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PURCHASING POWER PARITY HYPOTHESIS: NEW EMPIRICAL EVIDENCE FROM NONLINEAR PANEL UNIT ROOT TESTS

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ABSTRACT

PURCHASING POWER PARITY HYPOTHESIS: NEW EMPIRICAL EVIDENCE FROM NONLINEAR PANEL UNIT ROOT TESTS

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The purpose of this thesis is to provide a comprehensive analysis of the Purchasing Power Parity (PPP) hypothesis by re-examining its validity for a group of Organization for Economic Co-operation and Development (OECD) countries. To this end, we tested this theory by using a battery of unit root tests by using monthly data for the period 1990 to 2013. The unit root tests implemented in this study includes not only the conventional univariate and panel unit root tests but also their nonlinear counterparts. However, all results in general emphasize that the PPP hypothesis does not hold for the OECD countries included in this study. While the PPP hypothesis founds most support when thelinear panel unit root tests are implemented, strong unfavorable evidence exists by using the linear univariate unit root tests. The results of the nonlinear unit root tests seem also promising. Thus, the validity of the PPP hypothesis still remains an unsolved question.

Keywords: PPP, Unit Root Test, Nonlinear Unit Root Tests

ÖZ

SATIN ALMA GÜCÜ PARİTESİ HİPOTEZİ: DOĞRUSAL OLMAYAN PANEL BİRİM KÖK TESTİNDEN YENİ AMPİRİK KANITLAR

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Bu çalışmanın amacı İktisadi İşbirliği ve Gelişme Teşkilatındaki bir grup ülke için Satın alma Gücü Paritesi (SGP) hipotezini yeniden değerlendirerek kapsamlı bir analiz sunmaktır. Bu amaçla 1990 ve 2013 yılları arasında aylık verilerle bir sürü birim kök testi sınanmıştır. Bu çalışmada geleneksel tek değişkenli ve panel birim kök testlerinin yanında doğrusal olmayan birim kök testleri de uygulanmıştır. Ama bu çalışmadaki sonuçlara göre, SGP hipotezi İktisadi İşbirliği ve Gelişme Teşkilatı ülkeleri için geçerli değildir. SGP hipotezi en çok destekleyen test, doğrusal panel birim kök testleri iken, en az destekleyen ise doğrusal tek değişkenli birim kök testleridir. Doğrusal olmayan birim kök testlerinin sonuçları da ümit vericidir. Böylece, SGP hipotezinin geçerliliği hala çözülemeyen bir sorun olarak kalmaktadır.

Anahtar Kelimeler: Satın Alma Gücü Paritesi , Doğrusal Olmayan Birim Kök Testleri,Birim Kök Testi

To My Family

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TABLE OF CONTENTS

CHAPTERS

LIST OF TABLES

LIST OF FIGURE

ABBREVIATIONS

AIC	:Akaike Information Criteria
ADF	: Augmented Dickey Fuller Test
CPI	: Consumer Price Index
DF-GLS	:Dickey Fuller –Generalised Least Square
Fisher ADF	: Fisher Augmented Dickey Fuller Test
IFS	: International Financial Statistics
IPS	: Im-Pesaran-Shin
KPSS	:Kwiatkowski–Phillips–Schmidt–Shin
KSS	: Kapetanios-Snell-Shin
LLC	:Levin-Lin-Chu
LNV	:Leybourne, Newbold, Vougas
LOP	: Law of One Price
OECD	: Organisation for Economic Co-operation and Development
PP	: Phillips Perron Test
PPP	: Purchasing Power Parity
RERs	: Real Exchange Rate Series
SGP	: Satın Alma GücüParitesi
SIC	: Schwarz Information Criterion
SPSM	: Sequential Panel Selection Model
STR	: Smooth Transaction Regression
UO	: Uçar- Omay

CHAPTER1

1. INTRODUCTION

The Purchasing Power Parity (PPP) hypothesis is one of the most crucial hypotheses in the macroeconomics and international economics literature. The PPP hypothesis suggests that two countries have the same price level when the price level is transformed to the common currency. This hypothesis might hold true in two senses. Absolute PPP prevails if the same baskets of goods costs are the same when prices are converted to a common currency. On the other hand, the relative version of the PPP holds true if the ratio of two broadly defined price indices stay constant when corrected for changes in the exchange rate. However, the PPP hypothesis may not hold true in an economy due to the existence of trade restrictions, transportation costs, tariffs, taxes and non-tradable goods. In addition, the presence of imperfect competition and asymmetric information may also affect the PPP theory because these prevent the price equilibrium between countries.

Later, we analyzed empirical literature about the PPP hypothesis. The PPP hypothesis has vast empirical literature; therefore, we divided the studies into four different methodologies with respect to the econometric literature. First, we analyzed the studies that have applied the linear univariate unit root tests to the PPP hypothesis (He et al.2013; Hoque et al. 2012). Linear univariate unit root tests were used to the long span data series. The results of the linear univariate unit root tests have generally rejected the PPP hypothesis. Second, we investigated linear panel unit root tests studies (Cuestas, J.C. and Regis, P.J. 2013; Olayungbo D.O 2011; Wu, J., Cheng, S. and Hou, H. 2011). Panel unit root tests are more powerful tests, but some of the studies do not support the validity of the PPP hypothesis. Later, we researched nonlinear univariate unit root tests

studies (Carvalho et al. 2012; Su et al.2014; Cuestas, J.C. and Regis, P.J.2013). Nonlinear univariate unit root tests have the high possibility of accepting the validity of the PPP hypothesis. Finally, nonlinear panel unit root studies were analyzed (i.e.He and Chang 2013, He, Ranjbar and Chang 2013). In our case, we see that the nonlinear panel unit root tests were also successful in accepting the PPP hypothesis. Thus, according to the empirical literature, there is a contradiction among the alternative test results. Unfortunately, we cannot definitely say that the PPP hypothesis holds true because the results change with respect to countries and time periods.

In this thesis, therefore our main aim is to solve the aforementioned PPP puzzle and re-examine the validity of the PPP hypothesis for a group of OECD countries. For this purpose, we implemented a variety of unit root tests and tried to find out which unit root test was better in giving strong evidence in favor of the PPP hypothesis. We used monthly data that spans the period from January 1990 to November 2013.

The PPP hypothesis is examined by conducting a battery of unit root tests including the linear univariate, linear panel, nonlinear univariate and nonlinear panel unit root tests. Linear univariate unit root tests applied are Augmented Dickey Fuller (ADF), Dickey Fuller Generalized Least Square (DF-GLS), Philips Perron (PP) and Kwiatkowski Phillips Schmidt Shin (KPSS) tests. Empirical results show that linear univariate unit root tests are generally unable to support the PPP. This may stem from the low power of these conventional unit root tests. In addition to linear univariate unit root tests, linear panel unit root tests were also applied, which are Levin Lin Chug (LLC), Im Pearson and Shin (IPS), Fisher Augmented Dickey Fuller (Fisher ADF), and Hadri tests. According to the empirical results, linear panel unit root tests are generally successful in accepting the validity of the PPP hypothesis.

While using the conventional univariate and panel data approach, we discovered that they have some problems such as low power and cross sectional dependence. Linear univariate unit root tests do not support the evidence in favor of the PPP hypothesis due

to the low power of linear unit root tests. To eliminate the univariate unit root test deficiency, panel unit root tests were proposed in the time series, but it also gives cross sectional dependency problems. Cross sectional dependence may arise due to spatial correlation, spill-over effect, economic distance, omitted global variables and common unobserved shocks; and it may lead to biased estimates and misleading inferences (Omay and Kan, 2010). To decrease the linear univariate and panel unit root tests deficiency, we also used the nonlinear univariate and panel unit root tests.

The nonlinear univariate unit root tests applied includes the tests proposed by Kapetanios-Snell-Shin (KSS) and Leybourne, Newbold, Vougas (LNV).The KSS test is successful in eight out of the twenty four OECD countries and LNV test is holds in four countries. Finally, we applied nonlinear panel unit root tests proposed by Uçar and Omay (UO) and Im Pearson and Shin (IPS). As mentioned above we employed the UO tests under the cross sectional dependency assumption. UO test is support the evidence of the PPP in six out of the twenty four OECD countries. According to nonlinear unit root test results, in general there is still weak empirical evidence to support the PPP hypothesis. At the end of the research, although a battery of unit root tests were applied to analyze the PPP hypothesis strong evidence in favor of the PPP hypothesis still could not be found.

This thesis is organized as follows: Chapter 2 introduces the PPP theory by emphasizing its importance in the economy. This chapter also provides brief definitions of the absolute version and relative versions of the PPP. Chapter 3 searches the empirical literature by presenting previous studies that were conducted to test the PPP theory. The data set is explained in Chapter 4. The Consumer Price Index (CPI) is used between the years 1990 and 2013. In addition, methodology is explained in this chapter, and our analysis is divided into four parts: linear and nonlinear univariate unit root test, linear and nonlinear panel unit root test. In Chapter 5, the results of the tests utilized are presented, and the PPP hypothesis is discussed. Finally, Chapter 6 is allocated for the conclusion.

CHAPTER 2

2. PURCHASING POWER PARITY (PPP) THEORY

The purpose of this chapter is to introduce the theoretical foundations of the Purchasing Power Parity (PPP) theory. To this end, first the PPP hypothesis will be defined and its historical evolution will be briefly presented. Second, absolute and relative versions of the PPP theory will be explained. Then, the Law of One Price (LOP) and long run purchasing power parity will be discussed, and finally, we will elaborate more on the PPP hypothesis and examine how the PPP hypothesis is tested.

2.1 Purchasing Power Parity: Definition and History

The PPP is a theory about exchange rate determination. The most important determinant of exchange rates is the fact that in open economies the prices of traded goods should be the same everywhere after adjustment for custom duties and the cost of transportation. This is called the PPP theory of exchange rate determination.

The PPP theory was based on long standing studies; the idea of the PPP was dating back to scholars at the Universities of Salamanca in the 16^{th} century in Spain. They had significant contributions to the PPP theory. The quantity of money was formulated by scholars with using foreign exchange rate. They observed the effect of the money supply, price levels and exchange rates for calculating purchasing power in different countries. The PPP theory was also proposed by mercantilist Gerard de

Malynes in 17^{th}century. During the 19^{th} century, classical economists especially Ricardo, Mill, Goschen and Marshal developed the PPP theory.

Modern form of the PPP was developed by Swedish economist Gustav Cassel in 1918.Before and after the World War I ,Gustav Cassel observed belligerent countries such as; Germany, Hungary, US and Soviet Union. These countries had experienced hyperinflation and their currencies decreased sharply. He presented the PPP model with these observations. "That theory became the benchmark for long run nominal exchange rate determination in the years after the World War I, particularly during the intense debate concerning the appropriate level for nominal exchange rates for countries returning to the Gold Standard but also among the major industrialized countries after phenomena of hyperinflation experienced during and after the World War I" (Cassel, 1918).

In addition to Gustav Cassel, John Maynard Keynes was interested in calculating the exchange rates after the World War I. According to Keynes, there are two shortcomings of the PPP theory. First, the PPP isn't successful to take into account the elasticity of reciprocal demand .Second; the theory doesn't consider capital movements. So, Keynes claims that both capital movements and elasticity of reciprocal demand decide foreign exchange rates. Keynes stated clearly the PPP hypothesis: "This theory doesn't provide a simple measure of the true value of the exchange rate. When it is restricted to foreign trade goods, it is better than a reality. When it isn't so restricted, the conception of purchasing power parity becomes much more interesting, but it is no longer an accurate forecaster of the foreign exchanges. Thus purchasing power parity isn't always an accurate forecaster for the foreign exchanges" (Keynes, 1923).

Between 1913-1928 years, Cassel obtained supporting evidence to the PPP hypothesis. The US government and League of Nations commonly conducted studies of the PPP. The PPP discussion was emerged before the World War II in Britain in 1925.Then, French economist; Jacques Rueff described the principles of the PPP. He

used wage based the PPP to calculating the French's Poincare Stabilization between 1926 and 1928.While the PPP theory was applied by many economists, there were also many controversy between economists. Viner (1937) also criticized the PPP theory. According to Viner, the PPP couldn't be conceived without notion of a price level. Vinner claimed that the PPP as a theory was simply misstated and as a practical proposition overstated. (Dornbusch, 1985)

After World War II the PPP theory again emerged, Yeager (1958) and Haberler (1961) highlighted the practical usefulness of the PPP and they point out the role of the price elasticity in international trade. On the other hand, Hendrik Houthakker (1962) point out the dollar overvaluation, he calculated the absolute PPP; it based on consumer price comparisons. Samuelson (1964) formalized the PPP theory with using Houthaker's dollar overvaluation thesis.

In the late of the 1930's Harrod (1939) had taken attention to different production level on international markets. His idea based on the Cassel's absolute versions of the PPP. Balassa and Samuelson (1964) similarly accepted the absolute version of the PPP. According to Balassa, the purchasing power parity doctrine means different things to different people. Balassa dealt with two versions of the PPP theory that can be appropriately called the "absolute" and the "relative" interpretation of the doctrine. According to the absolute version, purchasing power parities calculated as a ratio of consumer goods prices for any pair of countries would tend to approximate the equilibrium rates of exchange. In turn, the relative interpretation of the doctrine asserts that, in comparison to a period when equilibrium rates prevailed, changes in relative prices would indicate the required adjustments in exchange rates. (Balassa, 1964)

In the 1970's PPP had turn point with flexible exchange rate. Robert Mundell improved the monetary approach to the balance of payments in 1971, and Harry Johnson (1975) used the PPP in the monetary approach. Exchange rate under the PPP conditions was interpreted in the manner of monetary phenomenon.

The PPP had been researched from beginning of the 1900's to 2000's even though, economists mainly concerned with the PPP theory after the 1980's.In the light of this information, the PPP theory is based on the law of one price which will be explained in the second part.

2.2 The Law of One Price (LOP)

The law of one price suggests that identical goods sell at the same price in two separate countries. The theory supposes that there are no transaction costs, taxes, trade barriers to international trade, and also assume that perfect competition exists in the markets. The law of one price formula is;

$$(P_{TR}^{i}) = (E_{\$/TL}) * (P_{US}^{i}) \quad (2.1)$$

where, $P_{US}^{i}$is the Dollar price of good i, P_{TR}^{i}denotes the TL price in Turkey and $E_{\$/TL}$gives the exchange rate between dollar and TL 's and is expressed in as unit of national currency per foreign currency

If $\left(P_{TR}^{i}\right) < (P_{US}^{i})$, then there is an arbitrage opportunity and arbitrageur can buy goods from the domestic market at (P_{TR}^{i}) price and sell it in a foreign market at (P_{US}^{i}) price. This arbitrageprocess will continue until equality holds between the two price levels. The same is true for the case that $\left(P_{TR}^{i}\right) > (P_{US}^{i})$.Therefore, if the law of one price doesn't hold, the arbitrage opportunity will occur and the price levels will gradually converge to each other.

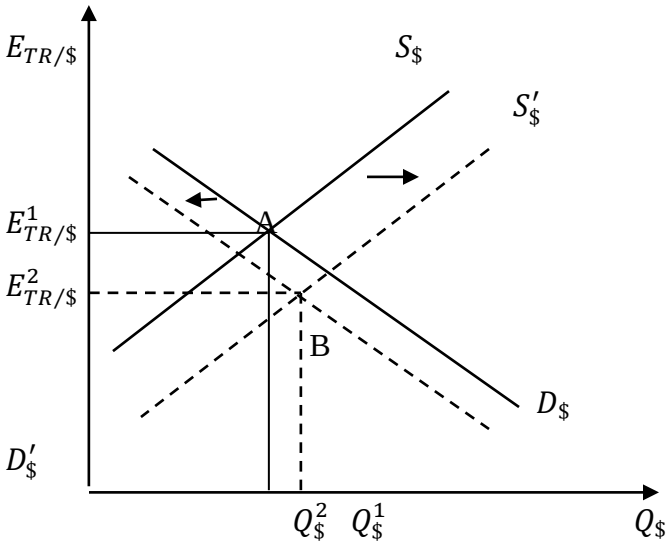

Figure 1. Law of One Price

In figure 1 $E_{TR/\$}$ is the exchange rate,$S_\$$ is supply of Dollar and $D_\$$ is the demand of Dollar in the market. Both the shift in demand and supply will cause a decrease in the value of the dollar and thus the exchange rate $E_{TR/\$}$ will decrease. Law of one price condition was established and thus, arbitrage opportunity didn't occur and the PPP also hold.

Law of one price theory is based on the following set of assumptions:

1) There is no limitation about the movement of commodities. Such as; tariff and quotas are banned for the exporter and importers between the two trading countries.
2) Tariff isn't imposed by countries, so countries can easily buy and sell their goods between countries.
3) Transaction cost is eliminated between countries so; exporter and importers trade with each other under the law of one price condition.

Under the law of one price assumption, market is perfectly competitive and goods are homogenous. This means that there is no price difference and consumers have perfect information about the market. If these assumptions do not hold true (law of one price will not hold), then arbitrage opportunity can emerge for importers and exporters in the international market.

2.2.1 Absolute Purchasing Power Parity

The absolute PPP theory is an aggregated version of the law of one price. "Absolute purchasing power parity holds when the purchasing power of a unit of currency is exactly equal in the domestic economy and in a foreign economy, once it is converted into foreign currency at the market exchange rate" (Taylor, 2004). Absolute purchasing parity suggests that same goods have the same price in two countries. According to absolute purchasing power parity, real exchange rate must be zero. Absolute version of purchasing power parity states that;

$$S_t . P^*_{i,t} = P_{i,t}; i = 1,2,3 \dots \dots \dots \dots, N, \forall t \quad (2.2)$$

where , $P_{i,t}$ is the price of good i at time t in the domestic currency, $P^*_{i,t}$ is the price of the same good at time t in a foreign country and S_t is nominal exchange rate, identified as the amount of domestic currency needed to buy one unit of foreign currency.

$$S_t = P_{i,t}/P^*_{i,t} \quad (2.3)$$

$$P_t = \sum_{i=1}^{N} \alpha_i P_{i,t} \quad (2.4)$$

where $\alpha_i \in [0,1]$, with $\sum_{i=1}^{N} \alpha_i = 1$, and N represents the number of tradable goods providing law of one price. Equation (2.2) is summed up as follows;

$$S_t P_t^* = P_t \tag{2.5}$$

According to the equation (2.5), absolute PPP prevails if the same basket of goods costs the same when prices are converted to a common currency. That is, when $P = S\,P^*$, where P and P^* are the local currency prices of the basket in the home and foreign country, respectively. When we take the logarithm of both sides of equation (2.2) we obtain;

$$s_t + p_t^* - p_t = 0 \tag{2.6}$$

$$s_t = \log(S_t)$$
$$p_t^* = \log(P_t^*)$$
$$p_t = \log(P_t)$$

There are some problems about absolute PPP; one of the most important problems is the choice of the price index. There is no general price index to calculate each weight of the commodities for each country in the international market. To solve this problem, Geary Khamis dollar was applied in the international market, but this isn't enough for measure the commodities in the international market. Geary Khamis dollar is very important for purchasing power parity, specifically it means international dollar. International dollars are represented as a current international dollar for a single year, for example by choosing the base year as 2010.The international dollar was suggested in 1958 by Roy C. Geary and later it was improved by Salem Hanna Khamis. Today many organizations, such as the International Monetary Fund (IMF) and World Bank, have also used international dollar for choosing such metrics.

2.2.2 Relative Purchasing Power Parity

Relative PPP prevails if the ratio of two broadly defined price indices stays constant when corrected for changes in the exchange rate. That is, if

$$S_t P_t^* / P_t = R \tag{2.7}$$

where, R in fact denotes the real exchange rate, which means that relative PPP infers a constant real exchange rate. In equation (2.7) the home and foreign aggregate price indices are obtained by applying the same mechanism discussed above for the absolute PPP.

R can also be interpreted as a positive constant that is included in the equation to take into account for trade barriers such as transportation costs, tariffs and quotas etc. If absolute PPP holds, then relative PPP must also hold. However, if relative PPP holds, then absolute PPP does not necessarily need to hold, because it is possible that common changes in nominal exchange rates can happen at different levels of purchasing power for the two currencies (Taylor, 2004).

If relative PPP holds, then real exchange rate can't change. This means that the competitive power is the same between countries. Taking logarithms on both sides of equation (2.6), relative PPP is obtained as;

$$s_t + p_t^* - p_t = r \tag{2.8}$$

$$r = \log(R)$$

Logarithmic version of the relative PPP is based on the law of one price. "Relative PPP is much easier to test empirically than its absolute version, since the data

collected on price is based on indices rather than on levels, which creates a wedge between the relative prices of different countries that can only be captured through the parameter"(Carvalho and Julio, 2012).

2.3 Problems with the Purchasing Power Parity Theory

As mentioned above, the PPP hypothesis suggests some assumptions to be holds. Many researchers examined the PPP with using many tests under these assumptions, but some problems arise in the practice. These problems can be outlined as follows;

1) **Transportation Cost and Trade Restriction:** The law of one price suggests that the transportation costs and trade restrictions were insignificant. However, people are importing and exporting goods from different countries and goods' cost are changing from country to country. This causes divergence in countries price ratios. Transportation cost and trade restrictions do exist in the real world thus, PPP may not hold with divergence of the price ratio for all markets.

2) **Tariff and Taxes:** The PPP theory suggests to removing taxes or tariffs but, governments impose taxes and tariffs to protect balance of trade. Free movement of the capitals and goods are prevented by the countries so, PPP theory may not hold with imposing taxes and tariffs.

3) **Non-tradable Goods:** Many goods and services are not subject to international trade due to the nature of the product. Non tradable goods also cause to deviations in the PPP because non-tradable goods prices are not linked internationally. The prices are decided by domestic supply and demand, and shifts in those curves cause to changes in the market basket of some goods relative to the foreign price of the same basket. If the non-

tradable good prices increase, the purchasing power of any given currency will decrease in that country. Krugman and Obstfeld (2009).Thus non-tradable goods will have deviations from the PPP theory.

4) **Asymmetry information:** Purchasing power parity claims that people have access to all of the same information regarding prices across all countries. As a result of this knowledge, people tend to export goods to high priced markets and import goods from low priced markets. However, people can't reach to perfect information in the real life. Trader doesn't reach to a profit opportunity with imperfect information so, prices can't be equalized in the market.

2.4 Long Run Purchasing Power Parity

The PPP theory was applied for short run and long run in the economy. Long run is an unspecified period of time according to economists; it refers to months, years and decades etc. Generally short run theory isn't successful for holding PPP; on the other hand PPP holds in the long run. Tariff, quota, transaction cost and other problems obstruct the PPP in the short run. In the short run importer and exporter cannot respond rapidly to deviations in the markets between countries. In other words, the arbitrage opportunity occurs in the international market so that the trader buys goods from a lower price and sells them at a higher price. This delay occurs due to a number of reasons. The first reason is the existence of imperfect information; importer and exporter are informed from the price difference in different markets. Second one is the existence of long term agreements; importer and exporter must finish the present contract to set up new contracts. Thirdly; advertisement costs, costs that occur from newly entering to a market and other costs are another reason of this delay. Today most economists believe that the PPP holds in the long run and thus, the Real Exchange Rate (RER) cannot change in the long run.

2.5Purchasing Power Parity and Unit Root Tests

The PPP theory claims that Real Exchange Rate should be stationary. As mentioned in equation (2.7), purchasing power of one unit currency is the same between countries when exchange rates are converted the same monetary unit. Thus Real Exchange Rates are stationary and they don't have unit root problems. If Real Exchange Rates have a unit root, then that means, they are found to be non-stationary. Under the PPP theory, deviations from a constant real exchange rate should be temporary. Because unit root processes have deviations that are permanent, studies, take rejection of a unit root in the logarithm of the Real Exchange Rate as evidence of the PPP, and failure to reject a unit root as evidence that PPP fails to hold (Steigerwald 1996).

CHAPTER 3

3. EMPIRICAL LITERATURE ON PURCHASING POWER PARITY (PPP) HYPOTHESIS

In the previous part, the PPP theory was widely explained and some of the problems in the PPP theory were discussed. In this present chapter, the empirical literature about the PPP theory will be identified. In recent years, many econometric tests have been developed thus, there is a vast empirical literature that analyzes whether the PPP hypothesis holds or not. When the PPP theory was analyzed by researchers, many tests were applied to the OECD, European, Asian and different developing countries. In this part, we will try to survey this vast literature by mainly focusing on the recent empirical evidence, especially the studies that were conducted after the 2000s. We will group this vast literature according to the type of econometric methodology utilized. To this end, in section 3.1 we will present the studies that employ a linear method then testing the validity of the PPP hypothesis and then in section 3.2 we will discuss the ones that take a nonlinear perspective.

3.1 Studies that Utilize Linear Methods

In the literature, many conventional unit root tests were applied to the PPP theory. We will discuss these linear tests by further grouping them in two parts. First, the studies that employ univariate unit root tests will be presented and then the ones that conduct a panel analysis will be discussed.

3.1.1Univariate Unit Root Tests

Many conventional univariate unit root tests, including the Augmented Dickey Fuller (ADF), Dickey Fuller Generalized Least Squares (DF-GLS), Kwiatkowski-Phillips–Schmidt–Shin (KPSS) and the Phillips Perron (PP) unit root tests were applied by many economists to different countries.

He et al. (2013) studied long run the PPP theory for the transition economies such as Bulgaria, the Czech Republic, Hungary, Latvia, Lithuania, Poland, Romanian, and Russia. They applied the Augmented Dickey Fuller (ADF), Philips Perron (PP) and Kwiatkowski-Phillips- Schmidt-Shin (KPSS) conventional unit root tests and found that the PPP theory failed in the long run for these countries.

Shiller (2013) performed Augmented Dickey Fuller (ADF), Dickey Fuller (DF) and Philips Perron (PP) to the United Kingdom, United State, France, Germany and Japan for the period 1982 to 1997. This application to the industrialized countries generally showed that PPP hypothesis fails, when univariate unit root tests are applied to the selected countries.

Carvalho and Julio (2012) analyzed the PPP theory using again the conventional tests including the ADF, Dickey DF-GLS and KPSS unit root tests. The tests were applied to 20 OECD member economies such as Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland and the UK. Their studies failed to provide strong evidence in favor of the PPP theory by using the standard univariate unit root tests. However, only the DF-GLS test offered some support for the PPP hypothesis in some countries. In addition more importantly they found that nonlinear tests were more powerful than the linear tests in obtaining empirical evidence in favor of the PPP hypothesis.

Many researchers in the literature claim that PPP holds for the long period. For example, Hoque and Rajabrata (2012) have tested the validity of the PPP theory for garment exporting for the period from 1994 to 2012 .They used the ADF test and PP test with structural change for developing countries such as; Bangladesh, Pakistan, India and Sri Lanka. They found that PPP doesn't hold for these selected developing countries.

Olayungbo (2011) utilized the ADF test for 16 Sub-Saharan African Countries and for the period 1980 to 2005.According to this study, while the PPP holds for16 Sub-Saharan African countries, it fails in Uganda and Ghana.

In another study, Christidou and Panagiotidis (2010) again employed the ADF test to 15 European Union Countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and Sweden) for the period between 1973 and 2009.For only UK and Sweden could the authors find some evidence in favor of the PPP hypothesis for the post-Maastricht period, but in all other economies they were unsuccessful to find any support in favor of the PPP theory.

Also Lopez (2008) examined the PPP theory using ADF and DF unit root tests for 21 industrialized countries for the period 1973 to 2001 and concluded that the univariate unit root tests were inadequate to use when analyzing the PPP under the floating exchange rate regime. Similarly, Froot and Rogoff (1995), Rogoff (1996), Sarno and Taylor (2002), Taylor and Taylor (2004) have used standard univariate unit root tests and failed to obtain favorable evidence for the Real Exchange Rates.

By contrast to the vast amount of studies those conclude that PPP fails to hold when univariate unit root tests are applied, there are only a limited number of studies that finds some evidence in favor of the PPP hypothesis by using these tests. For example, Nusair (2003) tested the validity of the PPP theory for 6 Asian Countries. He used the ADF, PP and KPSS tests and showed that PPP holds in four out of the six Asian

countries. Similarly, Tataloğlu (2009) tested the PPP hypothesis using the ADF test for 25 OECD Countries for the period 1997 to 2004 and found out that the ADF test is significant when structural break is ignored.

Table 1.A summary of the literature on the Univariate Unit Root Tests

Researcher	**Sample**	**Period**	**Frequency**	**Method**	**Result**
Shiller,I. (2013)	US,UK, Germany, French and Japan	1982:01-1997:05	Monthly	Univariate Unit Root Test(ADF,DF and PP)	PPP theory is generally failed.
He et al.(2013)	8 Transition countries	1995:01-2011:10	Monthly	Univariate Unit Root Test(ADF, PP and KPSS)	Long run PPP doesn't hold.
Hoque et al. (2012)	Developing countries	55 years period	Monthly	Univariate Unit Root Test(ADF)	Long run PPP doesn't hold
Carvalho et al.(2012)	20 Developed Countries	1973:01-2007:04	Quarterly	Univariate Unit Root Test(ADF,DF GLS and KPSS)	PPP doesn't hold
Olayungbo, D.O (2011)	16 Sub Saharan African Countries	1980:01-2005:01	Annual	Univariate Unit Root Test(ADF)	PPP theory holds for Sub Saharan Africa except Ghana and Uganda
Christidou et al. (2010)	15 EU Countries	1973:01-2009:04	Monthly	Univariate Unit Root Test(ADF)	PPP theory doesn't hold except UK and Sweden
Tatoğlu,F.Y. (2009)	25 OECD Countries	1977-2004	Annual	Univariate Unit Root Test(ADF)	PPP holds in the long run
Lopez,C. (2008)	21 Industrialized Countries	1973-2001	Quarterly	Univariate Unit Root Test(ADF and DF)	PPP doesn't hold.
Nusai, Salah A. (2003)	6 Asian Countries	1973:2-1999:4	Monthly	Univariate Unit Root Test (ADF, PP and KPSS)	PPP holds in four out of the six Asian countries

To summarize, many univariate unit root tests were applied to testing the PPP hypothesis in the literature but, unfortunately no conclusive evidences in favor of the PPP hypothesis could be obtained.

3.1.2 Panel Unit Root Tests

In some early studies, univariate unit root tests tested for the presence of the unit root in the Real Exchange Rates. In our literature part, early studies show that univariate unit root test didn't provide the significant support for Real Exchange Rate so, unit root problem occurred in the tests. To solve this problem, panel unit root test was proposed with increasing the size and power of the unit root test. In many studies, to increase the power of the standard unit root tests, panel data was gathered for several countries. An alternative way to increase the size and power of unit root tests is to expand the cross-section dimension of the database, by gathering several countries in a panel observation (Carvalho et al. 2012).

Carvalho et al. (2012) applied Levin Lin Chu Test (LLC),Im Pesaran Shin (IPS), Fisher-ADF and Hadri panel unit root tests to a selected number of OECD countries. According to this study the PPP is found to hold for some of the countries but not all of them when IPS and Fisher -ADF tests are used. Also LLC and Hadri tests show the same conclusion for testing the PPP theory, but LLC failed to reject the random walk for the real exchange rate series included in the study. According to Carvalho et al, the main result is unsatisfactory methods of the panel test.

In addition, Olayungbo (2011) utilized standard panel unit root tests (i.e. IPS and LLC) for 16 Sub- Saharan African Countries from 1980 to 2005. This study finds favorable evidence in favor of the PPP hypothesis for 16 Sub-Saharan African Countries due to strong power of the panel unit root tests. Likewise, Wu, Cheng and Hou (2011) have analyzed the validity of the PPP by using the standard IPS panel unit root test for

76 countries for the period 1976 to 2006. While the study shows that the PPP holds for African and Latin American countries, it fails to hold for Asia and Europe.

Christidou and Panagiotidis (2010) again conducted the panel tests such as the IPS and Hadri tests for the 15 European Union Countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and Sweden) for the period between 1973 and 2009.There was a evidence in favor of the PPP theory according to IPS test result. IPS test rejected the null of a unit root in all series for the whole period so; PPP theory was valid during the past 36 years. PPP hypothesis was also rejected by using the Hadri test. Thus, the null hypothesis of stationarity is rejected by Hadri test in all periods.

In addition ,Fleissig and Stratus (2000) applied IPS panel test to 19 OECD countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland ,Italy ,Japan ,Netherlands, New Zealand ,Norway ,Spain ,Sweden ,Switzerland ,UK and US) They used the quarterly data for the period of 1974-1996. According to this study, panel unit root tests are found to be more powerful than the univariate unit root tests. Panel unit root test supported the validity of PPP hypothesis.

In the literature, many other economists have also used panel unit root test to increase the power of the standard univariate unit root tests for the OECD economies. Along these lines, Papell (1997) tested the PPP hypothesis employing again panel data with monthly and quarterly observations in 20 developed countries that run from 1973 to 1994. However, Papell found strong evidence in favor of the PPP for monthly data but not quarterly data. Thus, with monthly data unit root in the Real Exchange Rates can be rejected at the 5% level using panel unit root tests. Also Frankel and Rose (1995) gathered a panel data set that spans from 1948 to 1992 for 152 countries. They rejected the random walk model using post -1973 floating data.

Coakley and Fuertes (1997) have applied the standard panel tests to G10 countries and Switzerland for the period 1973 to 1996, and they found strong support in favor of the PPP hypothesis.

Table 2.A summary of the literature that uses Linear Panel Unit Root Tests

Researcher	**Sample**	**Period**	**Frequency**	**Method**	**Result**
Cuestas et al. (2013)	20 OECD Countries	1972:01-2010:01	Monthly	Panel Unit Root Test (LLC,PP and IPS)	PPP holds for 20 Countries
Carvalho et al. (2012)	20 Developed Countries	1973:01-2007:04	Quarterly	Panel Unit Root Test (LLC,IPS, Fisher ADF and Hadri)	Some of the test holds but other doesn't hold.
Olayungbo D.O (2011)	16 Sub Saharan African Countries	1980:01-2005:01	Annual	Panel Unit Root Test (IPS and LLC)	PPP theory holds for Sub Saharan Africa
Wu et al. (2011)	76 Countries	1976:01-2006:06	Monthly	Panel Unit Root Test (IPS)	PPP holds for Africa and Latin America, PPP doesn’t hold for Asia and Europe.
Christidou et al. (2010)	15 EU Countries	1973:01-2009:04	Monthly	Panel Unit Root Test (IPS and Hadri)	PPP is rejected
Fleissig et al. (2000)	19 Countries	1974:01-1996:03	Quarterly	Panel Unit Root Test (IPS, LL)	PPP is support panel test
Papell (1997)	20 developed countries	1973 1994	Monthly	Panel Unit Root Test	PPP hypothesis holds.
Frankel et al. (1995)	150 countries	45 years	Annual	Panel Unit Root Test	PPP theory doesn’t hold.

To summarize, panel unit root tests were employed to the PPP hypothesis in the literature .Some of the studies support the PPP in the panel test but, unfortunately no conclusive evidence in favor of the PPP hypothesis could be obtained in other studies.

3.2Studies that Utilize Nonlinear Methods

In previous test, conventional linear unit root test have employed and observed contradictory evidence about validity of the PPP in the literature. To eliminate, this contradictory result nonlinear test conducted to the PPP hypothesis. The efficiency of the nonlinear methods seems superior to the traditional unit root tests. "Nonlinear test rely on a uniform autoregressive parameter that does not incorporate different corrective pressures that characterize transition to equilibrium" (Carvalho et al, 2012).

3.2.1 Univariate Unit Root Tests

After applying the standard univariate unit root tests and linear panel unit root tests, researchers still can't reach to a conclusive result about the PPP hypothesis. Therefore, researchers started to employ nonlinear models to analyze the PPP hypothesis in order to obtaining supportive evidence in favor of the PPP.

Su et al. (2014) analyzed the PPP hypothesis by using nonlinear univariate KSS test for 61 countries between the period 1994 and 2012.According to their results, the PPP hypothesis holds strongly for all of the 61 countries.

Similarly, Cuestas et al. (2013) tested the PPP hypothesis using the KSS test for OECD countries between the periods1972 to 2010. They find strong empirical evidence in favor of the PPP hypothesis for 20 OECD economies.

In addition, Christidou and Panagiotidis (2010) have also used the KSS test for EU 15 countries from 1973 to 2009 .Their result have indicated that PPP hypothesis supports for Sweden during pre-euro period. In addition to Sweden, United Kingdom has strongly support the PPP theory.

Studies that use nonlinear univariate unit root tests generally find support for the PPP theory, but Carvalho and Julio (2012) fail to find favorable evidence in their study. They tested nonlinear adjustment in the Real Exchange Rate series for 20 development countries (Canada, Australia, Japan, New Zealand, United Kingdom, Switzerland ,Sweden, Norway, Denmark ,Austria ,Belgium ,Finland, France, Greece ,Ireland, Italy, Luxembourg, Netherlands ,Portugal and Spain) between 1973 and 2007. They used KSS test for nonlinear adjustment of Real Exchange Rate and show that this test still fails to support the PPP theory.

Similarly, Zhou, Oskooee and Kutan (2008) have also applied the KSS test for the PPP hypothesis between 1973 and 2006.They have used KSS test for 14 EU Countries (Austria, Belgium, Finland, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Denmark, Sweden, and the U.K.) and 7 non EU industrial countries (Australia, Canada, Japan, New Zealand, Norway, Switzerland, and the U.S.).Their test results provide strong evidence for the PPP hypothesis in the industrial economies.0

To summarize, nonlinear univariate unit root tests are generally more successful than linear panel and univariate unit root tests in obtaining evidence in favor of the PPP hypothesis.

Table 3.A summary of studies that use Nonlinear KSS Univariate Unit Root Test

Researcher	Sample	Period	Frequency	Method	Result
Su et al. (2014)	61 Countries	1994-2012	Mounty	Nonlinear Univariate Test (KSS)	PPP holds strongly.
Cuestas et al. (2013)	20 OECD Countries	1972:01-2010:01	Monthly	Nonlinear Univariate Test(KSS)	PPP holds for 20 Countries
Carvalho et al.(2012)	20 Developed Countries	1973:01-2007:04	Quarterly	Nonlinear Univariate Test(KSS)	PPP doesn't hold.
Christidouet al. (2010)	15 EU Countries	1973:01-2009:04	Monthly	Nonlinear Univariate Test(KSS)	PPP is rejected for some period
Zhou et al. (2008)	11 EU Countries 7 Non –EU Countries	1973 2006	Quarterly	Nonlinear Univariate Test(KSS)	

3.2.2 Panel Unit Root Tests

Nonlinear panel unit root tests are very few in the literature. Uçar and Omay (2009) (UO) is mostly applied nonlinear panel unit root tests to the Real Exchange Rate series for testing the PPP hypothesis.

He, Ranjbar and Chang (2013) have also investigated the PPP hypothesis for transition economies including Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romanian, and Russia by using monthly data that runs from 1995 to 2011. In addition to the nonlinear univariate KSS unit root test, they have also employed the nonlinear Ucar and Omay (2009) (UO) panel unit root test. Their result have showed that the PPP theory have been found successful for Bulgaria, Lithuanian, Poland, Latvian and Romanian.

Another study investigating the PPP hypothesis by using nonlinear panel unit root test pertain to He and Chang (2013). They have analyzed the PPP for 14 transition countries (Austria ,Bulgaria ,Cyprus ,Czech Republic, Estonia, Croatia, Hungary, Lithuania, Latvia, Poland, Romania, Russia ,Slovenia and Slovak Republic) for the period between 1994 and 2012.They have used nonlinear panel unit root UO(2009) test with SPSM (Sequential Panel Selection Model) procedure in their study. They applied the UO test and the null hypothesis of a unit root was rejected for the whole sample. Then, they applied the SPSM procedure. Their results have indicated that validity of the PPP is accepted for Estonia and Lithuania from 14 transition countries.

Oskooee, Chang and Lee (2013) have also investigated the PPP for BRICS (Brazil, Russia, India, China, and South Africa) and MIST (Mexico, Indonesia, South Korea and Turkey) countries between 1994 and 2012 years. Their UO test results have indicated that the PPP theory is successful for South Korea, India and Indonesia.

Table 4. The studies that apply the Nonlinear Panel Unit Root Test (UO)

Researcher	**Sample**	**Period**	**Frequency**	**Method**	**Result**
He et al. (2013)	8 Transition Countries	1995:01-2011:10	Monthly	Nonlinear Panel Test(UO)	PPP holds for some countries.
He et al. (2013)	14 Transition Countries	1994-2012	Monthly and Quarterly	Nonlinear Panel Test(UO)	PPP holds for Estonia and Lithuania
Oskooee et al. (2013)	BRICS and MIST	1994-2012	Monthly	Nonlinear Panel Test(UO)	PPP holds for South Korea, India and Indonesia

3.3 A synopsis of Evidence

In this chapter, we tried to research the vast literature on the PPP hypothesis. According to all these studies included in this chapter, PPP theory is not successful. Researchers were unable to find conclusive results about this hypothesis. The results depend very much on the econometric methodology employed. We firstly have researched linear univariate unit root tests as summarized in Table 1. In addition, we have examined linear panel unit root test studies in Table 2. Later, we have searched nonlinear univariate and panel unit root tests in Table 3 and Table 4.In general, these studies show that the PPP hypothesis doesn't hold although, nonlinear methodologies offer more promising results than their linear counterparts.

CHAPTER4

4. DATA AND METHODOLOGY

This chapter supplies information about the data and methodology used in this research. First in section 4.1 the data used in the PPP tests will be presented. Later, the methodology will be explained and all the unit root tests conducted in this thesis will be discussed.

4.1 Data

The validity of the PPP hypothesis is examined by using monthly data of 24 OECD member[1] countries over the period 1990:1 and 2013:11. The countries included in these studies are Austria, Belgium, Canada, Denmark, Finland, France, Greece, Hungary, Iceland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey and the UK. Monthly data on bilateral exchange rates of the national currency against the U.S. dollar and on Consumer Price Indices (CPI) were taken from the International Financial Statistic (IFS) database. The base year for the CPI is 2010.All variables were put into natural logarithms before the analysis. The real exchange rate of each country is calculated according to equation (2.7) by taking United States (US) dollar as the numeracies currency. Then, p_t^*denotes the log of the US consumer price index p_t is the log of price

[1] OECD was established in 1961 which based on Paris Convention in 14 December 1961.OECD's founder members are Austria, Belgium, Canada, Denmark, France, Germany, Greece ,Iceland ,Ireland Italy ,Luxembourg, Holland ,Norway ,Portugal ,Spain ,Swedish, Switzerland, Turkey, UK and US. OECD's some countries are excluded from analyses due to data unavailability such as; Australia, Germany, Ireland, Czech Republic ,New Zealand, Slovakia , Chile ,Estonia ,Slovenia and US.

level of the country in question,$s_t$refers to the logarithm of the nominal exchange rate of the country with respect to US dollar.

4.2 Methodology

In this thesis, our purpose is to analyze the validity of the PPP theory using a battery of unit root tests. To this end, we tested the PPP using not only the standard linear univariate and panel unit root tests but also, their nonlinear counterparts. The univariate unit root tests implemented in this study include the Augmented Dickey Fuller (ADF) (Dickey and Fuller 1979; Said and Dickey, 1984; Fuller 1976) unit root test, Phillips Perron (PP) (1988) unit root test, the DF-GLS unit root test developed by Elliott et al. (1996) and the KPSS test proposed by Denis Kwiatkowski, Peter C. B. Phillips, Peter Schmidt and Yongcheol Shin(KPSS) (1992). The null hypothesis is accepted the existence of a unit root in all these tests, except the KPSS test. However, the null hypothesis of the KPSS test is the stationarity of the series to be tested. In addition to linear univariate tests, panel unit root tests are also used to test for the validity of the PPP in this study.

As mentioned literature, univariate unit root tests have applied many studies. Univariate unit root test have also implemented in this thesis but, these test will have very low power to reject a potentially false null hypothesis of non-stationarity (Carvalho, 2012). When we test unit root of null hypothesis against the alternative hypothesis, most of the sample doesn't reject the null hypothesis for stationarity. Because univariate unit root test are low power to reject the null hypothesis against alternative hypothesis .Thus, we cannot accept the validity of the PPP hypothesis. To solve the low power problem, researchers have proposed panel unit root tests as further evidence. Panel unit root test provide us many advantage; first, panel unit root test's power is significantly greater than the univariate unit root tests. Second, panel unit root tests' asymptotic distribution

is standard normal, contrary to univariate unit root tests which have non-standard limiting distributions.

In theory, there are two types of panel unit root tests; first-generation panel unit root tests and second-generation panel unit root tests. First generation tests are based on the cross-sectional independency. Second generation tests are based on the cross sectional correlation. We implemented first generation panel unit root tests in this thesis because, we ignored cross sectional dependency. The first generation panel unit root tests include the tests by Levin Lin Chu (2002) (LLC), Im, Pesaran and Shin (2003) (IPS), Mandala and Wu (1999) and Hadri (2000) While the LLC test considers pooling cross section time series as a means of generating a more powerful unit root, the IPS test is more flexible and involves more easy calculations .On the other hand, the Fisher – ADF was improved by Maddala and Wu (1999), and Choi (2001) and contains more general assumption than the IPS test. Finally, the Hadri test is different from the other panel unit root tests in the sense that Hadri (2000) tests for stationarity of the series in question in the null hypothesis, while the others analyze non-stationarity in the test.

Although many linear univariate and panel unit root tests are used in this thesis to investigate the PPP hypothesis, panel unit root tests do also share some problems. First, panel unit root test ignored the existence of the cross –sectional dependence. For that reason, we cannot obtain efficient and consistent result from panel unit root test. Second, rejecting the null hypothesis doesn't give clear information about panel unit root tests since, PPP holds for some countries but, PPP does not hold for all countries. Third, panel unit root tests assume a single autoregressive parameter under the null hypothesis. These tests cannot provide too much implication about results. To eliminate panel unit root disadvantage, researcher have been proposed nonlinear unit root tests. Therefore, to take into account the possibility of nonlinear adjustment in the Real Exchange Rates, we have also utilized nonlinear unit root tests to analyze the PPP hypothesis. The nonlinear univariate unit root tests implemented in this thesis include the tests proposed by Kapetanioset al. (2003) (KSS) and Leybourneet al. (1998) (LNV).They are both smooth-

transition models, but the difference lies in the LNV's adoption of the logic transition function which is used in the structural change series with the time item. (Zenget al.2011)

In addition to the KSS and LNV tests, we have also applied the Ucar and Omay (2009)(UO)nonlinear panel unit root test to the PPP hypothesis. Although the last decade has witnessed important advances in unit root testing procedures based on a nonlinear framework, the studies that extend the nonlinear unit root testing methodologies to a panel framework have been rather limited, though with a few notable exceptions. Ucar and Omay (2009) (UO) have proposed a new nonlinear panel unit root test where the alternative hypothesis is a stationary panel exponential smooth transition (ESTAR) model. This test generalizes the KSS test which developed by Kapetanios et al. (2003) to heterogeneous panels using the panel unit root testing framework of Im et al. (2003) (IPS) and achieves large power gains over the IPS test by dealing with the cross-sectional dependency problem while simultaneously introducing nonlinearities into the testing framework . The UO statistic is then obtained by taking the average of the individual KSS statistics. Wu and Lee (2009) have also generalized the KSS test to a panel framework but used the panel estimation method of SUR instead to obtain a series-specific nonlinear panel unit root test named as the SURKSS test. When the data generating process is significantly non-linear, the test is found to have a higher power than that of the series-specific unit root test provided by Breuer et al. (2001). Cerrato et al.(2008) have developed a new nonlinear panel unit root test where the alternative hypothesis allows a proportion of units to be generated by globally stationary ESTAR processes and a remaining non-zero proportion to be generated by unit root processes. To handle the cross section dependence problem the authors have used the Pesaran (2007) linear panel unit root framework but obtained better power than the Pesaran (2007) test by also introducing nonlinearity to the testing framework. In this thesis, we applied the nonlinear UO panel unit root test with the sequential panel selection method (SPSM) proposed by Choartareas and Kapetanios (2009) to identify the countries for

which the PPP holds. To correct the size distortion that is caused by cross-sectional dependence, we implement Chang's (2004) bootstrap methodology.

Table 5. Univariate Unit Root Tests

Linear Tests	
Non Stationary Test	**Stationary Test**
Augmented Dickey Fuller(ADF)	Kwiatkowski–Phillips–
Dickey Fuller Test-	Schmidt–Shin (KPSS)
Generalized Least Square(DF-GLS)	
Phillips Perron (PP)	
Nonlinear Tests	
Kapetanios-Snell-Shin (KSS)	
Leybourne, Newbold, Vougas(LNV)	

Table 6. Panel Unit Root Tests

Linear Tests	
Non Stationary Test	**Stationary Test**
Levin ,Lin and Chu (LLC)	Hadri
Im Pearson and Shin (IPS)	
Fisher Augmented Dickey Fuller (Fisher ADF)	
Nonlinear Tests	
Uçar and Omay (UO)	

4.2.1 Univariate Unit Root Tests

In this section both the linear and nonlinear univariate unit root tests will be discussed.

4.2.1.1 The Augmented- Dickey Fuller (ADF) Test

Dickey Fuller test was modeled as;

$$Y_t = Y_{t-1} + u_t \tag{4.1}$$

This equation leads to a random walk without drift while alternative hypothesis is stationary in AR (1) process.$u_t$is white noise error term,

$$Y_t = \rho Y_{t-1} + u_t \qquad\qquad 1 - \leq \rho \leq 1 \tag{4.2}$$

In equation (4.2)we know that if ρ = 1, that is, in the case of the unit root, becomesa random walk model without drift, which we know is a non-stationarystochastic process (Gujarati, 2004).In the equation (4.2) Y_{t-1} was subtracted in both side:

$$Y_{t-1} - Y_t = \rho Y_{t-1} - Y_{t-1} + u_t \quad \Longrightarrow (\rho - 1) Y_{t-1} \tag{4.3}$$

Equation 4.3 can be written as follows;

$$\Delta Y_t = \delta Y_{t-1} + u_t \quad (4.4)$$

$$\delta = (\rho - 1)$$

$H_0: \delta \geq 0$ (There is unit root / Series aren't stationary)
$H_1: \delta < 0$ (There isn't unit root / Series are stationary)

DF test has various possibilities and it estimated in three different forms:

$\Delta Y_t = \rho Y_{t-1} + u_t$ ($Y_t$has a random walk)

$\Delta Y_t = \beta_1 + \rho Y_{t-1} + u_t$ ($Y_t$has a random walk with drift)

$\Delta Y_t = \beta_1 + \beta_{2t} + \delta Y_{t-1} + u_t$ ($Y_t$has a random walk with drift around a stochastic trend)

It is extremely important to note that the critical values of the tau test to test the hypothesis that δ = 0, are different for each of the preceding three determinations of the DF test (Gujarati 2004).Critical values are three types such as; 1%, 5% and 10%.In Dickey Fuller Test, standard$t$ distribution and t statistic weren't used and DF or MacKinnon (1991) critical Tau value was used in the test;

$$|\tau| > |McK - DF|$$

In this condition, we reject to H_0, in which case time series is stationarity.

Augmented Dickey Fuller (ADF) test is development version of Dickey Fuller Test. ADF test was improved by using three different forms of the DF test.“Thistest is

conducted by "augmenting" the preceding three equations by adding the lagged values of the dependent variableΔY_t" (Gujarati 2004). ADF test was estimated in below:

$$\Delta Y_t = \beta_1 + \beta_{2t} + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t \quad (4.5)$$

where$\varepsilon_t$is pure white noise error term.$\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$and
$\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$

In ADF we have still test whether δ = 0 and the ADF test follows the same asymptotic distribution as the DF statistic thus, the same critical values can be used in the ADF test (Gujarati 2004).

ADF test provides us to test the null hypothesis $\delta = 0$ against the alternative hypothesis $\delta < 0$.If the test statistic is less than the critical value, later null hypothesis is rejected $\delta = 0$ and alternative hypothesis is accepted $\delta < 0$ so, unit root doesn't occur and series are stationary.

4.2.1.2 Phillips - Perron (PP) Test

DF GLS test has same deficiencies in standard univariate unit root test. To eliminate these deficiencies Phillips -Perron (1988) proposed tests with structural break. "Perron (1989) argue that if the time-series contains a structural break, then standard unit root tests will lead to the acceptance of the null of a unit root, when in fact the series is stationary. Therefore, it seems relevant to allow for structural breaks when testing real exchange rates for stationarity" (Nursai 2003).Unit root tests haven't correct results without considering structural break.

As we mentioned above DF test based on some hypothesis. Such as; error terms u_t are independently and identically distributed. "The ADF test adjusts the DF test to take care of possible serial correlation in the error terms by adding the lagged difference terms of the regressand. Phillips and Perron use nonparametric statistical methods to take care of the serial correlation in the error terms without adding lagged difference terms" (Gujarati, 2004). DF and ADF test included AR (Autoregressive) process, but they didn't contain MA process. Philips Perron wanted to add MA (Moving Average) process. Thus, Phillips Perron test was ARMA (Autoregressive Moving Average) process. Phillips –Perron test models as fallows;

$$Y_t = \delta Y_{(t-1)} + u_t \qquad (4.6)$$

$Y_t = \beta_1 + \delta Y_{(t-1)} + u_t$ (Constant term)

$Y_t = \beta_1 + \delta Y_{(t-1)} + \beta_2\left(t - {}^{T}/_{2}\right) + u_t$(Constant term and trend correlation)

In these equations, T represents the number of observation and u_t represents error terms. In the model, error term is equal to the zero ($Eu_t = 0$) .In addition, error terms can serially be correlated or it can ignore co-variance assumption. Thus, Phillips Perron test doesn't depend on the DF and ADF assumptions. Philips Perron removed serial correlation and applied co-variance hypothesis by using Newey -West error correction. Philips Peron test use the DF's all critical value and hypothesis test are the same as DF test.

$H_0: \delta \geq 0$ (There is unit root / Series aren't stationary)

$H_1: \delta < 0$ (There isn't unit root / Series are stationary)

4.2.1.3 DF- GLS Test

DF and ADF time series models try to determine whether series have a unit root or not. In 1996 Elliott et al. modified the Dickey Fuller test by using Generalized Least Square (GLS).They proposed that "a modified version of Dickey Fuller *t*test which has fundamentally improved power when an unknown mean or trend is present (Elliottet al.1996). Thus their studies have shown that DF-GLS test has significantly greater power than DF and ADF unit root tests.

$$\Delta Y_t^d = \delta Y_{t-1}^d + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i}^d + \varepsilon_t \qquad (4.7)$$

whereY_t^d denotes locally demeaned data.

H_0: $\delta = 0$ (There is unit root / Series aren't stationary)

H_1: $\delta < 0$ (There isn't unit root / Series are stationary)

4.2.1.4 Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Test

In contrast to the unit root tests just described, Kwiatkowski, Phillips, Schmidt and Shin (KPSS) proposed Lagrange Multiplier (LM) test for testing the null hypothesis. If the null hypothesis of stationarity is rejected, the series has a unit root.

H_0: $\delta < 1$ (There isn't unit root / Series are stationary)

H_1: $\delta \geq 1$ (There is unit root / Series aren't stationary)

The series is expressed as the sum of the deterministic trend, random walk, and stationary error, and the test is the LM (Lagrange Multiplier) test of the hypothesis that the random walk has zero variances. The asymptotic distribution of the statistic is derived under the null hypothesis and under the alternative hypothesis that the series is

difference-stationary (Kwiatkowski et al.1992).Some of the deterministic trends, random walk and a stationary error estimated in KPSS test;

$$Y_t = \xi t + r_t + \epsilon_t \qquad (4.8)$$

wherer_t is random walk;

$$r_t = r_{t-1} + u_t$$

where$u_t$is an independent and identically distributed error term. These equations helped to estimate test statistic, which based on Nabeya and Tanaka (1998).The test statistic;

$LM = \sum_{t=1}^{T} S_t^2 . \hat{\sigma}_u^{-2}$ (4.9)

where T is number of observation and S_t is residual function and its calculation;

$$S_t = \sum_{i=1}^{t} e_i \,, \qquad t = 1,2,3, \dots, T$$

In this test, the calculated value and the critical value are compared with each other. In KPSS test null hypothesis shows that series are stationary so, random walk hypothesis' variance is zero.

4.2.1.5 Kapetanios-Snell-Shin (KSS) Test

Kapetanios et al. (2003) proposed a nonlinear unit root testing procedure against an alternative of a globally stationary nonlinear exponential smooth transition autoregressive (ESTAR) process. The model developed is given by;

$$y_t = \beta y_{t-1} + \gamma y_{t-1} \Theta(\theta;\, y_{t-d}) + \varepsilon_t \quad t = 1, \dots, T \qquad (4.10)$$

$$\text{with}\Theta(\theta; y_{t-d}) = 1 - \exp(-\theta\, y_{t-d}^2)$$

where $\theta \geq 0\ and\ d \geq 1$, which gives

$$y_t = \beta y_{t-1} + \gamma y_{t-1}\{1 - \exp(-\theta\, y_{t-d}^2)\} + \varepsilon_t \qquad (4.11)$$

Equation (4.11) can be re-parameterized by subtracting y_{t-1} from both sides of the equation to obtain;

$$\Delta y_t = \phi y_{t-1} + \gamma\, y_{t-1}[1 - \exp(-\theta\, y_{t-d}^2)] + \varepsilon_t \qquad (4.12)$$

where $\phi = \beta - 1$.If $\theta$is positive, then it effectively determines the speed of mean reversion and $\varepsilon_t \backsim iid\,(0, \sigma^2)$, and $\beta, \phi, \theta\ and\ \gamma$ are unknown parameters. In the model, y_t is assumed that a mean zero stochastic process.Imposing$\phi = 0 \quad d = 1$ gives our specific ESTAR model (4.12) as

$$\Delta y_t = \gamma\, y_{t-1}[1 - \exp(-\theta\, y_{t-1}^2)] + \varepsilon_t \qquad (4.13)$$

$H_0: \theta = 0$ Null Hypothesis
$H_1: \theta > 0$ Alternative Hypothesis

4.2.1.6 Leybourne, Newbold, Vougas(LNV) Test

Leybourneet al. (1998) and Kapetanios et al. (2003) are both smooth-transition models, but the difference lies in the LNV's adoption of the logic transition function which is used in the structural change series with the time item (Zenget al.2011). LNV test was developed by Leybourne, Newbold, Vougas (1998) (LNV) this test proposes stationarity around a smoothly changing trend for alternative hypothesis. Leybourneet al.

(1998) tested null against three possible alternatives. The derivation of the LNV model as follows;

Model 1 : $y_t = \alpha + \alpha_2 S_t(\gamma.\tau) + \varepsilon_t$

Model 2 : $y_t = \alpha + \beta_1 t + \alpha_2 S_t(\gamma.\tau) + \varepsilon_t$

Model 3 : $y_t = \alpha + \beta_1 t + \alpha_2 S_t(\gamma.\tau) + \beta_2 t S_t(\gamma.\tau) + \varepsilon_t$

where y_t be a changing trend function with smooth transition on the time domain $t = 1,2,,\ldots,T$. ε_t is a zero mean I (0) process and $S_t(\gamma.\tau)$ is logistic smooth transition function, based on a sample of size T and N.

$$S_t(\gamma.\tau) = [1 + \exp\{-\gamma(t - \tau T)\}]^{-1} \ , \ \gamma > 0 \qquad (4.14)$$

In this modeling strategy, the structural change is modeled as smooth transition between different regimes rather than instantaneous structural break Leybourtne et al.(1996).“The transition function $S_t(\gamma.\tau)$ is continuous function bounded between 1 and 0. Thus the Smooth Transition Regression (STR) model can be interpreted as regime-switching model that allows for two regimes, associated with the extreme values of the transition function, $S_t(\gamma.\tau)$= 0 and $S_t(\gamma.\tau)$=1 , whereas the transition from one regime to the other is gradual. The parameter γ determines the smoothness of the transition, and thus, the smoothness of transition from one regime to the other. The two regimes are associated with small and large values of the transition variable $S_t = t$ relative to the threshold $c = \tau$.For the large values of γ , $S_t(\gamma.\tau)$ passes through the interval (0,1) very rapidly, and as γ approaches +∞ this function changes value from 0 to 1 instantaneously at time $t = \tau T$. Therefore, if we assume that ε_t is zero mean I (0) process and then model 1 y_t is stationary process around a mean which changes from initial value α_1 to final value $\alpha_1 + \alpha_2$” (Omay et al.2014).

Omay et al. (2014) establish the hypothesis for unit root testing based on equation 1, 2 and 3 as follows:

H_0: Unit Root, (Linear Nonstationary)

H_1: Nonlinear Stationary (Nonlinear and Stationary around smoothly changing trend and intercept)

4.2.2 Panel Unit Root Tests

In this thesis, we implemented the standard panel unit root tests of IPS, LLC, Fisher-ADF and Hadri; and the nonlinear UO panel unit root test to the Real Exchange Rate series of the 24 OECD countries. However, one major criticism of all these tests is that they require cross-sectional independence. As argued above, this is a restrictive assumption given the cross-section correlation and spillovers in the Real Exchange Rate series across countries. Although using the panel data approach has its own merits (i.e., increasing the power of the conventional unit root tests), it also creates additional problems otherwise absent in univariate time series techniques. For instance, most of the panel data models assume cross-sectional independence which is inappropriate for most applications and may arise due to spatial correlations, spill-over effects, economic distance, omitted global variables and common unobserved shocks (see, e.g., Omay and Kan, 2010). Also, it is well known that, ignoring the presence of cross-section dependence can lead to biased estimates and produce misleading inference. Therefore, to correct the size distortion that is caused by cross sectional dependence, we have implemented Chang's (2004) bootstrap methodology in the context of both the IPS and UO panel unit root tests.

4.2.2.1 Levin Lin Chu (LLC) Test

Panel unit root test is associated with cross-sectional and time series data to obtain more efficient test. “The test procedures are designed to evaluate the null hypothesis that each individual in the panel has integrated time series versus the alternative hypothesis that all individuals’ time series are stationary. The pooling approach yields higher test power than performing a separate unit root test for each individual” (Levin et al., 2002).LLC panel version of equation;

$$\Delta Y_{it} = \delta y_{i,t-1} + \sum_{L=1}^{p_i} \alpha_{iL} \Delta y_{i,t-1} + \theta_{mi} d_{mt} + u_{it} \quad (4.15)$$

With d_{mt} indicating the vector of deterministic variables and θ_{mi} the corresponding vector ofcoefficients for model m = 1, 2, 3. In particular, d_{1t} = {empty set}, d_{2t} = {1} and d_{3t}= {1, t}. (Baltagi, 2005).

Individual intercepts and homogeneity across the cross section is allowed in the model. The model assumes that individual regression error term is independent and identically distributed but, heteroskedasticity is present across individuals. The test improves the null hypothesis where series contain unit root against the alternative hypothesis. Series are stationary in alternative hypothesis.

H_0: $\delta = 0$ (There is unit root / Series aren’t stationary)
H_1: $\delta < 0$ (There isn’t unit root/ Series are stationary)

4.2.2.2Im Pearson and Shin (IPS)Test

Im et al.(2003) developed a more flexible panel unit root testing procedure which avoids the unrealistic assumption of the LLC test (Carvalho and Julio ,2012).This panel test calculation is easy because IPS used probability in simultaneous stationary and non-stationary panel.

Im et al. (2003) proposed unit root tests for dynamic heterogeneous panels based on the mean of individual unit root statistics in their studies. In particular, it proposed a standardized *t*-bar test statistic based on the (augmented) Dickey–Fuller statistics averaged across the groups (Im et al. 2003).Im Pearson Shin model as fallows;

$$\Delta Y_{it} = \delta_i \, y_{i,t-1} + \sum_{L=1}^{p_i} \alpha_{iL} \Delta y_{i,t-1} + \theta_{mi} d_{mt} + u_{it} \qquad m = 1,2,3 \qquad (4.16)$$

In LLC equation, δ and iare homogeneous, this means that LLC test is restrictive. Im et al. (2003) allows for a heterogeneous coefficient of$y_{i,t-1}$and propose an alternativetesting procedure based on averaging individual unit root test statistics. (Baltagi, 2005)

Null hypothesis $H_0 : \delta_i = 0$

Alternative hypothesis$H_1 : \delta_i < 0 \ , \ i = 1, \dots, N_1$

$$H_1 : \delta_i = 0 \ , \quad i = N_1 + 1, \dots, N \qquad 0 < N_1 \leq N \quad (4.17)$$

The alternative hypothesis proposed unit root for some of the individual series. When we compared LLC and IPS model, LLC model use pooling the data and IPS uses discrete unit root test for the N cross section data.

Im Pearson and Shin (IPS) test is based on the (Augmented) Dickey-Fuller statistics averaged across groups. Let$t_{iT}(\delta_i, \beta_i)$ with denote $\beta_i = (\beta_{i,1}, \dots, \beta_{i\delta_i})$the t-statistic for testing unit root in the i^{th}country, the IPS statistic is then defined as (Hurlinand Mignon, 2006):

$$t - bar_{\,NT} = \frac{1}{N}\sum_{i=1}^{N} t_{iT}(\delta_i, \beta_i) \qquad (4.18)$$

IPS developed a standardized *t* -bar statistic, this convergence to the normal distribution when T tends to infinity. When T tends to infinity, $t_{iT}(\delta_i, \beta_i)$ converges to the Augmented Dickey Fuller distribution. According to the Lindberg- Levy central limit theorem, standardized *t*- bar statistic convergences to a standardized normal distribution under the null hypothesis. (Carvalho and Julio, 2012)

4.2.2.3 The Fisher –ADF Test: Maddala and Wu (1999) and Choi (2001)

In fact, Fisher ADF test based on Fisher's (1932) studies but later Maddala and Wu (1999), and Choi (2001) proposed Fisher ADF test. The Fisher ADF tests are more reliable and exact than the other linear panel unit root tests because, Fisher ADF proposed more general assumptions than the IPS and LLC test.

Choi (2001) explained many common features with previous panel unit root test.

- Previous study needs to group be infinity if they don't have this condition, asymptotic normality of the test doesn't hold. In Fisher ADF test, they assumed that group number can be finite or infinite in the panel.
- The previous study assumes that the groups contain the same type of non-stochastic component, on the other hand, Fisher ADF test contain stochastic or non-stochastic for each group.
- None of the group has a unit root in the previous studies under alternative hypothesis. Some groups have a unit root in Fisher ADF test. If the other groups don't have a unit root, this test is not dealt with.

Choi's model defined as;

$$y_{i,t} = d_{i,t} + x_{i,t} (i = 1, \dots, N; t = 1, \dots, T) \quad (4.19)$$

where $d_{i,t} = \beta_{i,0} + \beta_{i,1} t + \cdots + \beta_{im_i} t^{m_i}$ and $x_{i,t} = \alpha_i x_{i(t-1)} + u_{it}$

In these model $y_{i,t}$ contain $d_{i,t}$ (non-stochastic process) and $x_{i,t}$(stochastic process).Where $y_{i,t}$ have different a sample size and a different specification of no stochastic and stochastic components depending on i . In this test; (Choi, 2001);

$$\Delta Y_{it} = \delta_i \, y_{i,t-1} + \sum_{L=1}^{p_i} \alpha_{iL} \Delta y_{i,t-1} + \theta_{mi} d_{mt} + u_{it} \quad m = 1,2,3 \quad (4.20)$$

$H_0 : \delta_i = 0$ (For all i) All-time series a have unit root, this means that series non-stationary.

$H_1: |\delta_i| < 1$ (For at least one i) Some time series are non-stationary while the other aren't

The main idea of the Fisher –ADF test lies in combining the δ values δ_i of the individual unit root test for each cross section unit, as a means to achieve extra power. The mechanics of the test comprise in the simple observation that, if the δ values for the i^{th}cross –section unit are uniformly distributed in (0, 1), then -2 log δ_i is chi-square distributed with two degrees of freedom (Carvalho and Julio, 2012).Fisher ADF Test was proposed by Mandala and Wu (1999) defined as;

$$P_{MW} = -2 \sum_{i=1}^{N} \log \, (p_i) \quad (4.21)$$

In equation Chi-square distributed with 2N degree of freedom. N is fixed in this model. In addition to this equation Choi (2001) proposed standardized statistic for large N value.

$$Z_{MW} = \frac{\sqrt{N}\{N^{-1}P_{MW} - E[-2\log(p_i)]\}}{\sqrt{Var\,[-2\log(p_i)]}} = -\frac{\sum_{i=1}^{N}\log(p_i) + N}{\sqrt{N}} \qquad (4.22)$$

This statistic confirm with the standardized cross-sectional average of individual p-values. Under the cross-sectional independence assumption, the Lindberg-Levy theorem is sufficient to demonstrate that it converges to a standard normal distribution under the unit root hypothesis (Hurlin and Mignon, 2006).

4.2.2.4 The Hadri Test

Hadri test was improved by Hadri (2000) and he proposed the test which is similar to the KPSS test (1992).Previous panel unit root test proposed alternative hypothesis is stationary and null hypothesis is non-stationary. On the other hand, Hadri evaluates the null that series is stationary or contain no unit root against the alternative non stationarity or random walk. Hadri test suggested that residual based Lagrange Multiplier (LM) test for null hypothesis $y_{i,t}$ is stationary for all i, against the alternative unit root panel. Hadri (2000) consider the following model;

$$y_{it} = r_{it} + \epsilon_{it} \qquad (4.23)$$

$$y_{it} = r_{it} + \beta_i t + \epsilon_{it} \qquad (4.24)$$

In equations (4.23 and 4.24),r_{it} is a random walk

$$r_{it} = r_{it-1} + u_{it} \quad (4.25)$$

where$u_{it}$is independent an identically distributed between 0 andσ_u^2 , u_{it} and ϵ_{it} are error term and they are independent.If $\sigma_u^2 = 0$, the null hypothesis can be obtained. Hadri (2000) assumed ϵ_{it} is independent and identically distributed, and later under the null hypothesis y_{it} is stationary for panel unit root.

$$e_{i,t} = \sum_{j=1}^{t} u_{i,j} + \varepsilon_{i,t} \quad (4.26)$$

$$\sigma_u^2 = 0 \implies e_{i,t} \equiv \varepsilon_{i,t} \quad (4.27)$$

Null Hypothesis (Series Stationary/ There isn't unit root)$H_0: \lambda = 0$

Alternative Hypothesis (Series Non-Stationary/There is unit root) $H_0: \lambda > 0$

$$\lambda = {\sigma_u^2}/{\sigma_\varepsilon^2} \quad (4.28)$$

4.2.2.5Uçarand Omay (UO)(2009)

UO test was developed by Uçar and Omay (2009). This test proposes a nonlinear unit root test for heterogeneous panels by combining the nonlinear univariate testing framework of Kapetenois et al.(2003) (KSS) with linear panel unit root testing methodology of Im et al. (2003) (IPS). The rest of this section will be explaining the UO nonlinear test.

"Let$y_{i,t}$ be panel exponential smooth transition autoregressive process of order one (PESTAR (1)) on the time domain t=1,2,…,T for the cross section units i=1,2,…,N. Consider$y_{i,t}$follows the data generating process (DGP) with fixed effect (heterogeneous intercept) parameter α_i"(Uçar and Omay 2009):

$$\Delta y_{i,t} = a_i + \phi_i y_{i,t-1} + \gamma_i y_{i,t-1}\left[1 - \exp(-\theta_i y_{i,t-d}^2)\right] + \varepsilon_{i,t} \quad (4.29)$$

where$d \geq 1$ is delay parameter and $\theta_i > 0$ is the speed of mean reversion for all i.As many previous studies, such as; KSS (2003) and Michael at al. (1997), UO (2009) set model with $\phi_i = 0$ and d=1, which gave specific PESTAR (1) model:

$$\Delta y_{i,t} = a_i + \gamma_i y_{i,t-1}\left[1 - \exp(-\theta_i y_{i,t-1}^2)\right] + \varepsilon_{i,t} \quad (4.30)$$

According to nonlinear panel data unit root test based on regression (4.30), the null hypothesis is $\theta_i = 1$ for all i and alternative hypothesis $\theta_i > 0$ for some i. They didn't use $\theta_i = 0$, because it was a problem for γ_i.This value cannot be defined under the null hypothesis. UO (2009) solve this problem with applying a first order Taylor series approximation to PESTAR (1) model with $\theta_i = 0$ for all i.The auxiliary regression model thereby obtained is;

$$\Delta y_{i,t} = a_i + \delta_i y_{i,t-1}^3 + \varepsilon_{i,t} \quad (4.31)$$

where δ_i=$\theta_i \gamma_i$

According to the UO (2009) test, the null and alternative hypotheses were based on (4.29) and are given as follows

$H_0 : \delta_i = 0 \; for \; all \; i$ (Linear nonstationarity)
$H_0 : \delta_i < 0 \; for \; some \; i$ (Nonlinear stationarity)

The UO test is calculated by average of the individual KSS statistics. The KSS statistic for the i^{th}individual is simply t-ratio of $\delta_i = 0$ in regression (4.31) specified by:

$$t_{i,NL} = \frac{\Delta y_i^{'} M_\tau y_{i,-1}^3}{\hat{\sigma}_{i,NL}(y_{i,-1}^{'} M_\tau y_{i,-1})^{3/2}} \tag{4.32}$$

where $\hat{\sigma}_{i,NL}$ is the consistent estimator such that :

$$\hat{\sigma}_{i,NL}^2 = \Delta y_i' M_\tau y_i^3/(T-1), M_\tau = I_T - \tau_T(\tau_T'\tau_T)^{-1}\tau_T' \tag{4.33}$$

Identified that $\Delta y_i = \left(\Delta y_{i,1}, \Delta y_{i,2}, \dots, \Delta y_{i,T}\right), y_{i,-1}^3 = (y_{i,0}^{'3}, y_{i,1}^3, \dots, y_{i,T-1}^3)$ and $\tau_T = (1,1, \dots,1)'$

Moreover, individual statistics $t_{i,NL}$are iid random variables with limited means and variances and limiting standard normal distribution as $N \longrightarrow \infty$ such that:

$$\bar{Z}_{NL} = \frac{\sqrt{N}(\bar{t}_{NL} - E(t_{i,NL}))}{\sqrt{Var(t_{i,NL})}} \xrightarrow{d} N(0,1) \tag{4.34}$$

where ,$\bar{t}_{NL} = \frac{1}{N}\sum_{i=1}^{N} t_{i,NL}, E\left(t_{i,NL}\right)$and $Var(t_{i,NL})$ values are identified in Table 7 of Ucar and Omay(2009) as in the following:

Table7. Moments of $\boldsymbol{t_{i,NL}}$ Statistic (Ucar and Omay, 2009:6)

T	$E(t_{i,NL})$	$Var(t_{i,NL})$
5	-1866	2.695
10	-1620	0.823
15	-1602	0.760
20	-1602	0.740
25	-1604	0.737
30	-1605	0.735
40	-1616	0.735
50	-1626	0.727
100	-1652	0.727
500	-1675	0.725
1000	-1677	0.721
10000	-1677	0.716

4.2.2.5.1 Sequential Panel Selection Method (SPSM)

Taylor and Sarno (1998) emphasized that panel unit root tests may reject joint non-stationarity even if only one of the processes is stationary under the alternative hypothesis. If the unit root null is rejected, it is important to distinguish between non-stationary and stationary series. To resolve this problem, the UO and the IPS tests were implemented together with the sequential panel selection method (SPSM) proposed by Choartareas and Kapetanios (2009). The SPSM is a sequential methodology that allows the identification of the series that are stationary.

Steps of the SPSM procedure are as follows:

1) The UO and IPS test equations are first estimated for all the series in the panel. If the unit root null is not rejected, then the non-stationary hypothesis is accepted and the procedure stops. In this case, all the series in the panel are found to be non-stationary. On the contrary, if the null is rejected, one should proceed on to Step 2.

2) Drop the series with the maximum KSS (the univariate counterpart of the UO test) or ADF (the univariate counterpart of the IPS test statistic) statistics, which shows the strongest evidence in favor of stationarity and go to Step 3.

3) Return to Step 1 for the remaining series, or stop the procedure if all the series are removed from the panel.

CHAPTER 5

5. EMPIRICAL RESULTS

This thesis aims to test the validity of the PPP hypothesis for 24 OECD countries over the period between January 1990 and November 2013.For this aim, we applied various univariate and panel unit root tests. The results of these tests are presented and discussed in this part of the thesis.

5.1 Univariate Unit Root Test Results

5.1.1Linear Test Results

The results of the four linear univariate unit root tests are reported in Table 8 and the results of these tests are summarized in Table 9.

Table 8.Results of the Linear Univariate Unit Root Tests

Country	ADF t- statistic	DF-GLS t- statistic	Phillips-Perron Test Adj. t-Stat	KPSS Test LM-Stat.
Australia	-1.891387	-2.097466	-1.822940	0.316828
Belgium	-1.818710	**-1.895384 ***	-1.756021	0.341670
Canada	-1.272254	-0.961679	-1.351723	**0.595652 ****
Denmark	-2.005774	**-2.243394 ****	-1.860131	**0.367810 ***
Finland	-1.910785	**-1.757776 ***	-1.868585	**0.380895 ***
France	-1.904502	**-1.677564 ***	-1.644797	**0.351162 ***
Greece	-2.026157	0.460041	**-2.697289 ***	**1.544077 *****
Hungary	-1.668834	0.066230	-1.659038	**1.613928 *****
Iceland	-2.264357	**-1.943676 ****	-2.040192	**0.439842 ***
Israel	-1.872264	**-1.819533 ***	-1.410737	**0.503451 ****
Italy	-1.981743	**-1.798460 ***	-1.942410	**0.529280 ****
Japan	-2.263630	**-2.109099 ****	-1.681170	**0.759789 *****
Korea	-2.451461	-1.556377	-2.382643	**0.495242 ****
Luxemburg	-1.998113	**-1.879203 ***	-1.768747	**0.362800 ***
Mexico	**-3.469764 *****	**-2.055981 ****	**-2.972005 ****	0.257199
Netherlands	-1.980853	**-2.198951 ****	-1.886571	**0.354918 ***
Norway	-2.247021	**-2.112791 ****	-1.765508	**0.403524 ***
Poland	**-3.768538 *****	0.527941	**-5.032049 *****	**1.663333 *****
Portugal	-2.081204	-0.649829	-2.011446	**0.860950 *****
Spain	-1.699166	-1.354600	-1.581659	**0.838456 *****
Sweden	-2.088284	-1.325095	-2.035738	**0.730161 ****
Switzerland	-2.133124	**-1.946844 ****	-1.851434	**0.365985 ***
Turkey	-1.582944	-1.464546	-1.491213	**1.369280 *****
UK	**-3.059619 ****	**-3.062821 *****	**-2.877413 ****	0.290780

Notes: *, **, *** represent rejection of the at 10, 5 and 1 % significance level respectively. ADF and DF-GLS tests take into account an intercept, but they don't have a trend in data. We use Akaike Information Criteria (AIC), and a lag selection criterion is 12 lag with an upper bound. ADF t-statistic has critical values which are -2.572154 at 10%, -2.871510 at 5% and -3.453234 at 1% significance levels. On the other hand, DF-GLS test's critical values are -1.615956 at 10%, -1.941941 at 5% and -2.573101 at 1% significant levels **(MacKinnon 1996).** The KPSS test and Philips Perron (PP) test involve an intercept, but it doesn't include trend. The Bartlett kernel methods were used in KPSS and PP test. Band selection was made automatically according to Newey –West criteria. The KPSS test critical value for LM –statistic 0.347 at 10%, 0.463 at 5% and 0.739 at 1% significance levels **(Kwiatkowski et al.1992).**The Phillips Perron (PP) test critical values for Adj. t-statistic -2.572116 at 10 % ,-2.871438 at 5% and -3.453072 1% significance levels **(MacKinnon 1996).**

As it can be seen from Tables 8 and 9 the standard ADF test rejects the null of a unit root in the Real Exchange Rate series of 3 countries out of a total of 24 OECD countries included in this study. ADF test gives us a considerably low percentage of rejections of the unit root hypothesis with approximately 12.5% in total, which means that the PPP hypothesis fails in about 87.5% of our sample. The rejection rates are 0, 4.17 percent and 8.33 percent at 10 %, 5% and 1% significance levels, respectively. Quite strikingly the ADF test cannot reject the null hypothesis at 10% significance level. As a rejection rate, 12.5% is very weak and means that the PPP theory doesn't hold for a majority of the OECD countries in the ADF test. The PPP hypothesis holds only for Mexico, Poland and United Kingdom according to the ADF test.

On the other hand, the DF-GLS results, with about 58% total rejections, give us the highest rejection level among the alternative unit root tests considered which have the non-stationarity null hypothesis. Specifically, the rejection rate is 25 percent, 29.16 percent and 4.17 percent at 10%, 5% and 1% significance level, respectively. Using the DF-GLS test, we rejected the null hypothesis of a unit root in only 14 economies out of a total of 24 countries. Therefore, the PPP theory fails to hold in about 42% of our sample (10 countries). Specifically, the PPP theory holds for UK , Denmark ,Finland ,France, Iceland ,Israel ,Italy ,Japan ,Luxemburg, Mexico ,Netherlands ,Norway ,Switzerland and Belgium. When we compare the ADF and DF-GLS unit root test results, in common only the Real Exchange Rate series of Mexico and United Kingdom do not seem to have a unit root. According to results of both of these tests the PPP theory only holds for these two countries.

Another univariate unit root test conducted is the PP test and its outcome gives us the weakest rejection rate among all the tests considered in this study, with 16.6 % of total rejections in the OECD sample. PP test rejection rate is 4.17 percent, 8.33 percent and 1.17 percent at 10%, 5% and 1% significance level, respectively. Using the PP unit root test, we rejected the null hypothesis of a unit root in the Real Exchange Rate series in only 4 countries. This means that there isn't a unit root problem and the Real

Exchange Rate series are stationary for 4 OECD economies, which include Greece, Mexico, Poland and United Kingdom. Therefore, PPP fails for the other 20 countries. When we compare the results of the ADF, PP and DF-GLS unit root tests, we see that their results are quite different from each other. However, these tests do share common conclusions: The Real Exchange Rate series of Mexico, Poland and the United Kingdom are stationary. Thus, according to the univariate unit root tests conducted so far on the Real Exchange Rate series of the OECD countries, the PPP hypothesis holds in common for only three countries in our sample.

Table 9. Rejection Test Result for Univariate Unit Root Test

Significance Level	ADF		DF-GLS		PP		KPSS	
	Rejection	%	Rejection	%	Rejection	%	Rejection	%
10%(*)	0	0	6	25	1	4.17	8	33,3
5%(**)	1	4.17	7	29.16	2	8.33	5	20,8
1%(***)	2	8.33	1	4.17	1	1.17	7	29,2
Total	3	12.5	14	58.33	4	16.6	20	83,3

The last univariate unit root test was implemented on the OECD data is the KPSS test; the KPSS is different from the other three univariate unit root tests conducted so far. The null hypothesis of the KPSS test does not involve non-stationarity, but it tests for the non- existence of a unit root, i.e., stationarity. Along these lines, the KPSS rejects the null hypothesis of stationarity of the Real Exchange Rate series of 20 OECD countries out of a total of 24. Thus, the PPP hypothesis fails for 83% of the OECD countries included in our sample. The PPP hypothesis holds for only 16.7% of our sample, which includes Australia, the UK, Mexico and Belgium. The PPP hypothesis also did not fail for Mexico and United Kingdom by using the KPSS test.

At this point, we cannot reach conclusive evidence in favor of the PPP theory, various number of studies the researchers have outlined the following problems of the standard univariate unit root tests:

- *Non-stationary Price:* Real exchange rate contains non-stationary elements and real exchange rate isn't available to using standard critical value in univariate unit root test (Phillips 1987).

- *Power Problem*: Univariate unit root tests have a power problem for testing the PPP.DF-GLS test is more powerful than the other tests, but it isn't sufficient to testing the PPP.

-*Linear Specification:* The linear specification can't reflect adjusted process faced by real exchange rate, which gives a bias towards the non-rejection of the null hypothesis(Taylor et al. 2001).

In our study, we have also tried to solve the resulting the PPP puzzle by refocusing to nonlinear and panel unit root tests. We will be explaining the results of these other tests in the following sections.

5.1.2 Nonlinear Test Results

In this study addition to the linear univariate unit root tests, we have also applied the univariate nonlinear KSS unit root test to the Real Exchange Rate series of the 24 OECD countries. The results of this test are presented and summarized in Tables 10 and 11, respectively.

Table10.KSS Unit Root Test Results under the No Cross Sectional Dependence

Country	**KSS Test Statistics**
Mexico	**-5.160 (***)**
Iceland	**-4.113 (***)**
Poland	**-4.048 (***)**
Turkey	**-3.858(***)**
UK	**-3.636(***)**
Greece	**-3.442(**)**
Korea	**-3.426(**)**
Hungary	**-2.794(*)**
Switzerland	-2.280
Israel	-2.277
Sweden	-2.206
Portugal	-2.178
Japan	-2.151
Spain	-1.970
Finland	-1.856
Norway	-1.725
Italy	-1.695
Austria	-1.679
Netherlands	-1.677
Denmark	-1.649
France	-1.646
Belgium	-1.623
Canada	-1.548
Luxembourg	-1.525

Notes: *, **, *** represent rejection of the at 10, 5 and 1 % significance level respectively. KSS test respects an intercept but no trend in data. We used Akaike Information Criteria (AIC), and a lag selection criterion is 12 lag with an upper bound. KSS t-statistic has critical values(for T:287) which are -2.66 at 10%, -2.93 at 5% and -3.48 1% significance levels **(Kapaetanios et al. 2003).**

We tested for the possibility of nonlinear adjustment in the Real Exchange Rate series with the KSS test. According to the results of Tables 10 and 11, KSS test rejects the null of unit root hypothesis in only 8 countries out of a total of 24 OECD countries. This means that the PPP theory holds for 8 countries including Mexico, Iceland, Poland, Turkey, UK, Greece, Korea and Hungary. KSS test has a low rate of rejection of the null hypothesis with the PPP holding in approximately %33 of our sample. Rejection rate is 4.17 percent at 10 % significance level, 8.33 percent at 5 % level and 20.8 at 1% level. Mexico, Iceland, Poland, Turkey and UK reject the null hypothesis with 1 %; Greece and Korea reject the null hypothesis with 5%; Hungary rejects the null hypothesis with 10% significance level. After taking the possibility of an ESTAR type of nonlinearity in the Real Exchange Rate series, the PPP hypothesis still seems to fail for a majority of the OECD countries. This may mean that nonlinearity by itself is not enough to recover mean reverting dynamics in the Real Exchange Rate series. Thus, to provide a more comprehensive analysis of the PPP hypothesis we have also conducted the LNV unit root test, which takes into account the possibility of smooth structural breaks in the Real Exchange Rate series. Since we are analyzing a period of almost 24 years, we have to take into account the possibility of structural breaks in the Real Exchange Rate series when analyzing the PPP hypothesis.

Table11. Rejection Test Result for Nonlinear Univariate KSS Unit Root Test

Significance Level	KSS	
	Rejection	%
10% (*)	1	4.17
5% (**)	2	8,33
1% (***)	5	20,8
Total	8	33,3

In this thesis, addition to nonlinear KSS test, we have also implemented the univariate nonlinear LNV unit root test to the Real Exchange Rate series .The result of this test are represented and summarized in Table 12 and 13, respectively.

Table12. LNV Unit Root Test Results

Country	AIC	SBC	Correlation	Cor with Hole
Australia	-2,123	-2,472	-2,472	-2,345
Belgium	-2,098	-2,415	-2,415	-2,430
Canada	-2,118	-2,118	-2,118	-2,500
Denmark	-2,415	-2,732	-2,732	-2,585
Finland	-2,138	-2,469	-2,469	-2,202
France	-2,099	-2,382	-2,382	-2,137
Greece	-3,047	-3,757	**-3,884***	-2,671
Hungary	**-3,998***	**-3,998***	**-3,998***	-3,070
Iceland	-3,311	-2,711	-2,711	-3,348
Israel	-2,106	-2,106	-2,106	-1,728
Italy	-2,567	-2,862	-2,862	-2,582
Japan	-2,782	-3,015	-3,015	-2,818
Korea	-2,618	-2,373	-3,446	-2,617
Luxemburg	-2,407	-2,407	-2,407	-2,405
Mexico	-3,195	-3,790	-3,790	-3,330
Netherlands	-2,359	-2,713	-2,713	-2,655
Norway	-2,655	-2,959	-2,959	-3,038
Poland	-4,054	**-3,985***	**-3,985***	-2,734
Portugal	-2,995	-3,260	-3,260	-2,669
Spain	-2,753	-3,102	-3,102	-2,816
Sweden	-2,923	-3,091	-3,091	-2,986
Switzerland	-2,650	-2,650	-2,650	-2,702
Turkey	**-4,800*****	**-4,800*****	**-4,800*****	-4,517
UK	-3,118	-3,254	-3,254	-2,997

Note 1: *, **, *** represent rejection of the at 10, 5 and 1 % significance level respectively. The results given in the first and second columns are obtained using the AIC and SIC, respectively. The results given in the third column are obtained by the serial correlation test, where the serial correlation is remedied by using the suitable lag structure. The last column considers the t values with significance levels and if the t value is not significant we delete that lag from the test.The critical values (for T: 287) are-3.797 at 10%,-4.103 at %5 and -4.685 at %1 significance levels, respectively.

According to the results of Tables 12 and 13, LNV test rejected the null hypothesis for Turkey at 1 % significance level .In addition to Turkey; LNV test rejected the null hypothesis for Poland, Hungary, and Greece at 10% significance level. Rejection rate is 4.17 percent,0 percent and 12.5 percent at 10 %, 5 % and 1% significance level, respectively. LNV test result provides evidence for the PPP hypothesis in Turkey, Poland, Hungary and Greece. In general, LNV test rejects the null of unit root hypothesis in only 4 countries out of a total of 24 OECD countries. LNV test has a significantly low rate of rejection of the null hypothesis with the PPP holding in approximately %17 of our sample in Table 17. Thus, the PPP hypothesis doesn't accept the validity of the PPP hypothesis.

Table13. Rejection Test Result for Nonlinear Univariate LNV Unit Root Test

Significance	AIC		SBC		Correlation		Cor with Hole	
Level	Rejection	%	Rejection	%	Rejection	%	Rejection	%
10% (*)	1	0,041	2	0,083	3	0,125	0	0
5% (**)	0	0	0	0	0	0	0	0
1% (***)	1	0,041	1	0,041	1	0,041	0	0
Total	2	0,083	3	0,125	4	0,16	0	0

5.2 Panel Unit Root Test Results

5.2.1 Linear Test Results

The classical univariate unit root tests are unsuccessful for testing stationarity in the Real Exchange Rate Series so; panel test can be used as solution to this problem. For that reason, we have applied four standard linear panel unit root tests to the Real Exchange Rate series of the OECD countries to solve the PPP puzzle. The result for the LLC, IPS, Fisher ADF and Hadri test are presented in Table 14.

Table 14. Linear Panel Unit Root Test under the Assumption of the Cross Sectional Independence

Test Type	Statistic	P- Value
Levin Lin Chu (LLC)	-1.7566	0.0395
ImPesaran Shin (IPS)	-3.81003	0.0001
ADF - Fisher Chi-square	75.7432	0.0065
Hadri Z-stat	4.93481	0.0000

Note: The number of lags was automatically selected according to Schwarz Information Criteria (SIC) for LLC, IPS, ADF-Fisher and Hadri tests. Upper bound was applied 12 lag in the tests. Bartlett kernel method was used in LLC and Hadri tests. Bandwidth selection was made according to Newey –West criteria for two tests. We used ADF Fisher Chi –Square test and we ignored ADF - Choi Z-stat in this study. Hadri test has two tests which are Hadri Z-stat and Heteroscedastic Consistent Z-statistic. They have the same result.

According to Table 14, the outcomes of the panel unit root tests that take non-stationary as the null hypothesis are clear. LLC, IPS and Fisher ADF tests reject the null hypothesis of a unit root in the panel in favor of the alternative hypothesis. This means that according to these tests, the Real Exchange Rate series are stationary and there isn't a unit root problem. However, with only these results, we cannot specifically say that the PPP hypothesis holds for all countries. Rejection of a null hypothesis doesn't give information us whether the PPP holds or not for all countries.

However, the Hadri test rejects the no unit root null hypothesis .Therefore, the PPP hypothesis doesn't hold for the OECD sample according to the Hadri test. The Hadri test suggests random walk behavior for all Real Exchange Rate series.

To summarize, Hadri test doesn't successful to accepting the validity of the PPP. On the other hand, only three panel tests are apparently successful in our study including LLC, IPS and Fisher ADF. Unfortunately, this doesn't mean that the PPP holds for all countries, because panel studies give us only one result about the whole countries.

5.2.2 Nonlinear Test Results

As mentioned before, in the previous section when conducting the panel unit root tests, we ignored the presence of cross-sectional dependence among the countries. However, we take into account cross-sectional dependence in this section using the UO and IPS tests. Conducting the unit root testing framework within a panel data context by also utilizing cross-sectional information (i.e., using the second generation panel unit root tests) is especially important for investigating hypothesis like the PPP that involves studying Real Exchange Rate series that have strong cross country links. This will permit us to analyze the PPP within a framework that allows for both cross-sectional dependence and nonlinearity simultaneously in theReal Exchange Rate series. For comparison purposes the results of the IPS tests under cross-sectional dependence are also provided. The UO and IPS test results are demonstrated in Table 15 and 16, respectively.

In the UO test, we give a sequence of the UO statistic with their bootstrap p-values. As we can see from Table 15, null hypothesis of unit root in Real Exchange Rate series were rejected when the UO unit root test was first applied. After implementing the SPSM procedure; we found that Mexico is stationary. Mexico is then removed from the panel and UO unit root test was implemented again to the remaining set of series. The procedure was continued until the UO unit root test failed to reject the unit root hypothesis at the 10% significance level, and finally we found that this procedure stopped at the sequence 6. Real Exchange Rate series for 6 countries (i.e., Mexico, Iceland, Poland, Turkey, UK and Greece) were removed from the panel. Rejection rate is 20, 83 at 10 % level, 4, 17 percent at 5 % level and 0 at 1% significance level. Mexico rejects the null hypothesis with 5% significance level; Iceland, Poland, Turkey, UK and Greece reject the null hypothesis with 10% significance level. We found that the UO test all failed to reject the unit root null hypothesis for the rest of sequences under the cross sectional dependency.

Table 15. The Panel Unit Root Tests Results under the Assumption of Cross Sectional Dependence

Country Name	**UO Panel Test**	**IPS Test**
Mexico	**-2.507(0.027)****	-2.109(0.104)
Iceland	**-2.391(0.058)***	
Poland	**-2.313(0.063)***	
Turkey	**-2.231(0.078)***	
UK	**-2.149(0.089)***	
Greece	**-2.071(0.097)***	
Korea	-1.995	
Hungary	-1.910	
Switzerland	-1.855	
Israel	-1.827	
Sweden	-1.795	
Portugal	-1.763	
Japan	-1.729	
Spain	-1.690	
Finland	-1.662	
Norway	-1.641	
Italy	-1.630	
Austria	-1.621	
Netherlands	-1.611	
Denmark	-1.598	
France	-1.585	
Belgium	-1.565	
Canada	-1.537	
Luxembourg	-1.525	

Notes:*, **, *** represent rejection of the at 10, 5 and 1 % significance level respectively. The bootstrap p values are obtained by 2000 replication. The values in the parenthesis are critical values.

Table 16. Rejection Test Result for Nonlinear Panel UO Unit Root Test

Significance Level	UO	
	Rejection	%
10% (*)	5	20.83
5% (**)	1	4.17
1% (***)	0	0.00
Total	6	25

UO and IPS test fails to reject the null hypothesis of non-stationarity under the cross –section dependency. According to the these results , Real Exchange Rate series still shows random walk behavior and the PPP hypothesis doesn't hold for nonlinear panel adjustments.

5.3 A Summary of the Results

We have tested the PPP hypothesis with comprehensive analysis. We have implemented many linear and nonlinear tests which have illustrated in Table17. In linear univariate unit root test, DF-GLS test has higher rejection rate with% 58.3 between the other tests, KSS test has second higher rejection rate of null hypothesis with %33. Later UO has rejection rate with %25.They are our most successful test according to the Table 17.Our another tests have low rejection rate such as PP, KPSS and LNV test .They are the same rejection rate with %16.6. Then, the ADF test has the least rejection rate with % 12.5 between all tests. In addition, we have applied linear panel unit root tests, these test result have shown in the Table 14. LLC, IPS and Fisher ADF test reject the null hypothesis of unit root but, Hadri test reject the null hypothesis for no unit root. We can't say that the PPP hypothesis holds for all countries in linear panel test because panel test give us whole countries results. Thus, the PPP is still unsolved hypothesis.

Table 17. General Results of Tests

Significance Level	ADF	DF-GLS	PP	KPSS	KSS	LNV	UO
	Rejection Rates						
10% (*)	0	25	4.17	33,3	4.17	4.17	20.83
5% (**)	4.17	29.16	8.33	20,8	8,33	0.00	4.17
1% (***)	8.33	4.17	1.17	29,2	20,8	12.5	0.00
Total	12.5	58.33	16.6	83,3	33,3	16.6	25

CHAPTER 6

6. CONCLUSION

The primary aim of this thesis was to test the PPP hypothesis. The reason of the testing the PPP hypothesis is to comparing the welfare of the countries' economic conditions because other economic indicators have some problems to comparing counties' economy. In line with this purpose, we have analyzed monthly data of twenty-four OECD countries for the period 1990:01 to 2013:11.We applied a variety of unit root tests to the Real Exchange Rate series of the OECD countries included in our study. These tests include the linear univariate unit root tests, linear panel unit root tests, nonlinear univariate unit root tests and nonlinear panel unit root tests.

The linear unit root tests applied to the PPP hypothesis include the Augmented Dickey Fuller (ADF) test, the Dickey Fuller Generalised Least Square (DF-GLS) test, Phillips Perron (PP) test and Kwiatkowski–Phillips–Schmidt -Shin (KPSS) test. These test results demonstrate that the four linear univariate unit root tests applied are highly unsuccessful, they don't reject the null hypothesis of a unit root which means that the Real Exchange Rate series aren't stationary for most of the countries .Thus at the first stage by using these tests in isolation, we conclude that the PPP hypothesis doesn't hold true for many of the OECD countries. When we compare the results of these four classical unit root tests, we have different results. DF-GLS test has the highest percentage of the rejection for the null hypothesis of unit root with 58% of a rejection rate. This means that the PPP hypothesis holds true for more than 50% of the countries by using the DF-GLS test. On the other hand, when we use the ADF, PP and KPSS tests, we have failed to obtain strong evidence in favor of the PPP. Only the Real Exchange Rate series of Mexico and United Kingdom are stationary according to these four linear univariate unit root tests. Thus, the PPP hypothesis holds true only in Mexico and United

Kingdom for these four tests. Therefore, it seems that in generally, the linear unit root tests are not much successful in obtaining favorable evidence about the PPP hypothesis.

In addition to the aforementioned conventional univariate unit root tests, linear panel unit root tests were also employed to Real Exchange Rate series of the OECD countries for testing the PPP hypothesis. The linear panel unit root tests applied include the Levin-Lin-Chu (LLC) test, Im Pearson and Shin (IPS) test, Fisher Augmented Dickey fuller (Fisher ADF) test and Hadri test. These panel tests results illustrate that Hadri test rejects null of no unit root for the PPP but, LLC, IPS and Fisher ADF tests are stationary and accept the alternative hypothesis. This means that the PPP hypothesis doesn't hold true according to Hadri test but, it holds true for LLC, IPS and Fisher ADF tests. According to these results, we cannot say the PPP hypothesis holds true completely for these three panel tests due to panel test's problems. Univariate unit root tests yield results separately but, each panel test gives us only one result for twenty-four OECD countries. In this direction, we don't know which country's series are stationary or the PPP holds in which countries.

Furthermore, we also employed nonlinear univariate unit root tests which are Kapetanios-Snell-Shin (KSS) and Leybourne-Newbold-Vougas (LNV). The KSS test results illustrate that the PPP hypothesis is successful for only eight out of twenty-four OECD countries. These countries are Mexico, Iceland, Poland, Turkey, UK, Greece, Korea and Hungary. These eight countries reject the null hypothesis, this means that Real Exchange Rate series are stationary and the KSS test evidently supports the PPP theory in those countries. When we compare the results of the linear univariate unit root tests with those of the nonlinear univariate unit root tests, we see that still Mexico and United Kingdom are the common countries for which the PPP holds true. On the other hand, when the LNV unit root test was applied to the Real Exchange Rate series of the OECD countries the number of rejections decreases considerably. The LNV test results show that the PPP holds true for only four out of twenty-four OECD countries. These countries are Turkey, Poland, Hungary, and Greece.

Finally, nonlinear panel test was also implemented to Real Exchange Rate series. Uçar and Omay (UO) test applied to test the PPP hypothesis. According to the test results, the PPP holds true for only six out of the twenty-four OECD countries. Mexico, Iceland, Poland, Turkey, UK and Greece accept to the validity of the PPP theory.

When we compare the linear - nonlinear univariate tests and linear- nonlinear panel tests results, Mexico and United Kingdom accepts the PPP hypothesis for all these tests except LNV tests. According to our results, Mexico and United Kingdom are different from other countries because, their Real Exchange Rates are more stable than the other twenty two OECD countries.

In this thesis some of the countries do not accept the validity of the PPP hypothesis in the all test results. These countries are Sweden, Portugal, Japan, Spain, Norway, Netherlands, and Canada. These countries' failure base on the existence of the taxes, tariffs and capital controls in the international trade. But main reason is exchange rate instability because we tested stability of the Real Exchange Rate for twenty four OECD countries. Thus, these seven countries reject the stability in Real Exchange Rate. This means that the PPP hypothesis doesn't valid in these countries.

When we compare our test results and literature studies, empirical literature results generally compromise with our test results. Linear univariate unit root tests generally failed to testing validity of the PPP hypothesis in literature and in our results. Linear panel tests are also same in our results and literature studies except the Hadri tests. In addition, nonlinear univariate and panel unit root tests give as the same results with literature studies. According to the overall results of this thesis, nonlinear tests are more successful than the linear tests.

The PPP hypothesis does not hold true for all tests which are applied in this thesis thus, the PPP hypothesis still remains an unsolved question with weak empirical

evidences. So we fail to find conclusive evidence in favor of the PPP hypothesis according to this thesis' results. However, the PPP hypothesis is one of the most crucial hypotheses in the macroeconomic literature and there seems to be a contradiction between theory and empirical results. Thus, further explanation is required to explain why the PPP hypothesis in general fails to hold .More advanced econometric techniques or models may be the solution to this PPP puzzle.

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