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TESTING THE VALIDITY OF THE PURCHASING POWER PARITY (PPP) HYPOTHESIS FOR TÜRKİYE: LINEAR AND NONLINEAR UNIT ROOT TESTS

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Abstract: In this paper, we test the validity of the purchasing power parity (PPP) hypothesis between Türkiye and its trading partners - the European Union, China, and the US - for the period from January 2001 to January 2020. We test the stationarity of the real exchange rates for the validity of the PPP hypothesis by applying linear and nonlinear unit root tests. We also employ Fourier-based tests to account for the structural changes that occurred in the considered period. Test results indicate that shocks are temporary, and the PPP hypothesis is valid for Türkiye.

Keywords: purchasing power parity, real exchange rate, unit root tests

JEL classification: C22, C61, F31

INTRODUCTION

The purchasing power parity (PPP) hypothesis is based upon the idea of the law of one price, which states that the price of an asset in different countries should be the same when expressed in the same currency. The PPP hypothesis might hold more closely in countries experiencing high inflation. This implies that the shocks in real exchange rates are temporary, and it is expected that the rates will return to a constant equilibrium level in the long run. In the literature, there are enormous studies that test the validity of the PPP hypothesis using cointegration and unit root tests. The fact that the real exchange rate series exhibits non-stationary

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characteristics shows that the PPP theory is invalid. On the other hand, the long-run relationship between the logarithmic transformation of the nominal exchange rate and the logarithmic difference between domestic and foreign consumer price indexes stress the validity of the PPP hypothesis. Although the validity of the PPP hypothesis has been extensively tested for both developed and developing economies, it still maintains popularity in the applied literature, especially for the high inflation countries, like Türkiye. The reason for considering Türkiye as a case is due to its unique features of high inflation and structural changes. Furthermore, the development observed simultaneously in tests and technology makes it possible to re-examine the results of studies such as Telatar and Kazdağlı [1998], Özdemir [2008], Kalyoncu [2009], Sarno [2000], Yazgan [2010], Yıldırım [2017]. However, most of the studies fail to prove the validity of the PPP hypothesis while the other part of the studies prove the stationarity of the real exchange rates through unit root tests and the link between the nominal exchange rate and the consumer price indexes through cointegration tests. For instance; Telatar and Kazdağlı [1998] examined the hypothesis of long-run PPP applying cointegration techniques for Türkiye. The results do not support any long-run bilateral exchange rate and consumer price index rates between Türkiye and France, Germany, the UK, and the USA. Sarno [2000] re-examined the validity of the PPP hypothesis for the period between 1980 and 1997 for Türkiye extending the work by Telatar and Kazdağlı [1998]. The results of the nonlinear modeling techniques provide strong evidence in favor of the PPP hypothesis. Özdemir [2008] re-examined the validity of the long-run PPP hypothesis for Türkiye with the monthly data set from January 1984 to December 2004. The findings provide evidence that the long-run PPP hypothesis is valid for the given period in Türkiye just as supported by Sarno [2000] and Erlat [2004]. Kalyoncu [2009] tested the validity of the PPP between Türkiye and its trading partners namely the USA, Germany, Japan, France, Netherlands, and the UK applying different unit root tests for the quarterly data from 1980 to 2005. The findings support that the validity of the PPP hypothesis is sensitive to the type of tests and the comparison country. Yazgan [2010] found strong evidence of long-run PPP in Türkiye for the period from January 1982 to April 2001 using standard multivariate cointegration techniques. Yıldırım [2017] employed nonlinear unit root tests for the analysis of the PPP hypothesis between Türkiye and its four trading partners. The findings indicate that nonlinear unit root tests give stronger evidence in favour of the PPP hypothesis compared to the classical unit root tests if the nonlinearities of the series are specified correctly.

In this study, we aim to investigate the validity of the PPP hypothesis between Türkiye and its three major trading partners, the US, the European Union (EU), and China for the period from January 2001 to January 2020. Rather than considering the linear behaviour of Turkish real exchange rates within the linear concept, we also utilize the recent development of the nonlinear unit root tests to enhance the reliability of the results. It is also noteworthy that the unit root tests without considering structural breaks and the nonlinear form of the series lose power. Thus,

results tend to be biased, and we are less likely to reject an incorrect null hypothesis. In this context, we employ Kapetanios et al. (KSS) [2003], Sollis [2009], Kruse [2011], Kılıç [2011], Christopoulos and Leon-Ledesma [2010], and Güriş [2018] along with the ADF, extended version of Dickey and Fuller [1979], and Zivot and Andrews [1992] tests.

The rest of the paper is organized as follows: Section 2 outlines the methods. Empirical data is detailed in Section 3. Section 4 presents the empirical results. Section 5 provides a summary of the article.

METHODS

In the nonlinear unit root tests, KSS [2003], Sollis [2009], Kruse [2011], and Kılıç [2011] are the most popular tests used in applied econometrics. KSS [2003] unit root test is the first nonlinear unit root test that considers the Taylor series approximation in the testing procedures. The test is known as a nonlinear form of the ADF unit root test. The exponential transition function is used as a transition function to define the nonlinearity in the model following the literature on smooth transition autoregressive (STAR) models.

The model can be written as follows:

$$y_t = \beta y_{t-1} + \rho y_{t-1} G(\gamma, y_{t-d}) + \varepsilon_t, \tag{1}$$

where the transition function $G(\gamma; y_{t-d}) = 1 - e^{(-\gamma y_{t-\mathrm{d}}^2)}$. In the function, we assume that $\gamma \geq 0$ and $d \geq 1$. The model can be reorganized by assuming that $\gamma \geq 0$ and $d = 1$ as follows:

$$\Delta y_t = \phi y_{t-1} + \rho y_{t-1}.\left[1 - e^{(-\gamma y_{t-1}^2)}\right] + \varepsilon_t, \tag{2}$$

where $\phi = \beta - 1$. Under the assumption of $\phi = 0$, the model can be formed as follows:

$$\Delta y_t = \rho y_{t-1}.\left[1 - e^{(-\gamma y_{t-1}^2)}\right] + \varepsilon_t. \tag{3}$$

In the KSS [2003] unit root test, the null hypothesis of unit root process $H_0: \gamma = 0$ is tested against the alternative of stationary exponential smooth transition autoregressive (ESTAR) process $H_1: \gamma > 0$. However, it is not feasible to directly test the null hypothesis since ρ is unidentified under the null hypothesis. Taylor series approximation is suggested to overcome the nuisance parameter problem, also called as Davies [1987] problem. The suggested model for the stationary test is created based on the first-order Taylor series approximation as follows:

$$\Delta y_t = \delta y_{t-1}^3 + \sum_{j=1}^{p} \rho_j \Delta y_{t-j} + \varepsilon_t. \tag{4}$$

The null and alternative hypotheses are formed as $H_0: \delta = 0$ and $H_a: \delta < 0$. Critical values are tabulated in the KSS [2003] for the row cases, demeaned, and detrended data. In the Sollis [2009] test, a new unit root test is proposed to test the unit root null hypothesis against the alternative hypothesis that allows symmetric or

asymmetric ESTAR nonlinearity unlike KSS [2003]. The suggested model is also known as asymmetric ESTAR (AESTAR) written as follows:

$$\Delta y_t = \phi_1 y_{t-1}^3 + \phi_2 y_{t-1}^4 + \sum_{i=1}^{k} \kappa_i \Delta y_{t-i} + e_t. \quad (5)$$

The rejection of the null hypothesis of unit root $H_0: \phi_1 = \phi_2 = 0$ may address to test the null of symmetric ESTAR nonlinearity $H_0: \phi_2 = 0$ against the alternative of asymmetric ESTAR nonlinearity $H_1: \phi_2 \neq 0$ using a standard F test statistics. Critical values of F tests are tabulated by Sollis [2009] for three cases as KSS [2003] since a standard F test cannot be used to test the unit root null hypothesis.

In the Kruse [2011] unit root test, the model is written based on the Taylor approximation as follows:

$$\Delta y_t = \phi_1 y_{t-1}^3 + \phi_2 y_{t-1}^2 + \sum_{i=1}^{k} \rho_i \Delta y_{t-i} + u_t, \quad (6)$$

where unit root null hypothesis $H_0: \phi_1 = \phi_2 = 0$ is tested against the alternative of globally stationary ESTAR process $H_1: \phi_1 < 0,\ \phi_2 \neq 0$. The asymptotic critical values are tabulated through stochastic simulations.

The unit root test proposed by Kılıç [2011] is similar to the KSS [2003] test process except for the way of dealing with the nuisance parameter problem. To test the null of a unit root against a globally stationary ESTAR process, the following representation of the ESTAR model is considered:

$$\Delta y_t = \rho y_{t-1} . \left[1 - e^{(-\gamma \Delta y_{t-1}^2)}\right] + \sum_{i=1}^{p} \rho_i \Delta y_{t-i} + \varepsilon_t \quad (7)$$

The null and alternative hypotheses are defined as $H_0: \rho = 0$ and $H_1: \rho < 0$ in Kılıç [2011] test. The test suffers from a nuisance parameter problem only defined under the alternative hypothesis as in KSS [2003]. Thus, the critical values are computed based on the grid research different from the Taylor expansion to overcome this problem as follows:

$$t_{ESTAR} = \inf_{\gamma \in \Gamma_T} \hat{t}_{\rho=0}(\gamma) = \inf_{\gamma \in \Gamma_T} \hat{\rho}(\gamma) / s.e.(\hat{\rho}(\gamma)), \quad (8)$$

where $s.e.$ is the standard error. Γ_T refers to the following equation:

$$\Gamma_T = \left[\underline{\gamma}_T, \bar{\gamma}_T\right] = \left[\frac{1}{100 s_{\Delta y_{t-1} T}}, \frac{100}{s_{\Delta y_{t-1} T}}\right] \in \mathrm{R}. \quad (9)$$

where $s_{\Delta y_{t-1} T}$ is the sample standard deviation of Δy_{t-1}. The asymptotic critical values are provided by Kılıç [2011].

The problems encountered in modelling structural breaks in unit root tests based on linear and non-linear models have raised the question of how to model the breaks in the literature as an alternative way to dummy variables. Gallant [1981], Gallant [1984], Gallant and Souza [1991], Becker et al. [2004], Becker et al. [2006], Enders and Lee [2012a], and Enders and Lee [2012b] have made important contributions to the literature suggested that these problems would be overcome with the Fourier approach. The main idea behind the Fourier-based unit root test is to capture structural breaks regardless of the number, date, and shape of the breaks by using trigonometric functions.

The general form of the Fourier function is as follows:

$$\alpha(t) = \alpha_1 sin\left(\frac{2k\pi}{T}\right) + \alpha_2 cos\left(\frac{2k\pi t}{T}\right), \quad (10)$$

where k is the Fourier frequency chosen for the approximation, α_1 and α_2 represent the measurement of the amplitude and displacement of the frequency component. T is the sample size, t is a trend term, and π≅ 3.1416. Christopoulos and Leon-Ledesma [2010] and Güriş [2018] developed the KSS [2003] and Kruse [2011] unit root tests by including the $\alpha(t)$ into the model as follows:

$$y_t = \delta_1 + \alpha(t) + e_t. \quad (11)$$

The model is estimated by OLS for the different values of k defined in the range [1,5] and the value that minimizes the sum of squared residuals is selected to compute the OLS residuals as follows:

$$\hat{e}_t = y_t - \delta_1 - \alpha(t). \quad (12)$$

Following, the unit root on the OLS residuals of equation 12 is tested by employing KSS [2003] and Kruse [2011] unit root test models as detailed in equations 4 and 6.

EMPIRICAL DATA

The data used in this study consist of two sets: The first one is nominal bilateral exchange rates for the Chinese Yuan, Euro, and the US Dollar (USD) against the Turkish lira (TL). The second set is the Consumer Price Indexes (CPI) conducted for each domestic and foreign country. All series are taken from the International Monetary Fund's International Financial Statistics and Federal Reserve databases from January 2001 to January 2020 (T = 229). The following equation shows the general structure for the PPP hypothesis, the relation between the nominal exchange rate and relative price levels:

$$s_t = \alpha_0 + \alpha_1(p_t - p_t^*) + u_t, \quad (13)$$

where s_t denotes the logarithm of the domestic nominal exchange rate, p_t^* is the logarithm of the foreign country's price level and p_t is the logarithm of the domestic country's price level, u_t is an error term with zero mean and constant variance. We consider the following equation and transform the variables to explore the validity of the PPP hypothesis between Türkiye and its trading partners by applying unit root tests.

$$r_t = s_t + (p_t^* - p_t), \quad (14)$$

where r_t is the real exchange rate and s_t, p_t^*, and p_t are as defined in equation (13). The nominal exchange rates are computed using the cross-exchange rates TL-US$, Euro €-US$, and Yuan ¥ - US$ and transferred to real exchange rates by using domestic and foreign consumer price indices in equation (14). The real exchange rate series should be stationary at the level following the assumption of the PPP hypothesis. If the r_t, the real exchange rate, is stationary at the level, this emerges

that the PPP hypothesis is valid between Türkiye and its trading partners the EU, the US, and China. On the other hand, shocks to the real exchange rates are temporary between two countries. Furthermore, the stationarity of the variables, the rejection of the null hypothesis in unit root tests, would indicate that the changes in the price levels between Türkiye and its trading partners taken into account in the study would be balanced by an equal depreciation or appreciation in the nominal exchange rate [Kalyoncu 2009].

RESULTS

In this part of the study, we present the linear and nonlinear unit root test results to test the validity of the PPP hypothesis in Türkiye. We initially employed the most popular unit root test, ADF and Zivot and Andrews [1992], as reported in Table 1. The results of the ADF test indicate that the null of the unit root is rejected for all cases, TL/USD, TL/EURO, and TL/YUAN. However, the results of the Zivot and Andrews [1992] test provide that the null of the unit root is rejected for the TL/USD and TL/YUAN.

Table 1. Linear Unit Root Test Results

Variables	ADF	Zivot and Andrews (1992)	Break Dates
TL/USD	-3.411** (1)	-5.730***(1)	2006M02
TL/EURO	-3.091** (1)	-4.254 (1)	2013M06
TL/YUAN	-2.883** (0)	-4.823* (5)	2005M04
Critical Values			
1%	-3.459	-5.57	
5%	-2.874	-5.08	
10%	-2.573	-4.82	

Note: Numbers in parentheses are the number of lags chosen by the minimum value of the Akaike Information Criteria. *, **, and *** denote the rejection of the unit root null hypothesis at 10%, 5%, and 1%.

Source: own calculations

The empirical investigation of nonlinear unit root tests is given in Table 2 for the KSS [2003], Kruse [2011], and Kılıç [2011]. Additionally, we include two tests, Fourier KSS [2010] and Fourier Kruse [2018], proposed by Christopoulos and Leon-Ledesma [2010] and Güriş [2018], to model the structural changes regardless of the number of breaks, dates, and form of the breaks. According to the test results in Table 2, we reject the unit root null hypothesis for three cases for all the reported test results with and without considering the breaks in the tests. The results in Tables 1 and 2 provide evidence that the PPP hypothesis is valid for three cases by rejecting the unit root null hypothesis. The results prove that shocks to the real exchange rates are temporary between two countries, Türkiye and the US, China, and the EU.

Table 2. Nonlinear Unit Root Test Results

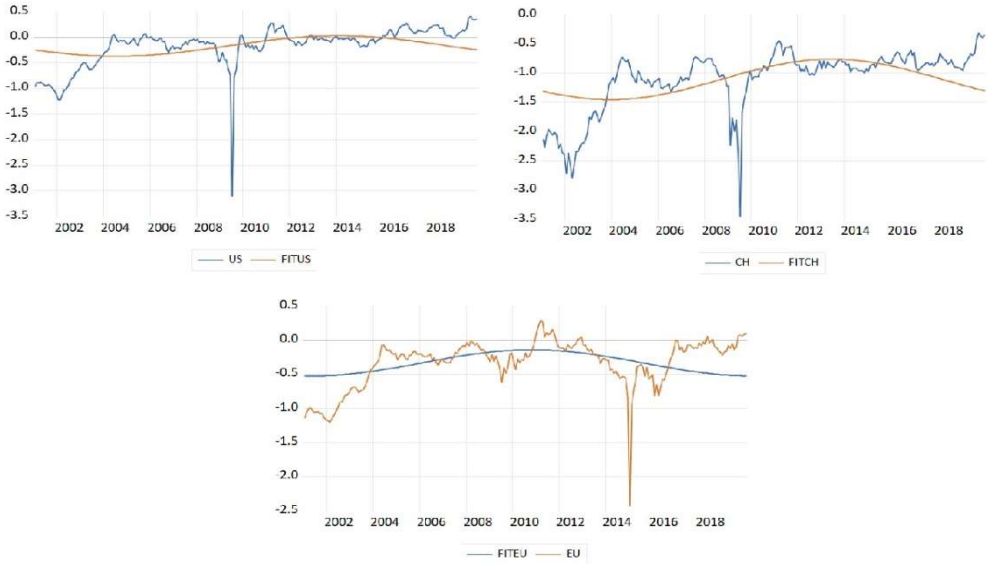
Variables	KSS (2003)	Kruse (2011)	Kılıç (2011)	Fourier KSS (2010)	Fourier Kruse (2018)
TL/USD	-11.125***	141.147***	-2.715***	-11.273***	141.235***
TL/ EURO	-10.384***	118.942***	-2.908***	-10.412***	110.619***
TL/YUAN	-8.628***	103.789***	-2.937***	-10.048***	106.542***
Critical Values					
1%	-3.48	13.75	-2.98	-4.19	18.82
5%	-2.93	10.17	-2.37	-3.60	14.80
10%	-2.66	8.60	-2.05	-3.29	12.52

Note: The signs *, **, and *** denote the rejection of the unit root null hypothesis at 10%, 5%, and 1%.

Source: own calculations

We also demonstrate the link between the real exchange rates and residuals fitted by the Fourier function for the cases TL/USD, TL/EURO, and TL/YUAN in Figure 1 to show how the Fourier function can catch the possible breaks in the series.

Figure 1. The comparison of the original series and residuals fitted by the Fourier function



*The US, CH, and the EU represent real exchange rates calculated taking into account the US, China, and the EU currencies, respectively. FITUS, FITCH, and FITEU demonstrate the residuals fitted by the Fourier function.

Source: own preparation

SUMMARY

In this paper, we used monthly data to indicate the validity of the PPP hypothesis for Türkiye for the period between January 2001 and January 2020. Instead of working only with the TR-US nominal exchange rates and consumer price index to compute the real exchange rates, we have considered the other major trading partners of Türkiye, China and the EU, to evaluate the results comparatively, different from most of the studies in the literature. Linear and nonlinear unit root tests have been employed to test if the unit root hypothesis is rejected for the variables. Furthermore, we have highlighted the importance of applying unit root tests that include structural changes in the unit root process to enhance the reliability of the test results. The results show that the unit root null hypothesis is rejected for all three cases, and all the series are found stationary. Thus, we can conclude that the rejection of the null hypothesis proves that the PPP hypothesis is valid between Türkiye and its trading partners for the given period and changes in the price levels between Türkiye and the US, China, and the EU would be balanced by an equal depreciation or appreciation in the nominal exchange rate as noted by Kalyoncu [2009].

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