Journal of Economics and Administrative Sciences
esjournal.cumhuriyet.edu.tr | Founded: 2000 Available online, ISSN: 1303-1279 Publisher: Sivas Cumhuriyet Üniversitesi

Research Article

Article Submission Date: 23.07.2025
Article Acceptance Date: 26.11.2025

INVESTIGATING THE VALIDITY OF THE PURCHASING POWER PARITY HYPOTHESIS: THE CASE OF TÜRKİYE

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Abstract: This study aims to test the validity of the Purchasing Power Parity (PPP) hypothesis for Türkiye using monthly data for the period February 2001-July 2024. To this end, the Augmented Dickey-Fuller (ADF) test, a conventional unit root test, and the Fractional Frequency Fourier ADF (FFFADF) test, which can take into account multiple nonlinear structural breaks, are applied. In the analysis, CPI- and D-PPI-based Real Effective Exchange Rates (REERs) as well as CPI-adjusted REER variables for developing and developed countries are analyzed separately. The ADF unit root tests do not provide consistent results on the validity of the PPP hypothesis in Türkiye in the relevant period. Since the ADF test ignores structural breaks, the FFFADF unit root test, which is a more advanced technique, is used to test the validity of the PPP hypothesis with stronger evidence. The FFFADF unit root test results reveal that the PPP hypothesis is valid only for the CPI-based and CPI developed countries-based REER definitions in Türkiye during the analyzed period. This finding implies that the applicability of PPP is highly conditional on the price index and trading partner group used. This concrete and most important impact for the Turkish economy is that the long-run stabilizing feature of the REER supports the effectiveness of the Inflation Targeting Regime, allowing the Central Bank to focus on other policy instruments in the fight against inflation.

Keywords: Purchasing Power Parity Hypothesis, Türkiye, Unit Root Analysis.

JEL Code: C12, C22, F31.

SATINALMA GÜCÜ PARİTESİ HİPOTEZİNİN GEÇERLİLİĞİNİN ARAŞTIRILMASI: TÜRKİYE ÖRNEĞİ

Özet: Bu çalışma, Şubat 2001-Temmuz 2024 dönemine ait aylık veriler ile Türkiye için Satınalma Gücü Paritesi (SGP) hipotezinin geçerliliğini test etmeyi amaçlamaktadır. Bu doğrultuda, geleneksel bir birim kök testlerinden Genişletilmiş Dickey-Fuller (ADF) testi ve çoklu doğrusal olmayan yapısal kırılmaları dikkate alabilen Kesirli Frekanslı Fourier ADF (FFFADF) testi uygulanmıştır. Analizde, TÜFE ve Yİ-ÜFE bazlı Reel Efektif Döviz Kurları (REERs) ile gelişmekte olan ve gelişmiş ülkeler bazında TÜFE ile hesaplanan REER değişkenleri ayrı ayrı incelenmiştir. ADF birim kök testleri, ilgili dönemde Türkiye'de SGP hipotezinin geçerliliği hakkında tutarlı sonuçlar sağlamamaktadır. ADF testi yapısal kırılmaları göz ardı ettiği için, SGP hipotezinin geçerliliğini daha güçlü kanıtlarla test etmek üzere daha gelişmiş bir teknik olan FFFADF birim kök testi kullanılmıştır. FFFADF birim kök testi sonuçları, SGP hipotezinin ilgili dönemde Türkiye'de yalnızca TÜFE bazlı ve TÜFE gelişmiş ülkeler bazlı REER tanımları için geçerli olduğunu ortaya koymaktadır. Bu bulgu, SGP'nin uygulanabilirliğinin kullanılan fiyat endeksine ve ticaret ortağı grubuna göre son derece koşullu olduğunu göstermektedir. Türkiye ekonomisi için bu somut ve en önemli etki, reel efektif döviz kurunun uzun dönemde istikrar sağlayıcı özelliğinin Enflasyon Hedeflemesi Rejiminin etkinliğini desteklemesi ve bu sayede Merkez Bankası'nın enflasyonla mücadelede diğer politika araçlarına odaklanmasına olanak tanımasıdır.

Anahtar Kelimeler: Satınalma Gücü Paritesi Hipotezi, Türkiye, Birim Kök Analizi.

JEL Kodu: C12, C22, F31.

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Introduction

The exchange rate stands as a central subject in economics and finance literature, primarily due to its profound direct and indirect impacts on critical macroeconomic variables. These include international trade equilibrium, national competitiveness, and global capital flows (Krugman and Obstfeld, 2003: 388-395). Among various theories developed to elucidate exchange rate dynamics, the PPP hypothesis is one of the most widely recognized and utilized. This theory posits that exchange rates should adjust to equate the purchasing power of different currencies, effectively neutralizing price level disparities across countries (Dornbusch, 1985: 1).

The PPP hypothesis offers vital insights for policymakers concerning a nation's international competitiveness, the global transmission of inflation, and the long-term viability of its trade balance. It does so by postulating that the real exchange rate tends to revert to its equilibrium mean over time. Consequently, PPP serves as a fundamental guideline for shaping economic strategies and initiatives (Akçay and Erataş, 2015: 82). Furthermore, as the real exchange rate is the primary metric for assessing external competitiveness between economies, the PPP concept holds significant importance in this regard (Şener et al., 2015: 54).

The systematic articulation of the PPP hypothesis is attributed to the Swedish economist Gustav Cassel (1918). Its prominence grew significantly after the dissolution of the fixed exchange rate system of the Bretton Woods era in 1973, which led to increased volatility in real exchange rates among International Monetary Fund member countries (Mussa, 1990: 1-5).

Fundamentally, the PPP hypothesis is rooted in the law of one price, asserting that identical goods should trade at comparable prices globally. This law dictates that in competitive markets, the prices of the same commodities, when expressed in a common currency, must be equivalent across different countries. In essence, the PPP hypothesis translates the fundamental principle of the law of one price into the realm of foreign exchange market analysis (Taylor, 2001: 473-479).

In the economic literature, the PPP hypothesis is typically explored through two distinct frameworks: absolute PPP and relative PPP. According to absolute PPP, a given national currency should command uniform purchasing power worldwide (Sarno and Taylor, 2002: 51). This theoretical stance suggests that while the real exchange rate remains stable in the long run, short-term deviations from this equilibrium are possible. The calculation for absolute PPP is:

$$E_t = \frac{P_t}{P_t^*} \qquad (1)$$

In the equation, (E_t) is the nominal exchange rate, (P_t) is the domestic price level and (P_t*) is the basket of price indices of foreign countries. It is argued that the absolute PPP hypothesis is valid when a country's national currency has the same purchasing power in all countries (Turgut and Uçan, 2024: 345). However, the absolute PPP hypothesis may lose its validity due to the non-homogeneity of many goods and services across countries, the existence of trade restrictions such as quotas and customs duties, administrative regulations and certain transaction costs. Such difficulties have led to the emergence of the relative PPP hypothesis, which is an alternative interpretation of the PPP hypothesis (Kızılkaya and Mike, 2021: 98).

The relative PPP hypothesis posits that the percentage shift in nominal exchange rates ought to correspond precisely to the disparity between percentage changes in domestic and international price levels (Ramsaran, 1998: 102-103). This version of the PPP hypothesis is formulated as:

$$\frac{E_t - E_{t-1}}{E_{t-1}} = \pi_t - \pi_t^* \qquad (2)$$

In the equation, (E_t) is the nominal exchange rate for the current period, (E_{t-1}) is the nominal exchange rate for the previous period, (π_t) is the domestic inflation rate and (π_t*) is the foreign inflation rate (Olaniran and Ismail, 2023). Therefore, according to the equation, the percentage change in nominal exchange rates is equal to the difference of the percentage change in the inflation rates of the two countries (Olaniran and Ismail, 2023).

The long-standing debate concerning the validity of the PPP hypothesis is largely rooted in the presence of various economic and practical impediments that cause deviations from the Law of One Price and impede the mean-reversion of the real exchange rate (Rogoff, 1996: 647-650). These barriers are categorized as trade barriers (tariffs, quotas), non-tradable goods (e.g., housing, services), high transaction costs, and differences in consumption patterns across countries (Obstfeld and Rogoff, 1996). Given these widespread issues, the focus of empirical research has shifted from strictly testing the absolute/relative forms of PPP to investigating the time-series properties of the real exchange rate, specifically testing for mean-reversion, which represents the weak form of the PPP hypothesis (Taylor and Sarno, 1998: 281-286).

According to the PPP hypothesis, the real exchange rate maintains a stable level over the long term. Therefore, the validity of this hypothesis hinges on the real exchange rate's tendency to revert to its mean in the long run, even after short-term fluctuations or deviations (Anoruo et al., 2002: 85-86). Should the real exchange rate fail to converge to its long-term mean, it signals an absence of a sustained relationship between the exchange rate and the respective countries' price levels (Çağlayan and Saçaklı, 2006: 126-127). In simpler terms, if the real exchange rate exhibits a unit root at its level, the PPP hypothesis does not hold, because any deviation would persist indefinitely. Conversely, the PPP hypothesis is considered valid when the real exchange rate is stationary. Consequently, examining the unit root properties of the time series is crucial for determining the applicability of the PPP hypothesis (Ceylan and Ulucan, 2014: 195-196).

This study endeavors to furnish robust empirical evidence regarding the PPP hypothesis's validity in Türkiye by investigating the stationarity characteristics of the REER. The central research inquiry guiding this work is: "Is the PPP hypothesis valid in Türkiye for the February 2001-July 2024 period, utilizing diverse REER definitions and advanced unit root tests?" The chosen analysis period, from February 2001 to July 2024, is particularly relevant as it encompasses a contemporary and extensive timeframe, covering Türkiye's transition to a floating exchange rate regime post-2001 crisis and subsequent significant structural economic transformations. The real exchange rate inherently possesses multiple definitions or forms, contingent upon the specific price index used for its calculation and the selection of comparator countries. For this reason, our analysis disaggregates the study into four distinct REER variables: the Consumer Price Index (CPI)-based REER, the CPI developing countries-based REER, the CPI developed countries-based REER, and the Domestic Producer Price Index (D-PPI)-based REER. This strategic selection of diverse definitions aims to conduct a multidimensional assessment of Türkiye's international competitiveness and the PPP hypothesis's validity. While the CPI-based REER generally reflects a country's international competitiveness through broad price levels, the D-PPI-based REER provides a more direct measure of cost competitiveness in foreign trade, focusing specifically on producer prices. Furthermore, the CPI REER based on developing countries is vital for understanding Türkiye's competitive standing against economies with comparable structures, whereas the CPI REER based on developed countries allows for an analysis of Türkiye's competitive position relative to larger, more integrated global economies. This comprehensive methodology enables a

detailed examination of potential varied dynamics within the real exchange rate and the PPP hypothesis's applicability in Türkiye across different trading partners or economic sectors.

To achieve these objectives, the study employs both the ADF test, a conventional unit root test, and the FFFADF test. The FFFADF test offers enhanced flexibility in modeling multiple and unspecified structural breaks within time series data. While unit root tests do not directly model relationships between variables, they remain a foundational and widely utilized tool for assessing the long-run stationarity of the real exchange rate, which is a core tenet of the PPP hypothesis. Demonstrating the real exchange rate's stationarity serves as compelling evidence for the long-term validity of PPP.

This paper offers distinct and significant contributions to the existing literature. These contributions stem from the broad spectrum of four different real exchange rate definitions utilized, the inclusion of a contemporary and extensive data period, and the unique approach of concurrently applying and comparing both the traditional ADF and the advanced FFFADF unit root tests. Although previous studies have used either the ADF or FFFADF test individually, our comprehensive methodology, which combines a variety of REER definitions with a comparative analysis of these two distinct testing methods, aims to address a gap in the literature by providing more robust and extensive empirical insights into the PPP hypothesis's validity specifically for Türkiye.

This research is structured into five principal sections. Following this introduction, the subsequent section presents a review of the relevant literature concerning the PPP hypothesis. This is succeeded by a segment detailing the dataset and chosen methodology. The empirical findings derived from the econometric analyses are then presented, with the study concluding in a final section that summarizes the outcomes and proposes relevant policy recommendations.

Literature Review

Exchange rates are highly susceptible to direct and rapid influences from both domestic and international economic shocks. This inherent volatility has spurred extensive research into the validity of the PPP hypothesis across the academic literature. Within this context, the following section reviews relevant empirical studies, both national and international, that examine the applicability of the PPP hypothesis.

The empirical literature on the PPP hypothesis is characterized by its wide scope and often contradictory findings, largely driven by the chosen time frame, country sample, and the evolution of econometric techniques. While traditional unit root tests applied to long-span data frequently reject the hypothesis, the adoption of advanced methods, especially those accounting for structural breaks and non-linearity, has substantially increased the evidence supporting PPP.

A significant portion of the literature focuses on the PPP validity in Türkiye, presenting a mixed but generally supportive view, particularly when advanced tests are utilized. Studies by Aydın (2019), Koçak and Özbek (2020), Tolgay and Kula (2020), Uğur (2021), Han (2022), Kar and Pazarcı (2023), and Yardımcı (2024) all find that PPP is valid in Türkiye, primarily by employing Fourier unit root tests (Aydın, 2019; Kar and Pazarcı, 2023), structural break tests (Koçak and Özbek, 2020; Uğur, 2021; Yardımcı, 2024), or non-linear approaches (Han, 2022). Specifically, Koçak and Özbek (2020) find validity using structural break tests covering 1994-2019. Conversely, Özbek (2020) and Yücesan (2021) reject the hypothesis for Türkiye using different methodologies, indicating that the choice of econometric approach is critical. Coşkun (2020), examining five countries including Türkiye, also found the hypothesis valid for Türkiye.

The investigation of PPP across regional groupings and panels tends to provide stronger statistical support, often through the use of non-linear and multiple break-inclusive methodologies. Panel studies across various emerging and developed blocs often find validity: Yıldırım et al. (2019) confirm PPP for ASEAN countries; Ergün-Tatar (2021) for NAFTA, MERCOSUR, and EU15 (except for MERCOSUR); Drissi and Boukhatem (2020) for developed and emerging countries using non-linear adjustment models under transaction costs; Gövdeli and Sumer (2021) for BRICS; Nazlıoğlu et al. (2021) for GIIPS economies using unit root tests with breaks and non-linearity; Hacıimamoğlu (2021) for N-11 countries; and Karademir and Evci (2022) for MIST countries. Even single-country studies in historical contexts, such as Aixalá et al. (2020) for Spain (1868-1914), find evidence in favor of the hypothesis using structural break and non-linear tests.

Recent literature highlights the success of advanced non-linear and non-stationary techniques in capturing the mean-reversion of real exchange rates. Omay et al. (2020) found PPP valid in most OECD countries using ESTAR-type non-linearity models. The application of the Fourier Quantile unit root test has been successful in studies covering diverse samples, including ASEAN-5 (Bahramian and Saliminezhad, 2021), developed, frontier, and developing market economies (Doğanlar et al., 2021), and OECD countries (Kızılkaya and Mike (2021); Uğur and Alper (2023)). Furthermore, Choji and Sek (2023) and Aydın and Zeren (2023) confirm PPP validity in developed and OECD countries using cointegration and RALS Fourier KPSS tests, respectively. Kardaşlar (2023), using Fourier KPSS tests on fragile economies including Türkiye, found evidence supporting the PPP hypothesis in all countries. However, evidence remains mixed even with these advanced tools; Karaoğlu (2022) rejects PPP for 10 OECD countries, and Nazlıoğlu et al. (2022) find rejection only for Kuwait in a 27-country developing sample.

Finally, studies focusing on specific geographical or economic groupings also find supporting evidence, such as Kasem and Al-Gasaymeh (2022) for a group of Middle Eastern economies using cointegration, and Turgut and Uçan (2024) for E-7 countries.

The notable heterogeneity in the PPP empirical findings, especially the conflicting evidence for Türkiye (where some studies find validity and others reject it), necessitates a deeper consideration of the underlying economic factors beyond mere econometric differences. Firstly, data frequency and sample period play a critical role; studies covering periods of high exchange rate volatility, such as those encompassing the 2001 financial crisis or recent periods of high inflation and capital flow instability in Türkiye, are more likely to reject stationarity (e.g., Özbek, 2020). Secondly, the type of price index used affects the result (CPI and PPI), as non-tradable components in the CPI tend to bias the real exchange rate towards non-stationarity, especially in developing economies.

Furthermore, since political instability or major regime changes can cause permanent deviations, the inclusion or exclusion of structural breaks is of vital importance. Therefore, conflicting results do not stem solely from statistical anomalies but generally reflect real differences in the speed and mechanism of price adjustments specific to the period or country group being analyzed.

In light of this extensive literature, which often yields conflicting results depending on the methodology chosen, this study makes an important contribution by using a robust FFFADF test against multiple, unspecified structural breaks in four different REER definitions for Türkiye, covering the critical post-2001 period up to 2024.

Data and Methodology

To assess the validity of the PPP hypothesis, determining the stationarity properties of the relevant time series is of critical importance. Particularly in the context of the PPP hypothesis, the stationarity of the REER indicates that exchange rate shocks are temporary and that the exchange rate returns to its long-term equilibrium in the long run. This is a theoretical prerequisite for the PPP to be valid in the long run (Taylor and Taylor, 2004). Non-stationarity of the series, on the other hand, indicates that shocks are permanent and that the hypothesis is rejected. To this end, the study uses two different unit root tests in the context of the Turkish economy: the ADF test, which is a traditional approach, and the FFFADF test, which is a newer generation unit root test.

The dataset for Türkiye's economy comprises four key REER variables: the CPI-based REER, the CPI for developing countries-based REER, the CPI for developed countries-based REER, and the D-PPI-based REER. All these monthly series were sourced from the Electronic Data Distribution System of the Central Bank of the Republic of Türkiye (CBRT, 2024). Covering the period from February 2001 to July 2024, our analysis includes a total of 282 observations. Data prior to February 2001 were excluded due to the significant financial crisis Türkiye experienced in that month, which led to a fundamental shift in the exchange rate regime (Koch and Chaudhary, 2001).

ADF Unit Root Test

Unit root tests are an important tool for understanding whether time series variables are stationary. The Dickey-Fuller (DF) unit root test, introduced by Dickey and Fuller (1979), was later developed into the ADF unit root test in 1981, finding a wider range of applications. The ADF test statistic is calculated using the following equations (Enders, 1995: 222);

$$\Delta Y_t = \delta Y_{t-1} + \sum_{j=2}^{p} \beta_j \, \Delta Y_{t-j+1} + \varepsilon_t \qquad (3)$$

$$\Delta Y_t = \alpha_0 + \delta Y_{t-1} + \sum_{j=2}^{p} \beta_j \, \Delta Y_{t-j+1} + \varepsilon_t \qquad (4)$$

$$\Delta Y_t = \alpha_0 + \delta Y_{t-1} + \alpha_{2^t} + \sum_{j=2}^{p} \beta_j \, \Delta Y_{t-j+1} + \varepsilon_t \qquad (5)$$

The model numbered (3), model numbered (4), model numbered (4) and model numbered (5) are used in stationarity tests with constant and trended effects (Enders, 1995: 222). The unit root data obtained through these models are determined according to the MacKinnon critical values of 1%, 5% and 10% significance levels. In terms of hypotheses, if the H_0 hypothesis can be rejected, the variable is stationary.

The null hypothesis (H_0: $\delta = 0$) indicates that the series is non-stationary, that is, it contains a unit root, while the alternative hypothesis (H_1: $\delta < 0$) indicates that the variable is stationary and does not contain a unit root (Uğur, 2021: 231).

FFFADF Unit Root Test

In the light of the difficulties encountered in the stationarity analysis of time series and recent solutions to these difficulties, econometric methods are chosen in this study. The ADF test, which is one of the traditional unit root tests, may give misleading results when it cannot

model nonlinear structural changes and breaks at unknown times. Specifically, the test's power drastically decreases when the true data generating process includes smooth shifts or multiple breaks, leading to a high probability of incorrectly accepting the null hypothesis of a unit root (Perron, 1989; Taylor, 2006). The FFFADF test, which was developed to overcome this shortcoming, has the capacity to capture multiple, unknown-time, nonlinear structural breaks and various nonlinear trends in the series more flexibly and accurately by incorporating fractional frequency Fourier functions into the model (Lee, 2014: 507-508). This makes the FFFADF test a more powerful and reliable tool than the ADF test in analyzing complex time series dynamics. Therefore, in addition to the ADF test, which represents the traditional approaches, the FFFADF test provides more accurate and robust results on the stationarity of the real exchange rate and offers more reliable inferences on the validity of the PPP hypothesis.

Pierre Perron (1989) pioneered the concept of structural breaks, highlighting that overlooking these shifts could lead to unit root tests incorrectly failing to reject the null hypothesis of a unit root. Subsequent unit root tests, developed by scholars like Perron (1989), Zivot and Andrews (1992), and Lee and Strazicich (2003), aimed to address this limitation. However, as these tests typically account for structural breaks through dummy variables, they are primarily designed to capture sharp, discrete changes (Lee and Strazicich, 2003: 1082). Consequently, to better identify smooth transitions and gradual transformations rather than sharp breaks, the literature saw the emergence of Fourier-based unit root tests. These methods allow for an indeterminate number of previously unknown functional structural breaks. The Fourier ADF unit root test, in particular, accommodates a range of smooth changes whose number, exact location, or specific form do not compromise the test's efficiency (Konat et al., 2022: 578-579).

More recently, in the relevant literature, Bozoklu et al. (2020) introduced the FFFADF unit root test. This test builds upon the methodology initially proposed by Enders and Lee (2012). Bozoklu et al. (2020) specifically enhanced the FFFADF unit root test by incorporating non-integer, fractional values for frequencies into the model. This distinguishing characteristic, allowing for fractional frequency numbers, sets the FFFADF test apart from Enders and Lee's (2012) original framework. The Fourier ADF test statistic is derived using the following equations (Bozoklu et al., 2020: 5):

$$\Delta Y_t = \delta_0 + \delta_1 \sin\left(\frac{2\pi kt}{T}\right) + \delta_2 \cos\left(\frac{2\pi kt}{T}\right) + \delta_3 Y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + \varepsilon_t \qquad (6)$$

In the aforementioned equation, (t) represents the trend component, (T) signifies the total number of observations, and π is approximated as 3.1416. The variable (k) denotes a specific frequency, while (p) indicates the optimal lag length. Bozoklu et al. (2020) employed the Akaike Information Criterion to determine the appropriate lag length. Following Omay's (2015) methodology, they selected the optimal frequency value ($\tilde{k}$), which yielded the smallest sum of squares within the range of [0.1, 0.2, ..., 5]. To assess for nonlinearities, the null hypothesis that $\delta_1 = \delta_2 = 0$ is evaluated using an F-test. The statistical significance of δ_3 is then examined to test the null hypothesis of a unit root. Omay (2015) initially developed a test allowing for fractional frequencies within the range of k=[0.1,0.2,0.3,...,2]. Bozoklu et al. (2020) subsequently expanded this frequency range to k=[0.1,0.2,...,5] and derived corresponding critical values through Monte Carlo simulations. By comparing the calculated test statistics against these critical values, researchers can determine whether the series under analysis contains a unit root (Konat et al., 2022: 578-579).

Whether structural breaks are temporary or permanent depends on whether the frequency value is integer or fractional. A fractional frequency value means that structural breaks are permanent, while an integer value means that structural breaks are temporary (Yılancı et al., 2022: 9-10).

Empirical Findings

This study investigates the validity of the PPP hypothesis for Türkiye using monthly data spanning from February 2001 to July 2024. We separately analyze the CPI-based REER, CPI developing and developed countries-based REER's, and D-PPI-based REER variables with both the ADF and FFFADF unit root tests. This section first presents the descriptive statistics for these variables, followed by the results from the ADF and FFFADF unit root tests for both constant, and constant and trend models.

Table 1. Descriptive statistics of variables

	CPI-Based REER	CPI REER Based on Emerging Economies	CPI REER Based on Developed Countries	D-PPI-Based REER
Mean	94.29202	82.6227	102.4367	96.13986
Median	101.18	86.575	107.97	98.47
Maximum	127.71	115.93	137.85	116.95
Minimum	47.61	38.85	54.35	66.83
Std. Dev.	21.40191	21.38584	22.04471	12.0384
Skewness	-0.59682	-0.49702	-0.45531	-0.31972
Kurtosis	2.147376	2.066526	2.002943	2.151047
Jarque-Bera	25.28284	21.84884	21.42418	13.27291
Probability	0.000003	0.000018	0.000022	0.001312
Sum	26590.35	23299.6	28887.16	27111.44
Sum Sq. Dev.	128709.8	128516.5	136557.3	40723.39
Observation	282	282	282	282

Table 1 displays the descriptive statistics for the four distinct REER series used to assess the PPP hypothesis. An examination of these statistics for Türkiye's CPI-based REER, the CPI-based REERs for both developing and developed countries, and the D-PPI-based REER reveals that the CPI-based REER for developed countries consistently exhibits the highest mean value.

The mean CPI-based REER for developed countries is successively followed by the D-PPI-based REER, the overall CPI-based REER, and lastly, the CPI-based REER for developing economies. A similar analysis of the maximum observed values, however, presents a different ranking. Here, the CPI-based REER for developed countries still holds the top position. It's then followed by the overall CPI-based REER in second place, the D-PPI-based REER in third, and finally, the CPI-based REER for developing countries in fourth.

Table 2. ADF unit root test results for the constant model

	ADF Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability Value
CPI-Based REER	-0.97998	-3.45365	-2.87169	-2.57225	0.7609
CPI REER Based on Emerging Economies	-0.53069	-3.45382	-2.87177	-2.57229	0.8817
CPI REER Based on Developed Countries	-1.24945	-3.45365	-2.87169	-2.57225	0.6534
D-PPI-Based REER	-2.52722	-3.45365	-2.87169	-2.57225	0.1101

Table 2, which presents the results of the ADF unit root test for the model incorporating a constant, clearly indicates that all analyzed series contain unit roots. The non-stationarity of the REER at its level is evident, as the absolute value of the ADF test statistic consistently falls below the critical table values across all significance levels. Consequently, these findings suggest that, based on all the REER variables examined, the PPP hypothesis is not valid in Türkiye.

Table 3. FFFADF unit root test model results with constant

	Frequency	Min SSR	F Test Statistics	Optimal Lag	FFFADF Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value
CPI-Based REER	0.8	3033.385	11.41988	15	-3.79368*	-4.39964	-3.85091	-3.56637
CPI REER Based on Emerging Economies	0.7	2551.607	7.682797	15	-3.02797	-4.43385	-3.88873	-3.59585
CPI REER Based on Developed Countries	0.8	3625.306	16.27015	15	-4.84095***	-4.39964	-3.85091	-3.56637
D-PPI-Based REER	1	2706.756	7.898873	15	-3.2975	-4.31227	-3.75622	-3.45668

Note: * and *** Critical values indicate 10% and 1% significance level, respectively.

Table 3 shows the outcomes of the FFFADF unit root test for the model incorporating a constant term. An analysis of these findings reveals that the CPI-based REER has a calculated FFFADF test statistic of -3.79. Since this value is statistically significant at the 10% level, this result represents weak evidence for stationarity and indicates that the PPP hypothesis is supported to a limited extent for this specific REER definition. Conversely, when examining the CPI-based REER for developed countries, the test statistic shows even stronger significance, at the 1% level. This finding indicates that the PPP hypothesis is strongly supported in Türkiye when using the REER variable derived from developed countries' CPI. However, the results for the CPI-based REER for developing countries and the D-PPI-based REER tell a different story; both variables are found to contain a unit root, signifying their non-stationary nature. Consequently, based on these two REER variables, the PPP hypothesis is not valid in Türkiye.

Table 4. ADF unit root test model results with constant and trend

	ADF Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value	Probability Value
CPI-Based REER	-2.73348	-3.99129	-3.42601	-3.1362	0.224
CPI REER Based on Emerging Economies	-3.30239*	-3.99153	-3.42613	-3.13627	0.068
CPI REER Based on Developed Countries	-2.4168	-3.99129	-3.42601	-3.1362	0.37
D-PPI-Based REER	-3.60328**	-3.99129	-3.42601	-3.1362	0.0313

Note: * and ** Critical values indicate 10% and 5% significance level, respectively.

Table 4 presents the findings from the ADF unit root test applied to the model incorporating both a constant and a trend. For the CPI-based REER for developing economies, the calculated ADF test statistic is -3.30, which is statistically significant at the 10% level. This result suggests weak evidence for stationarity and indicates that the PPP hypothesis is supported to a limited extent for this REER definition. Conversely, the D-PPI-based REER exhibits an

ADF test statistic of -3.60, which is significant at the stronger 5% level. As the absolute values of both test statistics exceed the critical values, we conclude that these two series do not contain a unit root, with the D-PPI result providing a more robust finding. Conversely, the CPI-based REER and the CPI-based REER for developed countries variables are found to contain unit roots. Consequently, according to these two REER variables, the PPP hypothesis is not valid in Türkiye.

Table 5. FFFADF unit root test model results with constant and trend

	Frequency	Min SSR	F Test Statistics	Optimal Lag	FFFADF Test Statistics	1% Critical Value	5% Critical Value	10% Critical Value
CPI-Based REER	0.2	2999.658	9.612307	15	-4.1603*	-4.74122	-4.20078	-3.9215
CPI REER Based on Emerging Economies	0.1	2498.981	4.389358	15	-3.47036	-4.76837	-4.21683	-3.93332
CPI REER Based on Developed Countries	0.8	3621.044	12.85188	15	-4.66378**	-4.80277	-4.26329	-3.98427
D-PPI-Based REER	0.1	2634.641	7.649963	15	-3.62138	-4.76837	-4.21683	-3.93332

Note: * and ** Critical values indicate 10% and 5% significance level, respectively.

Table 5 shows the results of the FFFADF unit root test for the model that includes both a constant and a trend. Upon analyzing these findings, the FFFADF test statistic for the CPI-based REER is found to be -4.16, a value that is statistically significant at the 10% level. This result represents weak evidence for stationarity and indicates that the PPP hypothesis is supported to a limited extent for this specific REER definition. Conversely, the CPI-based REER for developed countries yields an FFFADF test statistic of -4.66, achieving significance at the stronger 5% level. This finding provides more robust support for the validity of the PPP hypothesis in Türkiye when using the REER derived from developed countries' CPI. However, a different outcome is observed for the CPI-based REER for developing economies and the D-PPI-based REER variables. For these series, the calculated FFFADF test statistics are smaller in absolute value than the critical table values across all significance levels. This implies that these series contain unit roots and are thus non-stationary. Consequently, based on these two REER variables, the PPP hypothesis is found to be invalid in Türkiye.

Conclusion and Policy Recommendations

In this study, the validity of the PPP hypothesis for the Turkish economy with monthly data covering the period February 2001-July 2024 is analyzed using both the ADF test, a conventional unit root test, and the advanced FFFADF test. The analysis reveals that there is a complex picture regarding the validity of the PPP hypothesis in the literature on Türkiye. While studies such as Özbek (2020), Yücesan (2021) and Karaoğlu (2022) find that the PPP is not valid for Türkiye, many studies including Aydın (2019), Aixalá et al. (2020), Koçak and Özbek (2020), Tolgay and Kula (2020), Kasem and Al-Gasaymeh (2022), Choji and Sek (2023), Kar and Pazarcı (2023) and Yardımcı (2024) support the validity of PPP with different econometric methods. These results reflect a general trend that the PPP is valid in the long run in Türkiye, especially when tests that account for structural breaks are used.

In the empirical analysis, mixed results were obtained regarding the validity of the PPP hypothesis for Türkiye, highlighting the need for robust testing methods. While the conventional ADF unit root test yielded inconsistent and ambiguous findings across different model specifications and REER definitions, the FFFADF unit root test, employed as a more robust technique, provided clearer evidence. The FFFADF findings indicated that the CPI-based REER and CPI developed countries-based REER variables do not contain a unit root, thereby confirming the PPP hypothesis's validity in Türkiye for these definitions. Conversely, the FFFADF test results consistently showed that the CPI emerging economies-based REER and D-PPI-based REER variables continued to contain unit roots, implying non-stationarity. These findings collectively demonstrate that the applicability of the PPP hypothesis in Türkiye is highly variable, primarily determined by the base price index used to calculate the real exchange rate, and the country group against which Türkiye's competitiveness is measured.

The main finding of the study based on the FFFADF tests is that the PPP hypothesis is valid in Türkiye for some REER definitions. This implies that short-run shocks to the real exchange rate are transitory and tend to revert to the mean in the long run. This finding has important economic, financial and policy implications for the Turkish economy. From an economic perspective, the tendency of the real exchange rate to revert to equilibrium in the long run implies that short-term shocks do not cause permanent deterioration in prices and national competitiveness. This supports a more predictable economic environment in terms of price stability, trade balance and overall competitiveness. The real exchange rate's stabilization feature provides a more secure investment and trade environment for economic actors by showing that Türkiye's position in international trade depends on structural factors rather than temporary fluctuations. On the financial front, the expectation that temporary fluctuations in the exchange rate will stabilize in the long run significantly reduces uncertainty for domestic and international investors. This provides a more stable basis for long- term investments and capital flows, reducing the risk of the real exchange rate remaining overvalued or undervalued. Therefore, it contributes to a more manageable volatility in financial markets and increases the country's potential to attract external resources.

For policymakers, the validity of the PPP hypothesis implies a reduced need to continuously manipulate or over-control the exchange rate. Especially under the Inflation Targeting Regime implemented in Türkiye, it is of great importance that the real exchange rate is stable in the long run. This is because short-term deviations in the real exchange rate are not permanent in the long run, which prevents inflationary or deflationary pressures from feeding into the exchange rate. This increases the capacity of the Central Bank of the Republic of Türkiye (CBRT) to achieve its inflation targets and supports the effectiveness of monetary policy. The tendency for the real exchange rate to revert to the mean gives the monetary authority more room for maneuver in the fight against inflation, reducing the need to use the exchange rate as an anchor and allowing it to focus on other policy instruments such as interest rates.

In order to ensure macroeconomic stability and determine foreign trade strategies, policymakers need to implement policies that support investment, reduce external dependence and increase domestic production in light of the findings. The positive effects of such structural policies on real competitiveness could easily be neutralized by permanent exchange rate movements if the real exchange rate were to exhibit persistent deviations. The validity of the PPP increases the potential for such structural policies to deliver their intended results without being hampered by persistent real exchange rate imbalances. In this way, the effectiveness of the economic policies to be implemented will also gain importance. Therefore, the CBRT needs to set its intermediate targets well in order to effectively utilize the broad package of measures and instruments at its disposal.

Author contribution ratio

All processes of this study (design, data collection, analysis, writing, and editing) were carried out by İY.

Ethics committee approval

No ethics committee approval is required for this study.

Conflict of interest statement

There is no conflict of interest with any person/institution in this study.

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