Validity of Purchasing Power Parity for Selected Latin American Countries: Linear and Non-linear Unit Root Tests

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2 authors:

Cláudio Roberto Fóffano Vasconcelos
Federal University of Juiz de Fora

Luiz Antônio de Lima Junior
Federal University of Juiz de Fora

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Validity of purchasing power parity for selected Latin American countries: Linear and non-linear unit root tests☆

Claudio Roberto Fóffano Vasconcelos*, Luiz A. Lima Júnior

Postgraduate Program in Economics, Federal University of Juiz de Fora – PPGEA/UFJF, Brazil

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Abstract

The aim of this study is to examine empirically the validity of PPP in the context of unit root tests based on linear and non-linear models of the real effective exchange rate of Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela. For this purpose, we apply the Harvey et al. (2008) linearity test and the non-linear unit root test (Kruse, 2011). The results show that the series with linear characteristics are Argentina, Brazil, Chile, Colombia and Peru and those with non-linear characteristics are Mexico and Venezuela. The linear unit root tests indicate that the real effective exchange rate is stationary for Chile and Peru, and the non-linear unit root tests evidence that Mexico is stationary. In the period analyzed, the results show support for the validity of PPP in only three of the seven countries.

JEL classification: F31; F41; C22

Keywords: Purchasing power parity; Real effective exchange rate; Unit root

1. Introduction

The hypothesis that changes in the long-term nominal exchange rate follow a difference in the relative prices of two countries, i.e. the hypothesis of purchasing power parity (PPP), is a cornerstone of a series of macroeconomic models and has been a controversial topic in empirical terms in international economics (Sarno, 2005). Another issue regarding the importance of the study of PPP would be the use of PPP as a reference for the real exchange rate of long-term equilibrium, which would allow the assessment of the degree of misalignment of the real exchange rate. Moreover, the validity of the PPP hypothesis is required for the comparison of real income between countries.

Empirical studies of the validity of the PPP hypothesis developed *pari passu* with the advancement of econometric techniques. In the 1980s, the unit root test of the real exchange rate and the real effective exchange rate using the

☆ The authors thank the CNPq for financial support.
* Corresponding author. Tel.: +55 32 21023533; fax: +55 32 21023541.
E-mail address: claudio.foffano@ufjf.edu.br (C.R.F. Vasconcelos).
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approach of Dickey and Fuller was the standard approach. However, this unit root test suffered from low power (Enders and Granger, 1998; Lothian and Taylor, 1996). To solve the problem of the low power of the traditional unit root tests, a strategy involving the use of long-span data was considered (Taylor, 2002). However, the use of data over a time span as long as a century suffers from the existence of changes in exchange rate regimes; among other problems are real shocks that can cause structural breaks or changes in the exchange rate equilibrium.

Recent developments in econometrics panel data have been employed in the empirical tests of the PPP hypothesis. A potential problem with the panel unit root test is that the null hypothesis of this test is usually that all the series are generated by unit root process (Taylor et al., 2001). To overcome this potential problem of the panel unit root test, the use of the seemingly unrelated regressions augmented Dickey–Fuller panel (SURADF), which investigates the null hypothesis of a unit root for the panel and separately for each individual panel, has grown. The SURADF panel identifies how many and which series in the panel are a stationary process (He et al., 2014).

In recent years, the effect of non-linearity in the generation data process has become popular in studies of the validity of PPP. With respect to the unit root test for the real exchange rate and the real effective exchange rate in a non-linear context, see the work of Bahmani-Oskooee and Gelan (2006), Bahmani-Oskooee et al. (2008), Cuestas and Regis (2013), Divino et al. (2009), He et al. (2014), Kapetanios et al. (2003), Kruse (2011), Su et al. (2011), Su et al. (2014) and Taylor (2009), among others, who have provided in-depth information on the theoretical and empirical aspects. Another approach is the analysis of cointegration between the nominal exchange rate and the domestic and foreign prices (Bahamani-Oskooee and Hegerty, 2009; Chang et al., 2011; Drine and Rault, 2008; Liew et al., 2010; Taylor and Taylor, 2004; among others).

In this direction, Enders and Dibooglu (2001), Enders and Granger (1998) and Sollis (2009) highlight non-linearity and asymmetry as price rigidity for reductions and emphasize the fact that they do not occur for price increases in the adjustment process of the PPP. Thus, non-linear models treat the problem of the low power of the linear unit root and linear cointegration tests. Other grounds for the real exchange rate exhibiting non-linear behavior in the process of adjusting the PPP would be central bank intervention in the foreign exchange market, resulting in an asymmetric adjustment of the nominal exchange rate (Krugman, 1991; Taylor, 2004) and transaction costs that inhibit the international process of goods arbitrage (Michael et al., 1997; Sercu et al., 1995). Therefore, as stated by Kim and Moh (2010), the results of weak empirical evidence of the validity of the PPP hypothesis can be attributed to misspecification of the unit root and cointegration tests when they fail to consider the issue of non-linearity in the exchange rate.

Considering the increase interest in testing the PPP hypothesis in developing countries (Bahmani-Oskooee et al., 2008; Drine and Rault, 2008; Su et al., 2014) and that Latin American countries present some characteristics as trade openness, nominal shock and high inflation which might have led to contributed for PPP to hold (He et al., 2014; Su et al., 2011) the aim of this empirical study is to analyze the validation of PPP in its absolute version, considering the real effective exchange rate for principal Latin American countries from January 1994 to April 2014. The seven selected countries in Latin America, namely Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela, represented on average 91% of the region's GDP in the period 1994–2013.

For this purpose, the procedures adopted in the econometric analysis aim to test the linearity of the series according to the approach of Harvey et al. (2008) and, after identifying the linearity of the series, to apply the linear unit root test (Ng and Perron, 2001) or the non-linear unit root test (Kruse, 2011).

The use of the real effective exchange rate in this work is justified in terms of avoiding the potential bias associated with the choice of the base country (or reference) arising from the employment of the bilateral exchange rate and also in view of the fact that the real effective exchange rate is a better measure for understanding trade flows. Furthermore, according to Bahmani-Oskooee et al. (2008), unit root tests on real effective exchange rate set a more comprehensive stage to test PPP because they indicate movement in the overall of a country's currency rather than a movement against the currency of only one trading partner embodied in the real bilateral exchange rate.

Harvey et al. (2008) state that there are several approaches to the linearity test. However, these tests specify the null hypothesis of linearity against the alternative hypothesis of non-linearity considering the assumption that the data generating process is stationary. Thus, to solve this problem, Harvey et al. (2008) develop a test of linearity that is independent of the order of integration of the series.

Regarding the use of the unit root test for non-linearity (Kruse, 2011), this differs from the test by Kapetanios et al. (2003) to develop an analysis considering the locational constant in the smoothed transition function to be non-zero. Thus, the approach of Kruse (2011) has higher power than the Kapetanios test and fits the analysis of PPP better given

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that considering the locational constant to be different from zero, as suggested by Rapach and Wohar (2006) and Taylor et al. (2001), introduces transaction costs, such as transportation, into the analysis.

This paper is organized as follows: Section 2 review empirical literature for Latin America; Section 3 describes the econometric tests of linear and non-linear unit root procedures; Section 4 presents the empirical results; and finally Section 5 contains some concluding remarks.

2. The PPP hypothesis in Latin America

The existing literature has featured several different approaches to empirically test the purchasing power parity (PPP) hypothesis using time series and panel data approaches. Empirical evidence of PPP on the stationarity of the real exchange rate or a cointegration relationship between the nominal exchange rate and the price ratio is abundant, but unfortunately, thus far, the consensus has not yet reached.

In that context, He et al. (2014) applies Panel SURKSS test which is the Kapetanios et al. (2003) test based on the panel estimation method of seemingly unrelated regressions (SUR), with a Fourier function to test the validity of PPP, considering the real exchange rate, for fifteen Latin American countries over the period of December 1994 to February 2010. The empirical results from the Panel SURKSS test with a Fourier function indicate that PPP is valid for these fifteen countries, with the exception of Honduras.

Wu et al. (2011) using data from 76 countries (Latin America includes the Bahamas, Barbados, Chile, Colombia, Q5 Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Mexico, Paraguay, St. Lucia, Trinidad and Tobago, Uruguay, and Venezuela), investigates the relationship between country characteristics and the validity of PPP by examining the stationarity of real exchange rates. The authors used panel unit-root test. The principal results are that PPP holds for Africa and Latin America and PPP tends to be supported for countries with high or moderate openness, low growth rates, high inflation rates and high nominal exchange rate volatility, respectively.

Su et al. (2011) investigates the validity of long-run PPP in fifteen Latin American countries (includes Argentina, Bolivia, Brazil, Chile, Columbia, Costa Rica, Domanic, Ecuador, Haiti, Honduras, Mexico, Paraguay, Peru, Uruguay, and Venezuela) over the period of December 1994 to February 2010 considering the real exchange rate. In this empirical study the authors applies a univariate unit root tests[1] and the empirical results indicate that PPP does not hold for these fifteen countries under study. However, a stationary test with a Fourier function indicates that PPP is valid for four of these 15 Latin American countries and they are Brazil, Chile, Ecuador and Uruguay.

Bahmani-Oskooee et al. (2008) test PPP hypothesis employ monthly real effective exchange rate by (REER) using the conventional ADF test as well as the Kapetaneos et al. (2003) test for 88 developing countries (21 least developed countries of Latin American) for 1980 to 2005. The empirical results showed that the real effective exchange rates of developing countries revert to their mean following a nonlinear path more often than a linear path. Regarding the results for Latin America the null of nonstationarity in REER is rejected to Chile, Costa Rica, Ecuador and Mexico.

Divino et al. (2008) tests the strong version of PPP, if real exchange rates is stationary, for 26 Latin American countries over the period of January 1981 to December 2003. In the panel data framework and unit root under multiple structural breaks the results indicate that the real exchange rate is stationary. Thus, the results provide convincing evidence that PPP holds in Latin-America in the post-1980 period.

Using the panel cointegration approach, Cheng et al. (2008) investigate the validity of weak version of PPP por 61 countries (Latin American includes Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Paraguay, Trinidad and Tobago, Uruguay, and Venezuela) over the period of January 1976 to December 2005. The empirical results suggest that weak PPP hold for a panel of Latin Americam contries.

Su et al. (2014) provide new evidence on PPP hypothesis employed real effective exchange rate based on a new methodology that use the widely accepted KSS (Kapetanios et al., 2003) non-linear unit root tests which the authors wild bootstrapped. They applied this method to test PPP across 61 countries (for Latin America employed seven countries: Argentina, Brazil, Chile, Colombia, Peru, Mexico and Venezuela) over the period 1994–2012. After accounting for

[1] Augmented Dickey and Fuller (ADF), Phillips and Perron (PP), Kwiatkowski, Phillips, Schmidt and Shin (KPSS) and Kapetanios, Shin and Snell (KSS).

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heteroskedasticity as well as non-linearity through the use of the wild-bootstrapped KSS test, the results provide strong evidence that most of the REERs are non-stationary. In particular, for Latin America the empirical results indicate that PPP is not hold for all countries.

The results of Bahmani-Oskooee et al. (2008), Cheng et al. (2008), Divino et al. (2008), Su et al. (2011), Wu et al. (2011) and He et al. (2014) are not consistent with Drine and Rault (2008) and Su et al. (2014). Drine and Rault (2008) aimed to investigate whether the PPP concept could serve as a benchmark to determine the real exchange rate evolution in a large sample of developed and developing countries (for Latin America employed 18 countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, Paraguay, Uruguay, Venezuela). Considering panel unit root tests of strong version of PPP indicate that the null hypothesis of a unit root in the real exchange rate series cannot be rejected for Latin American, African, Asian, MENA and CEE countries). For the test of weak PPP, panel data cointegration tests indicate that weak PPP is rejected by data for Africa, Latin America, Asia and CEE countries (since the null hypothesis of no cointegration is not rejected for these countries).

3. Methodology

3.1. Linearity test

To test the null hypothesis of linearity against the alternative of non-linearity, we employ the test of Harvey et al. (2008). The advantage of the Harvey et al. (2008) test consists of developing a linearity test in which the integration order of the series, which is not known, is taken into consideration. According to Harvey et al. (2008), in standard tests, the null hypothesis of linearity against the alternative of non-linearity (proposed by Teräsvirta (1994) and Luukkonen et al. (1988)) presupposes that the series is stationary in levels, I(0). However, according to the authors, if the series is in fact generated by a linear process integrated of order I(1), then spurious rejections of the null hypothesis of linearity may occur.

Thus, Harvey et al. (2008) propose a test in which no a priori assumption is required about the order of integration of the variables. The idea of this approach consists of performing a test, which is the weighted average of two efficient Wald statistics, one for when the series is generated by an I(0) process and the other for an I(1) series. The weighting is determined by an auxiliary statistic that ensures that the two Wald statistics are efficient, depending on whether the data are generated by an I(0) or an I(1) process. According to the authors this new weight statistic has a standard chi-squared limiting null distribution in both the I(0) and I(1) cases. This test has better performance in terms of size and power than that proposed by Harvey and Leybourne (2007). The statistic is represented as follows:

$$W_\lambda = \{1-\lambda\}W_0 + \lambda W_1 \tag{1}$$

where λ is a function that converges in probability to zero when the series is I(0) and to one when the series is I(1).[2] W_0 is a standard Wald test with a null hypothesis of linearity against an alternative hypothesis of non-linearity considering the series as I(0) and W_1 for the same null and alternative hypotheses when the series is I(1).

The function λ is represented as follows:

$$\lambda(U, S) = \exp\left(-g\left(\frac{U}{S}\right)^2\right) \tag{2}$$

where g is a finite positive constant, U is the statistical standard unit root test of Dickey–Fuller and S the statistic of the stationarity non-parametric test of Harris et al. (2003).

To compute the statistic W_0 initially, we consider a stationary series $\{y_t\}$, I(0), with $t = 1, \ldots, T$, where T is the sample size, such that the data generating process is a non-linear AR(1) model as follows:

$$\begin{aligned} y_t &= \mu + \nu_t, \\ \nu_t &= \rho\nu_{t-1} + \delta f(\vee_{t-1}, \theta)\nu_{t-1} + \varepsilon_t \end{aligned} \tag{3}$$

[2] When the series is stationary, in Eq. (2) $(U/S)^2$diverges, resulting in λ converging to zero, and when the series is unit root, $(U/S)^2$converge to zero resulting in λ converging to one.

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where ρ, δ and $f(\cdot, \theta)$ are chosen such that $\vee_t$ is assumed to be globally stationary. $\{\varepsilon_t\}$ is a zero mean independent identically distributed (IID) white noise process.

Assuming that the function $f(\cdot, \theta)$ allows Taylor series expansion around $\theta = 0$, Eq. (3) can be approximated by second order:

$$\nu_t = \delta_1 \nu_{t-1} + \delta_2 \nu_{t-1}^2 + \delta_3 \nu_{t-1}^3 + \varepsilon_t \tag{4}$$

where δ_1, δ_2 and δ_3 are parameters.

According to Harvey et al. (2008), the second order expansion, as in Eq. (4), is sufficient to capture the essential characteristics of non-linear models such as exponential smooth transition autoregressive model (ESTAR) and logistic smooth transition autoregressive model (LSTAR).

Considering Eq. (4), then, the null hypothesis of linearity and the alternative of non-linearity can be expressed respectively as:

$$\begin{aligned} &\mathrm{H}_{0,0} : \delta_2 = \delta_3 = 0 \\ &\mathrm{H}_{1,0} : \delta_2 \neq 0 \quad \text{and} \quad \text{or} \quad \delta_3 \neq 0 \end{aligned}$$

where $\mathrm{H}_{\cdot,0}$ denotes the hypothesis about the assumption that $\{y_t\}$ is I(0). In terms of $\{y_t\}$, Eq. (4) can be rewritten as:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-1}^2 + \beta_3 y_{t-1}^3 + \varepsilon_t \tag{5}$$

where $\beta_0 = \mu(1 - \delta_1 + \delta_2\mu - \delta_3\mu^2)$, $\beta_1 = \delta_1 - 2\delta_2\mu + 3\delta_3\mu^2$, $\beta_2 = \delta_2 - 3\delta_3\mu$ e $\beta_3 = \delta_3$.

Regarding Eq. (5), the null and alternative hypotheses can be tested as:

$$\begin{aligned} &\mathrm{H}_{0,0} : \beta_2 = \beta_3 = 0 \\ &\mathrm{H}_{1,0} : \beta_2 \neq 0 \quad \text{and} \quad \text{or} \quad \beta_3 \neq 0 \end{aligned}$$

Thus, the statistic of the standard Wald test is:

$$W_0 = T\left(\frac{RSS_0^r}{RSS_0^u} - 1\right)$$

so that RSS_0^u denotes the sum of the squared residuals in OLS of the unrestricted regression of Eq. (5) and imposing $\beta_2 = \beta_3 = 0$ on Eq. (5) we have RSS_0^r, which is the sum of the squared residuals in OLS of the restricted regression, i.e. Eq. (6).

$$y_t = \beta_0 + \beta_1 y_{t-1} + \varepsilon_t \tag{6}$$

According to the authors, W_0 will follow an asymptotic distribution χ^2 (2) under the null hypothesis $\mathrm{H}_{0,0}$.

The W_1 statistic, which corresponds to the linearity test when the series under consideration is considered to be I(1), assumes that the first difference of the series, $\{y_t\}$, is non-linear. Thus, we assume the following non-linear process AR(1) for a series I(1):

$$\begin{aligned} y_t &= \mu + \nu_t, \\ \Delta\nu_t &= \varphi\Delta\nu_{t-1} + \omega f(\Delta\vee_{t-1}, \theta)\Delta\nu_{t-1} + \varepsilon_t \end{aligned} \tag{7}$$

where φ, ω and the function $f(\cdot, \theta)$ are chosen such that $\Delta\nu_t$ is assumed to be globally stationary. Accepting that the function $f(\cdot, \theta)$ admits a Taylor series expansion around $\theta = 0$, Eq. (7) can have the following second-order approximation[3]:

$$\Delta\nu_t = \omega_1\Delta\nu_{t-1} + \omega_2(\Delta\nu_{t-1})^2 + \omega_3(\Delta\nu_{t-1})^3 + \varepsilon_t \tag{8}$$

The null hypothesis of linearity and the alternative of non-linearity are expressed respectively as:

$$\begin{aligned} &\mathrm{H}_{0,1} : \omega_2 = \omega_3 = 0 \\ &\mathrm{H}_{1,1} : \omega_2 \neq 0 \quad \text{and} \quad \text{or} \quad \omega_3 \neq 0 \end{aligned}$$

[3] According to Harvey et al. (2008), the function $f(\cdot, \theta)$ is used in a generic sense but needs not be identical to that in Eq. (3).

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where $H_{\cdot,1}$ denotes the hypothesis on the assumption that $\{y_t\}$ is I(1). Like the previous case of analysis I(0), Eq. (8) can be rewritten as:

$$\Delta y_t = \gamma_1 \Delta y_{t-1} + \gamma_2 (\Delta y_{t-1})^2 + \gamma_3 (\Delta y_{t-1})^3 + \varepsilon_t \tag{9}$$

In this case, since $\Delta y_t = \Delta v_t$, the null and alternative hypotheses, $H_{0,1}$ and $H_{1,1}$, are the same as described above. The corresponding Wald statistic based on Eq. (9) is:

$$W_1 = T \left(\frac{RSS_1^r}{RSS_1^u} - 1 \right)$$

so that RSS_1^u denotes the sum of squared residuals for OLS of the unrestricted regression of Eq. (9) and RSS_1^r is the sum of squared residuals in OLS of the restricted regression when it imposes $\gamma_2 = \gamma_3 = 0$ on Eq. (9), i.e. Eq. (10).

$$\Delta y_t = \gamma_1 \Delta y_{t-1} + \varepsilon_t \tag{10}$$

The large sample standard theory also shows that W_1 follows an asymptotic χ^2 (2) distribution under the null hypothesis $H_{0,1}$.

Harvey et al. (2008) assume that Eqs. (5), (8)–(10) may permit a more general autoregressive structure to allow the correction of serial correlation in $\{y_t\}$, i.e. regressions can be expanded with values of lagged Δy_t.

3.2. Non-linear unit root test

Kapetanios et al. (2003) and Kruse (2011), as part of an exponentially smoothed transition autoregression model (ESTAR), develop a new test of the unit root hypothesis against a globally stationary ESTAR model.

In Kapetanios et al. (2003), the locational parameter of the transition function,[4] which is assumed to be exponential, assumes the value zero. However, according to Cuestas and Regis (2013), imposing a locational parameter equal to zero on the smoothed transition function can be particularly restrictive for the variables for which the threshold value can be different from zero, which is the case for the series of the real exchange rate, as observed by Rapach and Wohar (2006) and Taylor et al. (2001).

In this context, Kruse (2001) expands the unit root test of Kapetanios et al. (2003) by relaxing the assumption of the location parameter equal to zero for a non-zero parameter. Thus, Kruse (2001) test gains in power compared with Kapetanios et al. (2003).

In order to allow the locational parameter, c, to have a non-zero value in the exponential transition function, Kruse (2011) considers the following model of the non-linear time series:

$$\Delta y_t = \phi y_{t-1}(1 - \exp\{-\gamma (y_{t-1} - c)^2\}) + \varepsilon_t \tag{11}$$

where $\{\varepsilon_t\}$ is IID $(0, \sigma^2)$, γ is the smoothing parameter and c is the location parameter.

Following Kapetanios et al. (2003), Kruse (2011) applies a first-order Taylor expansion to the transition function $G(y_{t-1}; \gamma, c) = (1 - \exp\{-\gamma (y_{t-1} - c)^2\})$ around $\gamma = 0$ and proceeds with the regression test:

$$\Delta y_t = \beta_1 y_{t-1}^3 + \beta_2 y_{t-1}^2 + \beta_3 y_{t-1} + u_t \tag{12}$$

To increase the power of the test, the author imposes $\beta_3 = 0$ on Eq. (12); thus:

$$\Delta y_t = \beta_1 y_{t-1}^3 + \beta_2 y_{t-1}^2 + u_t \tag{13}$$

In this case, the null hypothesis of a unit root is H_0: $\beta_1 = \beta_2 = 0$ and the alternative hypothesis of a globally stationary ESTAR process is H_1: $\beta_1 < 0$, $\beta_2 \neq 0$. Note that in H_1 the β_2 has two-sidedness due to the fact that the location parameter, c, may assume real values. The problem of one parameter in the test being unilateral, $\beta_1 < 0$, and the other being two-sided, $\beta_2 \neq 0$, renders the use of the standard Wald test inappropriate. To solve the problem, Kruse (2011) proposes a test τ, which is a version of the Wald test proposed by Abadir and Distaso (2007).

[4] The transition function is: $F(\theta; y_{t-1}) = 1 - \exp\{-\theta (y_{t-1} - c)^2\}$, where locational parameter, c, assumes the value zero.

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3.3. Linear unit root and structural break test

As explained earlier, for the purpose of analysing linear series, we use the unit root tests of Ng and Perron (2001)[5] and the Dickey–Fuller generalized least squares (henceforth DF-GLS) (Elliot et al., 1996).[6] The choice of the Ng–Perron unit root test was made due to this test having greater power and not suffering from a size problem when the unit root process error is close to one.

However, the existence of a possible structural break in the series, a common feature among the selected countries during the period of analysis, may compromise the power of these tests or result in spurious stationarity. Therefore, to avoid these potential problems, we use the unit root test with endogenous structural breaks as proposed by Lee and Strazicich (2003, 2004).

The relevance of using the approach of Lee and Strazicich is to allow both the null hypotheses as the alternative containing the structural break. Thus, the null hypotheses would necessarily imply the rejection of the unit root, leaving no doubt about the condition of the stationarity of the series.

Based on the structural models developed by Perron (1989), Lee and Strazicich (2003) develop a model to test their structural break with the inclusion of two changes in the level of the series, Model A, called "crash," and two structural breaks in the level and the trend of the series, Model C, called "break". According to Lee and Strazicich (2003), the data generation process, DGP, should be considered such that:

$$y_t = \sigma' Z_t + e_t \tag{14}$$

where Z_t is a vector of exogenous variables and $e_t = \beta e_{t-1} + \varepsilon_t$, and $\{\varepsilon_t\}$ is white noise process, N(0, σ^2).

Model A for two changes in the level of the series is described as $Z_t = [1, t, D_{1t}, D_{2t}]$ and $D_{ij} = 1$ for all $t \geq \mathrm{TB}_j + 1$, $j = 1{,}2$, and 0 otherwise. TB_j denotes the period of time when the break occurs.

For Model C, the authors include two changes at the level of the series and two changes of trend described as: $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]$. Because $\mathrm{DT}_{ji} = t - \mathrm{TB}_j$ for all $t \geq \mathrm{TB}_j + 1$, $j = 1{,}2$, and 0 otherwise.

The test is estimated via the Lagrange multiplier (LM) as follows:

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \mu_t \tag{15}$$

where $\tilde{S}_y = y_t - \tilde{\psi}_x - Z_t\tilde{\sigma}$, $t = 2, \cdot, T$. The $\tilde{\sigma}$ are the regression coefficients of Δy_t on ΔZ_t. $\tilde{\psi}_x$ is given by $y_1 - Z_1\tilde{\sigma}$, and y_1 and Z_1 denote the first observation of y_t and Z_t, respectively. The null hypothesis of the unit root test is described as $\phi = 0$.

Finally, the unit root test with one endogenously determined structural break proposed by Lee and Strazicich (2004) is the same unit root test via the minimum Lagrange multiplier.

3.4. Data

As explained earlier, the goal of this work is to verify the validity of the PPP hypothesis. Both unit root tests were executed with the real effective exchange rate (REER) drawn up by the BIS[7] (Bank for International Settlements). The period of test is from January 1994 until April 2014, totaling 244 observations. The calculation of the real effective exchange rate of the BIS is made by the geometric average of the bilateral exchange rate between the country and its trading partners, with the reference year 2008 as consideration for the share of each partner, adjusted by the consumer

[5] Ng and Perron (2001) unit root test also seeks to improve the power of the test for the series with the presence of high moving average. The test seeks to solve or minimize the size of the selected lag problem, since the information criteria, like Akaike information criteria, tend to choose small number of lags. Additionally, Ng and Perron test does not suffer the problem of size when the process unit root error is close to one. Then, based on the idea of choosing the autoregressive spectral density estimator, Ng and Perron (2001) proposed modifications to the information criteria for choosing the optimal lag, taking into account the tests are sensitive to the size of the autoregressive lag.

[6] Elliot et al. (1996) propose an efficient test modifying the Dickey–Fuller test using instead of the method of ordinary least squares, OLS, the structure of generalized least squares, GLS.

[7] http://www.bis.org/statistics/eer/index.htm (accessed on May 2014).

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Table 1
Summary statistics.

	Mean	Median	Maximum	Minimum	Std. dev.	Skewness	Kurtosis	Jarque–Bera
Argentina	5.001	4.789	5.643	4.269	0.419	0.288	1.391	29.69*
Brazil	4.371	4.442	4.701	3.738	0.225	−0.703	2.416	23.55*
Chile	4.592	4.601	4.746	4.402	0.073	−0.394	2.765	6.881**
Colombia	4.453	4.465	4.658	4.169	0.131	−0.326	2.095	12.64*
Mexico	4.636	4.657	4.891	4.133	0.126	−0.878	4.488	53.86*
Peru	4.594	4.591	4.702	4.495	0.051	0.129	2.102	8.874*
Venezuela	4.645	4.626	5.197	3.948	0.257	−0.119	2.547	2.661

Source: Article calculations.
* Significance at 1%.
** Significance at 5%.

price index. An increase in the real effective exchange rate indicate an appreciation. The natural logarithm was applied to all the series. The software used for the analysis is Eviews 8, Matlab 8 and Rats Pro 8.1.

A summary of the statistics is given in Table 1. Based on the results from Table 1, the Jarque–Bera test indicate that, except to Venezuela, for all other 6 countries the real effective exchange rate data sets are approximately non-normal.

The evolution of the REER of the seven countries (Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela) is contained in Chart 1.

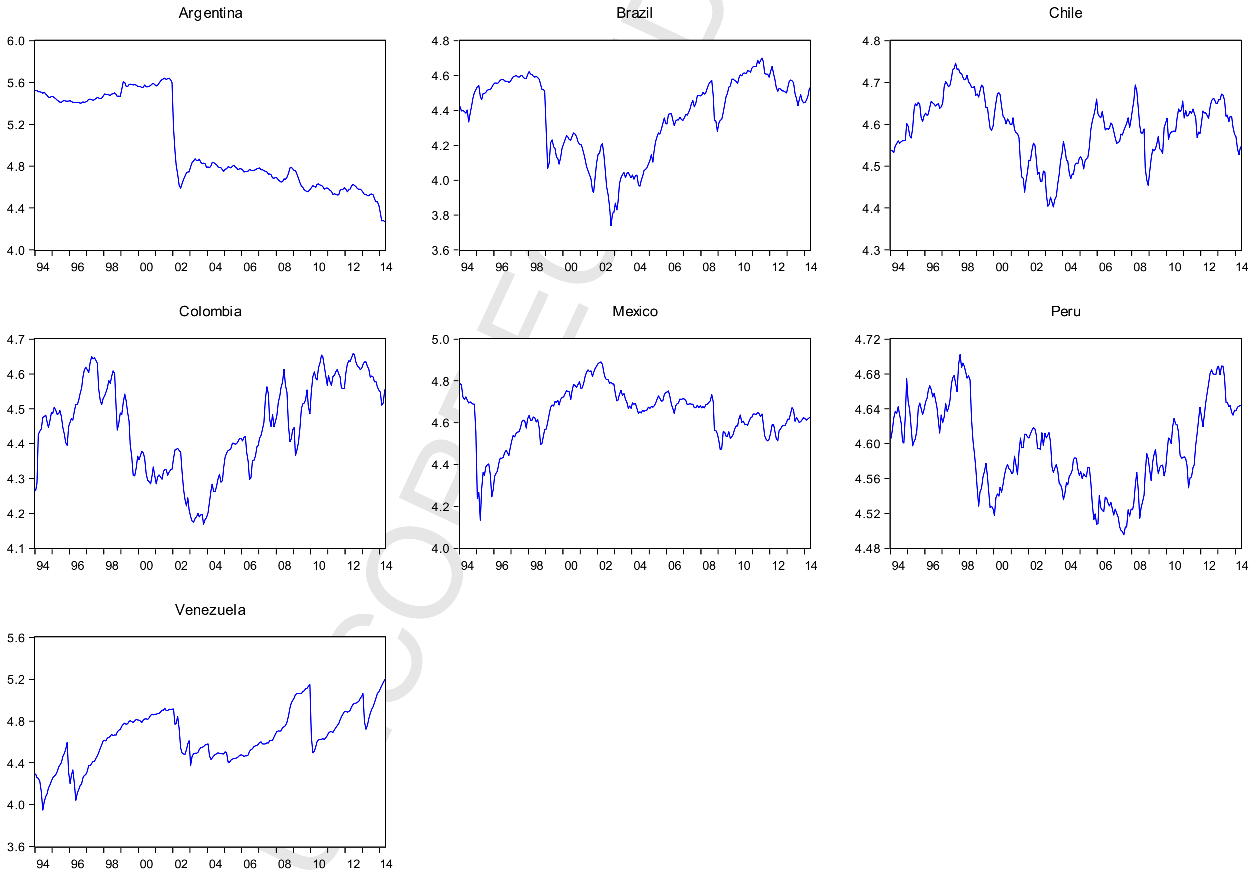

Chart 1. Evolution of REER from 01/1994 to 04/2014.

Source: BIS (2014).

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Q8

Table 2
Linearity test of Harvey et al. (2008).

Variable	Lags[a]	W_λ
Argentina	4	1.944
Brazil	4	2.146
Chile	3	0.061
Colombia	4	−1.940
Mexico	2	18.451***
Peru	1	3.347
Venezuela	2	6.275**

Source: Article calculations.
[a] The order of lags for the computation of the test was chosen according to the Akaike information criterion (AIC).
*** Denotes the rejection of the null hypothesis of the linearity test at the significance level of 1%.
** Denotes the rejection of the null hypothesis of the linearity test at the significance level of 5%.
* Denotes the rejection of the null hypothesis of the linearity test at the significance level of 10%.

In Chart 1, Argentina, Brazil, Mexico and Peru showed a visible structural break in the series. Argentina switched their exchange rate regime[8] to currency board from crawl-like arrangement in 2002, Brazil switched to pegged exchange rate within horizontal bands from floating in January 1999. In December 1994, Mexico changed the exchange rate regime to fixed from floating. As opposed to Argentina, Brazil and Mexico, Peru did not suffer switch in their exchange rate arrangement during the 1990s, but the Asian crises, in 1997–1998, causes a considerable depreciation of REER.

4. Empirical results

Initially, we conducted the linearity test of Harvey et al. (2008), the power of which is not affected by the order of integration of the series, as described in the methodology. The goal of this first step is to identify which series of the real effective exchange rate is linear or non-linear. In the second step, this information is utilized to perform the linear or non-linear unit root test.

According to Table 2, we reject the null hypothesis of linearity at the 5% level of significance for the real effective exchange rate of Mexico and Venezuela. The real effective exchange rate of these two countries is non-linear.

Since the linearity of the series was identified, we analyzed the validity of the hypothesis of purchasing power parity through the stationarity test of the real effective exchange rate. In this part, for the linear series, we decided to use the Elliot et al. (1996) generalized least squares detrending tests (DF-GLS) and Ng–Perron (2001) linear unit root tests. The choice of these tests was made because of the problem of the size and power of the other traditional tests. Table 3 shows the results of these unit root tests.

As shown in Table 3, we reject the null hypothesis of a unit root at the 5% level of significance only for the real effective exchange rate in Chile and Peru. In other words, the real effective exchange rate (henceforth called the REER) of these countries in the period analyzed is stationary and the PPP hypothesis is valid for these two countries. It is clear, too, that the linear unit root tests indicate that the REER series for Mexico and Venezuela would not be stationary. These results were expected since the series are considered non-linear by the Harvey et al. (2008) test.

For the three countries with linear series that were not stationary in the DF-GLS and Ng–Perron tests (Argentina, Brazil and Colombia), there is the possibility of the presence of structural breaks in the REER. These structural breaks could interfere with the DF-GLS and Ng–Perron unit root tests. Thus, unit root tests with an endogenous structural break (Lee and Strazicich, 2003, 2004) were executed. The results are shown in Table 4.

In Table 4, we cannot reject the null hypothesis of the Strazicich tests (2003, 2004) at the 5% level of significance. The real effective exchange rate for these countries is not stationary in the presence of structural breaks. Another result in Table 4 is that with two structural breaks, the exchange rate of Brazil and Colombia experienced a structural break

[8] In The literature, have different definitions of exchange rate arrangements. A widely used classification is that reported by the IMF in its Annual Report on Exchange Rate Arrangements and Exchange Rate Restrictions (IMF, 2014). Second IMF (2014) the de fato arrangements for Brazil, Colombia e Peru is floating, to Chile and Mexico is free floating, Argentina and Venezuela is a crawl-like and conventional peg, respectively.

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Table 3
Q9 Linear unit root test for the real effective exchange rate.

Variable	DF-GLS	MZA	MZT	MSB	MPT
Argentina	0.060	0.092	0.048	0.522**	20.671
Brazil	−1.613	−5.537	−1.646*	0.297	4.480
Chile	−2.373**	−11.281**	−2.375**	0.210**	2.172**
Colombia	−1.038	−2.402	−0.950	0.395	9.394
Mexico	−1.519	−5.695	−1.646*	0.289	4.431*
Peru	−2.375**	−11.550**	−2.375**	0.206**	2.235**
Venezuela	−0.338	−0.852	−0.331	0.388	12.562

Source: Article calculations.
** Denotes the significance level of 5%.
* Denotes the significance level of 10%.
*** Denotes the significance level of 1%.
[a] The order of lags for the computation of the test was chosen according to the modified Akaike information criterion (MAIC).

Table 4
Q10 Structural breaks unit root test.

Variable	Type	One break			Two breaks		
		Lags	*t*-Statistic	Date of structural break	Lags	*t*-Statistic	Date of structural break
Argentina	Crash	2	−3.47*	–	2	3.53*	–
Brazil	Break	2	−2.75	2002.11	1	−4.81	1998.10 2004.12
Colombia	Break	10	−2.22	1999.08	1	−5.08*	1998.08 2004.05

Source: Article calculations.
Note: The critical values for a break in the trend and level, type C, are reported in Lee and Strazicich (2004, Table 1) and two breaks, also model C, in Lee and Strazicich (2003, Table 2).
* Denotes the significance level of 10%.
*** Denotes the significance level of 1%.
* Denotes the significance level of 5%.

between August and October 1998. This structural break is associated with the capital outflow in emerging economies in the Asian crisis in 1997, the Russian crisis in August 1998. As a result, this outflow caused the overshooting of the exchange rate in Brazil in January 1999.

As discussed in Section 3.2, the characteristic of non-linearity of series can reduce the power of linear unit root tests. Regarding the exchange rate, according to Cuestas and Regis (2013), the non-linearity of the series occurs for changes in the exchange rate regimes, periods of hyperinflation and deflation. To these possibilities, Kapetanios et al. (2003) add the technology change, which implies a permanent change in the terms of trade and relative prices between tradables and non-tradables.

In this sense, with the results of the linearity test, in which the series of the effective real exchange rates in Mexico and Venezuela are configured as non-linear, we executed the non-linear unit root tests of Kapetanios et al. (2003) and Kruse (2011), reported in Table 5.

It is observed in Table 5 that the hypothesis is valid only for Mexico. This result was confirmed by both the Kapetanios et al. (2003) and the Kruse (2011). The Kruse approach is the most suitable since it has higher power than the Kapetanios et al. (2003) test.

In sum, of the seven Latin American countries in which the unit root tests were applied, only three (Chile, Mexico and Peru) found statistical support for the validation of PPC for the time period analyzed. These results are consistent with the work of Bahmani-Oskooee et al. (2008) and Su et al. (2014) that just as our work also use the real effective exchange rate. However, when considering the real exchange rate our results are consistent with Drine and Rault (2008), Su et al. (2011), as they conclude that the PPP hypothesis is valid only for some Latin American countries. In this context of real exchange rate the hypothesis of purchasing power parity is valid for all the countries of Latin America to Cheng et al. (2008), Divino et al. (2009) and He et al. (2014). The divergences identified in the results of

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Table 5
Q11 Non-linear unit root test.

Variable	KSS	KSS (m)	Kruse	Kruse (m)
Mexico	−0.43	−4.71***	12.75***	40.29***
Venezuela	0.72	−2.61	2.99	6.86

Source: Article calculations.
Note: The order of lags for the computation of the test was chosen according to the Akaike information criterion (AIC). KSS and KSS (m) denote the Kapetanios et al. (2003) test of the original series and filtered by averaging the series, respectively. Kruse and Kruse (m) denote the Kruse test (2011) of the original series and filtered by averaging the series, respectively.
*** Denotes the significance level of 1%.
** Denotes the significance level of 5%.
* Denotes the significance level of 10%.

these papers can be attributed to differences in the periods under review as well as the use of different approaches of exchange rates (RER or REER) as mentioned previously.

5. Conclusions

Initially, by analyzing the linearity of the real effective exchange rate series, we identified that the series for Mexico and Venezuela have non-linear characteristics. Thus, for these series, the best models for the verification of stationarity would be the category of models using non-linear unit root tests, as this category of tests has greater power than the traditional linear tests. For the other series that showed a linear feature, the best representation for the unit root tests would be linear models.

The results of the analysis of the validity of the PPP hypothesis in its absolute version showed that for the sample of five Latin American countries (Argentina, Brazil, Chile, Colombia, Peru) that showed linearity in their series, statistical evidence of stationarity of the real effective exchange rate series was found only for the countries Chile and Peru, confirming the validity of the PPP hypothesis for these countries. For non-linear series (Mexico and Venezuela), the validity of the PPP hypothesis was confirmed only for Mexico.

Empirical studies show that the validity of the PPP hypothesis depends largely on the period of analysis, the type of data used and the economic characteristics of the countries. As emphasized in the literature (Alba and Park, 2003; Divino et al., 2009; He et al., 2014; Su et al., 2011), it is known that the Latin American countries share important similarities in their economic histories, such as the period of high inflation and processes of trade liberalization after the 1980s. Thus, these specific characteristics of Latin America would be some of the factors that contribute to the empirical verification of the PPP hypothesis. However, our results contrasted with this expectation to verify the validity of the PPC only for three of the seven countries analyzed.

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