REVISITING THE PURCHASING POWER PARITY PRINCIPLE: AN EMPIRICAL ASSESSMENT FOR 163 ECONOMIES

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ABSTRACT

The paper examines the validity of the Purchasing Power Parity (PPP) principle, which dominates the discussion of Real Exchange Rates (RERS) and international trade policies. We employ a range of unit root tests on both time series and panel data to evaluate the stationarity properties of the real effective exchange rates for 163 economies grouped according to their level of development into developed, emerging, and low-income economies. For time series analysis, we use linear unit root tests with and without a structural break, and nonlinear unit root tests. To enhance the analysis, we additionally employ two first-generation panel unit root tests, as well as a second-generation unit root test. The empirical evidence aligns with the wide-ranging body of literature that discards the PPP as an effective analytical framework for explaining the behavior of RERS and for designing trade policy proposals.

Keywords: purchasing power parity, real exchange rates, unit root tests for panel, time series data.
JEL Classification: C22, C23, F31, F40.

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REEVALUANDO LA PARIDAD DEL PODER ADQUISITIVO:
EVIDENCIA EMPÍRICA PARA 163 ECONOMÍAS

RESUMEN

El presente estudio examina la validez empírica del principio de la paridad del poder adquisitivo (PPA), el cual constituye un marco teórico fundamental en el análisis de los tipos de cambio reales y las políticas comerciales internacionales. Se aplican diversas pruebas de raíz unitaria, tanto en series temporales como en datos de panel, para evaluar las propiedades de estacionariedad de los tipos de cambio reales efectivos de 163 economías, agrupadas según su nivel de desarrollo: desarrolladas, emergentes y de bajos ingresos. El análisis incluye pruebas lineales con y sin ruptura estructural, así como pruebas no lineales y de primera y segunda generación en panel. Los resultados empíricos coinciden con una amplia literatura que cuestiona la validez de la PPA, al mostrar escasa evidencia de estacionariedad en los tipos de cambio reales, particularmente en las economías desarrolladas, y un mayor grado de verificación en las economías de bajos ingresos.

Palabras clave: paridad del poder adquisitivo, tipos de cambio reales, pruebas de raíz unitaria, datos de panel.

Clasificación JEL: C22, C23, F31, F40.

1. INTRODUCTION

The prevailing theory of international trade and real exchange rates (RERS) determination is based on the principle of the Purchasing Power Parity (PPP) according to which the nominal exchange rates $e_{i/j}$ adjust in a way so as to equilibrate the relative price levels, p_i and p_j, between two trading partner-economies, i and j. That is, the price levels of the two economies (p_i/p_j) converge, at least in the long run, meaning that their nominal and RERS become eventually identical. Econometrically, this implies that the RERS must display stationarity properties.

The PPP, proposed by Cassel (1918; 1922), is founded on: the Law of One Price according to which free-trade ensures equal prices for iden-

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tical goods in different countries (Taylor and Taylor, 2004)[1]; and on the assumption that consumers' preferences are identical and homothetic as well the baskets of consumer goods across the various trade partners-economies. Specifically, the PPP posits that free-trade mechanism serves to equalize price levels between trading partners; that is, if a consumer basket is less expensive in one country, the demand will rise and prices will eventually increase. Such market-driven adjustments lead to price parity for the same consumer basket when expressed in a common currency and the RERs adjust to ensure that the countries become equally price-competitive. Nevertheless, considering the historical, cultural, technological, and climatic differences, the equalization of prices across different countries becomes a complex and most likely an uncertain scenario.

Expressing the above in econometric terms, the RER ought to be a stationary variable and, within the relevant literature, this exacting property has been the subject of intense empirical and theoretical analysis. Some scholars argue that stationarity in RERs, if present, manifests itself only over extra ordinarily protracted periods, such as 75 to 100 years (Froot and Rogoff, 1995), and the convergence of the price levels expressed in common currency are extremely slow (Rogoff, 1996). Others, being supported by a bulk of empirical findings, assert that the RERs essentially lack stationarity (Wang, 2000; Basher and Moshin, 2004; Bekő and Boršič, 2007; Boundi-Chraki and Tomé, 2022).

More recently, Stewart (2025) shows that the ARDL bounds testing approach can detect long-run relationships even when the dependent variable is stationary (I(0)). Using this framework, the study examines the validity of PPP and the Law of One Price, finding mixed empirical support for both hypotheses. Similarly, Goh *et al.* (2025) provide updated evidence on PPP in developed economies using a newly developed multivariate ARDL unit-root test, concluding that PPP does not hold.

Rogoff (1996, p. 647), in an effort to explain the meager empirical evidence on PPP premises, presented the 'PPP puzzle' and argues that

[1] The PPP can be traced back to the School of Salamanca in Spain during the 16th century. Nevertheless, the Swedish economist Gustav Cassel (1918) formalized the PPP theory and coined the term (Humphrey, 1979; Officer, 1982).

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the RERs are volatile in the short run due to financial factors, while their adjustment process is extremely slow in the long run. Nevertheless, how can one reconcile the significant volatility of the RERs in the short run with the very slow pace at which deviations from PPP seem to dissipate in the long run? Furthermore, he stated that the observed 'irregularities' of its behavior may be attributed to macroeconomic factors, such as productivity gap between tradable and non-tradable sectors (the Balassa-Samuelson effect), government spending, and current account balances. Taylor and Taylor (2004) expanded the list of factors influencing the RERs by including the relative size of non-tradable goods, transaction costs, heterogeneous composition of goods, etc. Nevertheless, Obstfeld and Rogoff (2000) argued for the inability of macroeconomic aggregates to explain the behavior of the RERs and stated that the 'PPP puzzle' is actually just an example of the broader 'exchange-rate disconnect puzzle' which refers to the disconnection of exchange rates from the fundamental macroeconomic variables[2]. In this light, many studies came to the conclusion that a random walk process might explain better the behavior of RERs (Meese and Rogoff, 1983; Cheung, Chinn, and Pascual, 2005).

Taylor and Taylor (2004) changed the narrative by invoking to Heckscher (1916), who was the first to suggest that the adjustment process is nonlinear. The 'rediscovery' of Heckscher's work initiated an extensive literature that uses nonlinear methods and/or structural breaks to validate the PPP principle (Obstfeld and Taylor, 1997; Taylor, Peel, and Sarno, 2001; Christidou and Panagiotidis, 2010; Cuestas and Regis, 2013; Bahmani-Oskooee, Chang, and Lee, 2016; Omay, Shahbaz, and Hasanov, 2020). Although the results of nonlinear tests are more supportive to the PPP hypothesis, there is also a plethora of studies that reject it (Acaravci and Ozturk, 2010; Liu, Zhang, and Chang, 2012; Chang and Tzeng, 2013; Karagöz and Saraç, 2016; Boundi-Chraki and Tomé, 2022; Poulakis and Kyrkilis, 2025). Thus, the relative literature, although

[2] The relative real unit labor cost of tradable goods, adjusted by the tradable-to-non-tradable price ratio, consistently shows strong results (Poulakis and Tsaliki, 2022, 2023; Boundi-Chraki, 2019; Boundi-Chraki and Perrotini-Hernández, 2021; Shaikh and Antonopoulos, 2013). Its theoretical foundation lies not in the PPP hypothesis but in classical political economy, which predicts RER stability only if a country's global competitiveness remains unchanged, rare given the dynamic nature of international trade.

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rich in methodologies and techniques, has not shed further light on the issue at hand and the soundness of the PPP principle is still under query.

The present paper aims to contribute to the extant literature by examining the empirical validity of the PPP principle which penetrates the discussions of RERs and international trade policies. We use a variety of unit root tests on time series and panel data to assess the stationarity properties of the Real Effective Exchange Rates (REERs) for 163 economies. Specifically, for time series analysis, we apply the commonly used Augmented Dickey-Fuller (Said and Dicky, 1984) and Phillips and Perron (1988) linear unit root tests. We also employ the Zivot and Andrews (2002) unit root test with a structural break, as well as the nonlinear unit root test proposed by Kapetanios, Shin, and Snell (2003). In addition, we apply two first-generation unit root tests proposed by Maddala and Wu (1999) and Levin, Lin, and Chu (2002), as well as a second-generation unit root test proposed by Pesaran (2007).

The structure of the paper is as follows: section 2 briefly analyzes the econometric tests applied for checking stationarity properties and presents the sources of data. Section 3 reports the results of the empirical analysis. Finally, Section 4 concludes and makes suggestions for further research.

2. UNIT ROOT TESTS, DATA SOURCES AND CLUSTERING OF ECONOMIES

2.1. Methodological issues: unit root tests

In the extant literature, the potency of the PPP principle is examined through the stationarity properties of the RERs; its main theoretical premise argues that the price levels of two economies converge in the long run while their nominal and RERs become eventually identical. Hence, in what follows we examine the extent to which the price levels for the same consumer basket, expressed in a common currency, converge between the trading partners-economies. We do that by applying several unit root tests on time series and panel data.

In our empirical investigation, we examine three cases based on whether the regression includes a constant, a constant and a trend, or neither. When a trend is included, the alternative hypothesis posits trend stationarity which implies that the deviations from the deterministic trend are stationary. It is important to note that the inclusion of a trend

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is consistent with neither the absolute nor the relative version of the PPP theory. However, many studies have introduced a time trend into their models to account for factors that contribute to deviations from PPP, such as the Balassa-Samuelson effect (Papell and Prodan, 2006; Taylor, 2002)[3]. This approach is commonly referred in the literature as the Trend PPP (TPPP).

2.1.1. Unit root tests on time series

We begin the empirical analysis by applying unit root tests to RER time series to assess their stationarity. Initially, we employ the commonly used Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) linear unit root tests. Considering potential structural breaks, and in light of the aforementioned literature, we also apply the Zivot-Andrews (ZA) test, which allows for a unit root in the presence of a single structural break. Moreover, in line with theoretical and empirical evidence of nonlinear behavior in the RER, we also employ the Kapetanios-Shin-Smith (KSS) nonlinear unit root test, where the null of a unit root is tested against a globally stationary Exponential Smooth Transition Autoregressive (ESTAR) process. We next briefly present the ZA and KSS tests.

The Zivot-Andrews unit root test with structural change. The ZA test takes into account an endogenously defined structural change in a time series data that may occur for several reasons and its impact may affect the stationarity properties of the variable under examination. Three different models depending on whether the structural change is related to constant, trend or both simultaneously are examined:

$$\Delta y_t = \alpha + \gamma t + \beta y_{t-1} + \psi D c_t + \sum_{j=1}^{k} b_j \Delta y_{t-j} + e_t \qquad [1.a]$$

[3] Balassa (1964) and Samuelson (1964) argued that Cassel's version of PPP didn't adequately capture the complexities of the RERS. They argued that international productivity disparities influence domestic wages and prices of home goods, which could, in turn, cause persistent variations from the standard PPP model. Hence, these productivity gaps among nations directly impact their domestic costs of non-tradable goods and, over time, result in consistent drifting away from the PPP equilibrium.

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$$\Delta y_t = \alpha + \gamma t + \beta y_{t-1} + zDt_t + \sum_{j=1}^{k} b_j \Delta y_{t-j} + e_t \qquad [1.b]$$

$$\Delta y_t = \alpha + \gamma t + \beta y_{t-1} + \psi Dc_t + zDt_t + \sum_{j=1}^{k} b_j \Delta y_{t-j} + e_t \qquad [1.c]$$

Where Dc_t and Dt_t are pseudo-variables used to control the structural change in the constant and trend, respectively, defined as:

$$Dc_t = \begin{cases} 1, & if \ t > t_B \\ 0, & \text{for remaining } t \end{cases} \text{ and } Dt_t = \begin{cases} t - t_B & if \ t < t_B \\ 0, & \text{for remaining } t \end{cases}$$

Where t_B is the time-moment of the structural change.

The null hypothesis H_0: $\beta = 0$ states that y_t has a unit root on top of the assumed structural break. The hypothesis H_1: $\beta < 0$ states that there is stationarity with structural change. The structural change occurs at that time when the statistic of the null hypothesis is at its minimum.

Kapetanios, Shin and Smith nonlinear unit root test. The KSS unit root test is used against an alternative hypothesis, which proposes a globally stationary process defined as an Exponential Smooth Transition Autoregressive (ESTAR) model. The following ESTAR model is applied:

$$\Delta y_t = b y_{t-1} \mathrm{F}\left(\theta; y_{t-\delta}\right) + e_t \qquad [2]$$

Where y_t is the time series and can be demeaned or detrended, $t = 1,\ldots,T$ is the total number of observations, e_t is the error term following an independent and identical distribution with 0 mean and variance σ^2, b and σ^2 are unknown parameters and $\mathrm{F}(\theta; y_{t-\delta})$ is an exponential transition function to present the nonlinear adjustment, such as:

$$\mathrm{F}\left(\theta; y_{t-\delta}\right) = 1 - \exp\left(-\theta y_{t-1}^2\right) \qquad [3]$$

Where $\theta \geq 0$ is the slope parameter and $\mathrm{F}(\theta; y_{t-\delta})$ is a symmetric U-shaped function around zero. Substituting relation [2] into relation [1] gives the following ESTAR model:

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$$\Delta y_t = b y_{t-1}\left[1 - \exp\left(-\theta y_{t-1}^2\right)\right] + \varepsilon_t \quad [4]$$

If $\theta > 0$, then it effectively determines the speed of mean reversion. The null hypothesis, H_0: $\theta = 0$, support that y_t exhibits a linear unit root behavior while under the alternative hypothesis, H_1: $\theta > 0$, y_t follows a globally stationary ESTAR process. However, the null hypothesis cannot be tested since b is not identified under the null. Thus, Kapetanios, Shin, and Snell (2003) use a first-order Taylor series approximation to the ESTAR model [4] around θ and the following auxiliary regression is derived:

$$\Delta y_t = \delta y_t^3 + v_t \quad [5]$$

Where v_t is the error term. If the errors in the auxiliary regression [5] are correlated, the regression can be augmented by including k lags of Δy_t to correct for serially correlated errors:

$$\Delta y_t = \delta y_t^3 + \sum_{j=1}^{k} \gamma_i \Delta y_{t-j} + v_t \quad [6]$$

Thus, the new null hypothesis is H_0: $\delta = 0$ against the alternative H_1: $\delta = 0$. As Kapetanios, Shin, and Snell (2003) showed, the asymptotic distribution of the t-statistic for null hypothesis, denoted by t_{NL}, is non-standard. Hence, they use stochastic simulations to tabulate asymptotic critical values of the t_{NL}-statistic.

2.1.2. Unit root tests on panel data and cross-sectional dependency tests

The expanding collection of panel-data studies has led to the consensus that panel-data models often display significant cross-sectional dependence in their error terms leading to unreliable results and forecasting errors (Banerjee and Carrion-i-Silvestre, 2017).

Cross-sectional dependence may stem from common shocks, unobserved components entering the error term, or idiosyncratic pairwise correlations without clear common or spatial patterns (De Hoyos and Serafidis, 2006). One notable explanation is the intensified economic and financial integration among countries and financial entities, which strengthens interconnections between cross-sectional units (De Hoyos

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and Serafidis, 2006; Banerjee and Carrion-i-Silvestre, 2017). Therefore, panel unit root tests are classified into first-generation tests, which ignore cross-sectional dependence, and second-generation tests, which account for it.

Pesaran's CD test of cross-sectional dependency. Pesaran (2021) provided a test for cross-sectional dependency based on the following relation:

$$y_{it} = a_i + bx_{it} + u_{it}\,;\, i = 1,\ldots,N \text{ and } t = 1,\ldots,T \qquad [7]$$

Where i is the cross-sectional dimension, t is the time-series dimension, a_i is a constant which may vary for every cross-sectional unit, and x_{it} is a $k\times1$ vector of observed time-varying regressors. The hypotheses of interest are the following:

$$H_0 : \rho_{ij} = \rho_{j\imath} = \text{cor}\left(u_{it}, u_{jt}\right) = 0 \text{ for } i \neq j \rightarrow \text{Cross Sectional Independence}$$

$$H_1 : \rho_{ij} = \rho_{j\imath} \neq 0 \text{ for some } i \neq j \rightarrow \text{Cross Sectional Dependence}$$

Where ρ_{ij} is the pair-wise correlation of the disturbances and calculated as follows:

$$\rho_{ij} = \frac{\sum_{t=1}^{T} u_{it} u_{jt}}{(\sum_{t=1}^{T} u_{it}^2)^{1/2} (\sum_{t=1}^{T} u_{jt}^2)^{1/2}} \qquad [8]$$

The null hypothesis of the cross-sectional independence is checked from:

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho_{ij}}\right)} \qquad [9]$$

Where $\widehat{\rho_{ij}}$ is the sample estimate of the pair-wise correlation of the residuals.

First generation tests in panel data: the Levin, Lin, and Chu (2002) unit root test. Levin, Lin, and Chu (2002) argued that single unit root tests have limited power against persistent deviations from equilibrium, especially in small samples.

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Thus, they developed a more robust test for panel data than applying individual unit root tests to each cross-section. The null hypothesis of the LLC test states the existence of a unit root in every cross-sectional unit, against the alternative that at least one unit is stationary. The test relies on the following specification:

$$\Delta y_{i,t} = \rho y_{i,t-1} + \sum_{j=1}^{k_i} \gamma_{ij} \Delta y_{i,t-L} + \delta_{mi} d_{mt} + e_{it} \text{ where } m = 1,2,3 \qquad [10]$$

Where i refers to the cross-sectional units, t refers to time-dimension, k_i is the number of time lags, ρ is the coefficient of interest and e_{it} is the error term. Also, $m = 1,2,3$ refers to whether the regression includes constant, constant and trend, or none of them, respectively; thus, δ_{mi} is the vector that includes the coefficients for each case. Given that the value of k_i is unknown, Levin, Lin, and Chu (2002) propose a three-stage process to carry out the test.

For each cross-section, an ADF regression is estimated to obtain residuals that are then orthogonalized and normalized. The long-run variance of the residuals is computed using a kernel estimator, and the ratio of long-run to short-run standard deviations is used to adjust the test statistic. In the final step, the pooled regression yields the adjusted t-statistic, using the corrections provided in Levin, Lin, and Chu (2002). Under the null, this statistic follows a standard normal distribution. The procedure accommodates heterogeneous lag structures and is suitable for moderately sized panels.

First generation tests in panel data: the Madala-Wu (1999) unit root test. To test for unit root in panel data, Madalla and Wu (1999) suggest to use a non-parametric Fisher-type test, which is based on a combination of the p-values of the unit root tests for each cross-sectional unit. Thus, the Madalla and Wu (MW) test, in contrast to the LLC test which imposes a common ρ, allows for different ρ_i for each cross-sectional unit. The MW test is based on the following statistic:

$$P = -2\sum_{i=1}^{N} \ln \pi_i \qquad [11]$$

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Where π_i is the *p*-values of the ADF test. In addition, the *P* follows the χ^2 distribution with two degrees of freedom as the $T_i \to \infty$ for finite *N*. The hypotheses of the test are the following:

$$H_0 : \rho_i = \rho = 0 \text{ for every } i$$

$$H_1 : \rho_i < 0 \text{ for } i = 1,\ldots,N \text{ and } \rho_i = 0 \text{ for } i = N_1+1,\ldots,N$$

Hence, in the first step, the ADF test is applied for each cross-sectional unit and the corresponding *t*-values and *p*-values are computed. In turn, the MW statistic is estimated and is compared with the critical values of the χ^2 distribution.

Second generation test in panel data Pesaran's unit root test (2007). A second-generation unit root test such as Pesaran's (2007) test is more appropriate to use once a cross-sectional dependence is detected. In the first step of the test, the Ordinary Least Squares (OLS) method is applied for each cross-sectional unit in a Cross-sectional Augmented Dickey Fuller (CADF) model of the form:

$$\Delta y_{it} = \beta_i y_{i,t-1} + \gamma_i \overline{y}_{i,t-1} + \sum_{j=0}^{k} d_{ij} \Delta \overline{y}_{i,t-1} + \sum_{j=0}^{k} g_{ij} \Delta y_{i,t-1} + \delta_{mi} d_{mt} + u_{it} \quad [12]$$

Where $m = 1,2,3$, $\overline{y}_{i,t-1} = \left(1/N\right)\sum_{t=1}^{N} y_{i,t-1}$, $\Delta \overline{y}_t$ the first differences of $\overline{y}_t$, and u_{it} the error term. Also, $m = 1,2,3$ refers to whether the regression includes constant, constant and trend, or none of them, respectively, and δ_{mi} is the vector that includes the coefficients for each case. The optimal number of lags, *k*, can be selected either according to the degree of autocorrelation in the residuals or based on some information criterion. In the above regression, a *t*-statistic is applied to coefficient β_i, from which the CADF statistics are calculated for each cross-section. The CIPS test is then calculated by averaging the individual CADF tests:

$$CIPS = \frac{\sum_{t=1}^{N} CADF_i}{N} \quad [13]$$

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Where N is the number of the cross-sectional units. The null hypothesis states that a homogeneous unit root exists in all cross-sectional units within the panel, while the alternative one argues for the existence of stationarity in at least one unit.

2.2. Data sources and clustering of economies

We examine the strength of the PPP premises by investigating the presence of a unit root in 163 countries which are grouped according to their level of development into developed, emerging and low-income economies. To conduct the tests, we use data on REERs from the database presented by Darvas (2021). The REERs in this database are calculated as follows:

$$REER_t = \frac{NEER_t CPI_t}{CPI_t^{(\text{foreign})}} \qquad [14]$$

Where $REER_t$ is the real effective exchange rate of the country under study against a basket of currencies of trading partners; CPI_t is the Consumer Price Index of the country under study; $NEER_t = \prod_{i=1}^{N=120} S(i)_t^{w^{(i)}}$ is the nominal effective exchange rate of the country under study, which is the geometrically weighted average of the nominal bilateral exchange rates, $S(i)$, between the country under study and its trading partner i (measured as the foreign currency price of one unit of domestic currency); $CPI_t = \prod_{i=1}^{N=120} CPI(i)_t^{w^{(i)}}$ is the geometrically weighted average of CPI of trading partners where $CPI(i)_t$ is the consumer price index of the trading partner i; $w^{(i)}$ is the trade weight of partner i and $N = 20$ is the number of trading partners considered. Darvas (2021) utilizes time-invariant weights and therefore the REER inx is measured against a basket of countries, whose composition is constt. This basket is representative of foreign trade in the period 1998-2003.

The REERs are transformed into natural logarithms and according to PPP hypothesis, they should be equal to zero (stationary at the level). That is:

$$\text{Log}\left(REER_t\right) = \text{Log}\left(NEER_t\right) + \text{Log}\left(CPI_t\right) - \text{Log}\left(CPI_t^{(\text{foreign})}\right)$$

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If $\text{Log}\left(NEER_t\right)+\text{Log}\left(CPI_t\right)-\text{Log}\left(CPI_t^{(\text{foreign})}\right)=0 \rightarrow$ PPP holds

If $\text{Log}\left(NEER_t\right)+\text{Log}\left(CPI_t\right)-\text{Log}\left(CPI_t^{(\text{foreign})}\right)\neq 0 \rightarrow$ PPP does not hold

The time period under investigation refers to monthly data starting from 1993:1 to 2022:10 and consists of balanced panel data, with observations for all countries available at each time point; hence, the time series of the obtained REERs is long enough capturing different phases of economic activity. By using monthly data, the expected volatility of REERs can be also captured.

By employing the database of 'Fiscal Monitor' of International Monetary Fund (IMF), we group the economies into three categories; so in Tables 1 to 3, we present the 163 economies clustered according to their level of development. In so doing, we add another dimension in the analysis of the PPP premises by taking into account the extent to which the different level of economic development affects the validity of PPP.

Table 1. Developed economies (total 35 countries)

Australia	Estonia	Israel	Malta	Slovenia
Austria	Finland	Italy	Netherlands	Spain
Belgium	France	Japan	New Zealand	Sweden
Canada	Germany	Korea South	Norway	Switzerland
Cyprus	Greece	Latvia	Portugal	Taiwan
Czech Republic	Hong Kong, China	Lithuania	Singapore	United Kingdom
Denmark	Iceland	Luxembourg	Slovakia	United States

Table 2. Emerging economies (total 78 economies)

Albania	Bulgaria	Eswatini	Kuwait	Panama	St. Kitts & Nevis
Algeria	Cape Verde	Fiji	Lebanon	Paraguay	St. Lucia
Angola	Chile	Gabon	Libya	Peru	St. Vincent & the Grenadines

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Table 2. Emerging economies (total 78 economies; concluded)

Argentina	China	Grenada	Malaysia	Philippines	Suriname
Armenia	Colombia	Guatemala	Maldives	Poland	Thailand
Azerbaijan	Costa Rica	Guyana	Mauritius	Qatar	Bahamas
Bahrain	Croatia	Hungary	Mexico	Romania	Tonga
Barbados	Dominica	India	Mongolia	Russia	Trinidad & Tobago
Belize	Dominican Republic	Indonesia	Morocco	Western Samoa	Tunisia
Bolivia	Ecuador	Iran	Namibia	Saudi Arabia	Turkey
Botswana	Egypt	Jamaica	North Macedonia	Seychelles	Ukraine
Brazil	El Salvador	Jordan	Oman	South Africa	Uruguay
Brunei Darussalam	Equatorial Guinea	Kazakhstan	Pakistan	Sri Lanka	Venezuela

Table 3. Low-income economies (total 50 countries)

Bangladesh	Congo, Democratic Republic	Ivory Coast	Mauritania	SierraLeone
Benin	Congo, Republic	Kenya	Moldova	Solomon Islands
Bhutan	Djibouti	Kyrgyzstan	Mozambique	Sudan
BurkinaFaso	Ethiopia	Lao	Nepal	Tajikistan
Burundi	Gambia	Lesotho	Nicaragua	Tanzania, United Republic of
Cambodia	Ghana	Liberia	Niger	Togo
Cameroon	Guinea	Madagascar	Nigeria	Uganda
Central African Republic	Guinea Bissau	Malawi	Papua New Guinea	Vietnam
Chad	Haiti	Mali	Rwanda	Yemen
Comoros	Honduras	São Tomé and Príncipe	Senegal	Zambia

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3. EMPIRICAL EVIDENCE

Next, we present the results from the various unit root tests in order to establish whether the REERs are a stationary variable indicating that the PPP principle is in effect. First, the results of unit root tests on time series data without structural change are presented in Table 4.

Table 4 reveals that the highest stationarity rate in REERs is observed when all countries are taken together and a constant is included in the regression model; that result is in contrast to the TPPP scenario. However, the above result changes if we consider the different groups of countries, as the highest stationarity rate is found for low-income economies and in the case of the TPPP model. Moreover, this group of economies also displays a very high stationarity rate when only a constant is included in the regression. Nevertheless, the stationarity rates are generally low, with developed economies exhibiting the lowest rates in all considered scenarios. For country specific results see Tables B1, B2 and B3 in Appendix A.

Having presented the results from the ADF and PP tests, we continue with the ZA time series unit root test, which introduces into the analysis an endogenously determined structural break.

Based on the ZA test, presented in Table 5, the rates validating the PPP principle remain notably low across all economies. Without being affected by the development level of the economies, the rates corroborating the PPP principle is markedly lower when the structural break is

Table 4. Combined results of the ADF and PP tests

	163 Economies		
Component	none	c	c & t
I(0)	12	60	55
Percent	7.36%	36.81%	33.74%

	Developed (35 economies)			Emerging (78 economies)			Low-income (50 economies)		
Component	none	c	c & t	none	c	c & t	none	c	c & t
I(0)	5	6	5	6	30	22	1	24	28
Percent	14.29%	17.14%	14.29%	7.69%	38.46%	28.21%	2.00%	46%	56.00%

Notes: c & t and c refer to constant and trend or constant only, respectively. The results correspond to 5% significance level.

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exclusively in the trend. Finally, low-income economies display overall higher rates compared to developed or emerging economies. For country specific results see Tables B4, B5 and B6 in Appendix A.

Table 6 displays the outcomes of the nonlinear KSS unit root test, where the null hypothesis of possessing a unit root is assessed in contrast to the alternative hypothesis, which posits global stationarity within the framework of an ESTAR process.

Table 5. Overall results of the ZA test

	163 Economies		
Component	c	t	c & t
I(0)	56	34	56
Percent	34.36%	20.86%	34.36%

	Developed (35 economies)			Emerging (78 economies)			Low-income (50 economies)		
Component	c	t	c & t	c	t	c & t	c	t	c & t
I(0)	11	6	12	25	15	23	20	13	21
Percent	31.43%	17.14%	34.29%	32.05%	19.23%	29.49%	40.00%	26.00%	42.00%

Notes: c, t, and c & t refer to constant, trend, and constant and trend, respectively. The results correspond to 5% significance level.

Table 6. Overall results of the KSS test

	163 Economies		
Component	none	c	c & t
I(0)	2	70	65
Percent	1.23%	42.94%	39.88%

	Developed (35 economies)			Emerging (78 economies)			Low-income (50 economies)		
Component	none	c	c & t	none	c	c & t	none	c	c & t
I(0)	0	12	15	1	32	35	1	28	15
Percent	0	34.29%	42.86%	1.28%	41.03%	44.87%	2.00%	56.00%	30.00%

Notes: c & t and c refer to constant and trend, and constant, respectively. The results correspond to 5% significance level.

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Table 6 indicates that the highest rate is observed in low-income economies when only a constant is included in the regression model. For emerging and developed economies, the highest rate is found in the TPPP version of the regression. The country specific results are presented in Tables B7, B8 and B9. in Appendix A.

We continue the empirical analysis for the presence of stationarity in these three groups of economies using three panel unit root tests: the LLC test, the MW test, and Pesaran's CADF test. As a first step, in Table 7, we present the results of the Pesaran's (2021) CD test for cross-sectional dependence in each panel separately.

The results in Table 7 show that the cross-sectional independence assumption is violated. This outcome was expected, given the large transnational interconnection that characterizes the REERs and because the REERs are weighted by the volume of trade. Next, we apply unit root tests on panel data, which are divided into the first- and second-generation tests. The main difference between the two tests is that the first-generation test does not take into account the cross-sectional dependence while the second-generation tests adjust for it. We apply the first-generation tests presented by Levin, Lin, and Chu (2002), and Madala and Wu (1999) and the second generation test presented by Pesaran (2007). The Akaike's information criterion is used, while the maximum lags are panel-adjusted. The results of the tests are presented in Table 8.

From Table 8 we conclude that the first-generation tests argue in favor of rejecting the stationarity property for the developed economies. In contrast, the second generation CIPS test concludes that the REERs under consideration of the developed economies are stationary.

In the panel encompassing emerging economies, both first-generation tests (LLC and MW) confirm the existence of a unit root (non-stationarity) when neither a constant nor a trend is incorporated into the regression. Conversely, when the regression incorporates either a constant or a

Table 7. CD test of cross-sectional dependency

Economies	Developed	Emerging	Low-income
CD statistic	52.448***	115.943***	57.423***

Note: the null hypothesis advocates the existence of cross-sectional independence. *** significance level of 0.01.

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Table 8. Panel unit root tests

	Unit root tests of first generation					
	Levin, Lin and Chu			Maddala and Wu		
	Without c & t	With c	With c & t	Without c & t	With c	With c & t
Developed	0.001	−1.021	4.034	29.577	129.128	64.833
Emerging	3.323	3.64***	−5.936	58.133	466.021***	468.66***
Low-income	0.173	−0.174	4.562	43.823	271.272***	271.637***
	Unit root tests of second generation, CIPS					
	Without c & t		With c		With c & t	
Developed	−2.067***		−2.309***		−3.014***	
Emerging	−1.705***		−1.919		−2.226	
Low-income	−1.367		−1.054*		−2.668**	

Notes: c is the constant and t is the trend. Developed economies: Maximum time lags = 24. Emerging economies: Maximum time lags = 32. Low-income economies: Maximum time lags = 48. ***, ** and * for significance level 0.01, 0.05 and 0.10, respectively.

constant and a trend, the MW test suggests that REERs are stationary. Additionally, the LLC test indicates stationarity when only a constant, and not a trend, is included in the model. However, according to the CIPS test, stagnation occurs only in the case where neither constant nor trend is included.

For low-income economies, the LLC test concludes, for all cases, that the REERs are non-stationary. The MW test, respectively, concludes that the REERs is stationary only when constant or constant and trend are included. Pesaran's (2007) second-generation test including a constant rejects stationarity at 5% significance level and accepts the stationarity hypothesis at 10% significance level. Finally, CIPS test concludes that the REERs is stationary when there is a constant and a trend in the model, which gives support to the TPPP version.

The results derived from the application of numerous unit root tests using time series and panel data align with those reached in the relevant literature assessing the validity of the PPP hypothesis; our results confirm

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the general apprehension about the soundness of the PPP premises. In addition, we checked the PPP hypothesis across 163 economies with different economic development profiles and not for a small group of countries with similar characteristics as usually is done. In so doing, we introduced one more dimension to the analysis that helps us to understand the relationship between the PPP principle and the level of economic development and to arrive at even more robust conclusions for the validity of the theory itself.

4. CONCLUSIONS

This paper examined the empirical validity of the PPP hypothesis for 163 economies, which were grouped into developed, emerging, and low-income economies. Using a broad set of unit root tests on both time series and panel data, we investigated whether REERs display the stationarity property required by PPP.

The results from the linear ADF and PP tests show that support for PPP is generally weak across all groups of economies. The highest verification rate appears among low-income economies, particularly when a time trend is included in the regression (TPPP specification), whereas developed and emerging economies display slightly higher rates under the standard version of the model without trend. However, even in these cases, the overall levels of support remain low. Introducing structural breaks through the Zivot-Andrews test yields similar conclusions: the PPP hypothesis finds its strongest, though still modest, support among low-income economies, while trend breaks consistently provide the lowest stationarity rates. The KSS nonlinear test, motivated by the literature emphasizing nonlinear mean reversion, also points to higher stationarity among low-income economies, but again, verification rates remain low overall.

Turning to panel data, we applied two first-generation unit root tests (LLC and MW) and a second-generation test (CIPS). The panel results closely mirror the time-series findings: evidence in favor of PPP is mixed and generally weak, with somewhat stronger support for low-income economies. The CIPS test, which accounts for cross-sectional dependence, confirms that stationarity is more likely in this group. These results suggest that low-income economies maintain a more stable relative position in

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international competitiveness, while developed and emerging economies experience more persistent deviations from PPP.

Three features strengthen the credibility of our findings. First, we examine a large and diverse sample of 163 economies, instead of focusing on a narrow set of countries with similar characteristics. Second, by clustering economies according to their level of development, we introduce a structural dimension rarely explored in the literature, enabling us to assess how development shapes the validity of PPP. Third, our use of multiple unit root tests, including linear, structural-break, nonlinear, and panel methods, ensures that the results are not driven by the choice of econometric technique.

Conceptually, the PPP hypothesis remains a core element of mainstream international economics, grounded in the quantitative theory of money and closely linked to theories of comparative advantage. PPP implies that, in the long run, the price levels of two economies expressed in a common currency should converge, and thus REERs should be stationary. Because REERs also capture international competitiveness, the stationarity implied by PPP presupposes that an economy maintains a constant relative competitive position over time, an assumption at odds with the dynamic and uneven nature of international competition. The empirical results of this paper reinforce this theoretical tension: the weak stationarity of REERs across most economies indicates that competitiveness does not converge, and price levels do not equalize, even over extended periods.

These findings have important policy implications. If PPP fails empirically, then exchange-rate policies that rely on its validity may be misguided. The experience of many economies suggests that persistent competitive asymmetries, not self-correcting parities, shape international trade outcomes. As shown in the relevant literature, economies that consistently maintain lower costs tend to dominate trade, while those relying on the presumed equilibrating forces of PPP often record chronic deficits (Seretis and Tsaliki, 2016; Tsoulfidis and Tsaliki, 2019; Poulakis and Tsaliki, 2022, 2023). The divergence of competitiveness within the Eurozone provides a clear example: if PPP held, member states would have converged in competitiveness, yet persistent surpluses and deficits remain a defining feature (Gymnopoulos *et al.*, 2017; Poulakis, Poulakis, and Chatzarakis, 2022). Hence, economies with persistent trade balance surpluses become international lenders, while economies with persistent

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trade balance deficits become international borrowers (Shaikh, 2016; Poulakis and Kyrkilis, 2024).

In conclusion, our empirical analysis adds to a substantial body of evidence showing that the PPP principle lacks strong empirical support. Given its central role in conventional trade and exchange rate theory, this raises concerns about the theoretical and policy frameworks built upon it. The results reinforce the need for alternative approaches to international competitiveness and exchange-rate determination, approaches grounded in realistic assumptions and capable of generating robust empirical insights. ◄

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APPENDIX A: COUNTRY SPECIFIC RESULTS OF UNIT ROOT TESTS IN TIME SERIES

Table B1. Linear unit root tests without constant and trend

Developed economies (5)					
Country	Czech Republic	Estonia	Lithuania	Latvia	Slovakia
Test	ADF	ADF	ADF	ADF	ADF
Emerging economies (6)					
Country	Albania	Guatemala	Honduras	Lebanon	Namibia	Qatar
Test	ADF	ADF	ADF	ADF	ADF	ADF
Low-income economies (1)					
Country	Tajikistan				
Test	ADF, PP				

Note: the results correspond to 5% significance level.

Table B2. Linear unit root tests with constant

Developed economies (6)						
Country	Estonia	Finland	Italy	Latvia	Lithuania	South Korea
Test	ADF, PP	ADF, PP	ADF	ADF, PP	ADF, PP	ADF, PP
Emerging Economies (24)						
Country	Albania	Angola	Azerbaijan	Algeria	Armenia	Venezuela
Test	ADF, PP	ADF, PP	ADF, PP	ADF	ADF, PP	ADF, PP
Country	North Macedonia	Gabon	Dominican Republic	El Salvador	Indonesia	Iran
Test	ADF, PP	ADF, PP	ADF, PP	ADF, PP	ADF, PP	ADF, PP
Country	Kazakhstan	Qatar	Croatia	Maldives	Mongolia	Namibia
Test	ADF, PP	ADF, PP	ADF, PP	PP	ADF	ADF, PP
Country	Ukraine	Cabo Verde	Romania	Russia	Surinam	Chile
Test	ADF, PP	ADF, PP	PP	ADF, PP	ADF, PP	ADF

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Table B2. Linear unit root tests with constant (concluded)

Low-income economies (23)				
Country	Benin	Burkina Faso	Cameroon	Chad
Test	ADF, PP	ADF, PP	ADF, PP	ADF, PP
Country	Comoros	Congo, Republic	Djibouti	Haiti
Test	ADF, PP	PP	ADF, PP	ADF
Country	Ivory Coast	Kyrgyzstan	Liberia	Madagascar
Test	ADF	ADF, PP	ADF, PP	ADF, PP
Country	Mali	Moldova	Mozambique	Nicaragua
Test	ADF, PP	ADF, PP	ADF, PP	ADF, PP
Country	Niger	Senegal	Sierra Leone	Tajikistan
Test	ADF, PP	ADF, PP	ADF, PP	ADF, PP
Country	Togo	Yemen	Zambia	
Test	ADF, PP	ADF, PP	ADF	

Note: the results correspond to 5% significance level.

Table B3. Linear unit root tests with constant and trend

Developed economies (5)					
Country	Estonia	Finland	South Korea	Latvia	Lithuania
Test	ADF, PP	ADF, PP	ADF	ADF, PP	ADF, PP
Emerging economies (22)					
Country	Albania	Algeria	Angola	Armenia	
Test	ADF, PP	ADF	ADF, PP	ADF, PP	
Country	Azerbaijan	Cape Verde	Croatia	Dominican Republic	
Test	ADF, PP	ADF	ADF, PP	PP	
Country	El Salvador	Gabon	India	Indonesia	
Test	ADF, PP	ADF	ADF, PP	ADF	
Country	Iran	Kazakhstan	Mongolia	Morocco	
Test	ADF, PP	ADF, PP	ADF	ADF	
Country	Russia	South Africa	Suriname	Trinidad and Tobago	
Test	ADF, PP	ADF	ADF, PP	ADF, PP	
Country	Ukraine	Venezuela			
Test	ADF, PP	ADF, PP			

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Table B3. Linear unit root tests with constant and trend (concluded)

Low-income economies (28)				
Country	Benin	BurkinaFaso	Cambodia	Cameroon
Test	ADF, PP	ADF, PP	ADF	ADF, PP
Country	Central African Republic	Chad	Comoros	Congo, Democratic Republic
Test	ADF, PP	ADF, PP	ADF, PP	ADF, PP
Country	Congo, Republic	Haiti	IvoryCoast	Kenya
Test	ADF, PP	ADF	ADF	ADF, PP
Country	Kyrgyzstan	Liberia	Madagascar	Malawi
Test	ADF, PP	ADF	ADF, PP	ADF
Country	Mali	Moldova	Mozambique	Nepal
Test	ADF, PP	ADF, PP	ADF	PP
Country	Nicaragua	Niger	Senegal	SierraLeone
Test	ADF, PP	ADF, PP	ADF, PP	ADF, PP
Country	Sudan	Tajikistan	Togo	Zambia
Test	ADF, PP	ADF, PP	ADF, PP	ADF

Note: the results correspond to 5% significance level.

Table B4. ZA unit root test with break in constant

Developed economies (11)					
Cyprus	Denmark	Estonia	Finland	Israel	Iceland
Italy	Lithuania	Slovenia	Uruguay	Portugal	
Emerging economies (25)					
Albania	Algeria	Angola	Argentina	Armenia	
Barbados	Bulgaria	Croatia	Dominican Republic	Ecuador	
Guatemala	Indonesia	Iran	Jamaica	Kazakhstan	
Malaysia	Mexico	Namibia	North Macedonia	Peru	
Romania	Suriname	Thailand	Ukraine	Venezuela	
Low-income economies (20)					
Burkina Faso	Comoros	Djibouti	Guinea	Guinea Bissau	
Ivory Coast	Kenya	Kyrgyzstan	Liberia	Madagascar	
Malawi	Mali	Moldova	Nicaragua	Nigeria	
Solomon Islands	Sudan	Tajikistan	Vietnam	Yemen	

Note: the results correspond to 5% significance level.

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Table B5. ZA unit root test with break in trend

Developed economies (6)					
Austria	Estonia	Finland	Lithuania	Slovenia	Taiwan
Emerging economies (15)					
Armenia	Angola	Bulgaria	Dominican Republic	Algeria	
Ecuador	Croatia	Indonesia	Kazakhstan	North Macedonia	
Mexico	Namibia	Romania	Suriname	Turkey	
Low-income economies (13)					
Burkina Faso	Djibouti	Ethiopia	Guinea Bissau	Kyrgyzstan	
Comoros	Madagascar	Malawi	Nicaragua	Tajikistan	
Uganda	Vietnam	Yemen			

Note: the results correspond to 5% significance level.

Table B6. ZA unit root test with breaks in constant and trend

Developed economies (12)					
Austria	Belgium	Denmark	Estonia	Finland	France
Germany	Iceland	Lithuania	Portugal	Slovenia	Taiwan
Emerging economies (23)					
Albania	Algeria	Angola	Argentina	Armenia	Barbados
Bulgaria	Dominican Republic	Ecuador	Indonesia	Iran	Jamaica
Kazakhstan	Mexico	Namibia	North Macedonia	Romania	St. Vincent & the Grenadines
Suriname	Thailand	Turkey	Ukraine	Uruguay	
Low-income economies (21)					
Burkina Faso	Burundi	Comoros	Congo, Democratic Republic	Croatia	Guinea
Guinea Bissau	Ivory Coast	Kenya	Kyrgyzstan	Liberia	Madagascar
Malawi	Mali	Moldova	Nicaragua	Nigeria	Sudan
Tajikistan	Vietnam	Yemen			

Note: the results correspond to 5% significance level.

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Table B7. Nonlinear KSS unit root test without constant and trend

Emerging economies (1)	Low-income economies (1)
Venezuela	Tajikistan

Note: the results correspond to 5% significance level.

Table B8. Nonlinear KSS unit root test with constant

Developed economies (12)				
Austria	Estonia	France	Iceland	Italy
Korea South	Latvia	Norway	Switzerland	Taiwan
Emerging economies (32)				
Albania	Algeria	Armenia	Azerbaijan	Bulgaria
Cape Verde	China	Croatia	Dominican Republic	Ecuador
El Salvador	Equatorial Guinea	Fiji	Gabon	Indonesia
Kazakhstan	Maldives	Mexico	Morocco	Namibia
Oman	Peru	Qatar	Romania	Russia
St. Vincent & the Grenadines	Seychelles	South Africa	Thailand	Turkey
Ukraine	Venezuela			
Low-income economies (28)				
Benin	Burkina Faso	Cambodia	Cameroon	Chad
Comoros	Congo, Democratic Republic	Congo, Republic	Ghana	Guinea Bissau
Haiti	IvoryCoast	Kenya	Kyrgyzstan	Lao
Madagascar	Mali	Mauritania	Mozambique	Nicaragua
Niger	Nigeria	Papua New Guinea	Sierra Leone	Tajikistan
Togo	Yemen	Zambia		

Note: the results correspond to 5% significance level.

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Table B9. Nonlinear KSS unit root test with constant and trend

Developed economies (15)				
Australia	Belgium	Canada	France	Greece
Iceland	Israel	Japan	Luxembourg	Netherlands
New Zealand	Norway	Sierra Leone	Slovakia	Switzerland
Emerging economies (35)				
Albania	Angola	Chile	Costa Rica	Dominica
Dominican Republic	Ecuador	Egypt	Grenada	Guatemala
Croatia	Hungary	Iran	Jordan	St. Kitts & Nevis
Kuwait	Kazakhstan	St. Lucia	Libya	North Macedonia
Mongolia	Maldives	Mexico	Malaysia	Namibia
Panama	Qatar	Romania	Seychelles	Suriname
Eswatini	Thailand	Tonga	St. Vincent & the Grenadines	South Africa
Low-income economies (15)				
Burkina Faso	Burundi	Chad	Congo, Democratic Republic	Congo, Republic
Gambia	Honduras	Madagascar	Malawi	Moldova
Niger	Nigeria	Tanzania, United Republic of	Togo	Vietnam

Note: the results correspond to 5% significance level.

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