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Received 19 October 2020
Revised 29 April 2021
Accepted 5 September 2021

Purchasing power parity in GIIPS countries: evidence from unit root tests with breaks and non-linearity

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Abstract

Purpose – This paper aims to test purchasing power parity (PPP) hypothesis for Greece, Italy, Ireland, Portugal and Spain, which are known as the GIIPS countries.

Design/methodology/approach – The authors conduct a comprehensive analysis by using unit root approaches without and with structural breaks and non-linearity.

Findings – The PPP is valid for the GIIPS countries. Considering structural breaks in non-linear framework plays a crucial role.

Originality/value – There is no empirical study testing PPP hypothesis by focusing on the GIIPS countries. This study further takes into account for structural breaks and non-linearity in the real exchange rates of these countries.

Keywords PPP, Unit root tests, Real exchange rate, GIIPS

Paper type Research paper

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JEL classification – C22, F31

The authors would like to thank anonymous referee for the invaluable comments that help them to improve their study. Any remaining errors are solely theirs.

1. Introduction

Purchasing power parity (PPP) hypothesis implies that exchange rates adjust to their equilibrium values until purchasing power discrepancy disappears across countries. It means that exchange rate between two countries changes according to relative prices and hence has a mean reverting (stationary) process. The importance of PPP for constructing equilibrium exchange rates and in open economy macroeconomics has attracted great interest in testing PPP hypothesis.

Unit root approach has widely used in the empirical literature. The early studies carried out conventional tests, particularly ADF unit root test, and failed to find evidence in favor of PPP. One drawback of conventional unit root methods is that they exhibit size distortions and have low power in finite samples (Stock, 1994). To address this issue, scholars use historical data [1] which not only leads to substantial increase in power of tests (Lothian and Taylor, 1996) but also is consistent with the view of that PPP holds in the long run (Christopoulos and León-Ledesma, 2010). Nonetheless, increase in time span has accompanied new issues to the agenda: structural changes and nonlinearity in real exchange rates (Taylor and Taylor, 2004). In longer time span, exchange rates may expose to structural breaks because of regime changes, unexpected crashes, shocks and shifts in inflation policy. Moreover, they may show non-linear behavior in the existence of market frictions (such as price rigidities, transactions costs and asymmetric information). Perron (1989) shows that if a structural break in (trend) stationary process is ignored, ADF test tends to be biased toward non-rejection of a false unit root null hypothesis. Furthermore, neglecting a break in a unit root (difference stationary) process can lead standard unit root tests to reach an incorrect conclusion of stationarity (Harvey *et al.*, 2010). Taylor *et al.* (2001) indicate that ADF unit root test has low power for the data generating process with nonlinear mean reversion.

The GIIPS countries, which is an acronym of Greece, Italy, Ireland, Portugal and Spain, correspond to approximately 35% of the Eurozone in terms of GDP (Legrenzi and Milas, 2011). There are economic reasons such as budget deficits, borrowing and unemployment for evaluating the GIIPS countries within their own category. They have higher public deficits and foreign trade imbalances compared to other EU countries (Algieri, 2013). Moreover, these countries with higher borrowing problems have had difficulties in financing their debts after the outbreak of the 2007/2008 global financial crisis (Hughes Hallett and Richter, 2014). The European sovereign debt crisis began in 2008 with the collapse of banking system in Iceland, then spread primarily to Portugal, Italy, Ireland, Greece and Spain in 2009. Aftermaths of the global financial crisis and the European sovereign debt crisis, the unemployment has become an urgent problem in the GIIPS countries by jumping to 26.2% in Spain, 26% in Greece and 16.2% in Portugal in 2012 (Cheng *et al.*, 2014).

The disturbances in the GIIPS countries have triggered ongoing research to better understand the dynamics of their economic conditions and variables. The validity of PPP is analyzed by Kouretas and Zarangas (2001) and Karfakis and Moschos (1989) for Greece; Thom (1989) for Ireland; Narayan and Narayan (2007) for Italy; Koedijk *et al.* (2004) for 10 Eurozone countries including Greece, Italy, Portugal and Spain; finally, Narayan (2005) for 17 OECD countries including Spain, Italy and Portugal. Nonetheless, to the best our knowledge, there is no empirical study that focuses on the GIIPS countries as a group.

We investigate the validity of PPP hypothesis in the GIIPS countries within a comprehensive context. The conventional unit root tests are first used, which do not take structural breaks and non-linearity into consideration, developed by Dickey and Fuller (1979), and Phillips and Perron (1988) as well as the stationarity test proposed by Kwiatkowski *et al.* (1992). Structural changes in real exchange rates are accommodated by means of the unit root tests with a sudden structural break developed by Perron (1990) and Zivot and Andrews (1992), and the unit root test with smooth/gradual shifts proposed by Enders and Lee (2012). We then proceed with the non-linear unit root test of Kapetanios *et al.* (2003), and finally conduct the non-linear unit root test with smooth breaks suggested by Christopoulos and León-Ledesma (2010). This study hence contributes to the literature not only by focusing on the GIIPS countries but also by paying attention to modelling structural breaks and non-linearity in their real exchange rates.

The results from the conventional tests indicate the random walk behavior of the real exchange rates, implying that PPP does not hold in the GIIPS countries. The unit root tests with sudden structural breaks further shed light on the prevalence of shocks to the real exchange rates. The findings from the unit root test with smooth breaks are in sharp contrast and reveal that the real exchange rates are mean reverting. Furthermore, the non-linear unit root test with smooth structural breaks reinforces PPP in the GIIPS countries.

The remainder of the paper is organized as follows: Section 2 presents the basic theoretical framework, followed by the empirical literature in Section 3. Section 4 outlines the econometric methodology. Section 5 describes the data. Section 6 discusses the empirical findings. Finally, Section 7 is devoted to conclusion and policy discussion.

2. Theoretical framework

PPP hypothesis states that domestic prices of goods in a basket should be equal to foreign prices of the same basket of goods in local currency. Accordingly, it is formulized as:

$$P_t = E_t P_t^* \tag{1}$$

where E_t is nominal exchange rate (domestic price of foreign currency), P_t (P_t^*) represents domestic (foreign) price level. Equation (1) can be re-written in logarithmic form as follows:

$$e_t = p_t - p_t^*. \tag{2}$$

PPP equation then can be used to define real exchange rate, r_t, given by:

$$r_t = e_t - p_t + p_t^*. \tag{3}$$

As outlined in Taylor *et al.* (2001), real exchange rate may be interpreted as an extent of deviation from PPP condition. In the case of deviations, adjustment toward PPP is based on adjustment conditions in goods markets. As discussed in Holmes and Maghrebi (2004), adjustment process is gradual in goods markets because prices are sticky in the presence of transaction costs. Intuitively, arbitrage is unprofitable in response to small deviations from the law of one price and relative prices do not revert to mean (Imbs *et al.*, 2003). As deviation from PPP is larger, increasing arbitrage flows accelerates speed of adjustment, implying stronger tendency to move back to equilibrium (Kapetanios *et al.*, 2003). This also means that real exchange rate has a non-linear adjustment toward the long-run equilibrium. More specifically, it tends to be more persistent with small shocks around the equilibrium and has faster adjustment with larger shocks away from the equilibrium (Taylor *et al.*, 2001).

Non-linear behavior of real exchange rate is compatible with PPP, but in a transaction costs band. On theoretical basis, band of transaction costs makes arbitrage in goods market unprofitable unless price differentials excess shipping costs, which would generate a threshold-like behavior (i.e. discrete adjustment) (Michael *et al.*, 1997; Taylor *et al.*, 2001). Nonetheless, discrete adjustment of real exchange rate would be appropriate when agents and traded goods are identical. Kilian and Taylor (2003) suggest that heterogeneity in agents' opinions in foreign exchange rate markets with respect to equilibrium level of nominal exchange rates may raise nonlinearity. This kind of nonlinear behavior is clarified in Taylor and Taylor (2004) and emerges from that as nominal exchange rates have extreme values, a greater degree of consensus on the appropriate direction of exchange rates prevails and international traders act accordingly. Taylor (2004) argues that nonlinearity may also arise from interventions of monetary authority to alleviate exchange rate fluctuations as exchange rates are away from its PPP or fundamental equilibrium.

In the presence of transaction costs, nonsynchronous adjustment by heterogenous agents, intervention of central banks and time aggregation, real exchange rate may have a smooth adjustment rather than discrete adjustment. If real exchange rate is measured with price indices consisting of goods prices each with a different size of international arbitrage costs, adjustment behavior is expected to be smooth rather than instantaneous (Taylor *et al.*, 2001). Changes in the level of exchange rates may immediately occur as a result of revaluations and devaluations in a fixed exchange rate regime, but they may take time as exchange rates adjust to its new level in a floating exchange rate regime (Christopoulos and León-Ledesma, 2010).

This theoretical background unveils that framework, considering structural changes as smooth process with a non-linear modelling framework can be appropriate for testing PPP. Modelling framework with smooth changes can also be considered as a complement to the models with sudden changes. It hence can provide insightful information to better understand arbitrage opportunities of economic operators in response to deviations from PPP equilibrium.

3. Literature review

The empirical literature questions whether deviations from PPP are temporary or permanent, and thereby generally examines the stationarity of real exchange rate. PPP hypothesis is valid if real exchange rate is stationary; otherwise, deviations are permanent and PPP hypothesis does not hold. Table 1 summarizes the selected studies with respect to country/country group, period with its frequency, unit root method and findings.

The early studies carry out the conventional unit root (well-known ADF) test and find that deviations from PPP are characterized by a random walk (non-stationary) process (Karfakis and Moschos, 1989; Thom, 1989). The lack of empirical evidence is referred as the PPP puzzle [2]. The PPP puzzle is attributed to the low power of conventional unit root tests in small samples (Taylor *et al.*, 2001). To increase the power of tests, Lothian and Taylor (1996) and Taylor (2002), among others, use long time span as a first way to find more support in favor of stationary real exchange rates. Second, some other studies (Abuaf and Jorion, 1990; O'Connell, 1998; Taylor and Sarno, 1998) benefit from panel data procedures that gain more power by using information from both cross-sectional and time dimensions.

To overcome the PPP puzzle, a relevant development in the empirical PPP literature is to allow for structural breaks in deterministic components of real exchange rates. Hegwood and Papell (1998) indicate that allowing for structural changes is important as time span increases. Authors find out that real exchange rates show faster mean reversion to an occasionally changing mean, that this result is called as quasi-PPP. An empirical evidence for quasi-PPP is also provided by Erlat (2003) for Turkey and Mladenović *et al.* (2013) for Hungary, Turkey, Poland, Romania and Serbia. These studies capture structural breaks in real exchange rates as instantaneous (sharp) process by using dummy variable approach. This approach entails to *a priori* know number and dates of breaks. In practice, it may be difficult to have such information. Moreover, real exchange rates may contain multiple

Study	Country/Group and data	Method	PPP
Karfakis and Moschos (1989)	Greece (1975:Q1-1987:Q1)	DF	Not valid
Thom (1989)	Ireland (1980:M01-1987:M12)	ADF	Valid for UK and Germany
Abuaf and Jorion (1990)	10 developed countries (1973:M01-1987:M01)	Panel unit root	Valid
Lothian and Taylor (1996)	France, UK, USA (1971-1990)	ADF and PP	Valid
Taylor (2002)	20 developed and developing countries (1870-1990)	ADF and DF-GLS	Valid
Erlat (2003)	Turkey (1984:M01-2000:M09)	ADF Multiple Breaks	Not valid Valid
Narayan and Prasad (2005)	11 Middle Eastern countries (1971:M01-1994:M04)	ADF One break ADF Two breaks ADF Panel Break LM	Valid for Lebanon, S. Arabia and Sudan Valid for S. Arabia, Iran, Syria, Tunisia and Sudan Valid for S. Arabia, Egypt, Iran, Syria, Tunisia and Sudan Valid for panel
Narayan and Narayan (2007)	Italy (1973:M01-2002:M12)	Threshold unit root test	Valid
Bahmani-Oskooee *et al.* (2009)	52 countries (1994:M01-2000:M06)	ADF Non-linear KSS	Valid for 11 countries Valid for 28 countries
Su *et al.* (2011)	15 Latin American countries (1994:M12-2010:M02)	ADF, PP, KPSS, and KSS Fourier-KPSS	Not valid Valid for Brazil, Chile, Ecuador and Uruguay
Chang *et al.* (2012)	7 CEE countries (1993:M01-2008:M12)	ADF, PP and KPSS Fourier-LM	Not valid Valid
Mladenović *et al.* (2013)	Czech Republic, Latvia, Lithuania, Hungary, Poland, Romania, Turkey, and Serbia (2000:M01-2011:M08)	ADF, DF-GLS, KPSS Two breaks LM	Not valid Valid for Hungary, Turkey, Poland, Romania and Serbia
Drissi and Boukhatem (2020)	14 Developed countries 9 EM countries (1988:Q1–2018:Q2)	ADF Nonlinear KSS	Valid for 10 developed and 2 EM countries Valid for all countries
Aixalá *et al.* (2020)	Spain (1868–1914)	Non-linear KSS, Nonlinear-ESTAR, Fourier-ESTAR	Valid

Table 1.
Summary of selected literature

smooth breaks at unknown dates. To deal with these issues, a recent development is to use Fourier approximation which captures structural breaks as a gradual process and does not require to know number, dates and form of breaks. Su *et al.* (2011) and Chang *et al.* (2012) find that although the conventional tests cannot support PPP, the unit root test with Fourier approximation provides more evidence on the validity of PPP.

Finally, the PPP puzzle is tried to be solved through accounting for non-linearities in real exchange rates. Taylor *et al.* (2001) indicate strong evidence on non-linear adjustment in major real exchange rates during the post Bretton Woods period. Recent studies by relying on non-linear unit root tests find out much more support in favor of PPP

(Narayan and Narayan, 2007; Bahmani-Oskooee *et al.*, 2009; Drissi and Boukhatem, 2020). In a recent study, Aixalá *et al.* (2020) by using historical data show that only the non-linear unit roots are able to detect the fulfilment of PPP for consumer price indices in Spain.

4. Econometric methodology

We start with the augmented Dickey–Fuller (ADF) test developed by Dickey and Fuller (1979) and estimate the regression model:

$$\Delta y_t = \alpha y_{t-1} + z_t^{'}\beta + \sum_{j=1}^{p} \alpha_j \Delta y_{t-j} + \varepsilon_t \tag{4}$$

where Δ is the difference operator, z_t is the deterministic component and ε_t is an error term with $\varepsilon_t \sim i.i.d.(0,\sigma^2)$. The model can be estimated with different deterministic components specifications that $z_t=\{1\}$ defines the model with constant and $z_t=\{1, t\}$ defines the model with constant and trend. Equation (4) includes p lags of the dependent variable to correct for possible serial correlation in ε_t. The null hypothesis of the unit root (H_0:α=0) is tested against the alternative hypothesis of stationarity (H_1:α=<0). The test statistic is defined as the t-statistic with respect to α, denoted as $ADF = \alpha/se(\hat{\alpha})$ where $\hat{\alpha}$ is the estimated parameter and $se(\hat{\alpha})$ is its standard error [3].

4.1 Unit toot tests with sharp break

Perron (1989) indicates that ignoring a structural break in y_t leads ADF test to have low power because the test statistic tends to be biased toward non-rejection of a false unit root null hypothesis. Perron (1990) proposes the unit root test with an exogenous break at a known time. Zivot and Andrews (1992) further develop the unit root test with an endogenous break at an unknown time. The endogenous breakpoint test eliminates the problem of defining a break date *a priori* if it is not possible to know a specific shock. We consider the model specifications with a break in level (Model A), a break in level with trend (Model B) and a break in both level and trend (Model C), that are defined as:

$$\text{Model A}: \quad \Delta y_t = \alpha y_{t-1} + \mu_0 + \mu_1 DU_t + \sum_{j=1}^{p} \alpha_j \Delta y_{t-j} + \varepsilon_t \tag{5}$$

$$\text{Model B}: \quad \Delta y_t = \alpha y_{t-1} + \mu_0 + \beta_0 t + \mu_1 DU_t + \sum_{j=1}^{p} \alpha_j \Delta y_{t-j} + \varepsilon_t \tag{6}$$

$$\text{Model C}: \quad \Delta y_t = \alpha y_{t-1} + \mu_0 + \beta_0 t + \mu_1 DU_t + \beta_1 DT_t + \sum_{j=1}^{p} \alpha_j \Delta y_{t-j} + \varepsilon_t \tag{7}$$

where $DU_t = 1$ *if* $t>T_B$ and 0 otherwise, $DT_t = t-T_B$ for $t>T_B$ and 0 otherwise, and T_B refers to break date. The test statistic for the null hypothesis of unit root is described as the t-statistic of α, denoted as $ADF(\lambda)$. Here, $\lambda = T_B/T$ is the location of break and is chosen to minimize $ADF(\lambda)$statistics for all possible breakpoints, ranging from $j = 2/T$ to $j = (T-1)/T$.

Let λ_{inf} denotes a minimizing value, then the unit root test statistic in Zivot and Andrews (1992) is $ADF(\lambda_{\text{inf}}) = \inf ADF(\lambda)$ [4].

4.2 Unit toot test with smooth breaks

It is worthwhile noting that structural break models in Perron (1990) and Zivot and Andrews (1992) assume that the form and number of breaks are known. In practice, economic series may contain multiple smooth breaks, and it may be difficult to know form and number of breaks. To deal with these problems, the use of Fourier approximation is recently proposed to capture structural shifts in the unit root literature (Enders and Lee, 2012). The Fourier approximation does not require a prior knowledge on form and number of breaks and it captures structural shifts as a gradual/smooth process. Enders and Lee (2012) augment the ADF model by introducing Fourier approximation. The level shift model is defined as:

$$\Delta y_t = \mu + \delta_1 sin\left(\frac{2\pi kt}{T}\right) + \delta_2 cos\left(\frac{2\pi kt}{T}\right) + \alpha y_{t-1} + \sum_{j=1}^{p} \alpha_j \Delta y_{t-j} + \varepsilon_t \tag{8}$$

and the level and trend shift model is defined as:

$$\Delta y_t = \mu + \beta t + \delta_1 sin\left(\frac{2\pi kt}{T}\right) + \delta_2 cos\left(\frac{2\pi kt}{T}\right) + \alpha y_{t-1} + \sum_{j=1}^{p} \alpha_j \Delta y_{t-j} + \varepsilon_t \tag{9}$$

where k represents an integer Fourier frequency, and δ_1 and δ_2 measure the amplitude and displacement of the frequency, respectively. The test statistic for the null hypothesis of unit root is described as the t-statistic of α, denoted as $ADF(k)$ where k is the Fourier frequency [5].

4.3 Non-linear unit root test

Monte Carlo simulations carried out by Balke and Fomby (1997) show that the power of DF test dramatically falls when the data generating process is based on threshold autoregressive models. To test unit root in the presence of nonlinear dynamics, Kapetanios *et al.* (2003) propose an alternative framework for testing the null hypothesis of unit root against the alternative hypothesis of a non-linear exponential smooth transition autoregressive (ESTAR) process, which is globally stationary. They start with defining ESTAR model, given by:

$$\Delta y_t = \alpha y_{t-1} + \gamma y_{t-1}\left[1 - \exp\left(-\theta y_{t-d}^2\right)\right] + \varepsilon_t \tag{10}$$

where $\theta \geq 0$ and $d \geq 0$ is the delay parameter. By imposing $\alpha = 0$ (which implies that y_t follows a unit root process) and $d = 1$ for simplicity, we obtain:

$$\Delta y_t = \gamma y_{t-1}\left[1 - \exp\left(-\theta y_{t-1}^2\right)\right] + \varepsilon_t \tag{11}$$

where θ is of interest which is zero under the null hypothesis of unit root (H_0:θ=0) and positive under the alternative hypothesis of globally stationary ESTAR process (H_1:θ>0). However, testing the null hypothesis is not directly feasible because γ is not identified under the null. Kapetanios *et al.* (2003) overcome this issue by using first-order Taylor approximation to ESTAR model under the null and get the following auxiliary regression:

$$\Delta y_t = \phi y_{t-1}^3 + \text{error}. \tag{12}$$

For serially correlated errors in equation (11), the augmented model, in the spirit of ADF methodology, can be defined as:

$$\Delta y_t = \phi y_{t-1}^3 + \sum_{j=1}^{p} \alpha_j \, \Delta y_{t-j} + \text{error}. \tag{13}$$

The null hypothesis of H_0:ϕ=0 can easily be tested against the alternative hypothesis of H_0:ϕ<0 by the t-statistic of ϕ. The test statistic is defined as $t_{NL} = \hat{\phi}/se(\hat{\phi})$ that $\hat{\phi}$ is the OLS estimate of ϕ and $se(\hat{\phi})$ is the corresponding standard error [6].

4.4 Non-linear unit root test with smooth structural shifts

Christopoulos and León-Ledesma (2010) propose the unit root test that jointly accounts for structural breaks and non-linear adjustment. It can be considered as an extension of the non-linear unit root test of Kapetanios *et al.* (2003) with a Fourier approximation. The data is assumed to be generated with:

$$y_t = \mu + \delta_1 sin\left(\frac{2\pi kt}{T}\right) + \delta_2 cos\left(\frac{2\pi kt}{T}\right) + v_t \tag{14}$$

in the case of level shifts, and with:

$$y_t = \mu + \beta t + \delta_1 sin\left(\frac{2\pi kt}{T}\right) + \delta_2 cos\left(\frac{2\pi kt}{T}\right) + v_t \tag{15}$$

the case of level and trend shifts. Then the OLS residuals $\hat{v}_t$ is used to test for unit root in following model:

$$\Delta \hat{v}_t = \phi \hat{v}_{t-1}^3 + \sum_{j=1}^{p} \alpha_j \Delta \hat{v}_{t-j} + \text{error}. \tag{16}$$

The unit root null hypothesis H_0:ϕ=0 is tested against the stationarity alternative H_0:ϕ<0 by the t-statistic of ϕ, denoted as $Ft_{NL} = \hat{\phi}/se(\hat{\phi})$ [7].

5. Data

The use of real bilateral real exchange rates for testing PPP is criticized because of not being a comprehensive measurement of competitiveness. The real bilateral exchange rate defined in equation (3) is a measure of evaluation of competitiveness of a country with respect to another country. In practice, it is of more interest in general development of competitiveness position, not just relative to one country in particular (Van Marrewijk *et al.*, 2012, p. 433). Domestic price level could be affected not just by depreciation of national currency against one trading partner, but against many of trading partners (Bahmani-Oskooee *et al.*, 2020).

To overcome this drawback of bilateral exchange rates, real effective exchange rate (REER) is used in testing PPP (among others, Sarantis, 1999; Paya *et al.*, 2003; Bahmani-Oskooee *et al.*, 2020; Nazlioglu *et al.*, 2021).

Following this strand of empirical literature, we use the logarithm of REER index (2007M12 = 100) for the GIIPS countries. The REER data obtained from 38 trading partners covers the longest time span and consists of the 1970:M01-2020:M11 period [8]. It is worthwhile noting that power of ADF-type unit root tests depends more on time span than frequency (Shiller and Perron, 1985). More frequent observations, however, might improve the estimation of short-run dynamics (Stock, 1994, p. 2776) and increase finite sample power at higher frequencies (Choi, 1992). Papell (1997, p. 323) document that empirical findings in favor of PPP are stronger for monthly data than quarterly data; and Hegwood and Papell (1998, p. 280) further point out that the null of unit root tends to be rejected if a sample of low frequency data is large enough.

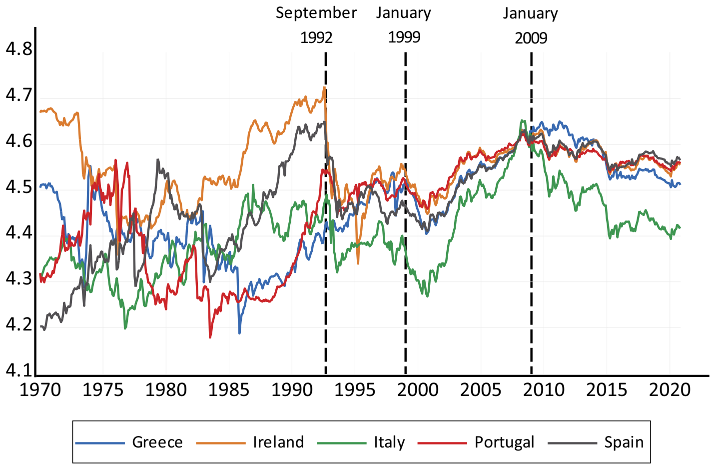
Table 2 reports the descriptive statistics. The mean, median, and maximum of the REERs in the GIIPS countries appear to be close each other. Standard deviation in Portugal is higher than other countries, signaling relatively more volatility. The volatility in Greece and Spain looks similar while Italy and Ireland have less volatility. The skewness is negative in four countries (Greece, Ireland, Portugal and Spain), implying a left-tailed distribution; and it is positive in Italy, indicating a prevalence of right-tailed distribution. All the countries have negative excess kurtosis ($K < 3$) which signals an existence of a platykurtic distribution. The JB normality test of Jarque and Bera (1987) indicates that the null of normality is rejected at 1% for four countries (Greece, Italy, Portugal and Spain) and at 10% for Ireland, providing an evidence for non-Gaussian distributions and indicating an asymmetric behavior.

The plots the REERs in Figure 1 provide some insightful observations for the GIIPS countries as a group. At a first glance, the REERs exhibited very volatile structure up to the early 1990s. Following the brake down of the Exchange Rate Mechanism (ERM) of the European Monetary System in September 1992, they declined substantially in all countries (with the exception of Greece) and continued to be volatile. With the introduction of the euro in January 1999, the REERs depreciated until the early 2000s and appreciated by the end of the 2000s. This appreciation period was ended by the European sovereign debt crisis (started in Iceland as of 2008) which affected the GIIPS countries in 2009 in addition to the 2007/2008 global financial crisis. The REERs have depreciated in all countries during the past decade. Nonetheless, Italy stands out from other countries with much more depreciation. The figure also indicates that the REERs not only have several breaks but also show asymmetric dynamics in different episodes. Therefore, using testing approaches that can capture structural breaks and non-linearity may be important to testing PPP hypothesis for robust investigation in the GIIPS countries.

Country	Mean	Median	Max.	Min.	SD	S	K	JB	*p*-val.
Greece	4.466	4.469	4.650	4.187	0.100	−0.100	2.237	15.847	0.000
Italy	4.409	4.403	4.652	4.198	0.086	0.298	2.833	9.751	0.008
Ireland	4.554	4.552	4.726	4.340	0.071	−0.014	2.565	4.831	0.089
Portugal	4.460	4.500	4.623	4.179	0.120	−0.569	1.874	65.237	0.000
Spain	4.482	4.491	4.650	4.195	0.108	−0.680	2.709	49.181	0.000

Notes: SD is standard deviation, S is Skewness, K is Kurtosis, JB is Jarque and Bera (1987) normality statistic

Table 2.
Descriptive statistics



Notes: September 1992 is the collapse of the Exchange Rate Mechanism (ERM) of the European Monetary System, January 1999 is the introduction of the Euro, and January 2009 corresponds to effects of the European sovereign debt crisis and the global financial crisis

Figure 1. Real effective exchange rates

6. Empirical findings

The results from the conventional tests are provided in Table 3. In addition to ADF statistics, we report the Phillips and Perron (1988)'s unit root statistic (PP) and the Kwiatkowski *et al.*'s (1992) stationarity statistic (KPSS) [9]. As it is well-known, the null hypothesis is unit root for ADF and PP tests but is stationarity for KPSS test. For the model with constant, ADF and PP tests reject the null hypothesis only for Ireland where KPSS test cannot reject the null of stationarity. For the model with constant and trend, ADF test rejects the null hypothesis only for Spain, but PP test cannot reject it for any country. KPSS test cannot reject the null of stationarity only for Ireland.

	Constant				Constant and trend			
Country	ADF	p	PP	KPSS	ADF	p	PP	KPSS
Greece	−1.475	12	−1.621	2.005***	−2.643	12	−2.647	0.383***
Ireland	−2.936**	3	−2.704***	0.177	−3.026	3	−2.782	0.112
Italy	−2.065	11	−2.174	1.515***	−2.490	11	−2.422	0.139*
Portugal	−1.635	10	−1.551	2.159***	−2.150	10	−2.097	0.271***
Spain	−2.500	7	−2.531	2.069***	−3.271*	9	−2.766	0.202**

Notes: The optimal lag(s), p, for ADF test were determined by the t-stat significance of the last lagged dependent variable at the 10% significance level by setting the maximum number of lags to 12. Bartlett kernel spectral estimation method with Newey–West automatic bandwidth was used for PP, and KPSS tests. The critical values for ADF, and PP test are −3.44 (1%), −2.86 (5%) and −2.56 (10%) for model with constant; and −3.97 (1%), −3.41 (5%) and −3.13 (10%) for model with constant and trend. The critical values for KPSS test are 0.73 (1%), 0.46 (5%) and 0.34 (10%) for model with constant; and 0.21 (1%), 0.14 (5%) and 0.11 (1%) for model with constant and trend. ***(1%), **(5%) and *(10%)

Table 3. Results from conventional tests

The results from the unit root tests with a break proposed by Perron (1990) and Zivot and Andrews (1992) are listed in Tables 4 and 5, respectively. The former uses an exogenous break date, while the latter determines it endogenously. We carry out the Perron's test by considering three different break dates which are September 1992 (the collapse of ERM), January 1999 (the introduction of the euro) and January 2009 (corresponding to effects of the European sovereign debt crisis and the global financial crisis). For September 1992, the null hypothesis of unit root is rejected at 10% with Model B and Model C in the case of Spain. For January 1999, the null hypothesis cannot be rejected in none of the countries. For January 2009, the null hypothesis is rejected at 10% for Model B in the case of Ireland and Spain. The results from the Zivot and Andrews's endogenous break test show that the REERs in the GIIPS countries have unit root. The endogenously estimated break dates appear to differ with respect to the model specification and do not provide us with reaching a uniform break date for the GIIPS countries. Nonetheless, the break date based on Model B and Model C is found as August 1992 for Ireland and Spain, which is coincide with the brake down of the ERM of the European Monetary System.

The results from the unit root tests with smooth shifts are given in Table 6. Table also reports the test for the significance of Fourier terms (labeled as F*trig)* which is the usual F-statistic for the null hypothesis of the absence of trigonometric terms (i.e. $\delta_1=\delta_2=0$) in equations (8) and (9). We use $k = k*$ that k^* is the optimal Fourier frequency determined by minimizing the sum of squared residuals from OLS estimation with $k \in [1,\ldots,5]$. The null hypothesis is rejected in three countries (Greece, Ireland and Portugal) for the level shift model and in all countries for the level and trend shift model. The ADF test with Fourier approximation, *ADF*(*k*), rejects the null hypothesis of unit root in Greece, Ireland and Portugal for the level shift model, and one additional

	Model A		Model B		Model C	
Panel A: September 1992	*ADF*(λ)	*p*	*ADF*(λ)	*p*	*ADF*(λ)	*p*
Greece	−3.048	12	−3.081	12	−2.471	12
Ireland	−2.562	3	−3.438	3	−3.492	3
Italy	−2.049	11	−2.690	11	−2.843	11
Portugal	−1.835	10	−1.894	10	−1.670	10
Spain	−1.826	7	−3.563*	9	−4.139*	9
Panel B: January 1999						
Greece	−2.316	12	−2.509	12	−2.206	12
Ireland	−2.979	3	−3.031	3	−2.975	3
Italy	−2.533	11	−2.484	11	−2.529	11
Portugal	−1.998	10	−2.136	10	−2.138	10
Spain	−2.985	9	−3.222	9	−3.243	9
Panel C: January 2009						
Greece	−1.111	12	−2.161	12	−2.613	12
Ireland	−2.893*	3	−2.891*	3	−2.919	3
Italy	−1.393	11	−2.397	11	−2.327	11
Portugal	−1.466	10	−2.136	10	−2.145	10
Spain	−2.596*	9	−3.295*	9	−3.365	9

Notes: The optimal lag(s), *p*, were determined by the t-stat significance of the last lagged dependent variable at the 10% significance level by setting the maximum number of lags to 12. λ is breakpoint ($\lambda = T_B/T$) λ is 0.4 for *September 1992*, 0.6 for *January 1999*, and 0.8 for *January 2009* that corresponding critical values are available in Perron (1990). *** (1%), ** (5%) and * (10%)

Table 4.
Results from unit root test with exogenous break

Table 5.
Results from unit root test with endogenous break

Country	Model A $ADF(\lambda_{inf})$	p	T_B	Model B $ADF(\lambda_{inf})$	p	T_B	Model C $ADF(\lambda_{inf})$	p	T_B
Greece	−3.316	12	1990M04	−3.280	12	1994M01	−3.204	12	2002M04
Ireland	−3.360	3	1982M06	−4.035	3	1992M08	−4.077	3	1992M08
Italy	−3.238	11	2001M06	−3.132	11	2014M03	−3.821	9	2005M12
Portugal	−3.352	10	1989M10	−4.459	10	1977M02	−4.400	10	1977M02
Spain	−3.704	9	1985M10	−3.968	9	1992M08	−4.493	9	1992M08

Notes: The optimal lag(s), p, were determined by the t-stat significance of the last lagged dependent variable at the 10% significance level by setting the maximum number of lags to 12. The break date, T_B, is endogenously determined. The critical values are −4.94 (1%), −4.44 (5%) and −4.19 (10%) for Model A; −5.34 (1%), −4.85 (5%), and −4.60 (10%) for Model B; −5.71 (1%), −5.17 (5%) and −4.89 (10%) for Model C. *** (1%), ** (5%) and * (10%)

Table 6.
Results from unit root test with smooth breaks

Country	Level shift $ADF(k^*)$	p	k^*	F*trig*	p-val.	Level and trend shift $ADF(k^*)$	p	k^*	F*trig*	p-val.
Greece	-3.596^{*}	12	1	7.329^{***}	0.000	−3.610	12	1	4.826^{***}	0.008
Ireland	-3.392^{**}	3	3	3.165^{**}	0.042	-3.646^{*}	3	3	3.644^{**}	0.026
Italy	−2.403	11	2	2.311	0.100	−3.247	11	2	3.714^{**}	0.024
Portugal	-3.591^{*}	10	1	5.443^{***}	0.004	−3.525	10	1	4.431^{**}	0.012
Spain	−2.809	9	2	0.800	0.449	-3.524^{*}	9	3	3.391^{*}	0.092

Notes: The optimal lag(s), p, were determined by the t-stat significance of the last lagged dependent variable at the 10% significance level by setting the maximum number of lags to 12. The optimal Fourier frequency k^* was selected by minimizing the sum of squared residuals from OLS estimation with $k \in [1,\ldots,5]$. F*trig* is the usual F-statistic for testing the null hypothesis of the absence of trigonometric terms (i.e. $\delta_1=\delta_2 = 0$) in equation (8) for the model with level shift and equation (9) for the model with level and trend shift by using $k = k^*$. The critical values for Fourier ADF, $ADF(k^*)$, test are available in Enders and Lee (2012). ***(1%), **(5%) and *(10%)

country (Spain) for the level and trend shift model. This empirical result indicates that modelling structural shifts as a smooth process instead of an instantaneous (sudden) break appears to be crucial for analyzing the behavior of the REERs in the GIIPS countries.

To better visualize how instantaneous break model and smooth shift model capture structural breaks, we display plots of each series with their fitted break function in Figure 2(a) for the level shift model and in Figure 2(b) for the level and trend shift model. At a glance, even though the REERs have many shifts in their mean and trend, dummy variable approach is able to capture only one of these important shocks. On the other hand, Fourier approximation seems well to capture the dynamics of the series. It also shows that there are long swings in the data which is consistent with the smooth shift modelling framework.

We now question whether taking into account for non-linearity in the REER plays a role in analyzing unit root dynamics. To this end, we first test for the existence of non-linearity by using the conventional BDS test proposed by Broock *et al.* (1996). The BDS statistics reported in Table 7 reject the null hypothesis of linearity at 1% for all countries, providing evidence in favor non-linear behavior of the REERs of the GIIPS countries. We then proceed with the non-linear unit root test developed by Kapetanios *et al.* (2003). Note that we use the

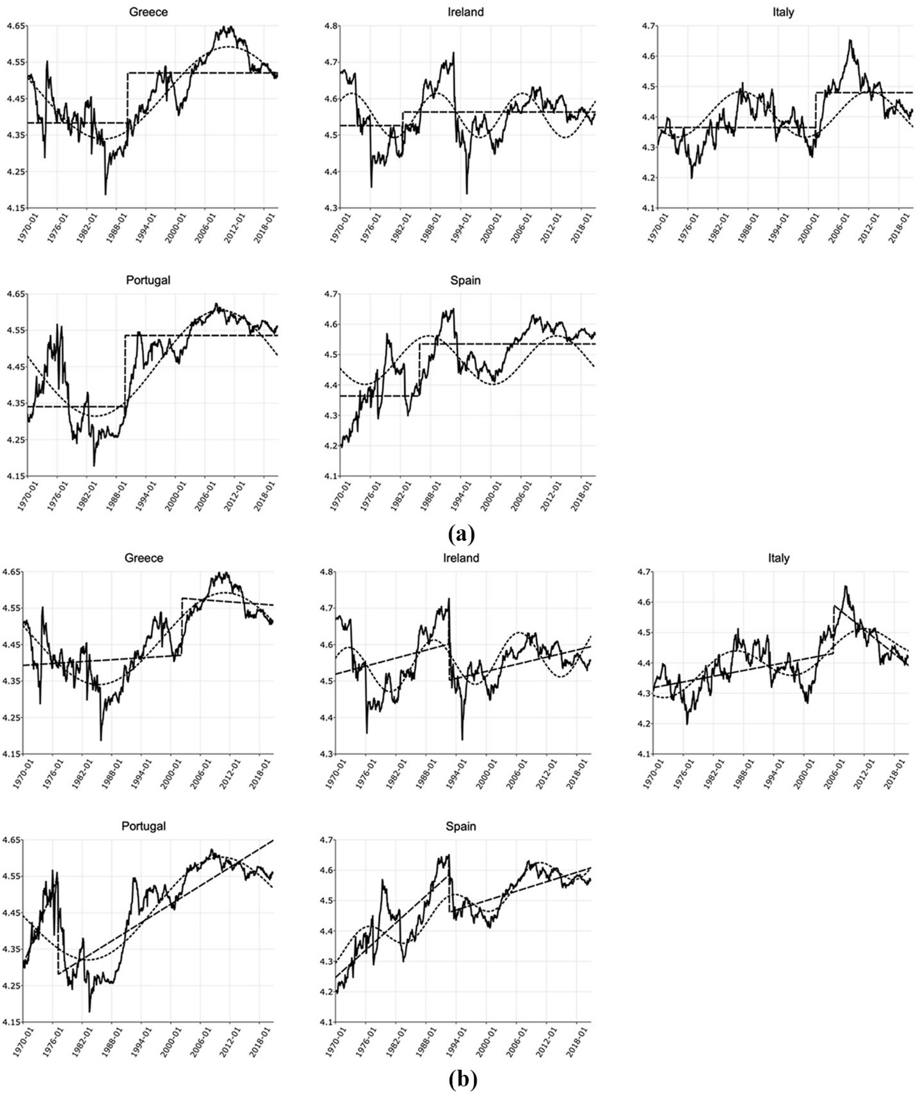


Figure 2.
(a) Real effective exchange rates and break functions (Level shift model), (b) real effective exchange rates and break functions (Level and trend shift model)

Notes: Level shift model corresponds to Equation (5) for the ADF test with endogenous break and to Equation (8) for the ADF test with Fourier approximation. Level and trend shift model corresponds to Equation (7) for the ADF test with endogenous break and to Equation (9) for the ADF test with Fourier approximation. Solid line denotes the shift function with dummy variables, and dashed line denotes the shift function with Fourier approximation

Country	Linearity BDS	p-val.	Constant t_{NL}	p	Constant and trend t_{NL}	p
Greece	241.087***	0.000	−1.974	12	−2.243	12
Ireland	137.688***	0.000	−5.185***	3	−5.031***	3
Italy	146.701***	0.000	−1.712	11	−2.359	11
Portugal	134.835***	0.000	−1.454	10	−3.454	10
Spain	172.488***	0.000	−2.499	2	−2.404	9

Notes: BDS is Broock *et al.* (1996) linearity statistic. The optimal lag(s), p, were determined by the t-stat significance of the last lagged dependent variable at the 10% significance level by setting the maximum number of lags to 12. The critical values for t_{NL} test are −3.38 (1%), −2.93 (5%) and −2.66 (10%) for model with constant (demeaned data); and −3.93 (1%), −3.40 (5%) and −3.13 (10%) for model with constant and trend (demeaned and detrended data). ***(1%), **(5%) and *(10%)

Table 7. Results from non-linear unit root test

demeaned data for the model with constant, and the demeaned and de-trended data for the model with constant and linear trend (Kapetanios *et al.*, 2003, p. 364). The test statistics, t_{NL}, in Table 7 show that the null of unit root is rejected only in the case of Ireland for both the demeaned (the model with constant) and the demeaned and detrended (the model with constant and trend) data.

As indicated by Christopoulos and León-Ledesma (2010), jointly accounting for structural breaks and non-linear adjustment might be crucial for examining unit root in exchange rates. To consider structural breaks and non-linearity together, we conduct the non-linear unit root test with Fourier approximation proposed by Christopoulos and León-Ledesma (2010). The results are reported in Table 8. We also carry out the test for the significance of Fourier terms (labeled as F*trig)* which is the usual F-statistic for the null hypothesis of the absence of trigonometric terms (i.e. $\delta_1=\delta_2=0$) in equations (14) and (15). We use $k = k^*$ that k^* is determined by minimizing the sum of squared residuals from OLS estimation with $k \in [1,...,5]$. The F*trig* statistics reject the null hypothesis in all countries for both the level shift and the level and trend shift models, indicating the significance of Fourier terms.

Country	Level shift Ft_{NL}	p	k^*	F*trig*	p-val	Level and trend shift Ft_{NL}	p	k^*	F*trig*	p-val
Greece	−5.499***	12	1	1276.455***	0.000	−5.489***	12	1	559.260***	0.000
Ireland	−6.554***	3	2	172.107***	0.000	−7.062***	3	3	211.677***	0.000
Italy	−1.971	11	3	188.410***	0.000	−3.602*	11	3	152.142***	0.000
Portugal	−4.635***	10	1	846.623***	0.000	−4.440***	10	1	254.281***	0.000
Spain	−2.349	9	1	119.951***	0.000	−3.364***	9	3	107.982***	0.000

Notes: The optimal lag(s), p, were determined by the t-stat significance of the last lagged dependent variable at the 10% significance level by setting the maximum number of lags to 12. The optimal Fourier frequency k^* was selected by minimizing the sum of squared residuals from OLS estimation with $k \in [1,...,5]$. F*trig* is the usual F-statistic for testing the null hypothesis of the absence of trigonometric terms (i.e., $\delta_1=\delta_2=0$) in equation (14) for the model with level shift and in equation (15) for the model with level and trend shift by using $k = k^*$. The critical values for Ft_{NL} test are available for the level shift model in Christopoulos and León-Ledesma (2010). We simulate the critical values for the level and trend shift model based on Monte Carlo simulations as defined in Christopoulos and León-Ledesma (2010, p. 1082). ***(1%), **(5%) and *(10%)

Table 8. Results from non-linear unit root test with smooth breaks

The non-linear unit root test with Fourier approximation, Ft_{NL} rejects the null hypothesis of unit root in Greece, Ireland and Portugal for the level shift model, and in all countries for the level and trend shift model. In comparison to the non-linear unit root test, it supports the stationarity in two more cases (Greece and Portugal) for the level shift model; and in four more cases (Greece, Italy, Portugal and Spain) for the level and trend shift model. In comparison to the unit root test with smooth breaks, it yields stronger rejections (i.e. the rejection of the null hypothesis at 1% instead of 5 or 10%) for the level shift model and rejects the null hypothesis in three more cases for the level and trend shift model.

7. Conclusion

This study tests PPP hypothesis in the GIIPS countries by conducting a comprehensive unit root analysis. The conventional tests indicate that the real effective exchange rates during the 1970–2020 period have unit root, implying that PPP does not hold in the GIIPS countries. This finding also supported with the unit root tests with sharp break. The unit root test with smooth breaks, in contrast, provides evidence in favor of PPP in Greece, Ireland, Portugal and Spain. While the non-linear unit root test indicates the validity of PPP only for Ireland, the non-linear unit root test with smooth structural breaks reinforces the PPP for all the GIIPS countries. Our finding hence places the importance of accounting for non-linearity and structural breaks to analyze the behavior of real exchange rates in the GIIPS countries.

The validity of PPP means that the real exchange rates are mean reverting (stationary) and converge to their equilibrium values in the long-run. The non-linear mean reversion with smooth structural breaks further indicates that as the real exchange rates deviate from their long-run equilibrium, they tend to have faster speed of adjustment even in the presence of temporary breaks. This finding implies that international investors and speculators are not able to obtain unbounded gains from arbitrage in the GIIPS countries' exchange markets with portfolio allocations. The stationarity of reel effective exchange rates further suggest that depreciations could increase international competitiveness and improve trade balance in the short run, but improvements in trade balance are not unbounded in the long run.

PPP condition provides information whether exchange rates are over- or under-valued in the short-run. Understanding short-run volatility in exchange rates, in particular under floating exchange rate regime, keeps its importance for monetary policy. In the short-run, nominal exchange rates can move substantially but prices cannot, and thereby real exchange rate volatility can be in tandem with nominal exchange rate volatility. The literature addresses exchange rate disturbances with real factors (such as taste and technology shocks in flexible price models), frictions in trade, monetary regimes, and price stickiness. As discussed in Taylor and Taylor (2004), small monetary shocks can result in high levels of exchange rate volatility. Volatility of exchange rates in the short-run may challenge stability of price levels over the long-run. As the price stability is at the center of monetary policy, monetary policy stance can be an essential to determine whether monetary policy contributes economic, financial and monetary developments for maintaining price stability. In particular, the ECB (European Central Bank)'s monetary policy stance, which is based on cross-checking indicators regarding risks to price stability, may allow policy makers to obtain a meaningful assessment of underlying developments and associated risks to price stability in environment marked by a high level of uncertainties including exchange rate volatilities.

Even though there can be substantial deviations from PPP in the short run, PPP is remarkably valid in the long run. There are many structural models to determine equilibrium exchange rates and explain exchange rate fluctuations. Most of international economists instinctively believe in some variant of purchasing power parity as an anchor for long-run real exchange rates (Rogoff, 1996). In the late 1980s and early 1990s, exchange rate was the favored nominal anchor for monetary policy to achieve inflation stabilization. As a response to the currency crises in mid of 1990s and early 2000s, inflation targeting is preferred as the anchor for monetary policy in place of exchange rate targets. But events associated with the 2007/2008 global financial crisis have brought forth limitations to the choice of consumer price index for price stabilization (Frankel, 2011). During last decades, fluctuations in the terms of trade and commodity prices raise a wide range of concerns as regards to global imbalances; and confront monetary policymakers with the issue of optimal monetary policy (Coudert *et al.*, 2011). Such kind of challenge is a particular concern for the GIIPS countries having a higher public deficit and foreign trade imbalances compared to other EU countries. To deal with price fluctuations and trade imbalances, Frankel and Saiki (2002) propose that a country specialized in the export of a particular commodity can peg exchange rate to the price of the export commodity. As another proposal, Engel (2009) argues that monetary policy can target not only inflation and output gap but also the currency misalignment.

Notes

1. We are grateful to amanous reviewer for referring us to Harvey *et al.* (2010) for a detailed discussion of using historical data. To test for the well-known Prebisch–Singer hypothesis (PSH), Harvey *et al.* (2010) suggest to use longer data as far back as is sensibly possible to have more information and potentially eliminate the effect of order of integration issues on the PSH testing procedure.
2. We refer to Taylor (1995) and Rogoff (1996) for comprehensive surveys.
3. Under the null hypothesis, ADF statistic does not follow the asymptotic t-distribution and the critical values are provided by Dickey and Fuller (1979).
4. Under the null hypothesis,$ADF(\lambda_{\text{inf}})$ statistic does not follow the asymptotic t-distribution and the critical values are reported in Zivot and Andrews (1992).
5. Under the null hypothesis, the asymptotic distribution of $ADF(k)$ statistic depends on the Fourier frequency k that the critical are reported in Enders and Lee (2012).
6. Under the null hypothesis, t_{NL} statistic does not follow the asymptotic t-distribution and the critical values are reported in Kapetanios *et al.* (2003).
7. Under the null hypothesis, Ft_{NL} statistic does not follow the asymptotic t-distribution. The critical values are available for the level shift model in Christopoulos and León-Ledesma (2010). We simulate the critical values for the level and trend shift model based on Monte Carlo simulations as defined in Christopoulos and León-Ledesma (2010, p. 1082).
8. The data is available at www.bruegel.org/publications/datasets/real-effective-exchange-rates-for-178-countries-a-new-database Accession Date: 11 January, 2021.
9. The ADF test eliminates the autocorrelation problem in the residuals with a parametric approach by using the lagged dependent variables. The PP and KPSS tests—unlike the ADF test—eliminate the autocorrelation with a non-parametric approach which estimates the consistent long-run variance of the residuals with kernel estimators such as Bartlett method. The ADF-type tests require determining the number lags (p) for Δy_t. Unless the value of p which fits best is

known, using-data dependent methods provides test statistics with better size and power properties. The common data-dependent procedures are the general-to-specific approach (known as the t-stat significance) and the information criteria such as Akaike or Schwarz. Ng and Perron (1995) indicate that the latter approach will tend to select low lag orders that are often not enough to capture serial correlation in the data and leads unit root tests to have size distortions. Perron (1997) further finds out that the general-to-specific approach has good size and power properties and is superior to using a fixed number of lags. We determine the number of lags (p) with the general-to-specific approach. Specifically, we start with first 12 lags and examine the significance of the 12th lag (or Δy_{t-12}). If it is significant at 10% level, we select 12 lags as the optimal lags; if not we use 11 lags and repeat the procedure. This procedure ends with the last significant lag, selected as the optimal lag, otherwise proceed with zero lag.

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