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# TESTING PURCHASING POWER PARITY USING SYMMETRIC AND ASYMMETRIC COINTEGRATION METHODS: EVIDENCES FROM TURKEY

**Dr. Öğr. Üyesi İsmail Erkan ÇELİK[1]**
**Prof. Dr. Muhittin KAPLAN[2]**

## ABSTRACT

Testing the validity of purchasing power parity (PPP) has always been a hot topic in the empirical literature. Recently, researchers Arize and Bahmain-Oskooee (2021) investigated the possible effects of nonlinearities in exchange rate adjustments on testing results of the PPP hypothesis and found that application of the asymmetric cointegration method increased the number of cointegration between the nominal exchange rate and relative prices to 51 out of 82 countries including Turkey. This study employed symmetric and asymmetric bound testing cointegration approaches to test the validity of PPP hypothesis for Turkey. The results showed that the PPP hypothesis holds for Turkey, but the impact of relative prices (measured with producer price index) on the nominal exchange rate is symmetrical, implying that nonlinear adjustment of relative prices has no role in the relationship between relative prices and exchange rate in the long-run. However, relative prices affect nominal exchange rates asymmetrically in the short-run, suggesting the importance of nonlinearities in relative price adjustments in the short-run. More importantly, the findings of empirical analysis in this study showed that the PPP hypothesis test results are very sensitive to a number of choices that researchers make while they are undertaking their empirical analysis. The so-called choices are related to the choice of proxies used to represent relative prices (producer price index or consumer price index), the choice about the sample period (whether the sample data includes different exchange rate systems, such as flexible, fixed, or managed floating periods), the estimation methods such as the nonlinear ARDL and linear ARDL model, and whether researchers handle outliers in the dataset adequately.

**Keywords:** Purchasing Power Parity, Symmetric Cointegration Methods, Asymmetric Cointegration Methods.

[1],Doğuş Ün., İİBF,ORCID: 0000-0002-2274-0750, ismailerkancelik@gmail.com
[2] İstanbul Ün., İktisat Fakültesi, ORCID: 0000-0002-0685-7641, muhittin.kaplan@istanbul.edu.tr
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# SİMETRİK VE ASİMETRİK EŞLEŞTİRME YÖNTEMLERİYLE SATIN ALMA GÜÇ PARİTESİNİN TEST EDİLMESİ: TÜRKİYE'DEN DELİLLER

## ÖZET

Satın alma gücü paritesinin (PPP) geçerliliğinin test edilmesi, ampirik literatürde her zaman sıcak bir konu olmuştur. Son zamanlarda araştırmacılar Arize ve Bahmain-Oskooee (2021), döviz kuru ayarlamalarındaki doğrusal olmama durumunun PPP hipotezinin test sonuçları üzerindeki olası etkilerini araştırmışlar ve asimetrik eşbütünleşme yönteminin uygulanmasının nominal döviz kuru ile göreli fiyatlar arasındaki eşbütünleşme sayısını artırdığını Türkiye dahil 82 ülkeden 51'inde.bulmuşlardır. Bu çalışmada, Türkiye için PPP hipotezinin geçerliliğini test etmek için simetrik ve asimetrik sınır testi eşbütünleşme yaklaşımları kullanılmıştır. Sonuçlar, SAGP hipotezinin Türkiye için geçerli olduğunu, ancak nispi fiyatların (üretici fiyat endeksi ile ölçülen) nominal döviz kuru üzerindeki etkisinin simetrik olduğunu ve nispi fiyatların doğrusal olmayan düzeltmesinin nispi fiyatlar ile döviz arasındaki ilişkide hiçbir rolü olmadığını uzun vadede göstermiştir. Ancak, nispi fiyatlar nominal döviz kurlarını kısa vadede asimetrik olarak etkiler ve bu da kısa vadede nispi fiyat ayarlamalarında doğrusal olmamaların önemini ortaya koyar. Daha da önemlisi, bu çalışmadaki ampirik analizin bulguları, PPP hipotez testi sonuçlarının, araştırmacıların ampirik analizlerini gerçekleştirirken yaptıkları bir dizi seçime çok duyarlı olduğunu göstermiştir. Adlandırılan seçenekler, göreli fiyatları temsil etmek için kullanılan vekillerin seçimi (üretici fiyat endeksi veya tüketici fiyat endeksi), örnekleme dönemi hakkındaki seçim (örnek verilerin esnek, sabit, veya yönetilen değişken dönemler), doğrusal olmayan ARDL ve doğrusal ARDL modeli gibi tahmin yöntemleri ve araştırmacıların veri kümesindeki aykırı değerleri yeterince ele alıp almadığıdır.

**Anahtar Kelimeler:** Satın Alma Gücü Paritesi, Simetrik Eşbütünleşme Yöntemleri, Asimetrik Eşbütünleşme Yöntemleri.

## INTRODUCTION

Purchasing power parity describes a rate of change that eliminates price level differences between countries and equalizes the purchasing power of different currencies. PPP hypothesis based on one price theory predicts that there is one to one relationship between change in relative prices and change in exchange rates. Although it has a strong intuition behind it, the empirical evidence does not support the PPP hypothesis in many instances. For this reason, testing the validity of purchasing power parity has always been a hot topic in the empirical literature.

In a recent paper, Arize and Bahmain-Oskooee (2021) have shown that the application of the asymmetric cointegration method increased the number of cointegration between the nominal exchange rate and relative prices (to 51 out of 82 countries), significantly implying that incorporating nonlinearities is crucial in testing the validity of the PPP hypothesis. This study examines the long-run relationship between nominal exchange rate and relative prices using the linear and an asymmetric ARDL method for Turkey.

The PPP hypothesis is traditionally called absolute PPP, which suggests that the nominal exchange rate among two countries should reflect the relative prices in the home and the host country. The relative PPP hypothesis suggests that change in the nominal exchange rate between two countries should equal the difference between price inflation in two countries. Hence, testing the validity of the PPP hypothesis involves testing whether the coefficient of relative prices is equal to one or not. Equivalently, it involves testing whether real exchange (is equal to nominal exchange rate adjusted by relative prices) is stationary or not. In this sense, deviation from PPP is taken as an indication of rejection of the PPP hypothesis.

The empirical literature on testing purchasing power parity has developed over time. First economic tests are done in the ’70s using OLS, which ignored dynamics in the data often rejected the hypothesis. Since the ’80s, following developments in econometric techniques, the PPP hypothesis extended to unit root tests and cointegration (Freixo and Barbosa, 2004). The underlying assumption in the conventional unit root tests and cointegration methods is that a linear autoregressive process generates the REER variable. However, the presence of nonlinearities in the RER due to transactions costs and barriers to international arbitrage may cause REER to deviate from PPP may invalidate the results obtained from conventional tests (Michael et al., 1997; Sarno and Taylor, 2003, Freixo and Barbosa, 2004). Furthermore, the studies in empirical literature also showed that the data used in the studies (producer prices or consumer prices) are crucial for the determination of results. If producer prices are used in the analysis, the null hypothesis of non-cointegration is rejected easily, but it is not the same if consumer prices are used (Freixo and Barbosa, 2004).

For these reasons, this study has tested the validity of PPP for Turkey over the period of 1993M01-2021M06 using linear and nonlinear cointegration methods. In the empirical tests, both consumer price and producer prices will be used in line with the empirical literature. The remaining part of this study is as follows. Section 2 provides the empirical literature review on testing PPP. Section 3 introduces data and methodology. Section 4 presents empirical results, and Section 5 summarizes and concludes.

## 1. LITERATURE REVIEW ON TESTING PURCHASING POWER PARITY

A vast literature has accumulated and improved with new econometric techniques over time on the empirical test of PPP. The literature on PPP can be divided into two big groups. The first group of studies involve linear approaches to PPP and have five stages: ordinary least squares regressions; unit root test of the real exchange rate; cointegration tests; studies using long data series and data panels (see Freixo and Barbosa, 2004 for details). Second big group of studies involves the empirical studies that involve testing PPP using nonlinear unit root and cointegration tests.

The first tests of the PPP hypothesis until the late 1970s employed the absolute PPP form of the hypothesis, ignored dynamics in the model, and often rejected the PPP (Freixo and Barbosa, 2004). Freixo and Barbosa (2004) tested the validity of PPP for Brazil using data from 1959 to 2004. While the study results using the STAR model show the nonlinear behavior of the consumer price index-based real exchange rate, the wholesale price index-based real exchange rate is linear stationery.

Liu et al. (2012) used data for the period 1986M01-2009M10 to measure the long-term validity of purchasing power parity. The empirical results of the ADL test for East Asian Countries show that the PPP is valid for all the countries studied except Japan and the Philippines, and the long-term PPP adjustment process for its equilibrium is asymmetrical. Bozoklu ve Kutlu (2012) used the data from 1983M01 to 2010M06 to search the empirical validity of PPP. 8 developing countries constituted the study sample. The study was performed using both linear and nonlinear cointegration tests. The study findings show that the results from Breitung's rank test, when sources of nonlinearities are taken into account, provide stronger evidence for empirical fulfillment of PPP.

Mike (2018) tested the long-term validity of the PPP for 15 emerging market economies by using data for the period 2003Q1-2015Q4. The study's findings on the real exchange rate model and the purchasing power parity model are that purchasing power parity is not valid for 15 emerging market economies in general. Traditional and structural break unit root tests were used for the real exchange rate model, time series and panel data analyzes were used for the PPP model. Jacobo and Sosvilla-Rivero (2020) conducted a study to provide more empirical evidence by examining PPP behavior in Argentina for the period 1810-2016 using cointegration analysis and error correction models that allow for structural breaks. As a result of the study, they found a long-run relationship between the AR$/USD exchange rate and the price difference between Argentina and the USA.

Arize and Bahmani-Oskooee (2021) used the quarterly data between 1974 and 2018 (although the dates vary on a country basis) and discussed PPP with new techniques for 82 countries. When they apply the symmetric cointegration test and Bounds-test approaches to the analysis of level relationships by Pesaran et al., they found cointegration between nominal exchange rates and relative prices in 22 of 82 countries. However, with the application of Shin et al.'s asymmetric cointegration method and modeling of asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework, the number increased to 51 among 82 countries. Accordingly, it can be said that the nonlinear adjustment of relative prices is the main contributing factor. Anderl and Caporale (2021) conducted a study covering the period 1993M02-2019M07 for 5 inflation-targeting countries. Both a comparative linear ARDL model and a nonlinear ARDL (NARDL) specification were considered in the study. The results show that the nonlinear framework is more appropriate to capture the behavior of real exchange rates, given the existence of asymmetries in both the long and short run. In particular, the rate of adjustment for long-term equilibrium implied by PPP is three times faster in a non-linear framework, providing much stronger evidence in support of PPP.

When the study examples made in Turkey are examined, it is seen that the studies are mainly included in the two large groups mentioned. Sarno (2000) tested the long-run purchasing power parity (PPP) hypothesis for the period 1980M01-1997M12 using the samples of Turkey, the USA, England, Germany, and France. The empirical results obtained in the study using the ESTAR model show that conventional unit root tests do not detect mean reversion in real exchange rates and imply rejection of long-run PPP over the sample, using recently developed nonlinear modeling techniques.

Yazgan (2003) used data for the period 1982Q1-2001Q4 to test the validity of the PPP hypotheses in Turkey. Study results using cointegration and VAR analysis provided strong evidence for long-term PPP. Erlat (2003) reached findings supporting the validity of the absolute version of the "quasi" purchasing power parity hypothesis for Turkey in his study using 1984M01-2000M09 data and Unit Root-ARFIMA analysis for Turkey. Özdemir (2008) tested the validity of PPP for Turkey using nonlinear STAR error correction models. The study was carried out using monthly data for the period 1984M01-2004M12. The findings of the study provide evidence that the long-term PPP hypothesis is valid by using the nonlinear cointegration technique.

Karagöz and Saraç (2016) examined the validity of PPP theory for Turkey between 2003M01-2014M06. According to the study's nonlinear unit root test results, they concluded that the PPP theory is not valid. Yıldırım (2017) tested the empirical validity of the PPP hypothesis by using the 2001M03-2015M10 period data between Turkey and the four largest trading partners Euro zone, Russia, USA, and China. The study's empirical results reveal that nonlinear unit root tests provide stronger evidence in favor of the PPP hypothesis than traditional unit root tests only if the nonlinearities in real exchange rates are correctly specified.

## 2. METHODOLOGY AND DATA

This study aims to test the validity of PPP model estimating the following model:

$$ER_t = \alpha_0 + \beta_1 RP_t + \varepsilon_t \qquad (1)$$

where $ER_t$ is nominal exchange rate between domestic and foreign currency, $RP_t$ is the relative prices defined as the ratio of domestic price level ($P^d$) over the foreign price level ($P^f$). The nominal exchange rate used in this study is the dollar exchange rate of Turkish lira defined as a number of units of domestic currency per dollar. Considering the discussions in the empirical literature in the previous section, we employed two different measures of price indices, namely producer price index and consumer price index to represent domestic price level and foreign price level. Therefore, empirical purchasing power parity model estimated in this study can be written as follows:

$$ERD_t = \alpha_0 + \beta_1 PRP_t + \varepsilon_t \quad (2)$$

$$ERD_t = \alpha_0 + \beta_1 CRP_t + \varepsilon_t \quad (3)$$

where $ERD_t$ is the dollar exchange rate of Turkish lira, $PRP_t$ is the ratio of Turkish producer price index ($P^d$) over the US producer price index ($P^f$), $CRP_t$ is the ratio of Turkish consumer price index ($P^d$) over the US consumer price index ($P^f$). All variables are seasonally adjusted and are in log form.

The data used for this study is monthly data covering the period 2003M01-2021M06. While producer price indices and consumer price indices for both Turkey and United States are obtained from OECD statistics data, the dollar exchange rate of Turkey is obtained from the Central Bank of Turkey's online data delivery system.

To test the validity of PPP hypothesis for Tukey, we estimated the empirical PPP models given in equations (2) and (3) individually using symmetric (linear) and asymmetric (nonlinear) ARDL models. Then we tested whether there is long-run relationship or cointegration between nominal exchange rate ($ERD_t$) and relative prices ($PRP_t$ or $CRP_t$) employing bound testing approach.

Pesaran and Shin (1998) and Pesaran et al. (2001) have shown that cointegration among variables can be tested using autoregressive distributed lag (ARDL) models since the ARDL model performs better in small samples and can be used even variables are I(0) or I(1). The ARDL model form of Equation (2) can be written as (Pesaran and Shin, 1998):

$$ERD_t = \gamma_0 + \sum_{j=1}^{p} \gamma_{1j} ERD_{t-j} + \sum_{j=0}^{q} \gamma_{2j} PRP_{t-j} + u_t \qquad (4)$$

The error correction form of the ARDL model can be expressed as (Pesaran et al., 2001):

$$\Delta ERD_t = \gamma_0 + \rho_1 ERD_{t-1} + \rho_2 PRP_{t-1} + \sum_{i=1}^{p} \gamma_{1i} \Delta ERD_{t-i} + \sum_{i=1}^{q} \gamma_{2i} \Delta PRP_{t-i} + \varepsilon_t \qquad (5)$$

where Δ is first difference operator. To test for cointegration relationship in the linear model given in equation (9), Pesaran et al. (2001) introduced the bound test that involves testing the joint null hypothesis that the coefficients of the lagged level variables are jointly equal to zero, that is, $H_0$: $\rho_1$=$\rho_2$=0. The equations (3) and (4) assume that there is a linear relationship between relative prices and exchange rate and that changes in relative prices have symmetric effects on the exchange rate. That is, if relative prices increase (decrease) a%, the exchange rate increase (decrease) b%.

However, the change in relative prices may affect exchange rates asymmetrically due to downward rigidity of prices and interventions to foreign markets and failing to incorporate such nonlinearity in testing cointegration may lead to the rejection of long-run relationship among variables of the model. To account for asymmetric effects of independent variables on dependent variable, Shin et al. (2014) developed the asymmetric version of the ARDL model that involves separating the effects of positive and negative changes in the independent variables on dependent variable. Following Shin et al. (2014), an asymmetric ARDL (NARDL) form of equation (2) can be specified as:

$$ERD_t = \beta_0 + \beta_1^+ PRP_t^+ + \beta_2^- PRP_t^- + \varepsilon_t \qquad (6)$$

where $\beta_1^+$, $\beta_2^-$ are long-run parameters, $PRP_t^+$ is the partial sum of positive changes of imports, and $PRP_t^-$ is the partial sum of negative changes in imports. $PRP_t^+$ and $PRP_t^-$ variables are measured as:

$$PRP_t^+ = \sum_{i=1}^{t} \Delta PRP_i^+ = \sum_{i=1}^{t} \max(\Delta PRP_i, 0) \qquad (7)$$

$$PRP_t^- = \sum_{i=1}^{t} \Delta PRP_i^- = \sum_{i=1}^{t} \min(\Delta PRP_i, 0) \qquad (8)$$

An asymmetric ARDL (NARDL) form of equation (6) can be specified as:

$$ERD_t = \beta_0 + \sum_{j=1}^{p} \delta_i ERD_{t-j} + \sum_{j=0}^{q} (\theta_j^+ PRP_{t-j}^+ + \theta_j^- PRP_{t-j}^-) + u_t \qquad (9)$$

And an error correction version of the asymmetric PPP model given in Equation (6) can be specified as:

$$\Delta ERD_t = \beta_0 + \rho ERD_{t-1} + \gamma_1^+ PRP_{t-1}^+ + \gamma_2^- PRP_{t-1}^- + \sum_{j=1}^{p} \delta_i \Delta ERD_{t-j}$$

$$+ \sum_{j=0}^{q} (\theta_j^+ \Delta PRP_{t-j}^+ + \theta_j^- \Delta PRP_{t-j}^-) + \varepsilon_t \qquad (10)$$

where $\varepsilon_t$ is error term, p and q are lag lengths. The long-run and short-run asymmetric effects of positive and negative changes in relative prices on exchange rates can be specified as: The asymmetric long-run parameters: $\beta_1^+ = -\left(\frac{\gamma_1^+}{\rho}\right)$, $\beta_2^- = -\left(\frac{\gamma_2^-}{\rho}\right)$. The asymmetric short-run parameters: $\sum_{j=0}^{q} \theta_j^+$, $\sum_{j=0}^{q} \theta_j^-$

## 3. RESULTS AND DISCUSSIONS

To test the validity of purchasing power parity hypothesis for Turkey, the PPP models are given in equations (2) and (3) are estimated by employing the linear (equation 4) and asymmetric (Equation 9) ARDL models for the period of 2003M01-2021M06. The sample period is determined as the period that Turkey adopted the floating exchange rate regime. Since the empirical analysis involves time series data, we started our analysis by employing the unit root tests to determine the level of integration of variables subject to empirical analysis at first stage. Table 1 presents unit root test results for relevant variables. Examination of Table 1 shows that the variables subject to empirical analysis have a unit root, I(1) variables.

**Table 1: Unit Root Test Results**

| Unit Root Tests | Dependent Variable | | | | | |
|---|---|---|---|---|---|---|
| | ERD | PRP | CRP | ΔERD | ΔPRP | ΔCRP |
| ADF | 1.9282(4) | 2.2623(2) | 0.6373(4) | -7.8854(3)* | -9.0868(1)* | -8.1169(3)* |
| PP | 1.9649(7) | 2.2897(5) | 0.4700(1) | -9.9206(8)* | -9.5679(1)* | -9.6240(10)* |

**Note:** * indicates statistical significance at 1% level. Figures in parenthesis show the number of lags chosen by SIC (Schwarz Information Criterion) in ADF regession and Bandwith in PP test. Δ is a first difference operator. ADF is Augmented Dickey-Fuller unit root test, and PP represents the Phillips-Perron unit root test.

At second step, we constructed the empirical ARDL forms of PPP models with optimal lag length using the Akaike Information Criterion (AIC) with maximum lag of 14. The AIC determined that the ARDL(2,3) (ARDL(5,5)) is the best model in the linear case and the NARDL(5,1,1) (NARDL(5,0,0)) is the best model in the nonlinear case when the independent variable is PRP (CRP). However, the examination the diagnostic statistics of these models revealed that the normality, homoscedasticity, stability, and the functional form assumptions were violated leading to misspecification problems. Although we did not add these results' Tables into the text due to space limitations, these findings can be provided upon request.

Examining the graphs of residuals has indicated that there are a number of outliers in the error terms. The outliers that caused the misspecification problems are then determined empirically using influence statistics. In the errors of equations (4) and (9) with relative producer prices, the outliers are detected as the periods of 2008M09-2009M01, 2021M11, and 2004M01. These periods correspond to the effects of global financial crisis, covid-19 pandemic and the concerns about the sustainability of the debt due to the heavy redemptions made in the first months of 2004, respectively (Tüsiad, 2004). In the errors of equation (4) and (9) with relative consumer prices, the outliers are in the dates of 2008M10, 2018M08 2006M06, and 2004M04. The outliers are due to the global financial crisis, an increased political tension with the USA caused rapid deterioration in exchange rate and interest rates, the rapid outflow of short-term capital caused domestic currency depreciate by 25%, and the concerns about the sustainability of the debt respectively. To overcome the misspecification problems associated with outliers, we incorporated dummy variables for each event in estimating the empirical PPP models given in Equation (4) and (5).

At the third step, we estimated the linear and non-linear PPP models using the linear ARDL and asymmetric ARDL techniques employing relative producer and consumer prices in turn. Table 2 presents the estimation results obtained from linear ARDL and nonliner ARDL models given in equations (4) and (9) using relative consumer prices as independent variable. Examination of diagnostic statistics in Table 2 shows that about 99 percent of change in exchange rate is explained by change in relative consumer prices (the $R^2$ is very high), that the error terms are normally distributed, serially correlated, have a constant variance in both the linear and nonlinear ARDL models. RESET test results indicate that the functional forms of the models are correctly specified. Moreover, the CUSUM and CUSUM square test of stability show that the estimated models in Table 2 are stable.

**Table 2: Diagnostic Statistics of the Linear and the Asymmetric ARDL Models**

| **Diagnostic Statistics** | | | | **Diagnostic Statistics** | | | |
|---|---|---|---|---|---|---|---|
| **Linear ARDL(1,3)**[§] | | **NARDL(1,3,2)** [§§] | | **Linear ARDL(6, 5)** | | **NARDL(3, 3, 0)** | |
| $R^2$ | 0.9990 | $R^2$ | 0.9990 | $R^2$ | 0.9979 | $R^2$ | 0.9977 |
| $F-stat.$ | 25647* | $F-stat.$ | 19667* | $F-stat.$ | 6221.7* | $F-stat.$ | 7660* |
| $Normality$ | 2.8355 | $Normality$ | 5.3618 | $Normality$ | 0.3409 | $Normality$ | 0.3285 |
| $\chi^2_{sc}$ | 0.1089 | $\chi^2_{sc}$ | 0.0925 | $\chi^2_{sc}$ | 0.0344 | $\chi^2_{sc}$ | 0.1202 |
| $\chi^2_{het}$ | 13.145 | $\chi^2_{het}$ | 15.961 | $\chi^2_{het}$ | 14.443 | $\chi^2_{het}$ | 13.8491 |
| $RESET$ | 2.0157 | $RESET$ | 2.6292 | $RESET$ | 0.0580 | $RESET$ | 0.6884 |
| $CUSUM$ | Stable | $CUSUM$ | STable | $CUSUM$ | Stable | $CUSUM$ | Stable |
| $CUSUM2$ | STable | $CUSUM2$ | STable | $CUSUM2$ | Stable | $CUSUM2$ | Stable |

**Note:** *, **, *** indicate statistical significance at 1%, 5% and 10% level, respectively. $\chi^2_{sc}$: Serial correlation test of Breusch-Godfrey LM Test, $\chi^2_{het}$: Heteroskedasticity Test of Breusch-Pagan-Godfrey, Normality: Jarque-Bera Test, $R^2$: coefficient of determination, $F-stat.$: overall significance test; $CUSUM$: stability test; $CUSUM2$: $CUSUM$ of squares' stability test; $RESET$: Functional Form test. [§] $ERD_t = \gamma_0 + \sum_{j=1}^{p} \gamma_{1j} ERD_{t-j} + \sum_{j=0}^{q} \gamma_{2j} PRP_{t-j} + u_t$. [§§] $ERD_t = \beta_0 + \sum_{j=1}^{p} \delta_i ERD_{t-j} + \sum_{j=0}^{q} (\theta_j^+ PRP_{t-j}^+ + \theta_j^- PRP_{t-j}^-) + u_t$.

**Table 3: Estimation Results from the Linear and the Asymmetric ARDL Models**

| **Original PPP Model: ERD** $= F(PRP)$ | | | | **Original PPP Model: ERD** $= F(CRP)$ | | | |
|---|---|---|---|---|---|---|---|
| **Linear ARDL(1,3)**[§] | | **NARDL(1,3,2)** [§§] | | **Linear ARDL(6, 5)** | | **NARDL(3, 3, 0)** | |
| Variable | Coefficient | Variable | Coefficient | **Variable** | **Coefficient** | **Variable** | **Coefficient** |
| $ERD(-1)$ | 0.9619*<br>(0.0135) | $ERD(-1)$ | 0.9645*<br>(0.0158) | $ERD(-1)$ | 1.3044*<br>(0.0618) | $ERD(-1)$ | 1.3239*<br>(0.0566) |
| $PRP$ | 2.3265*<br>(0.1028) | $PRP^{+}$ | 2.4492*<br>(0.1218) | $ERD(-2)$ | -0.6105*<br>(0.1038) | $ERD(-2)$ | -0.6059*<br>(0.0897) |
| $PRP(-1)$ | -2.6742*<br>(0.1791) | $PRP^{+}(-1)$ | -3.0243*<br>(0.2105) | $ERD(-3)$ | 0.3667*<br>(0.1110) | $ERD(-3)$ | 0.2393*<br>(0.0564) |
| $PRP(-2)$ | 0.1318<br>(0.1781) | $PRP^{+}(-2)$ | 0.2657<br>(0.2121) | $ERD(-4)$ | -0.201***<br>(0.1105) | $CRP^{+}$ | -0.0758<br>(0.1414) |
| $PRP(-3)$ | 0.2724**<br>(0.1057) | $PRP^{+}(-3)$ | 0.3576*<br>(0.1251) | $ERD(-5)$ | 0.0272<br>(0.0992) | $CRP^{+}(-1)$ | 0.0626<br>(0.1973) |
| $D0401$ | -0.0643*<br>(0.0188) | $PRP^{-}$ | 1.7464*<br>(0.3669) | $ERD(-6)$ | 0.0817<br>(0.0576) | $CRP^{+}(-2)$ | -0.2492<br>(0.1949) |
| $D0891$ | 0.0668*<br>(0.0111) | $PRP^{-}(-1)$ | -1.0194**<br>(0.5132) | $CRP$ | 1.1113*<br>(0.2480) | $CRP^{+}(-3)$ | 0.3669*<br>(0.1379) |
| $D2011$ | -0.0500*<br>(0.0113) | $PRP^{-}(-2)$ | -0.6984***<br>(0.3600) | $CRP$(-1) | -1.8619*<br>(0.3972) | $CRP^{-}$ | 0.2244<br>(0.1650) |
| $CONS$ | 0.0335*<br>(0.0127) | $D0401$ | -0.0636*<br>(0.0185) | $CRP$(-2) | 1.0425**<br>(0.4112) | $D0405$ | 0.1042*<br>(0.0279) |
| | | $D0891$ | 0.0754*<br>(0.0112) | $CRP$(-2) | -0.5961<br>(0.4136) | $D0606$ | 0.1039*<br>(0.0280) |
| | | $D2011$ | -0.0452*<br>(0.0111) | $CRP$(-4) | 0.9787**<br>(0.4046) | $D0810$ | 0.1487*<br>(0.0285) |
| | | $CONS$ | -0.0026)<br>(0.0045) | $CRP$(-5) | -0.6095**<br>(0.2415) | $D1808$ | 0.1883*<br>(0.0280) |
| | | | | $D0405$ | 0.1035*<br>(0.0271) | $CONS$ | -0.0059<br>(0.0041) |
| | | | | $D0606$ | 0.1142*<br>(0.0271) | | |
| | | | | $D0810$ | 0.1236*<br>(0.0278) | | |
| | | | | $D1808$ | 0.1565*<br>(0.0276) | | |
| | | | | $CONS$ | 0.0371*<br>(0.0110) | | |

**Note:** *, **, *** indicate statistical significance at 1%, 5% and 10% level, respectively. [§]$ERD_t = \gamma_0 + \sum_{j=1}^{p} \gamma_{1j} ERD_{t-j} + \sum_{j=0}^{q} \gamma_{2j} PRP_{t-j} + u_t$. [§§]$ERD_t = \beta_0 + \sum_{j=1}^{p} \delta_i ERD_{t-j} + \sum_{j=0}^{q} (\theta_j^{+} PRP_{t-j}^{+} + \theta_j^{-} PRP_{t-j}^{-}) + u_t$.

Estimation Results of Linear and Asymmetric ARDL Models are presented in Table 3. Having established that the diagnostic properties of both linear and nonlinear ARDL forms are verified, we next test for cointegration among relevant variables of PPP models using the bounds testing model of Pesaran et al. (2001). The bounds testing procedure comprises using a modified form of F-test to determine whether the coefficients of the lagged level variables are jointly equal to zero or not. If the F-statistic obtained from the linear and nonlinear ARDL model is higher than the upper bound, we reject the null hypothesis of no cointegration among nominal exchange rate and relative producer (and/or consumer) prices supporting the validity of the PPP hypothesis.

Otherwise, we conclude that the exchange rate and relative producer (and/or consumer) prices have no long-run relationship (no cointegration), and hence the PPP hypothesis does not hold for Turkey. Table 4 presents four different bounds testing results from the linear and nonlinear ARDL models. The first two columns of Table 4 bounds tests related to the first model of PPP with relative producer prices. In the last two columns of Table 4, bounds testing results from the second model of PPP with relative consumer prices are presented. Examination of Table 4 shows that the null hypothesis of no cointegration is rejected in the linear ARDL models since the F-statistics for the first and the second PPP model is lower than 95% upper bound critical value. However, for the Asymmetric ARDL models, we reject the null hypothesis of no cointegration only for the second model with relative consumer prices, but the null hypothesis of no cointegration is not rejected for the second PPP model with relative producer prices.

As explained before, the presence of a cointegration relationship between exchange rate and relative prices is considered evidence for the validity of the PPP hypothesis in the empirical literature. In this sense, the cointegration test results presented in Table 4 send mixed signals and provide more information on the validity of PPP for the Turkish case. The results indicate that the test results related to the PPP hypothesis are very sensitive to the choice of proxies used to represent relative prices. Moreover, the linear and nonlinear econometric techniques provide different results on cointegration depending on which relative prices are used in the empirical analysis, namely producer prices or consumer prices. For these reasons, we cannot decide precisely whether the PPP hypothesis hold for Turkey-based only on the bonds testing results presented in Table 4. One should investigate the short-run and long-run effects of relative prices on the exchange to clarify this point.

**Table 4: Bound Tests for Cointegration in the Linear and the Asymmetric ARDL Models**

| | **Dependent Variable: $ERD = F(PRP)$** | | **Dependent Variable: $ERD = F(CRP)$** | |
|---|---|---|---|---|
| | **Linear ARDL(1,3)** | **NARDL(1,3,2)** | **Linear ARDL (6,5)** | **Asymmetric ARDL (3,3,0)** |
| F-statistics | 4.9240** | 2.9125 | 8.2087* | 8.0030* |
| 95% Lower bound | 3.62 | 3.1 | 3.62 | 3.1 |
| 95% Upper bound | 4.16 | 3.87 | 4.16 | 3.87 |
| Conclusion | Cointegration | No Cointegration | Cointegration | Cointegration |

Note: *, ** indicate significance level at 1% and 5% respectively.

Table 5 presents the results obtained from estimating the conditional error correction form of the PPP models given in equations (5) and (10), making relative producer prices and consumer prices independent variables for each equation. The results show that error correction terms, the coefficient of, are negative and statistically significant in each of the four models suggesting that about 4% of deviations in the short-run will be corrected in each month. The size of the error correction coefficients (about 4%) is quite small, showing that it takes pretty long for changes in exchange rates to adjust to their long-run equilibrium level. The results also show that the level of relative prices (whether it is the producer or consumer prices) in linear ARDL models have a positive and significant effect on the rate of change of exchange rates in the short-run.

However, the change in relative consumer prices has a positive and significant effect on the rate of change in the exchange rate, but change in producer prices has no short-run effect in the linear model.

**Table 5: Dynamics in Linear ARDL and Asymmetric ARDL Models**

| **Conditional Error Correction Regression-Dependent Variable $\Delta ERD$** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Independent Variable: $PRP$ | | | | Independent Variable: $CRP$ | | | |
| **Linear ARDL(1, 3)** | | **NARDL(1, 3, 2)** | | **Linear ARDL(6, 5)** | | **NARDL(3, 3, 0)** | |
| Variable | Coeffic. | Variable | Coeffic. | Variable | Coeffic. | Variable | Coeffic. |
| $CONS$ | 0.0335* (0.0127) | $CONS$ | -0.0026* (0.0045) | $CONS$ | 0.0371* (0.0110) | $CONS$ | -0.0059 (0.0041) |
| $ERD(-1)$ | -0.0381* (0.0135) | $ERD(-1)$ | -0.0355** (0.0158) | $ERD(-1)$ | -0.0315* (0.0111) | $ERD(-1)$ | -0.0427** (0.0171) |
| $PRP$(-1) | 0.0565* (0.0186) | $PRP^{+}(-1)$ | 0.0482** (0.0249) | $CRP$(-1) | 0.0650* (0.0163) | $CRP^{+}(-1)$ | 0.1044** (0.0431) |
| $\Delta ERD$ | 2.3265* (0.1028) | $PRP^{-}(-1)$ | 0.0286* (0.0401) | $\Delta ERD(-1)$ | 0.3359* (0.0607) | $CRP^{-}(-1)$ | 0.2244 (0.1650) |
| $\Delta ERD(-1)$ | -0.4041* (0.1114) | $\Delta PRP^{+}$ | 2.4492* (0.1218) | $\Delta ERD(-2)$ | -0.2746* (0.0643) | $\Delta ERD(-1)$ | 0.3666* (0.0556) |
| $\Delta ERD(-2)$ | -0.2724** (0.1057) | $\Delta PRP^{+}(-1)$ | -0.6233* (0.1325) | $\Delta ERD(-3)$ | 0.0921 (0.0670) | $\Delta ERD(-2)$ | -0.2393* (0.0564) |
| $D0401$ | -0.0643* (0.0188) | $\Delta PRP^{+}(-2)$ | -0.3576* (0.1251) | $\Delta ERD(-4)$ | -0.1098*** (0.0633) | $\Delta CRP^{+}$ | -0.0758 (0.1414) |
| $D0891$ | 0.0668* (0.0111) | $\Delta PRP^{-}$ | 1.7464* (0.3669) | $\Delta ERD(-5)$ | -0.0817 (0.0576) | $\Delta CRP^{+}(-1)$ | -0.1176 (0.1406) |
| $D2011$ | -0.0500* (0.0113) | $\Delta PRP^{-}(-1)$ | 0.699*** (0.3600) | $\Delta CRP$ | 1.1113* (0.2480) | $\Delta CRP^{+}(-2)$ | -0.3669* (0.1379) |
| | | $D0401$ | -0.0636* (0.0185) | $\Delta CRP$(-1) | -0.8156* (0.2479) | $D0405$ | 0.1042* (0.0279) |
| | | $D0891$ | 0.0754* (0.0112) | $\Delta CRP$(-2) | 0.2269 (0.2520) | $D0606$ | 0.1039* (0.0280) |
| | | $D2011$ | -0.0452* (0.0111) | $\Delta CRP$(-3) | -0.3692 (0.2494) | $D0810$ | 0.1487* (0.0285) |
| | | | | $\Delta CRP$(-4) | 0.6095* (0.2415) | $D1808$ | 0.1883* (0.0280) |
| | | | | $D0405$ | 0.1035* (0.0271) | | |
| | | | | $D0606$ | 0.1142* (0.0271) | | |
| | | | | $D0810$ | 0.1236* (0.0278) | | |
| | | | | $D1808$ | 0.1565* (0.0276) | | |

Note: *, **, *** indicate significance level at 1%, 5% and %10 respectively.

In the NARDL models, the results indicate that the impact of both positive ($\mathrm{PRP}^{+}(-1)$) and negative shocks ($\mathrm{PRP}^{-}(-1)$) to relative producer prices on the rate of change in exchange rate ($\Delta$ERD) are statistically significantly and positive suggesting that an increase (decrease) in positive (negative) relative producer prices increase (decrease) the growth rate of exchange rate in the short-run.

However, positive ($\mathrm{CRP}^{+}(-1)$) relative consumer prices have a significant and positive effect on the rate of change in exchange rate ($\Delta$ERD) but negative shocks to consumer prices ($\mathrm{CPRP}^{-}(-1)$) have no significant effect on the rate of change in exchange rate ($\Delta$ERD). The results also confirmed that while there is significant and positive short-run relationship between positive ($\Delta\mathrm{PRP}^{+}$) and negative ($\Delta\mathrm{PRP}^{-}$) change in relative producer prices and change in exchange rate ($\Delta$ERD), there is only significant and positive short-run relationship between positive ($\Delta\mathrm{PRP}^{+}$) change in relative consumer prices and change in exchange rate ($\Delta$ERD).

Table 6 presents the estimation results related to the long-run form of the PPP model given in equations (2) in the linear case and equation (6) in the NARDL case. Examination of the linear ARDL models in Table 6 shows that the coefficient of relative producer prices (relative consumer prices) is positive and statistically significant. When we test whether the null hypothesis that the coefficients of and are equal to 1 using Wald test, we found that while the null hypothesis is rejected for the coefficient of, we failed to reject the null hypothesis for the coefficient of. This implies that the PPP hypothesis holds for Turkey if one uses relative producer prices as an independent variable in their analysis.

Table 6 also presents the long-run effects of both relative producer and relative consumer prices on the exchange rate for an asymmetric ARDL models. The results indicate that the coefficients of positive and negative relative consumer prices are positive and statistically significant, verifying that the effect of relative consumer prices on the exchange rate is asymmetric in the long-run. However, only positive ($PRP^{+}$) relative producer prices seem to have a positive and significant asymmetric effect on the exchange rate in the long-run.

**Table 6: Long-run Effects**

| **Level Equation-Dependent Variable: *ERD*** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Independent Variable- *PRP*** | | | | **Independent Variable- *CRP*** | | | |
| Linear ARDL(1, 3) | | NARDL(1, 3, 2) | | Linear ARDL(6, 5) | | NARDL(3, 3, 0) | |
| Variable | Coefficient | Variable | Coefficient | Variable | Coefficient | Variable | Coefficient |
| $PRP$ | 1.4812* (0.1051) | $PRP^{+}$ | 1.3593* (0.1877) | $CRP$ | 2.0625* (0.2947) | $CRP^{+}$ | 2.4442* (0.3385) |
| $CONS$ | 0.8784* (0.0499) | $PRP^{-}$ | 0.8070 (0.8617) | $CONS$ | 1.1782* (0.1345) | $CRP^{-}$ | 5.2544** (2.4333) |
| | | $CONS$ | -0.0738 (0.1478) | | | $CONS$ | -0.1375 (0.1214) |

Note: *, **, *** indicate significance level at 1%, 5% and %10 respectively.

Table 7 presents the symmetry test results associated with the PPP models with relative producer prices and relative consumer prices given in Equation (10). Table 7 shows that the null hypothesis that the impact of positive and negative relative producer (consumer) prices on the exchange rate is symmetrical in the long-run could not be rejected. The Wald test results in Table 7 shows that positive and negative short-run effects of relative producer (consumer) prices on the exchange rate are asymmetrical, suggesting that the nonlinearity in purchasing power parity only exists in the short-run for both models with relative producer prices and consumer prices.

The symmetry test results also clarify the uncertainty observed in-bounds test results for linear and nonlinear cointegration. The symmetry test results confirmed that nonlinear purchasing power parity is not important for the Turkish case in the long-run.

**Table 7: Long-run and Short-run Symmetry Tests-Wald Test**

| **Panel A: Symmetry tests for the ERD=F(PRP) Model** | | | | | |
|---|---|---|---|---|---|
| | $H_0$ | t-statistic (207) | F-statistic (1,207) | Chi-square (1) | Decision |
| Long-run | $\beta_1^+ = \beta_1^-$ | 0.7857 | 0.6173 | 0.6173 | Symmetric |
| Short-run | $\sum_{j=0}^{q} \theta_j^+ = \sum_{j=0}^{q} \theta_j^-$ | -1.6985*** | 2.8849*** | 2.8849*** | Asymmetric |
| **Panel B: Symmetry tests for the ERD=F(CRP) Model** | | | | | |
| | $H_0$ | t-statistic (209) | F-statistic (1,209) | Chi-square (1) | Decision |
| Long-run | $\beta_1^+ = \beta_1^-$ | -1.2958 | 1.6791 | 1.6791 | Symmetric |
| Short-run | $\sum_{j=0}^{q} \theta_j^+ = \sum_{j=0}^{q} \theta_j^-$ | -2.2080** | 4.8751** | 4.8751** | Asymmetric |

Note: *, **, *** indicate significance level at 1%, 5% and %10 respectively.

## CONCLUSION

PPP hypothesis based on one price theory predicts that there is one to one relationship between change in relative prices and change in exchange rates among two countries. Although the PPP hypothesis has a strong intuition behind it, the empirical evidence does not support it in many cases. For this reason, testing the validity of PPP has always been a hot topic in the empirical literature. Recently, the researcher began to investigate the possible effects of nonlinearities in exchange rate adjustments on testing the PPP hypothesis. Arize and Bahmain-Oskooee (2021) found out that the application of the asymmetric cointegration method increased the number of cointegration between the nominal exchange rate and relative prices to 51 out of 82 countries, including Turkey. This implies that the nonlinear adjustment of relative prices plays an important role in the verification of the PPP hypothesis. This study attempted to examine the long-run relationship between nominal exchange rate and relative prices using the asymmetric ARDL method for Turkey. The results showed that the PPP hypothesis holds for Turkey, but the impact of relative prices on the nominal exchange rate is symmetrical, suggesting that y% increase (or decrease) in relative prices increase (or decrease) nominal exchange rates x%. More importantly, the findings of empirical analysis in this study showed that the PPP hypothesis test results are very sensitive to a number of choices that researchers make while they are undertaking their empirical analysis. The so-called choices are related to the choice of proxies used to represent relative prices (producer price index or consumer price index), the choice about the sample period (whether the sample data includes different exchange rate systems, such as flexible, fixed, or managed floating periods), and whether researchers handle outliers in the dataset adequately.

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