the US dollar and Japanese yen for 11 Asian countries, using a KSS unit root test based on the non-linear ESTAR model. As a result of their tests they determined that when the real exchange rate is obtained based on the US dollar, PPP was valid in 8 Asian countries. However, if the Japanese yen was taken as the base currency then PPP was valid in only 6 Asian countries.

Alba and Park (2005) analyzed the stationarity of the German mark-TL real exchange rate for Turkey, using a unit root test in which stationarity in threshold autoregressive models is analyzed. They found that the mark-TL exchange rate was stationary in only one regime. Breitung and Candelon (2005) studied the validity of the PPP hypothesis for five South and Latin American and Asian countries, employing a panel unit root test with structural breaks. The test results show that while the PPP hypothesis was valid for Asian countries that switched to a fluctuating exchange rate system, it did not hold true in South and Latin America countries which adopted a fixed exchange rate system.

Brissimis, Sideris and Voumvaki (2005), who analyzed the PPP hypothesis for Greece and France using the Johansen co-integration test, found that the strong form of PPP was valid for Greece, while the weak form was valid for France. Using unit root tests based on linear time series for Turkey, Tastan (2005) tested the stationarity of real exchange rates in USD-TL, British pound-TL, German mark-TL, and Italian lira-TL pairs that were based on consumer and producer price indices. Tastan obtained stronger results in regards to the validity of the PPP hypothesis in the USD-TL and sterling-TL pairs, which were calculated based on both consumer and production price indices. Narayan (2005) calculated the stationarity of real exchange rates for 17 OECD countries using a panel unit root test with structural breaks. The study concluded that for the real exchange rates that were calculated by taking the US dollar as the base, the PPP hypothesis held true in France, Portugal and Denmark, whereas for the real exchange rates that were calculated by taking the German mark as the base. The PPP hypothesis was valid in Austria, Belgium, Norway, Spain, the Netherlands, Switzerland and Denmark. Payne, Lee and Hofler (2005), who analyzed the stationarity of real exchange rates for Croatia using the LM unit root test with one and two structural breaks, determined results that did not support the validity of the PPP hypothesis.

Amara and Papell (2006) investigated the stationarity of real exchange rates for 20 developed countries which adopted a flexible exchange rate system, using the Covariate augmented version of the Augment Dickey-Fuller (CADF) and Feasible Point Optimal (CPT) unit root tests. They reached the conclusion that CPT test results were stronger and that the PPP hypothesis held for 12 countries. Bahmani-Oskoee and Gelan (2006), who analyzed the validity of the PPP hypothesis for 21 countries using a unit root test based on the non-linear ESTAR model, found that the PPP hypothesis held true for 11 African countries. Narayan (2006) analyzed the stationarity of real exchange rate data for the currency pairs which he obtained from the currencies of India's trade partners, using ADF and Lee-Strazicich unit root tests which allow for one and two structural breaks. His test results show that the PPP hypothesis is valid for India. In a study in which they covered 10 developed and 11 developing countries, Acaravci and Acaravci (2007) used a panel unit root test and found that the PPP hypothesis did not hold. Baharumshah, Aggarwal and Haw (2007), who took the US dollar and Japanese yen as the base foreign currencies for six Eastern Asian countries, employed traditional unit root tests and panel unit root tests with structural breaks, and found that there was stronger evidence for the validity of the PPP hypothesis in the post-South-East Asia financial crisis period. Cerrato and Sarantis (2007) investigated the validity of the PPP hypothesis for 34 developing countries using both a heterogeneous panel unit root test and a panel co-integration test. Their panel co-integration test results showed that the PPP hypothesis held true. Hooi and Smyth (2007), who analyzed the stationarity of real exchange rates for 15 Asian countries using the LM (Lagrange Multiplier) panel unit root test that allows for one and two structural breaks, obtained strong results to the effect that PPP was valid.

Baharumshah, Tze-Haw and Fountas (2008) examined the validity of the PPP hypothesis for 6 Western European countries using a co-integration test based on the Autoregressive-Distributed Lag (ARDL) model. Their test

results show that in the period prior to the South-East Asian crisis PPP did not hold true; however, in the post-crisis period PPP was valid. Kalyoncu and Kalyoncu (2008), who analyzed the stationarity of real exchange rates in 25 OECD countries using a heterogeneous panel unit root test found that real exchange rates were stationary, and hence the PPP hypothesis was valid in the long term. Using a unit root test based on the non-linear ESTAR model for 13 Asian and Pacific countries, Zhou (2008) analyzed the stationarity of real exchange rates. Zhou's results show that when the Singapore dollar is taken as the base foreign currency, real exchange rates do not have a unit root. Koukouitakis (2009) analyzed the validity of the PPP hypothesis for 12 new member countries of the EU using the Johansen co-integration test, concluding that PPP was credibly applied in Bulgaria, Cyprus, Romania and Slovenia in the long term. Mohammad, Umer and Lal (2009), who analyzed PPP for India using the Enge-Granger co-integration test and the VECM method, obtained results showing that the PPP hypothesis did not hold true.

Arize, Malindretos and Nam (2010) investigated the validity of the PPP for 14 African countries using the Johansen co-integration test and the VECM method. Based on the test results they obtained, the authors state that the PPP hypothesis holds true in those countries. Chang, Liu, and Yu (2010) analyzed the validity of PPP for the G7 countries, using linear and non-linear panel unit root tests. While linear panel unit root test results showed that PPP did not hold for all countries, non-linear panel unit root test results showed that PPP was valid for more than half of the G7 countries. Kasman, Kasman and Ayhan (2010) investigated the validity of PPP for 11 Central and Western European countries, along with Cyprus, Malta and Turkey, using the LM unit root test, which allows for one and two structural breaks. According to the test results the authors conclude that when the US dollar was taken as the foreign currency the PPP hypothesis held true for Romania and Turkey, and when the German mark was taken as the foreign currency PPP held true for Bulgaria, Croatia, Estonia, Romania, Slovakia, Slovenia and Turkey. Narayan (2010), who analyzed the validity of PPP for six Asian countries using the Gragory-Hansen and co-integration tests with panel LM structural breaks, obtained strong findings supporting the validity of PPP.

Aizenman and Hutchison (2011) examined the real exchange rate and inflation targeting (IT) in emerging economies (16 countries including Argentina, Brazil, Colombia, Czech Republic, Hungary, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Morocco, Peru, Philippines, Poland, and Thailand) by using panel unit root test and Hausman-Taylor (H-T) three step estimation methodology. They found a significant and stable response running from inflation to policy interest rates in emerging markets. They stated that external considerations should play an important role in central bank policy in emerging markets and they identified countries that were more vulnerable to terms-of-trade shocks as ones who respond more aggressively to movements in the real exchange rates. They also found that the response to real exchange rates was strongest in those countries following IT policies that were relatively intensive in exporting basic commodities. By Guloglu, Ispira and Okat (2011) took the currencies of Turkey's 18 trade partner countries as the base foreign currency and analyzed the stationarity of real exchange rates using a panel unit root test with structural breaks. According to the results of their tests PPP was conditionally valid in Turkey. Haug and Basher (2011), who analyze the validity of PPP for G10 countries in the post-Bretton-Woods period using the Johansen and non-linear co-integration methods, found that PPP held true in weak form. Josheski and Koteski (2011), who employed the Engle-Granger and VECM methods for Macedonia, state that PPP held in the long term. Olayungbo (2011) researched the validity of the PPP hypothesis for 16 Sub-Saharan countries using traditional ADF and panel unit root tests. Test results showed that, except for in Ghana and Uganda, PPP did not hold.

Sadoveanu and Ghiba (2012) analyzed the validity of PPP for the Czech Republic, Hungaria, Poland and Romania, using the Johansen co-integration test. Their tests resulted in strong findings as to the validity of PPP only in Hungary. Bahmani-Oskoee, Chang and Hung (2013) used the Sequential Panel Selection Method (SPSM) for 15 Latin America countries, and found strong evidence that PPP holds in 11 Latin America countries. He and Chang (2013) used monthly and quarterly real exchange rate data for 14 transitional economies and analyzed the validity of PPP using the SPSM. With their monthly data the authors found that PPP was valid in all the countries except Bulgaria, Slovakia, Austria and Romania.

4. Econometric Methodology and Empirical Findings

4.1 Theoretical Model and Data Set

The PPP hypothesis, which is one of the approaches used in determining exchange rates, makes reference to the "law of one price", that is based on the assumptions that there are no transportation costs, and that there exists free foreign trade and perfectly competitive markets. It is shown as follows (Sadoveanu & Ghiba, 2012):

$$P_{i,t}=NER_t P^*_{i,t} \quad i=1,2,...,n \tag{1}$$

Where, $P_{i,t}$ and $P^*_{i,t}$ denote the value of good i at time t in terms of national currency and foreign currency, respectively; and NER_t represents the nominal exchange rate at time t. The law of one price, stated in the form of a basket which includes n goods and services that are traded domestically, is called absolute purchasing power parity. This parity states that the domestic price of a certain basket is equal to the foreign (abroad) price of the same basket. Absolute purchasing power parity is calculated as follows:

$$P_t=NER_t P^*_t \tag{2}$$

Where P_t represents the domestic price index at time t, NER_t represents the nominal exchange rate at time t, and P^*_t denotes the foreign price index at time t. Equation (2) is expressed in logarithmic form as below:

$$ner_t=p_t-p^*_t \tag{3}$$

On the other hand, real exchange rate is calculated using the following formula:

$$RER_t=NER_t\frac{P^*_t}{P_t} \tag{4}$$

Equation (4) is expressed in logarithmic form as below:

$$rer_t=ner_t+p^*_t-p_t \tag{5}$$

Equation (5) contains important inferences. First, in case PPP holds true, the logarithm of real exchange rate is equal to zero. Therefore, under the assumptions of the PPP hypothesis, the divergences occurring at the level of equilibrium exchange rate envisioned by PPP are not different from the divergences occurring in real exchange rates. Therefore, when the validity of the PPP hypothesis is analyzed in a country, usually the stationarity of the real exchange rate series is tested. If the real exchange rate series is stationary then PPP holds true. In other words, change taking place in domestic and foreign price levels will be balanced against a value gain/value loss, which will correspond to the change in domestic and foreign price levels in nominal exchange rates. To explain further, when the domestic price index is higher/lower than the foreign price index, a country's imports/exports increase, and the balance of foreign trade deteriorates or improves. This situation leads to an increase/decrease in currency demand in the country, and the nominal exchange rate increases/decreases as much as the difference between the domestic and foreign price indices.

What PPP implies econometrically is that real exchange rate series should be trend stationary or, in other words, real exchange rate constituents (nominal exchange rate and relative prices) should be co-integrated (Guloglu, Ispir, & Okat, 2011, p. 1817).

In this study, in order to analyze PPP for the fragile five countries monthly data were used for the period 2003:01-2015:10 and real exchange rates were calculated using Equation (5). In the calculation of real exchange rates the nominal exchange rate in terms of the US dollar (value of each country's currency in terms of the US dollar) was used. Likewise, in order to represent domestic price levels and foreign price levels the domestic consumer price index (CPI; 2010=100) and the consumer price index of the USA's economy (2010=100) were used, respectively. All data used in the analysis were taken from the International Monetary Fund-International Financial Statistics (IMF-IFS). In testing the stationarity of the CPI-based real exchange rates which were calculated for these countries traditional ADF/PP and Zivot-Andrews/Lee-Strazicich/Carrion-i-Silvestre unit root tests with one/two/five structural breaks were used.

4.2 Traditional Unit Root Tests

The most commonly used unit root tests to determine whether a time series is stationary or not are the Augmented Dickey Fuller (ADF) unit root test, developed by Dickey and Fuller (1979, 1981), and the

Phillips-Perron (PP) unit root test, developed by Phillips and Perron (1988). Therefore the stationarity of real exchange series pertaining to fragile five countries was tested primarily using the ADF and PP unit root tests. The test results are presented in Tables 3 and 4.

Table 3. ADF unit root test results

Countries	Constant			Constant and Trend		
	ADF Test Statistic	MacKinnon Critical Values (%)		ADF Test Statistic	MacKinnon Critical Values (%)	
		1	5		1	**5**
Brazil	-1.82 (10)	-3.476	-2.881	0.89 (12)	-4.024	-3.442
India	-1.49 (13)	-3.477	-2.882	-2.88 (6)	-4.021	-3.440
Indonesia	-1.85 (3)	-3.474	-2.880	-1.31 (3)	-4.020	-3.440
Turkey	-2.24 (4)	-3.474	-2.880	-1.50 (4)	-4.020	-3.440
South Africa	-1.59 (2)	-3.473	-2.880	-1.86 (2)	-4.019	-3.439

Note. The values in the parentheses indicate the lag numbers selected by Akaike Information Criterion (AIC).

Table 4. PP unit root test results

Countries	Constant			Constant and Trend		
	PP Test	PP Critical Values (%)		PP Test	PP Critical Values (%)	
	Statistic	1	5	Statistic	1	5
India	-1.74 (2)	-3.473	-2.880	-1.844 (0)	-4.019	-3.439
Brazil	-2.31 (3)	-3.473	-2.880	-0.254 (2)	-4.019	-3.439
Indonesia	-1.77 (5)	-3.473	-2.880	-1.171 (5)	-4.019	-3.439
Turkey	-3.10 (0)	-3.473	-2.880	-2.251 (3)	-4.019	-3.439
South Africa	-2.01 (4)	-3.473	-2.880	-2.192 (3)	-4.019	-3.439

Note. The values in the parentheses indicate the harmonised lag numbers. Harmonised lag numbers are determined according to Newey-West and by applying the Barlett-Kernel.

ADF and PP unit root test results show that the fragile five countries' real exchange rate series have a unit root at 1% and 5% significance levels, and therefore the real exchange series of these countries were not stationary. In other words, according to traditional unit root test results, the conclusion has been reached that PPP does not hold true in these countries.

4.3 Unit Root Tests with Structural Breaks

Traditional ADF (1979, 1981) and PP (1981) unit root tests do not take into consideration the structural breaks occurring in the time series during the analysis period. The existence of structural breaks in time series, however, diminishes the reliability of the results of the tests in question. This situation was first investigated by Perron (1989). Perron developed a unit root test which is applied with the assumption of a single structural break that is known to be external. However, Perron's unit root test requires correct determination of the time of the structural break. In other words, the inability to correctly determine the structural break time causes the stationary time series with a structural break to be seen as if it is non-stationary. Zivot and Andrews (1992) have criticized Perron's (1989) unit root test and developed a unit root test in which there exists a single structural break which is determined internally.

The Zivot-Andrews (ZA) unit root test is based on the estimation of the following regression equation (Zivot & Andrews, 1992, p. 254):

$$\text{Model A:}\quad Y_t=\mu+\beta_t+\theta_1 DU_t(\lambda)+\sum_{j=1}^{k} c_j \Delta Y_{t-j}+e_t \tag{6}$$

$$\text{Model B:}\quad Y_t=\mu+\beta_t+\theta_2 DT_t(\lambda)+\sum_{j=1}^{k} c_j \Delta Y_{t-j}+e_t \tag{7}$$

$$\text{Model C:}\quad Y_t=\mu+\beta_t+\theta_1 DU_t(\lambda)+\theta_2 DT_t(\lambda)+\sum_{j=1}^{k} c_j \Delta Y_{t-j}+e_t \tag{8}$$

Model A represents the model which allows for one break in the constant, while Model B represents the model

which allows for one break in the trend, and Model C represents the model which allows for one break both in the constant and in the trend. In the equations $t=(1,2,.....T)$ denotes the time; e_t denotes the error term without autocorrelation and with normal distribution; T_B denotes break time and with the condition of $\lambda\in(0.15,0.85)$, $\lambda=T_B/T$ denotes the break time. On the other hand, while DU shows the structural change occurring in the constant term, it takes on the value of 1 when $t>T_B$, and 0 in all other circumstances. Structural change occurring in the trend is expressed by the DT dummy variable. Accordingly, when $t>T_B$, the DT variable takes on the value of 1, and 0 in all other circumstances. In addition, ΔY_{t-j}, which is on the right hand side of the equation, has been incorporated into the model to obtain an error term without autocorrelation.

In order to determine break time (T_B) the above regressions are estimated using the Ordinary Least Squares (OLS) method and the date in the model, in which α – the coefficient of Y_{t-1} term – has the minimum *t* value, and is determined as the appropriate break point.

After the break date has been determined, the *t* statistics, which were calculated for α which is the coefficient of Y_{t-1}, are compared with the ZA critical values in absolute values. If the calculated *t* statistics is greater than the ZA critical values in absolute terms, the null hypothesis (H_0) is rejected and the alternative hypothesis, which shows that the time series is trend stationary with a structural break is accepted. If the calculated *t* statistics is less than the ZA critical values in absolute value then the null hypothesis (H_0), which shows that there exists a unit root but no structural break in the time series, is accepted.

When the ZA unit root test is implemented, firstly Model C is estimated. As a result of this estimation, depending on the significance of the parameters belonging to the *DU* and *DT* dummy variables, the appropriate model is selected. If the parameters belonging to these variables are significant, the estimation of Model C is appropriate. If only the parameter belonging to the *DU* dummy variable is significant, the estimation of Model A is appropriate. If only the parameter belonging to the *DT* dummy variable is significant, the estimation of Model B is appropriate. Despite the fact that there has been no consensus reached as to which of these models is superior to the others, in practice usually Model A and Model C are used (Yavuz, 2006, pp. 166-167).

Due to the fact that the fragile five countries have encountered negative external and internal shocks (e.g. the 2008 financial crisis in the USA, the 2013 FED announcement, election periods), the stationarity of the real exchange rate series belonging to these countries should be tested with unit root tests which contain structural changes. In line with this objective, the stationarity of the series in the analysis period has first been analyzed using the ZA unit root test, which allows for one structural break. ZA unit root test results are presented in Table 5.

Table 5. ZA unit root test results

Countries	Model	k	T_B	δ	θ_1	θ_2
Brazil	B	1	2011:02	-0.14 (-4.14) ***	-	0.002 (3.18) *
Indian	C	6	2010:07	-0.22 (-5.04) ***	-0.02 (-2.73) *	0.001 (4.08) *
Indonesia	C	3	2010:06	-0.16 (-3.95)	-0.03 (-2.63) *	0.001 (3.91) *
Turkey	C	4	2008:09	-0.23 (-4.32)	0.03 (2.95) *	0.001 (3.45) *
South Africa	A	6	2009:04	-0.13 (-4.29)	-0.08 (-5.88) *	-

Note. k; shows the number of lags chosen by AIC, T_B; the estimate break time, δ; test statistic of ZA test unit root, the values in the parentheses indicate the t-statistics. Critical values excerpted from Zivot and Andrews (1992, p. 256-257) for models are as follows: Model A: 1%; -5.34, 5%; -4.80, %10; -4.58, Model B: 1%; -4.93, 5%; -4.42, %10; -4.11, Model C: 1%; -5.57, 5%; -5.08, %10; -4.82. * and *** icons indicate %1 and %10 level of signifiance and. Normal distribution table are used for critical values of the shadow variables and 1%, 5% and 10% level of significance are respectively 2.60, 1.97 and 1.65.

In the application of the ZA unit root test Model C has been primarily tested for the real exchange rate series belonging to the fragile five countries. Since parameter θ_1 for Brazil was not statistically significant and only

parameter θ_2 was significant Model B was estimated. Likewise, since parameter θ_2 was insignificant and only parameter θ_1 was significant for South Africa Model A was estimated. Since parameters θ_1 and θ_2 were significant for Indonesia, India and Turkey, Model C was estimated (see Table 5).

According to the ZA unit root test results, the null hypothesis, that for Brazil and India real exchange rate series at 10% significance level are trend stationary at the structural break dates given in Table 5, is accepted. In other words, for these countries real exchange rate series are stationary and hence the PPP hypothesis holds true for these countries.

On the other hand, testing the stationarity of macroeconomic data using unit root tests with one structural break leads to erroneous results. In cases where there are two structural breaks, in such series the power of the ZA unit root test diminishes. Therefore Lumsdaine and Papell (1997) have expanded the ZA unit root test and developed a unit root test which allows for two breaks. However, in the basic assumptions of the ZA and LP unit root tests it is assumed that there is no unit root under the structural break, and critical values are obtained based on this assumption. In the alternative hypothesis to the basic hypothesis used in these tests, Lee and Strazicich (2003, 2004) have claimed that the series should not be stationary with a structural break. The reason for this is that an alternative hypothesis can state the existence of structural breaks and this situation can show the existence of a unit root with a structural break in the series. In other words, rejecting the null hypothesis does not require rejection of the unit root, it rejects the existence of a unit root without a structural break. In order to eliminate this problem, Lee and Strazicich have developed a unit root test with one break, which is an alternative to the ZA unit root test based on Lagrange multipliers (LM) developed by Schmidt and Phillips (1992). Likewise, they developed a unit root test with two breaks which provides an alternative to the Lumsdaine-Papell unit root test. The Lee-Strazicich (LS) unit root test with two breaks, in which the structural break is determined internally, is based on two models with respect to breaks occurring in the constant (Model AA) and in the trend (Model CC).

Lee and Strazicich establish their structural break models based on Perron (1989). The data generation process used in the LS unit root test is given below:

$$y_t=\delta' Z_t+e_t \qquad e_t=\beta e_{t-1}+\varepsilon_t \tag{9}$$

Where Z_t represents vector of external variables, ε_t represents the error term. In this test, which allows for two breaks, Model AA allows for two breaks at level and in this model the vector of external variables is defined as $Z_t=[1,t,D_{1t},D_{2t}]$. Model CC allows for two breaks at level and in the trend. In this model the vector of external variables is defined as $Z_t=[1,t,D_{1t},D_{2t},DT_{1t},DT_{2t}]$. The t statistics of the LS unit root test is obtained by $\tilde{\tau}$. In order to determine break times, the points, where $\tilde{\tau}$ test statistic is at a minimum, are chosen.

$$LM_\tau=\inf_\lambda \tilde{\tau}(\lambda) \tag{10}$$

Here, $\lambda=T_B/T$. T_B represents break time and T represents number of observations. If the calculated test statistic is less than the critical value, the null hypothesis (H_0), showing that there exists a unit root under the structural breaks, is accepted. If the calculated test statistic is greater than the critical values, the null hypothesis (H_0), showing that there exists a unit root with structural breaks, is rejected (Lee & Strazicich, 2003, pp. 1082-1089). Since the LM unit root test with two breaks is superior to the ZA unit root test with one break, the stationarity of the series has been analyzed using the LS unit root test with two breaks.

Table 6. Two-Break LS unit roots test results

Countries	Model	λ	k	T_B	S_{t-1}	D_{1t}	DT_{1t}	D_{2t}	DT_{2t}
Brazil	AA		5	2006:01, 2011.08	-0.08 (-2.48)	-0.05 (-1.69)***	-	0.08 (2.57)*	-
	CC	λ_1: 0.4 λ_2: 0.6	6	2008:09, 2011:07	-0.38 (-5.15)	0.15 (5.21)*	0.02 (2.95)*	-0.02 (-0.68)	0.05 (5.59)*
India	AA		6	2012:04, 2013:07	-0.12 (-3.74)***	0.04 (2.15)**	-	0.06 (3.04)*	-
	CC	λ_1: 0.4 λ_2: 0.6	6	2008:07, 2010:10	-0.24 (-5.35)***	-0.04 (-2.10)**	0.01 (2.56)**	0.001 (0.06)	0.014 (3.16)*
Indonesia	AA		3	2008:11, 2013:08	-0.05 (-2.24)	-0.1 (-3.54)*	-	0.06 (2.45)*	-
	CC	λ_1: 0.4 λ_2: 0.6	4	2008:06, 2010:10	-0.20 (-4.41)	-0.03 (-1.41)	0.01 (1.73)***	0.005 (0.21)	-0.01 (-1.88)***
Turkey	AA		1	2009:01, 2010:11	-0.06 (-2.01)	0.04 (1.39)	-	0.05 (1.72)***	-
	CC	λ_1: 0.2 λ_2: 0.4	8	2005:01, 2007:07	-0.33 (-4.90)	-0.02 (-0.73)	0.04 (3.64)*	0.06 (2.01)**	-0.03 (-3.18)*
South Africa	AA		8	2005:11, 2009:03	-0.06 (-1.87)	-0.06 (-1.70)***	-	-0.15 (-4.03)*	-
	CC	λ_1: 0.2 λ_2: 0.6	8	2006:03, 2010:02	-0.26 (-4.31)	-0.05 (-1.31)	0.06 (4.07)*	-0.03 (-0.83)	-0.05 (-3.41)*

Note. k; shows the number of optimal delay selected by AIC, TB; the estimate break time, St-1; test statistic of LS test unit root, the values in the parentheses indicate the t-statistics. Critical values excerpted from Lee and Strazicich (2003, 1084). For model AA, for 1%, 5% and 10% critical values are respectively -4,545, -3,842 and -3,504, *, ** and *** indicate respectively 1%, 5% and 10% level of significance. Normal distribution table are used for critical values of the shadow variables and 1%, 5% and 10% level of significance are respectively 2.60, 1.97 and 1.65.

Table 7. Critical values for model CC

λ_1	λ_2								
	0.4			0.6			0.8		
	1%	5%	10%	1%	5%	10%	1%	5%	10%
0.2	-6.16	-5.59	-5.27	-6.41	-5.74	-5.32	-6.33	-5.71	-5.33
0.4	-	-	-	-6.54	-5.67	-5.31	-6.42	-5.65	-5.32
0.6	-	-	-				-6.32	-5.73	-5.32

Note. Critical values are excerpted from Lee-Strazicich (2003, p. 1084).

According to the LS unit root test results, the null hypothesis, that for the real exchange rate series belonging to India there exists a unit root with a structural break at a 10% significance level, is rejected (see Table 6 and Table 7). According to this result, the real exchange rate series is stationary and the PPP hypothesis holds true for India. In addition, the results of the LS unit root test with two breaks have shown that for the real exchange rate series of the fragile five countries two breaks are significant at level (model AA), and both at level and in the trend (model CC) (see Table 6). Therefore, when analyzing real exchange rate series pertaining to these countries, one should take into account the results of the LS unit root test with two breaks, rather than traditional and ZA unit root tests with one break. However, in the studies conducted with the time series, the reliability of the results of the LS unit root test with more than two breaks has been diminishing. In response to this problem, Carrion-i-Silvestre, Kim and Perron (2009) developed the Carrion-i-Silvestre (CS) unit root test with multiple structural breaks, which allows for five structural breaks. In the CS unit root test, structural break dates are determined using the Bai and Perron (2003) algorithm, with the help of the quasi-GLS (Generalized Least Squares) method dynamic programming approach and by a minimization of the sum of error squares (Carrion-i-Silvestre, Kim, & Perron, 2009). The stochastic data generation process used in this test is given below.

$$y_t = d_t + u_t \quad (11)$$

In order to test the stationarity of the series obtained in this process, Carrion-i-Silvestre et al. (2009) developed five test statistics for multiple structural breaks. These test statistics are: P_T, probable optimal point test statistic, as developed by Perron and Rodriguez (2003); MP_T, modified probably optimal point test statistics, developed by Ng and Perron (2001); and MZ_α, MSB and MZ_t, which are called M-class test statistics, which allow for multiple structural breaks and which were developed by Perron and Rodriguez (2003).

In a CS unit root test with multiple structural breaks when calculated test statistics turn out to be less than critical values, the null hypothesis (H_0), stating that there exists a unit root with structural breaks, is rejected against the alternative hypothesis (H_1), which states that there is no unit root and structural breaks. In other words, it is accepted that the series being investigated is stationary under structural breaks. In this study, due to the fact that many internal and external negative shocks were experienced in the fragile five countries during the analysis period, the stationarity of the real exchange rate series has been re-tested with CS unit root test with multiple structural breaks.

Table 8. CS unit roots test results

Countries	P_T	MP_T	MZ_α	MSB	MZ_T	Break Period
Brazil	11.55	10.80	-39.61	0.11	-4.44	2004:03,2006:02,2008:08,
	(8.97)	(8.97)	(-46.63)	(0.10)	(-4.83)	2011:08,2014:07
India	7.55*	6.98*	-55.19*	0.09 *	-5.25*	2005:08,2007:03,2009:03,
	(8.30)	(8.30)	(-45.76)	(0.10)	(-4.79)	2010:10, 2013:09
Indonesia	15.70	14.03	-30.95	0.13	-3.93	2004:04,2005:09,2009:03,
	(9.11)	(9.11)	(-47.03)	(0.10)	(-4.84)	2011:08,2013:07
Turkey	11.440	10.77	-41.59	0.11	-4.56	2004:03,2006:04,2008:08,2009:11,
	(9.442)	(9.44)	(-46.66)	(0.10)	(-4.80)	2014:07
South Africa	6.969*	6.33*	-66.59*	0.09*	-5.77*	2004:12,2006:09,2007:12,
	(9.018)	(9.02)	(-46.35)	(0.10)	(-4.78)	2009:03,2013:07

Note. *, icon implies that the series that examined at the level of 5% significance is stationary. Critical values shown in the parentheses and with the help of bootstrap with 1000 iterations made. Structure break dates were determined by the test method.

The results of the CS unit root test with multiple structural breaks show that test statistics calculated for real exchange rate series of South Africa and India in the analysis period have turned out to be less than critical values. According to these results, it has been determined that real exchange rate series for these countries were [I(0)] stationary at the break dates given in Table 8, and that the PPP hypothesis is valid in these countries. In addition, it has been found that calculated test statistics for real exchange rate series of Brazil, Indonesia and Turkey were greater than critical values, therefore real exchange rate series of these countries had a unit root. This finding shows that the PPP hypothesis does not hold in the countries in question. On the other hand, the results of CS unit root test with structural breaks show that the test method was successful in predicting structural break dates (the 2008 financial crisis, the 2013 FED announcement, political election periods) (see Table 8).

5. Conclusion

In this study the stationarity of real exchange rates for the fragile five countries has been analyzed using monthly data for the period 2003:01-2015:10, and employing traditional ADF/PP unit root tests and Zivot-Andrews/Lee-Strazicich/Carrion-i-Silvestre unit root tests with one/two/five structural breaks. The primary contribution of this study to the literature is that it analyzes the stationarity of real exchange rates and hence the validity of the Purchasing Power Parity (PPP) for the fragile five countries. Secondly, it applies unit root tests which take into account the existence of structural breaks in the real exchange rates of these countries.

As a result of the traditional ADF and PP unit root tests that were applied within the context of empirical analysis it has been determined that the real exchange rate series of the fragile five countries has a unit root and therefore the PPP hypothesis does not hold in the countries in question. However, these countries have experienced many internal/external negative shocks during the analysis period (the 2008 global crisis, the 2003 FED decisions, and political election periods). Therefore, utilizing unit root tests with structural breaks, the stationarity of the real

exchange series was re-tested.

Within this context, firstly the stationarity of real exchange rate series has been analyzed using the Zivot-Andrews (ZA) unit root test, which allows for one structural break. ZA unit root test results show that real exchange rate series were stationary for Brazil and India, and therefore the PPP hypothesis is valid for these countries. When the stationarity of real exchange rate series was analyzed employing the Lee-Strazicich (LS) unit root test with two structural breaks, we reached the conclusion that the PPP hypothesis holds only for India.

In addition, LS unit root test results show that for the real exchange rate series of all countries, structural break dates calculated by the test method were statistically significant. Based on this outcome, it has been concluded that, rather than traditional unit root test and ZA unit root test with one structural break, it would be wiser to draw conclusions based on LS unit root test results. However, due to the fact that the existence of more than two breaks in a series lessens the reliability of LS unit root test results, the stationarity of real exchange rates was re-tested using the Carrion-i-Silvestre (CS) unit root test, which allows for five structural breaks in the time series. Looking at the CS unit root test results, however, it has been determined that real exchange rate series for South Africa and India did not have a unit root. In other words, according to the CS unit root test results, it has been found that the PPP hypothesis is valid only in South Africa and India.

The CS unit root test results of this study show that economic shocks did not cause permanent shocks only on the real exchange rate series of South Africa and India with in the fragile five countries, and that the series returned to their averages in the long term. Moving from this point onwards, it can be claimed that, despite the fact that the fragile five countries adopted inflation targeting regimes, except for South Africa and India, the central banks of the other fragile five countries did not have the possibility to implement an independent monetary policy in eliminating the risks that real exchange rate volatilities would cause. In other words, due to the fact that the central banks of South Africa and India, in which real exchange rates are stationary, are not under pressure to establish exchange rate stability, they have the possibility of implementing an independent monetary policy.

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