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Purchasing power parity for 15 Latin American countries: Panel SURKSS test with a Fourier function

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ABSTRACT

This study applies Panel SURKSS test with a Fourier function to investigate the properties of long-run purchasing power parity (PPP) in fifteen Latin American countries over the period of December 1994 to February 2010. The empirical results from the univariate unit root and panel-based unit root tests indicate that PPP does not hold for these fifteen countries under study. However, results from the Panel SURKSS test with a Fourier function indicate that PPP is valid for these fifteen countries, with the exception of Honduras. Our results highlight the importance of incorporating both nonlinearities and structural breaks when testing the validity of long-run PPP. These results have important policy implications for these fifteen Latin American countries under study.

1. Introduction

During much of the past few decades, a plethora of studies has centered on the investigation of the stationarity of the real exchange rate (O'Connell, 1998; Papell, 1997; Taylor and Sarno, 2001). The results from such studies are not only valuable for empirical researchers and policy makers, but they have also unveiled extremely important implications in international finance. To be more to the point, a non-stationary real exchange rate indicates that any long-run relationship between the nominal exchange rate and domestic and foreign prices is virtually non-existent, therefore invalidating the theory of purchasing power parity (hereafter, PPP). In this event, PPP cannot be used to determine the equilibrium exchange rate; what's more, the invalidation of PPP disqualifies any monetary approach to determining the exchange rate since that would necessitate that PPP holds true.[1]

Empirical evidence of PPP on the stationarity of the real exchange rate is abundant, but unfortunately, thus far, the consensus has not yet reached. For details about previous studies, see the work of MacDonald and Taylor (1992), Taylor (1995), Rogoff (1996), Taylor and Sarno (1998), Sarno and Taylor (2002), Taylor and Taylor (2004), and Lothian and Taylor (2000, 2008) who have provided in-depth information on the theoretical and empirical aspects of PPP and the real exchange rate.

Recently, there is a growing consensus that real exchange rate exhibits nonlinearities and, consequently, conventional unit root tests,

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[1] According to Holmes (2001) and Sarno (2005), PPP is important to policymakers for several reasons. First, it can be used to predict the exchange rate and determine whether a currency is over- or undervalued, which is particularly important for less developed countries and countries experiencing large differences between domestic and foreign inflation rates. Secondly, the notion of PPP is used as the foundation on which many theories of exchange rate determination are built. Consequently, the validity is important to policymakers in developing countries who base their adjustments on PPP. Thirdly, from a theoretical perspective, if PPP is not a valid long-run international parity condition, this casts doubts on the predictions of open-economy macroeconomics, which are based on the assumption of long-run PPP. Indeed, the implications of open-economy dynamic models are sensitive to the presence or absence of a unit root in the real exchange rate. Finally, estimates of PPP exchange rates are often used for practical purposes, such as determining the degree of misalignment of the nominal exchange rate and the appropriate policy response, the setting of exchange rate parities, and the international comparison of national income levels.

such as the Augmented Dickey Fuller (ADF) test, have low power in detecting mean reversion of exchange rate. To be sure, a number of studies have provided solid empirical evidence for the non-linear and/or asymmetric adjustment of the exchange rate in developed countries (Baum et al., 2001; Taylor and Sarno, 2001), in the G7 countries (Kilian and Taylor, 2003), in the Middle East (Sarno and Taylor, 2002), in Asian economies (Enders and Chumrusphonlert, 2004), in African countries (Chang et al., 2011), as well as in ten Latin American Integration Association countries (Chang et al., 2010). It is important to note, nevertheless, that under no circumstance does the finding of non-linear adjustment necessarily signifies the existence of non-linear mean reversion or stationarity. Thus, it is essential that stationary tests based on a non-linear framework be applied.[2]

More recently, it has been reported that conventional unit root tests not only fail to consider information across regions, thereby leading to less efficient estimations, but also have lower power when compared with near-unit-root but stationary alternatives (Choi and Chue, 2007; Im et al., 2003; Levin et al., 2002; Maddala and Wu, 1999; Pesaran, 2007; Taylor and Sarno, 1998) It is not surprising that these factors have induced considerable doubt on many of the earlier findings, which are based on a unit root in real exchange rate. In order to increase the power in testing for a unit root, many researchers have employed panel data. Levin et al. (2002) and Im et al. (2003), for instance, have developed the asymptotic theory and the finite-sample properties of ADF tests for use with panel data. These two tests have significantly improved power even in relatively small panels, but the problem inherent to both is cross-sectional dependence. Zellner (1962) put forth a straightforward approach to handle cross-sectional dependence across countries, and this is to estimate equations using the seemingly unrelated regression (SUR) estimator. Furthermore, O'Connell (1998) demonstrated that size distortions can be avoided without a significant loss of power by basing the panel-based test on SUR estimations instead of OLS estimations.

Taylor and Sarno (1998) and Breuer et al. (2001) have shown that the "all-or-nothing" nature of the tests has not been fully addressed by recent methodological refinements to the Levin et al. (2002) test. Although Im et al. (2003), Maddala and Wu (1999) and Taylor and Sarno (1998) developed tests that permit the autoregressive parameters to differ across panel members under the stationary alternative, they are not informative in terms of the number of series that are stationary processes when the null hypothesis is rejected. The reason is simple: they are not joint tests of the null hypothesis. In this regards, Breuer et al. (2001) claim that, by analogy to a simple regression, when an F-statistic rejects the null that a vector of coefficients is equal to zero, it is not necessarily true that each coefficient is nonzero. Likewise, when the unit-root null hypothesis is rejected, it may very well not be justified to assume that all series in the panel are stationary. In contrast to those panel-based unit root tests that are joint tests of a unit root for all members of a panel and that are incapable of determining the mix of I(0) and I(1) series in a panel setting, Panel Seemingly Unrelated Regression Augmented Dickey–Fuller tests (hereafter, Panel SURADF) investigate a separate unit-root null hypothesis for each and every individual panel member. In doing so, they clearly identify how many and which series in the panel are stationary processes.

[2] A number of studies have also provided solid empirical evidence for the non-linear and/or asymmetric adjustment of the exchange rate. Reasons for the asymmetric adjustment are the presence of transactions costs that inhibit international goods arbitrage and official intervention in the foreign exchange market may be such that nominal exchange rate movements are asymmetric (see, Taylor and Peel (2000); Taylor (2004); Juvenal and Taylor (2008)). Kilian and Taylor (2003) also suggest that nonlinearity may arise from the heterogeneity of opinion in the foreign exchange market concerning the equilibrium level of the nominal exchange rate: as the nominal rate takes on more extreme values, a great degree of consensus develops concerning the appropriate direction of exchange rate moves, and traders act as accordingly.

Perron (1989) argued that if there is a structural break, the power to reject a unit root decreases when the stationary alternative is true and the structural break is ignored. Meanwhile, structural changes present in the data generating process, but have been neglected, sway the analysis toward accepting the null hypothesis of a unit root. The general method to account for breaks is to approximate them using dummy variables. However, this approach has several undesirable consequences. First, one has to know the exact number and location of the breaks. These are not usually known and therefore need to be estimated. This in turn introduces an undesirable pre-selection bias (see Maddala and Kim, 1998). Second, current available tests account only for one to two breaks. Third, the use of dummies suggests sharp and sudden changes in the trend or level. However, for low frequency data it is more likely that structural changes take the form of large swings which cannot be captured well using only dummies. Breaks should therefore be approximated as smooth and gradual processes (see Leybourne et al., 1998). These arguments motivate the use of a recently developed set of unit root and stationary tests that avoid this problem. Both Becker et al. (2004, 2006) and Enders and Lee (2012) develop tests which model any structural break of an unknown form as a smooth process via means of Flexible Fourier transforms. Several authors, including Gallant (1981), Becker et al. (2004) and Enders and Lee (2012), and Pascalau (2010), show that a Fourier approximation can often capture the behavior of an unknown function even if the function itself is not periodic. The authors argue that their testing framework requires only the specification of the proper frequency in the estimating equations. By reducing the number of estimated parameters, they ensure that the tests have good size and power irrespective of the time or shape of the break. Hence, this empirical study applies Panel SURKSS test, which are the Kapetanios et al. (2003, hereafter, KSS) tests based on the panel estimation method of seemingly unrelated regressions (SUR), with a Fourier function to test the validity of PPP for fifteen Latin American countries. As we know, these countries share some characteristics as high inflation, nominal shocks, and trade openness which might have led to quicker adjustment in relative prices and contributed for PPP to hold. This empirical study contributes to field of empirical research by determining whether PPP holds true for these fifteen Latin American countries. Precisely, what we find here is that long-run PPP holds true for most of these fifteen Latin American countries under study, with the exception of Honduras.

The plan of this paper is organized as follows. Section 2 presents the data used in our study. Section 3 first outlines the methodology we employ, then discusses the empirical findings, and some economic and policy implications are also present in this section. Finally, Section 4 reviews the conclusions we draw.

2. Data

The monthly end-of-period nominal exchange rate and CPIs in this empirical analysis are obtained from the Datastream International. Among a sample of these 15 Latin American countries includes Argentina, Bolivia, Brazil, Chile, Columbia, Costa Rica, Domanic, Ecuador, Haiti, Honduras, Mexico, Paraguay, Peru, Uruguay, and Venezuela. The sample period is from 1994:M12 to 2010:M2. Each of the series starts and ends with the date of the earliest data available on the database. The real exchange rate series of a country at time t is defined as $(S_t \times P_t^{US})/P_t^H$, where S_t is the nominal exchange rate of home country per dollar, and P_t^{US} and P_t^H denote the consumer price indices (CPI 2005 = 100) of home country and the USA respectively. Each of the consumer price index and nominal exchange rate series was transformed into natural logarithms before the econometric analysis. Testing for PPP against the USA is based on the argument that internal foreign exchange markets are mostly dollar dominated. A summary of the statistics is given in Table 1. Our Jarque–Bera test results indicate that, but for that of Honduras/USD, for all other 14 country

Table 1
Summary statistics.

	Mean	Maximum	Minimum	Std. dev.	Skewness	Kurtosis	Jarque–Bera
Argentina	0.987	1.709	0.475	0.410	−0.036	1.247	23.477***
Bolivia	1.899	2.102	1.726	0.138	0.251	1.364	22.324***
Brazil	−2.447	−1.705	−2.813	0.287	0.328	1.943	11.785***
Chile	6.440	6.763	6.218	0.145	0.463	2.196	11.476***
Colombia	7.709	8.051	7.370	0.169	0.229	2.009	9.094**
Costa Rica	6.114	6.191	5.978	0.048	−0.465	2.550	8.134**
Dominica	3.042	3.843	2.478	0.437	0.159	1.312	22.501***
Ecuador	10.163	10.883	10.009	0.161	2.407	8.848	437.545***
Haiti	3.764	4.450	3.374	0.256	0.505	3.000	7.776***
Honduras	2.967	3.260	2.737	0.114	0.010	2.813	0.271
Mexico	2.444	2.945	2.261	0.119	1.220	4.673	66.777***
Paraguay	8.446	8.957	8.102	0.238	0.336	1.875	13.101***
Peru	1.138	1.283	0.970	0.094	−0.398	1.611	19.529***
Uruguay	2.985	3.516	2.701	0.238	0.625	2.116	17.868***
Venezuela	0.572	1.085	−0.065	0.229	−0.569	3.159	10.081***

Note:
1. The sample period is from Dec. 1994 to Feb. 2010.
2. ln(real exchange rate) = ln(nominal exchange rate) + ln(foreign price level) − ln(domestic price level); the US as the base country.
3. ** and *** indicate significance at the 5% and 1% level, respectively.

pairs, the bilateral real exchange rate data sets are approximately non-normal.

3. Methodology and empirical results

3.1. Panel SURKSS test with a Fourier function

As we stated earlier, the Panel SURKSS tests are the mixtures of Breuer et al. (2001) Panel SURADF test and the Kapetanios et al. (2003) nonlinear unit test, which are the KSS tests based on the panel estimation method of seemingly unrelated regressions (SUR). This test was first proposed by Wu and Lee (2009) and proved very powerful in their study. According to Wu and Lee (2009), this nonlinear panel unit-root test is superior in power to the Breuer et al. (2001) when the data generating process is highly nonlinear. In contrast to those panel-based unit root tests that are joint tests of a unit root for all members of a panel and that are incapable of determining the mix of I(0) and I(1) series in a panel setting, Panel SURKSS tests investigate a separate unit-root null hypothesis for each and every individual panel member. In doing so, they clearly identify how many and which series in the panel are stationary processes.

In line with Kapetanios et al. (2003), the KSS test is based on detecting the presence of non-stationarity against a nonlinear but globally stationary exponential smooth transition autoregressive (ESTAR) process. The model is given by

$$\Delta X_t = \gamma X_{t-1}\left\{1-\exp\left(-\theta X_{t-1}^2\right)\right\} + \nu_t, \tag{1}$$

where X_t is the data series of interest, ν_t is an i.i.d. error with zero mean and constant variance, and $\theta \geq 0$ is the transition parameter of the ESTAR model and governs the speed of transition. Under the null hypothesis X_t follows a linear unit root process, but X_t follows a nonlinear stationary ESTAR process under the alternative. One shortcoming of this framework is that the parameter γ is not identified under the null hypothesis. Kapetanios et al. (2003) have used a first-order Taylor series approximation for $\{1-\exp(-\theta X_{t-1}^2)\}$ under the null hypothesis $\theta = 0$ and have then approximated Eq. (1) by using the following auxiliary regression:

$$\Delta X_t = \xi + \delta X_{t-1}^3 + \sum_{i=1}^{k} b_i \Delta X_{t-i} + \nu_t, \quad t = 1, 2\ldots, T. \tag{2}$$

In this framework the null hypothesis and alternative hypotheses are expressed as $\delta = 0$ (non-stationarity) against $\delta < 0$ (non-linear ESTAR stationarity). The system of the KSS equations with a Fourier function that we estimate here is:

$$\begin{aligned}
\Delta X_{1,t} &= \alpha_1 + \beta_1 {X^3}_{1,t-1} + \sum_{j=1}^{k1} \theta_{1,j}\Delta X_{1,t-j} + a_1 \sin\left(\frac{2\pi kt}{T}\right) \\
&\quad + b_1 \cos\left(\frac{2\pi kt}{T}\right) + \varepsilon_{1,t} \quad t = 1, 2\ldots, T \\
\Delta X_{2,t} &= \alpha_2 + \beta_2 {X^3}_{2,t-1} + \sum_{j=1}^{k2} \theta_{2,j}\Delta X_{2,t-j} + a_2 \sin\left(\frac{2\pi kt}{T}\right) \\
&\quad + b_2 \cos\left(\frac{2\pi kt}{T}\right) + \varepsilon_{2,t} \quad t = 1, 2\ldots, T \\
&\quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
&\quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\
\Delta X_{N,t} &= \alpha_N + \beta_N {X^3}_{N,t-1} + \sum_{j=1}^{kN} \theta_{N,j}\Delta X_{N,t-j} + a_N \sin\left(\frac{2\pi kt}{T}\right) \\
&\quad + b_N \cos\left(\frac{2\pi kt}{T}\right) + \varepsilon_{N,t} \quad t = 1, 2\ldots, T.
\end{aligned} \tag{3}$$

We test the N null and alternative hypotheses individually:

$$\begin{aligned}
&H_0^1 : \beta_1 = 0; H_A^1 : \beta_1 < 0 \\
&H_0^2 : \beta_2 = 0; H_A^2 : \beta_2 < 0 \\
&\quad \cdot \qquad\qquad \cdot \\
&\quad \cdot \qquad\qquad \cdot \\
&H_0^N : \beta_N = 0; H_A^N : \beta_N < 0.
\end{aligned}$$

The rational for selecting $[\sin(2\pi kt/T), \cos(2\pi kt/T)]$ is based on the fact that a Fourier expression is capable of approximating absolutely integrable functions to any desired degree of accuracy. Where k represents the frequency selected for the approximation, and $[a_i, b_j]'$ measures the amplitude and displacement of the frequency component. It also follows that at least one frequency component must be present if there is a structural break.[3] Gallant (1981), Becker et al. (2004) and Enders and Lee (2012), and Pascalau (2010), show that a Fourier approximation can often capture the behavior of an unknown function even if the function itself is not periodic. The authors argue that their testing framework requires only the specification of the proper

[3] Becker et al. (2006) suggest that the frequencies in Eq. (1) should be obtained via the minimization of the sum of squared residuals. However, their Monte Carlo experiments suggest that no more than one or two frequencies should be used because of the loss of power associated with a larger number of frequencies.

Table 2
Univariate unit root tests.

	Level			1st difference		
	ADF	PP	KPSS	ADF	PP	KPSS
Argentina	−1.455(2)	−1.350(8)	1.342[10]***	−6.51(1)***	−10.83(7)***	0.079[8]
Bolivia	−1.546(6)	−0.741(8)	1.641[11]**	−2.55(5)*	−9.42(6)***	0.596[8]**
Brazil	−1.513(1)	−1.341(4)	0.465[10]**	−10.17(0)***	−10.14(2)***	0.304[4]
Chile	−1.614(1)	−1.562(3)	0.533[10]**	−10.82(0)***	−10.82(0)***	0.157[3]
Colombia	−1.012(0)	−1.215(3)	0.388[10]*	−11.52(0)***	−11.52(1)***	0.243[2]
Costa Rica	−0.591(0)	−0.798(4)	0.369[10]*	−12.72(0)***	−12.75(4)***	0.409[5]*
Dominica	−1.208(4)	−0.959(9)	1.588[10]***	−4.13(3)***	−13.52(9)***	0.067[9]
Ecuador	−2.073(6)	−2.067(8)	0.255[10]	−4.94(5)***	−14.61(8)***	0.109[7]
Haiti	−2.319(0)	−2.321(3)	1.168[10]***	−13.72(0)***	−13.72(4)***	0.224[4]
Honduras	−1.718(0)	−1.616(6)	1.580[10]***	−10.99(0)***	−10.99(0)***	0.159[5]
Mexico	−3.114(2)**	−2.278(6)	0.741[10]***	−10.24(1)***	−18.23(2)***	0.072[12]
Paraguay	−0.984(0)	−1.184(7)	0.582[10]**	−12.59(0)***	−12.87(6)***	0.402[7]*
Peru	−1.271(0)	−1.349(4)	0.599[10]**	−11.56(0)***	−11.52(2)***	0.627[4]**
Uruguay	−1.030(1)	−1.180(7)	0.788[10]***	−10.11(0)***	−10.33(4)***	0.351[8]*
Venezuela	−2.640(0)*	−2.461(3)	0.454[10]*	−14.89(0)***	−15.08(6)***	0.083[8]

Note: *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively. The number in parenthesis indicates the lag order selected based on the recursive t-statistic, as suggested by Perron (1989). The number in the brackets indicates the truncation for the Bartlett Kernel, as suggested by the Newey and West (1994).

frequency in the estimating equations. By reducing the number of estimated parameters, they ensure that the tests have good size and power irrespective of the time or shape of the break. As there is no a priori knowledge concerning the shape of the breaks in the data, a grid-search is first performed to find the best frequency and then we compute the test statistics from the SUR estimates of system (Eq. (1)).[4] Breuer et al. (2001) have demonstrated that the imposition of an identical lag structure across panel members could bias test statistics; thus, we select the lag structures for each equation based on the approach adopted by Perron (1989). Wu and Lee (2009) have indicated that this test has non-standard distributions and the critical values must be obtained by simulation.

3.2. Empirical results

For comparison, several univariate unit root and panel-based unit root tests are first employed to examine the null of a unit root in bilateral real exchange rates for these fifteen Latin American countries that we study. Here, both the first generation and second generation of panel-based unit root tests are employed in our study. Based on the results from Table 2, there is no question that three univariate unit root tests—the Augmented Dickey and Fuller (1981, ADF), the Phillips and Perron (1988, PP) and the Kwiatkowski et al. (1992, KPSS) tests all fail to reject the null of non-stationary real exchange rates for these fifteen Latin American countries. This result is consistent with that of existing literature and is due to the low power of these three univariate unit root tests when the real exchange rates are highly persistent. This result implies that PPP did not hold for these fifteen Latin American countries during the sample period. As we know, univariate unit root tests might have lower power when they are applied to a finite sample. In this situation, the panel-based unit tests are found to be of great help provided that they allow for an increase in the power of the order of the integration analysis by allowing the cross-section and temporal dimensions to be combined. Tables 3 and 4 report the results for the first generation and second generation panel-based unit tests. Three first generation panel-based unit root tests—the Im–Pesaran–Shin (Im et al., 2003) and the MW (Maddala and Wu, 1999) tests both yield the same results indicating that real exchange rates are non-stationary in these fifteen Latin American countries. As we know that there exists a serious drawback of the first generation panel-based unit root tests is that they do not take the cross-sectional dependencies into account in the panel-based unit root test procedure. O'Connell (1998) points out that fail to consider contemporaneous correlations among data will bias the panel-based unit root test toward rejecting the joint unit root hypothesis. Cross-sectional dependencies are acknowledged in the second generation panel unit root tests. Hence, these methods offer a superior way to study the long run behavior of the real exchange rates. Both the linear panel unit root tests of Bai and Ng (2004) and Pesaran (2007) and nonlinear panel unit root tests of Chang (2002) and Ucar and Omay (2009) are used in our study. Table 4 reports the results of these four second generation panel-based unit root tests and results also indicate that real exchange rates are all non-stationary in these fifteen Latin American countries. Our results signify that real exchange rate is a random process. In other words, PPP did not hold among these fifteen Latin American countries under study.

As we stated earlier that panel-based unit root tests are joint tests of a unit root for all members of a panel and that are incapable of determining the mix of I(0) and I(1) series in a panel setting, and also if we fail to incorporate the structural breaks in the model — have low power in detecting the mean reversion of real exchange rates. Perron (1989) argued that if there is a structural break, the power to reject a unit root decreases when the stationary alternative is true and the structural break is ignored. Meanwhile, structural changes present in the data generating process, but have been neglected, sway the analysis toward accepting the null hypothesis of a unit root. Therefore, we proceed to test the real exchange rates by using the Panel SURKSS test with a Fourier function to investigate a separate unit-root null hypothesis for each and every individual panel member. In doing so, we

Table 3
First generation panel unit root tests.

Im, Pesaran and Shin (2003)	t_bar_{NT} −1.529	$W_{t,bar}$ 0.013 (0.505)	$Z_{t,bar}$ −0.177 (0.430)	$t\_bar_{NT}^{DF}$ −1.432	$Z_{t,bar}^{DF}$ 0.453 (0.675)
Maddala and Wu (1999)	P_{MW} 26.966 (0.625)	Z_{MW} −0.392 (0.652)			

Im, Pesaran and Shin (2003): $t\_bar_{NT}^{DF}$ (respectively t_bar_{NT}) denotes the mean of Dickey–Fuller (respectively Augmented Dickey–Fuller) individual statistics. $Z_{t,bar}^{DF}$ is the standardized $t\_bar_{NT}^{DF}$ statistic and associated p-values are in parentheses. $Z_{t,bar}$ is the standardized t_bar_{NT} statistic based on the moments of the Dickey–Fuller distribution. $W_{t,bar}$ denotes the standardized t_bar_{NT} statistic based on simulated approximated moments (Im, Pesaran and Shin, 2003, Table 3). The corresponding p-values are in parentheses. * indicates significance at the 5% level.
Maddala and Wu (1999): P_{MW} denotes the Fisher's test statistic defined as $P_{MW} = -2\sum \log(p_i)$; where p_i is the p-values from ADF unit root tests for each cross-section. Under H_0; P_{MW} has χ^2 distribution with 2 N of freedom when T tends to infinity and N is fixed. ZMW is the standardized statistic used for large N samples: under H0; Z_{MW} has a N (0, 1) distribution when T and N tend to infinity.

[4] In our study, we only consider a specification with a constant but without a time trend because time trend in real exchange rates is not consistent with the long-run PPP.

Table 4
Second generation panel unit root tests.

Bai and Ng (2004)	$\hat{r}$	$Z_{\hat{e}}^{c}$	$P_{\hat{e}}^{c}$	MQ_c	MQ_f
	2	0.674	35.217	1	2
		(0.250)	(0.235)		
Pesaran (2007)	P^*	*CIPS*	*CIPS**		
	6	−1.580	−1.580		
		(0.775)	(0.775)		
Chang (2002)	S_N				
	1.346				
	(0.911)				
Ucar and Omay (2009)	$\bar{t}^*_{NL}$		$\bar{Z}^*_{ANL}$		
	−1.605		0.112		
	(0.248)		(0.247)		

Notes:
Linear Panel Unit Root Tests.
Bai and Ng (2004): $\hat{r}$ is the estimated number of common factors, based on IC criteria functions. $P_{\hat{e}}^{c}$ is a Fisher's type statistic based on p-values of the individual ADF tests. $Z_{\hat{e}}^{c}$ is a standardized Choi's type statistic for large N samples. p-Values are in parentheses. The first estimated value $\hat{r}_1$ is derived from the filtered test MQ_f and the second one is derived from the corrected test MQ_c. * indicates significance at the 5% level.
Pesaran (2007): *CIPS* is the mean of individual Cross sectionally augmented ADF statistics (CADF). *CIPS** denotes the mean of truncated individual CADF statistics. Corresponding p-values are in parentheses. P^* denotes the nearest integer of the mean of the individual lag lengths in ADF tests.
Nonlinear Panel Unit Root Tests.
Chang (2002) and Ucar and Omay (2009): The S_N statistic corresponds to the average of individual nonlinear IV t-ratio statistics (Chang, 2002). $\bar{t}^*_{NL}$ is invariant average KSS $t_{i,NL}$ statistic and $\bar{Z}^*_{ANL}$ is normalized average KSS statistic (Ucar and Omay, 2009). Corresponding p-values are in parentheses.

can clearly identify how many and which series in the panel are stationary processes.

First, a grid-search is performed to find the best frequency, as there is no a priori knowledge concerning the shape of the breaks in the data. We estimate Eq. (1) for each integer $k = 1, \ldots 5$, following the recommendations of Enders and Lee (2012) that a single frequency can capture a wide variety of breaks. The residual sum of squares (RSSs) indicates that a single frequency ($k = 1$) works best for all of the series. Tables 5 and 6 report the results from the Panel SURKSS test without and with a Fourier function, respectively, substantiate that there exists stationarity in real exchange rate for most of the bilateral real exchange rates among these fifteen Latin American countries. We find that Panel SURKSS test with a Fourier function has more power than that of Panel SURKSS without a Fourier function in rejecting the null of a unit root in real exchange. We find that Panel SURKSS with a Fourier function rejects all the unit root null in bilateral real exchange rates, with the exception of Honduras/USD. To avoid the small-sample size bias, we

Table 5
Panel SURKSS unit root test.

Country	t-ratio	Critical value		
		1%	5%	10%
Argentina	−1.959	−3.042	−2.411	−2.028
Bolivia	−1.892*	−2.869	−2.170	−1.812
Brazil	−3.109**	−3.300	−2.669	−2.347
Chile	−3.274***	−2.932	−2.241	−1.879
Colombia	−2.520**	−2.922	−2.212	−1.876
Costa Rica	−1.136	−2.388	−1.781	−1.412
Dominica	−0.922	−3.110	−2.400	−2.086
Ecuador	−2.496***	−2.376	−1.676	−1.284
Haiti	−2.414**	−2.634	−1.944	−1.575
Honduras	0.761	−2.455	−1.812	−1.467
Mexico	−1.499	−2.747	−2.124	−1.793
Paraguay	−2.428**	−2.625	−1.988	−1.626
Peru	−2.734**	−3.102	−2.431	−2.067
Uruguay	−1.621	−3.072	−2.358	−1.976
Venezuela	−2.892**	−3.017	−2.391	−2.019

Notes:
1. The critical values are computed by means of Monte Carlo simulations using 10,000 replications.
2. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 6
Panel SURKSS Test with Fourier Function.

Country	β	SUR Fourier	Critical value		
			1%	5%	10%
Argentina	−0.0135	−3.1794***	−2.918	−2.249	−1.896
Bolivia	−0.0041	−2.8162*	−3.731	−3.050	−2.740
Brazil	−0.0342	−4.4791***	−3.321	−2.681	−2.325
Chile	−0.0008	−4.2070***	−1.563	−1.035	−0.760
Colombia	−0.0006	−3.7547***	−1.379	−0.801	−0.500
Costa Rica	−0.0008	−2.9714***	−0.682	−0.236	0.002
Dominica	−0.0014	−2.6686*	−3.453	−2.764	−2.398
Ecuador	−0.0002	−3.1202***	−1.304	−0.738	−0.424
Haiti	−0.0009	−2.9062***	−2.044	−1.433	−1.073
Honduras	0.0002	0.6738	−2.293	−1.617	−1.279
Mexico	−0.0030	−2.1376**	−2.549	−1.897	−1.546
Paraguay	−0.0001	−1.3847*	−2.173	−1.515	−1.151
Peru	−0.0200	−3.0316***	−2.502	−1.793	−1.427
Uruguay	−0.0019	−2.9718***	−2.682	−1.989	−1.618
Venezuela	−0.0736	−2.9378**	−3.229	−2.617	−2.282

Notes: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Critical values are calculated by Monte Carlo simulation with 10,000 draws, tailored to the present sample size.

estimate the 1%, 5%, and 10% critical values, obtained from simulations based on observations for each series and 10,000 replications using the lag and covariance structure from the panel of real exchange rate data series for each of the 15 panel members. These are also presented in Table 5. One justification of this finding is that in the case of Honduras, the exchange rate is known to be especially ill-behaved. Following the Lau (2009), we further examine the power and size properties of our Panel SURKSS test with and without a Fourier function. Table 7 repots the size and power results of our Panel SURKSS test with and without a Fourier function. Size and power were determined by the rejection rate of the unit root null hypothesis using 5% critical values, reported at Tables 5 and 6, respectively. Lower rejection rate leads to better size behavior while higher rejection rate leads to more power gains. Apparently, our Panel SURKSS test with a Fourier function performs better than that of Panel SURKSS test without a Fourier function, in terms of power and size properties.

3.3. Economic and policy implications

As we know, Latin American countries share important similarities in their economic history, which might lead to co-movements in their real exchange rates. Our results do not come as a surprise because most of the Latin American countries have experienced periods of high inflation and processes of trade openness in the post-1980 period.

Table 7
Empirical size/power of Panel SURKSS test with and without a Fourier function.

Country	Size		Power	
	Fourier function	Without Fourier function	Fourier function	Without Fourier function
Argentina	0.051	0.052	0.912	0.882
Bolivia	0.049	0.052	0.923	0.912
Brazil	0.048	0.052	0.899	0.889
Chile	0.049	0.053	0.901	0.896
Colombia	0.048	0.052	0.913	0.905
Costa Rica	0.049	0.053	0.924	0.899
Dominica	0.048	0.051	0.933	0.911
Ecuador	0.051	0.052	0.941	0,915
Haiti	0.049	0.049	0.872	0.841
Honduras	0.049	0.051	0.921	0,741
Mexico	0.049	0.052	0.933	0.811
Paraguay	0.049	0.051	0.941	0.922
Peru	0.048	0.052	0.922	0.899
Uruguay	0.049	0.051	0.942	0.788
Venezuela	0.049	0.051	0.941	0.911

Note: Details about the simulation procedures (see Lau, 2009).

As argued by Alba and Park (2003), those country-specific characteristics ensure parity and can decisively contribute to empirical evidence of PPP. Our results are consistent with these expectations. Apparently, our results are not consistent with those of the Drine and Rault (2008), Bahmani-Oskooee et al. (2008, 2009), and Lu et al. (2010) that they found PPP holding for only some of the Latin American countries. However, our results are consistent with those of the Cheng et al. (2008) and Divino et al. (2009), these studies found that long-run PPP holds for all of the Latin American countries.

One major policy implication of our study is that the validity of using PPP to determine the equilibrium exchange is mostly unambiguous of these fifteen Latina American countries. The governments of these fourteen countries can use PPP to predict exchange rate that determines whether a currency is over or undervalued and experiencing difference between domestic and foreign inflation rates. Nevertheless, reaping unbounded gains from arbitrage in traded goods is not possible in these fourteen countries.

Fig. 1 displays the time paths of the real exchange rates where a positive change in the real exchange rate indicates real depreciation. We can clearly observe structural shifts in the trend of the data. Accordingly, it appears sensible to allow for structural breaks in testing for a unit root (and/or stationary). The estimated time paths of the time-varying intercepts are also shown in Fig. 1. As we know, the actual nature of break(s) is generally unknown, and there is no specific guide as to where and how many breaks to use in testing for a unit root or stationarity. Using an incorrect specification for the form and number of breaks can be as problematic as ignoring the breaks altogether. A further examination of the figures indicates that all Fourier approximations seem reasonable and support the notion of long swings in real exchange rates.

4. Conclusions

Using monthly data over the period of December 1994 to February 2010, this study empirically tests whether PPP holds among fifteen Latin American countries. The results from the univariate unit root and two generations' panel-based unit root tests all fail to support the PPP throughout all fifteen countries. However, when we conduct Panel SURKSS test with a Fourier function, we find that PPP holds true for these fifteen Latin American countries, with the exception of Honduras. Our results highlight the importance of incorporating both nonlinearities and structural breaks when testing the validity of long-run PPP. As concerns major policy, our study implies that PPP can be used to determine the equilibrium exchange rate for Argentina,

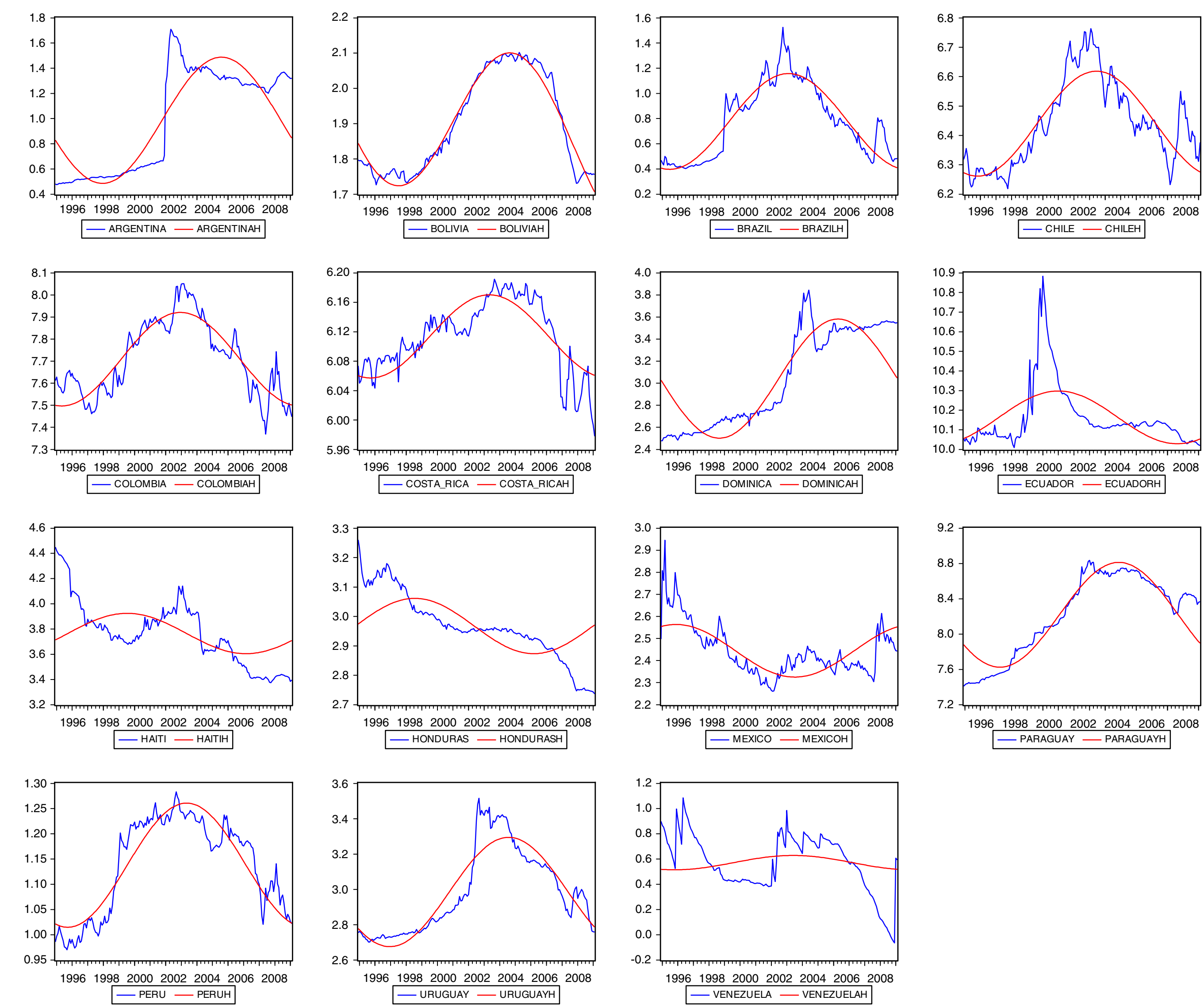

Fig. 1. Logs of Real Exchange Rates and Fitted Nonlinearities for 15 Latin American Countries.

Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Ecuador, Haiti, Mexico, Paraguay, Peru, Uruguay, and Venezuela (fourteen countries under study).

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