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Testing the Purchasing Power Parity Hypothesis: Case of ASEAN Economies

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Abstract

We examine the purchasing power parity (PPP) hypothesis of 10 members of ASEAN. A battery of panel unit root tests is employed on data series from January 1995 to January 2018 in order to search for validity of PPP in the period before the Great Recession and in the post-crisis period. All the calculations are based on four numeraire currencies: Chinese yuan (CNY), Japanese yen (JPY), US dollar (USD), and the euro (EUR). First, following the outcome of the present study for ASEAN countries, the PPP holds mostly with respect to CNY rates. Second, for the post-financial crisis period, our research proves conclusively that the PPP supposition is predominantly valid between the currencies of ASEAN countries and EUR rates. The sample of countries in the study is limited to the ASEAN group of economies. Based on the evaluated parity conditions, the emergence of global economic crisis brought about significant currency shifts in the ASEAN. The selection and testing of a broader range of numeraire currencies is vital to provide empirical underpinning for PPP notion.

Keywords: purchasing power parity, panel unit root tests, ASEAN countries, currency markets

Introduction

The concept of purchasing power parity (PPP) encapsulates the basic idea of competitive open markets and represents an essential part of international macroeconomics. The relative version of PPP implies that variations in the exchange rates correspond to the changes in the ratio of price levels of the observed countries. Shifts in relative prices are, therefore, in the long run, the main driving force behind the development of exchange rates. Due to numerous market frictions, obstacles in cross-border trade, and nonlinearities in the adjustment of exchange rates, deviations from PPP can be substantial (Taylor & Taylor, 2004). Although the empirical literature on PPP for developed market economies is enormous and is continuing to expand with the introduction of new methodological approaches and estimation techniques, the interest of experts is progressively turning toward the emerging Asian economies. Their growing importance in international trade and in global supply chains as well as their increasing participation in international financial flows makes Asian countries particularly interesting candidates for PPP testing.

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Our paper scrutinizes the PPP hypothesis on the members of the Association of Southeast Asian Nations (ASEAN): Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. The economic footprint of the ASEAN camp is important also on a global scale. When taken as a single economy, ASEAN's GDP is the fifth largest in the world, and it has the third largest population. Especially in terms of trade and foreign direct investment inflows, the group cultivates firm ties with EU, China, Japan, and the USA (Feng, 2018). The novelty of this paper is twofold. First, we use a battery of panel unit root tests on extended data series from January 1995 to January 2018 in order to search for validity of PPP in the period before the Great Recession and in the post-crisis period. Second, we run the unit root tests concurrently for Chinese yuan (CNY), Japanese yen (JPY), US dollar (USD), and euro (EUR) rates.

The paper is organized as follows. The next chapter offers a short overview of the literature, while the basic theory of PPP, the data, and the econometric methodology are described in the following chapter. Thereafter, the empirical results are discussed. The main findings of our work are delineated in the concluding part of the paper.

Concise Review of Literature

The study of Bec and Zeng (2013) operates with data set covering the early years of the Association of Southeast Asian Nations. The researchers examine real exchange rates of five charter members of the Association (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) over the period from 1970–2010. Estimating nonlinear models, they reject the null of a unit root for all the five exchange rates with respect to the USD and thus confirm the nonlinear mean-reverting supposition for the group of ASEAN-5. The stationarity of real exchange rates on the USD is also proven in seven out of eight Asian economies in the paper of Zhou and Kutan (2011). Further, Arize *et al.* (2015) inspected the cointegration characteristics of exchange rates and prices of 27 Asian economies against the USD and found support for PPP in a significant number of countries. Lau *et al.* (2012) also confirmed PPP in the period from 1997–2009 for four ASEAN countries when China is used as a base country. Findings on the PPP in Lau *et al.* (2012) at least indirectly point to the importance of cooperation in trade and finance and economic policy coordination among economies in the Asian region.

The remaining studies on our list provide more mixed evidence on PPP or at least some reservations about the empirical validity of this exchange rate concept. Chang *et al.* (2010) rejected the unit root hypothesis for merely four countries' real exchange rates among eight ASEAN members only after the panel's seemingly unrelated regression of the Kapetanios–Shin–Snell (SURKSS) tests are applied with respect to the USD and the JPY. Based on nonlinear unit root tests employing the USD as the numeraire, Chang *et al.* (2012) also reported that PPP is relevant only for three among eight of the ASEAN economies. The PPP proposition has been carefully examined by Munir and Kok (2015) as well, namely, for the class of ASEAN-5 with a wide range of advanced panel unit root tests and cointegration analysis. The evidence on stationarity attributes of real exchange rates toward the USD is, in this study, fragmentary; thus, considerably more support for the theory is reported from the application of panel cointegration test. According to Munir and Kok (2015), an important piece of empirical evidence on PPP could be obtained by elaborating on the different numeraire currencies in future studies. Additionally, we emphasize the work of Choji and Sek (2017) who analysed five ASEAN members via threshold cointegration tests but detected long-run PPP in only two cases.

Recently, Dang and Yang (2017) tested the law of one price on the sample of local retail prices for 78 goods and services in ASEAN-8 countries. The main conclusion from the quoted study is that, under the nonlinear ESTAR regime, in the period from 1990–2013, the convergence to the law of one price can be observed only in approximately 20%–23% of the analysed traded and nontraded prices.

Methodology and Data

Froot and Rogoff (1995) have formally stated the purchasing power parity (PPP) as

$$e_t = \alpha_0 + \alpha_1 p_t + \alpha_2 p_t^* + \xi_t , \quad (1)$$

where e_t stands for the nominal exchange rates defined as the price of foreign currency in the units of domestic currency, p_t presents domestic price index, and p_t^* foreign price index. The error term ξ_t indicates deviations from PPP. All the variables are expressed in logarithms.

The empirical investigation is based on monthly data spanning from January 1995 to January 2018 for ASEAN economies, including Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. The consumer price indices (CPI, 2010=100) and the monthly averages of nominal exchange rates with reference currencies of EUR and USD were assembled from IMF (2018). For the purpose of this empirical investigation, exchange rates of CNY and JPY were calculated as cross rates among the USD rates of observed ASEAN economies and USD rates of CNY and JPY, respectively. Due to the

limited availability of CPI data for Euroarea, the analysis of EUR reference rates starts in January 1996.

The empirical study was conducted in three parts, considering the whole observed period: (1) the pre-economic crisis period; (2) spanning from January 1995 to December 2007; and the post-economic crisis period; (3) ranging from July 2009 to January 2018. NBER (2012) methodology for defining the US business cycles was applied in determination of the subperiods.

In this paper, we estimate the peculiarities of real exchange rates in accordance to the strict version of PPP in Equation 1, where $\alpha_0=0$, $\alpha_1=1$, and $\alpha_2= -1$. The nominal exchange rates should adjust in such a way to eliminate the changes in relative prices. Therefore, the real exchange rates should be constant over the long-run, and their time series are expected to be stationary, with no unit roots (Parikh & Wakerley, 2000).

In search for evidence in favour of PPP, this paper applies panel unit root tests. As described in Boršič and Bekő (2018), the model takes into account the following autoregressive [AR(1)] process for panel data:

$$y_{i,t} = \rho_i y_{i,t-1} + X_{i,t}\delta_i + \varepsilon_{i,t} \ , \tag{2}$$

where i represents N cross-section units observed over periods t=1, 2, ..., T_i, $X_{i,t}$ are exogenous variables in the model (any fixed effects or individual trends), ρ_i are autoregressive coefficients, while errors ($\varepsilon_{i,t}$) are assumed as mutually independent idiosyncratic disturbance. When the absolute value of ρ_i is less than 1, y_i is weakly stationary. When the absolute value of ρ_i is 1, y_i contains a unit root. The panel unit root tests in our analysis differ in two assumptions about the ρ_i in panel unit root tests. Levin, Lin, and Chu (2002) and Breitung (2000) approaches consider common unit root processes, with common autoregressive coefficients across cross-sections ($\rho_i=\rho$) for all i. On the other hand, Im, Pesaran, and Shin (2003), Fisher ADF and Fisher PP (Maddala & Wu, 1999; Choi, 2001) procedures deal with individual unit root processes, where ρ_i varies across cross-sections. According to Boršič and Bekő (2018), the precending subchapters denote the specific characteristics of panel unit tests applied in this study.

Characteristics of Levin, Lin, and Chu test and Breitung test

The Levin, Lin, and Chu (2002) test takes into account the following augmented Dickey–Fuller (ADF) specification

$$\Delta y_{i,t} = \alpha y_{i,t-1} + \sum_{j=1}^{p_i} \beta_{i,j}\Delta y_{i,t-j} + X'_{i,t}\,\delta + \varepsilon_{i,t} \ , \tag{3}$$

where a common $\alpha = \rho-1$ is assumed, while the lag order for difference terms (p_i) varies across cross-sections. The null hypothesis (H_0: $\alpha = 0$) implies that there is a unit root. While the alternative hypothesis (H_1: $\alpha < 0$) implies stationarity. In the Levin, Lin, and Chu (2002) approach, the first step requires an assessment of auxiliary regressions of $\Delta y_{i,t}$ and $y_{i,t}$ on lagged terms $\Delta y_{i,t-j}$ and on exogenous variables $X_{i,t}$. Residuals (denoted by ~) are used as proxies for $\Delta y_{i,t}$ and $y_{i,t}$. In the next step, an estimate of α ($\hat{\alpha}$) is calculated from the pooled equation

$$\Delta\tilde{y}_{i,t} = \alpha\tilde{y}_{i,t-1} + \eta_{i,t} \, , \tag{4}$$

where $\eta_{i,t}$ denotes the error process. Levin, Lin, and Chu (2002) derive the modified t statistics [t* in Eq. (5)] for the resulting $\hat{\alpha}$ and show that it is asymptotically normally distributed:

$$t^* = \frac{1}{\sigma^*}\left(t - NT\cdot\hat{S}_N\hat{\sigma}^{-2}\hat{\sigma}_\alpha\mu^*\right), \tag{5}$$

where μ^* and σ^* are adjustment terms for the mean and standard deviation calculated by Levin, Lin, and Chu (2002), $\hat{\sigma}_\alpha$ is the standard error of $\hat{\alpha}$, $\hat{\sigma}^2$ is the estimated variance of the residuals from Eq. (4), and $\hat{S}_N$ denotes the average of individual ratios of long- to short-run standard deviations. $\hat{S}_N$ is estimated with kernel-based techniques. In accordance with Levin, Lin, and Chu (2002) and Hurlin (2010), we applied the Bartlett kernel, Parzen kernel, and quadratic spectral kernel. In order to check the robustness of the results, we also considered the regression in Eq. (3) augmented with individual linear deterministic trends. The number of lags in each cross-section ADF regression (p_i) was selected by the Schwarz information criterion.

The Breitung test is similar to the Lin, Levin, and Chu test. It estimates auxiliary regressions of $\Delta y_{i,t}$ and $y_{i,t}$ on lagged terms $\Delta y_{i,t-j}$ only, while proxies are transformed and detrended ($\Delta y_{i,t}$*). Panel proxy equation is used to estimate the persistence parameter α:

$$\Delta y_{i,t}^* = \alpha\, y_{i,t-1}^* + v_{i,t}. \tag{6}$$

According to Breitung (2000), under the null hypothesis, the estimate of the persistence parameter α is asymptotically normally distributed.

Characteristics of Im, Pesaran, and Shin test

Im, Pesaran, and Shin (2003) take into account individual unit root processes and calculate individual ADF regression for each cross-section:

$$\Delta y_{i,t} = \alpha y_{i,t-1} + \sum_{j=1}^{p_i} \beta_{i,j}\Delta y_{i,t-j} + X'_{i,t}\,\delta + \varepsilon_{i,t} \ , \tag{7}$$

where the null hypothesis is

$$H_0 : \alpha_i = 0, \quad \text{for all } i, \tag{8}$$

while the alternative hypothesis is defined as

$$H_1: \begin{cases} \alpha_i = 0 & \text{for} \quad i = 1,2,\ldots,N_1 \\ \alpha_i < 0 & \text{for} \quad i = N_1 + 1,\ldots,N \end{cases}, \tag{9}$$

$\bar{t}$ stands for the average of the *t*-statistics for α_i from individual ADF regressions:

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_i \ . \tag{10}$$

Im, Pesaran, Shin (2003) standardize the $\bar{t}$ -statistic and prove that the new statistic *W* is asymptotically normally distributed.

Characteristics of Fisher ADF and Fisher PP Tests

Considering the results of Fischer (1932), Maddala and Wu (1999) and Choi (2001) developed tests that integrate the individual *p*-values. π_i denotes the *p*-value from individual unit root test for cross-section *i*. According to Hurlin (2010), the corresponding *p*-values are uniform [0, 1] variables. Maddala and Wu (1999) define their statistic as

$$\chi^2 = -2\sum_{i=1}^{N} \log(\pi_i) \tag{11}$$

and prove that it has an asymptotic χ^2-distribution with 2N degrees of freedom. Choi (2001) defines a similar *Z* statistic:

$$Z = -\frac{\sum_{i=1}^{N} \log(\pi_i) + N}{\sqrt{N}} \ . \tag{12}$$

The null and alternative hypotheses are the same as for the Im, Pesaran, and Shin test above [Eqs. (8) and (9)]. Under the null hypothesis, Z-statistic is normally distributed.

Presentation of Results

Results of the Levin, Lin, and Chu panel unit root test are presented in Table 1. For the whole period under investigation (January 1995–January 2018), the null of a unit root is strictly rejected in all variations of the test for CNY and EUR as base currencies, while it is rejected for USD base currency when individual effects and individual linear trends are included regardless of kernel specification. As for JPY base currency, the null is rejected only in one out of six variations of the test. Applying these empirical results to PPP theory, we can conclude that, for the whole observed period, there is very strong evidence for validity of PPP in the case of CNY and EUR, quite strong evidence in the case of USD, and very little evidence in the case of JPY as a reference currency.

The precrisis period (January 1995–December 2007) provides less evidence for the validity of PPP because the unit root is rejected only when individual effects are considered with a 10% level of significance for the CNY as reference currency. In the case of EUR, the null is rejected more firmly with a 1% significance level when individual effects are allowed for, while the unit root is not rejected for USD and JPY base currency in any variation of the Levin, Lin, and Chu test. Consequently, the PPP is proven for CNY and EUR as base currencies.

Regarding the post-crisis period (July 2009–January 2018), the null of a unit root is rejected strongly (1% significance level) for USD base currency in all variations of the test, while it is also strongly rejected when individual effects are considered for all kernel-based techniques in the case of EUR as base currency. However, the unit root is not rejected, and PPP not proven in the case of CNY and JPY as reference currencies. Thus, the PPP theory is confirmed in the case of USD and EUR as reference currencies.

Table 1. Results of Levin, Lin, and Chu Test

Sample	Base currency	Bartlett Kernel		Parzen Kernel		Quadratic Spectral Kernel	
		Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends
		t^* (*p*-value)	t^* (*p*-value)	t^* (*p*-value)	t^* (*p*-value)	t^* (*p*-value)	t^* (*p*-value)
1995M1-2018M1	CNY	-2.84467*** (0.0022)	-3.62520*** (0.0001)	-2.75534*** (0.0029)	-3.39716*** (0.0003)	-2.71046*** (0.0034)	-3.29122*** (0.0005)
	JPY	0.20157 (0.5799)	-1.34766* (0.0889)	0.35966 (0.6404)	-1.03958 (0.1493)	0.30566 (0.6201)	-1.07637 (0.1409)
	USD	-0.03777 (0.4849)	-2.75271*** (0.0030)	0.02757 (0.5110)	-2.61838*** (0.0044)	0.00323 (0.5013)	-2.64823*** (0.0040)
	EUR	-2.19054** (0.0142)	-1.81003** (0.0351)	-2.15267** (0.0157)	-1.77429** (0.0380)	-2.19212** (0.0142)	-1.76768** (0.0386)

Table 1. Results of Levin, Lin, and Chu Test – continuation

1995M1-2007M12	CNY	1.59711* (0.0551	-1.02347 (0.1530)	-1.57767* (0.0573)	-1.20267 (0.1146)	-1.58037* (0.0570)	-1.15362 (0.1243)
	JPY	0.36711 (0.6432)	1.69213 (0.9547)	0.35278 (0.379)	1.72024 (0.9573)	0.33934 (0.6328)	1.69327 (0.9548)
	USD	-0.68964 (0.2452)	3.61977 (0.9999)	-0.66254 (0.2538)	3.57239 (0.9998)	-0.67525 (0.2498)	3.61217 (0.9998)
	EUR	-2.84479*** (0.0022)	-1.27696 (0.1008)	-2.76144*** (0.0029)	-1.08868 (0.1381)	-2.78141*** (0.0027)	-1.09787 (0.1361)
2009M7-2018M1	CNY	-0.34785 (0.3640)	-1.05809 (0.1450)	-0.22398 (0.4114)	-0.75396 (0.2254)	-0.18528 (0.4265)	-0.56833 (0.2849)
	JPY	-0.34558 (0.3648)	1.45723 (0.9275)	-0.23131 (0.4085)	1.69499 (0.9550)	-0.25693 (0.3986)	1.61862 (0.9472)
	USD	-2.73269*** (0.0031)	-3.11251*** (0.0009)	-2.65208*** (0.0040)	-2.98523*** (0.0014)	-2.69401*** (0.0035)	-2.90644*** (0.0018)
	EUR	-3.44511*** (0.0003)	0.69641 (0.7569)	-3.29210*** (0.0005)	0.98820 (0.8385)	-3.30661*** (0.0005)	1.05484 (0.8543)

Notes: (1) The number of lags used in each cross-section ADF regression (p_i) was defined by the Schwarz information criterion. Computation was conducted with Newey–West bandwidth selection. (2) *** denotes the significance level of 1%, ** significance level of 5% and * significance level of 10%. (3) The whole period and the precrisis period for EUR reference rates starts with January 1996.

Table 2 displays results of the Breitung panel unit root test. It can be observed that the null of a unit root is firmly rejected in the case of JPY and CNY as base currencies in the whole observed period for all alternative specifications, while the null cannot be rejected for USD and EUR reference currencies. When the presence of the Great Recession is taken into consideration, the null cannot be rejected for either the reference currencies or for time-period specifications. Along with results of the Breitung test, PPP can be confirmed only for the whole period when JPY and CNY are applied as base currencies.

Results of the Im, Pesaran, and Shin test are introduced in Table 3. For the whole observed period, the null of a unit root can be strongly rejected in the case of CNY reference currency for all test specifications. If JPY is considered, the null is rejected with 10% significance level when individual effects and individual linear trends are included and lag selection is determined by Schwarz and Hannan–Quinn information criteria, while the null cannot be rejected in the case of EUR and USD reference currencies. Thus, there is strong evidence for validity of PPP in the case of CNY and

Table 2. Results of Breitung Test

Sample	Base currency	Akaike Information Criterion	Schwarz Information Criterion	Hannan–Quinn Information Criterion
		Individual effects and individual linear trends	Individual effects and individual linear trends	Individual effects and individual linear trends
		t-stat (*p*-value)	*t*-stat (*p*-value)	*t*-stat (*p*-value)
1995M1-2018M1	CNY	-1.59019* (0.0559)	-2.15920** (0.0154)	-1.73752** (0.0411)
	JPY	-3.65533*** (0.0001)	-4.08082*** (0.0000)	-4.08082*** (0.0000)
	USD	0.37221 (0.6451)	-0.13866 (0.4449)	0.02514 (0.5100)
	EUR	-0.51106 (0.3047)	-0.31344 (0.3770)	-0.34121 (0.3665)
1995M1-2007M12	CNY	0.41781 (0.6620)	-0.10945 (0.4564)	-0.04845 (0.4807)
	JPY	-0.73655 (0.2307)	-1.15655 (0.1237)	-1.35898* (0.0871)
	USD	1.45084 (0.9266)	1.77285 (0.9619)	1.77285 (0.9619)
	EUR	-0.69291 (0.2442)	-0.25792 (0.3982)	-0.26064 (0.3972)

Table 2. Results of Breitung Test – continuation

2009M7-2018M1	CNY	-0.20769 (0.4177)	-0.18410 (0.4270)	-0.25420 (0.3997)
	JPY	-1.24490 (0.1066)	-0.76801 (0.2212)	-0.94437 (0.1725)
	USD	1.28435 (0.9005)	1.38266 (0.9166)	1.33883 (0.9097)
	EUR	0.41605 (0.6613)	0.87160 (0.8083)	0.73559 (0.7690)

Notes: (1) *** denotes the significance level of 1%, ** significance level of 5% and * significance level of 10%. (2) The whole period and the precrisis period for EUR reference rates starts with January 1996.

some evidence in favour of PPP in the case of JPY as base currency.

For the precrisis period, the results show the rejection of the null for CNY as reference currency when individual effects are included for all three lag selection criteria. The null can also be rejected when EUR is taken into account in the case of lag selection by Akaike information criteria regardless for both deterministic specifications, while for JPY and USD the null of a unit root cannot be rejected. Consequently, these results show evidence for the validity of PPP in the case of CNY and EUR as reference currencies. As for the post-crisis period, one cannot reject the unit root when CNY, JPY, and USD are considered as reference currencies regardless of test specification. In the case of EUR rates, the null can be rejected when individual effects are included in the specification with all three lag selection criteria. Hence, there is evidence for validity of PPP when EUR is the reference currency.

Maddala and Wu χ^2 statistics, as the results of Fisher ADF panel unit root tests, are stated in Table 4. Considering the whole time period, the null of a unit root cannot be rejected for JPY and USD no matter what the specification of the test is, while the unit root is strongly rejected (1% significance level) in the case of CNY and rejected by 5% and 10% significance level in the case of EUR. Along with these results, one can confirm the validity of PPP in the

Table 3. Results of Im, Pesaran, and Shin Test

Sample	Base currency	Schwarz Information Criterion		Akaike Information Criterion		Hannan–Quinn Information Criterion	
		Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends
		W-stat (*p*-value)	*W*-stat (*p*-value)	*W*-stat (*p*-value)	*W*-stat (*p*-value)	*W*-stat (*p*-value)	*W*-stat (*p*-value)
1995M1-2018M1	CNY	-3.32945*** (0.0004)	-2.99199*** (0.0014)	-3.19978*** (0.0007)	-2.97777*** (0.0015)	-3.11683*** (0.0009)	-2.94016*** (0.0016)
	JPY	0.06908 (0.5275)	-1.44953* (0.0736)	0.48948 (0.6877)	-1.25101 (0.1055)	0.20671 (0.5819)	-1.44953* (0.0736)
	USD	0.31929 (0.6252)	0.57846 (0.7185)	0.41518 (0.6610)	-0.20441 (0.4190)	0.40498 (0.6573)	0.45398 (0.6751)
	EUR	-1.21038 (0.1131)	-0.14190 (0.4439)	-1.11461 (0.1325)	-1.08613 (0.1387)	-1.21038 (0.1131)	-0.73303 (0.2318)
1995M1-2007M12	CNY	-2.28701** (0.0111)	0.27314 (0.6076)	-2.81715*** (0.0024)	-053008 (0.2980)	-2.27783** (0.0114)	0.40716 (0.6581)
	JPY	0.20472 (0.5811)	1.65316 (0.9509)	-0.38098 (0.3516)	0.40852 (0.6586)	-0.34869 (0.3637)	1.02405 (0.8471)
	USD	-0.14988 (0.4404)	4.86334 (1.0000)	-0.81643 (0.2071)	4.53882 (1.0000)	-0.13955 (0.4445)	4.86334 (1.0000)
	EUR	-0.96414 (0.1682)	-0.50872 (0.3055)	-1.44758* (0.0739)	-1.32083* (0.0933)	-0.96141 (0.1682)	-0.50537 (0.3066)

Table 3. Results of Im, Pesaran, and Shin Test – continuation

2009M7-2018M1	CNY	0.01376 (0.5055)	-1.19389 (0.1163)	0.26061 (0.6028)	-1.08572 (0.1388)	0.11609 (0.5462)	-1.06584 (0.1432)
	JPY	0.08081 (0.5322)	1.59587 (0.9447)	0.12700 (0.5505)	0.80247 (0.7889)	-0.10073 (0.4599)	0.80247 (0.7889)
	USD	-0.58358 (0.2798)	-0.45074 (0.3261)	-0.71958 (0.2359)	0.25144 (0.5993)	-0.59358 (0.2764)	-0.18332 (0.4273)
	EUR	-2.42068*** (0.0077)	0.22655 (0.5896)	-2.68312*** (0.0036)	-0.78884 (0.2151)	-2.54072*** (0.0055)	-0.19460 (0.4229)

Notes: (1) *** denotes the significance level of 1%, ** significance level of 5% and * significance level of 10%. (2) The whole period and the precrisis period for EUR reference rates starts with January 1996.

whole period when CNY and EUR are considered as reference currencies.

The evidence for PPP is similar, yet less strong, when the precrisis period is examined. There is no affirmation of PPP in the case of JPY and USD, while PPP can be confirmed when CNY and EUR are base currencies. The null is rejected when individual effects are considered for all three lag selection criteria in the case of CNY. The evidence for PPP is not as strong in the case of EUR, when the null can be rejected only when individual effects are included and Akaike information criterion is used for lag selection. Dealing with the post-crisis period results demonstrate that the null cannot be rejected in the case of CNY, JPY, and USD

Table 4. Results of Fisher ADF Tests (Maddala and Wu χ^2 Statistic)

Sample	Base currency	Schwarz information criterion		Akaike information criterion		Hannan–Quinn information criterion	
		Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends
		χ^2 (*p*-value)	χ^2 (*p*-value)	χ^2 (*p*-value)	χ^2 (*p*-value)	χ^2 (*p*-value)	χ^2 (*p*-value)
1995M1-2018M1	CNY	47.8525*** (0.0004)	40.2466*** (0.0046)	45.9678*** (0.0008)	39.3257*** (0.0061)	46.2142*** (0.0008)	39.5045*** (0.0058)
	JPY	16.4218 (0.6901)	26.3424 (0.1548)	15.5364 (0.7449)	23.6678 (0.2572)	16.1829 (0.7052)	26.3424 (0.1548)
	USD	18.0275 (0.5856)	13.9025 (0.8354)	16.9385 (0.6570)	18.0340 (0.5852)	18.7442 (0.5385)	15.0365 (0.7743)
	EUR	28.9691* (0.0884)	21.0815 (0.3923)	28.8146* (0.0915)	35.9699** (0.0155)	28.9691* (0.0884)	31.2629* (0.0518)
1995M1-2007M12	CNY	34.5334** (0.0227)	13.7195 (0.8444)	41.9868*** (0.0028)	21.5022 (0.3681)	34.4452** (0.0233)	13.6889 (0.8459)
	JPY	14.0657 (0.8272)	8.15253 (0.9908)	17.9265 (0.5923)	16.1911 (0.7047)	17.6815 (0.6084)	10.3226 (0.9619)
	USD	18.2235 (0.5727)	4.72183 (0.9998)	22.8137 (0.2980)	5.95651 (0.9990)	18.1499 (0.5775)	4.72183 (0.9998)
	EUR	27.3593 (0.1255)	21.0813 (0.3924)	34.0973** (0.0255)	27.2264 (0.1290)	27.3593 (0.1255)	21.0047 (0.3969)
2009M7-2018M1	CNY	24.1550 (0.2357)	22.6554 (0.3060)	22.7721 (0.3001)	22.8452 (0.2965)	25.2461 (0.1922)	23.8583 (0.2486)
	JPY	11.1853 (0.9413)	19.9705 (0.4598)	12.4129 (0.9011)	23.9718 (0.2436)	11.1853 (0.9413)	20.5449 (0.4243)
	USD	20.8592 (0.4055)	20.0991 (0.4517)	21.9432 (0.3436)	15.3765 (0.7545)	20.8950 (0.4033)	18.6685 (0.5435)
	EUR	35.1598** (0.0193)	14.8457 (0.7852)	37.5138** (0.0101)	22.1255 (0.3337)	36.2600** (0.0143)	17.6592 (0.6098)

Notes: (1) *** denotes the significance level of 1%, ** significance level of 5% and * significance level of 10%. (2) The whole period and the precrisis period for EUR reference rates starts with January 1996.

as reference currencies, showing no support for PPP theory. However, the null can be rejected when EUR is considered as reference currency and individual effects are included for all three lag selection criteria.

Choi Z statistics resulting from Fisher ADF panel unit root test is presented in Table 5. In the whole period, there is again strong rejection of the unit root when CNY is the base currency. If individual effects and individual linear trends are included and either Schwarz or Hannan–Quinn lag selection criterion is applied the null can be rejected also in the case of JPY. While the unit root cannot be rejected in the case of USD and EUR. Thus, there is strong evidence for PPP in the case of CNY and some evidence for PPP in the case of JPY.

For the precrisis period, the results are practically the same as in the case of Maddala and Wu χ^2 statistics (Table 4). The results support the PPP theory in the case of CNY when individual effects are included, regardless of lag selection criterion and in the case of EUR rates when individual effects are included and Akaike information criterion is applied. As for the post-crisis period, the null cannot be rejected when JPY and USD are reference currencies, providing no support for PPP. The unit root can be rejected at a 10% significance level if CNY is the reference currency when Schwarz information criterion defines the lag with individual effects and Hannan–Quinn information criterion defines the lag regardless of deterministic specification. While in the case of EUR, the null can be rejected when individual effects are included, regardless of lag selection

Table 5. Results of Fisher ADF Tests (Choi Z-Statistic)

Sample	Reference currency	Schwarz Information Criterion		Akaike Information Criterion		Hannan–Quinn Information Criterion	
		Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends
		Z (*p*-value)	*Z* (*p*-value)	*Z* (*p*-value)	*Z* (*p*-value)	*Z* (*p*-value)	*Z* (*p*-value)
1995M1-2018M1	CNY	-3.47810*** (0.0003)	-3.08320*** (0.0010)	-3.29225*** (0.0005)	-3.01163*** (0.0013)	-3.20748*** (0.0007)	-2.97789*** (0.0015)
	JPY	0.15187 (0.5604)	-1.51149* (0.0653)	0.58926 (0.7222)	-1.19860 (0.1153)	0.28753 (0.6131)	-1.51149* (0.0653)
	USD	0.32240 (0.6264)	064219 (0.7396)	0.54587 (0.7074)	-0.01755 (0.4930)	0.42446 (0.6644)	0.56074 (0.7125)
	EUR	-1.17573 (0.1199)	-0.05621 (0.4776)	-1.00647 (0.1571)	-0.80504 (0.2104)	-1.17573 (0.1199)	-0.54456 (0.2930)
1995M1-2007M12	CNY	-2.42300*** (0.0077)	0.29064 (0.6143)	-2.91573*** (0.0018)	-0.42342 (0.3360)	-2.41405*** (0.0079)	0.42343 (0.6640)
	JPY	0.28270 (0.6113)	1.74641 (0.9596)	-0.29206 (0.3851)	0.59682 (0.7247)	-0.31085 (0.3780)	1.09831 (0.8640)
	USD	-0.14421 (0.4427)	4.68820 (1.0000)	-0.81917 (0.2063)	4.55611 (1.0000)	-0.13207 (0.4475)	4.68820 (1.0000)
	EUR	-0.95286 (0.1703)	-0.49809 (0.3092)	-1.39073* (0.0822)	-1.22500 (0.1103)	-0.95285 (0.1703)	-0.48724 (0.3130)
2009M7-2018M1	CNY	-1.27747* (0.1007)	-1.09983 (0.1357)	-1.09093 (0.1377)	-1.15650 (0.1237)	-1.39959** (0.0808)	-1.33317* (0.0912)
	JPY	1.02932 (0.8483)	-0.43337 (0.3324)	0.80733 (0.7903)	-1.09548 (0.1367)	1.02932 (0.8483)	-0.56753 (0.2852)
	USD	-0.52297 (0.3005)	-0.45599 (0.3242)	-0.60951 (0.2711)	0.34336 (0.6343)	-0.50040 (0.3084)	-0.17718 (0.4297)
	EUR	-2.48687*** (0.0064)	0.23943 (0.5946)	-2.70204*** (0.0034)	-0.65594 (0.2559)	-2.61343*** (0.0045)	-0.17040 (0.4323)

Notes: (1) *** denotes the significance level of 1%, ** significance level of 5% and * significance level of 10%. (2) The whole period and the precrisis period for EUR reference rates starts with January 1996.

Table 6. Results of Fisher PP Tests (Maddala and Wu χ^2 Statistic)

Sample	Reference currency	Bartlett Kernel		Parzen Kernel		Quadratic Spectral Kernel	
		Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends
		χ^2 (p-value)	χ^2 (p-value)	χ^2 (p-value)	χ^2 (p-value)	χ^2 (p-value)	χ^2 (p-value)
1995M1-2018M1	CNY	42.0686*** (0.0027)	30.2595* (0.0658)	42.3277*** (0.0025)	30.3690* (0.0641)	41.4027*** (0.0033)	30.4296* (0.0632)
	JPY	12.7235 (0.8889)	19.4272 (0.4942)	14.0402 (0.8285)	21.0033 (0.3969)	13.8234 (0.8393)	20.6993 (0.4150)
	USD	16.0456 (0.7138)	11.1287 (0.9428)	16.0847 (0.7114)	11.4545 (0.9336)	15.8214 (0.7276)	11.3596 (0.9364)
	EUR	26.1754 (0.1601)	15.5690 (0.7430)	26.0181 (0.1652)	15.5066 (0.7467)	25.4429 (0.1850)	15.4561 (0.7497)
1995M1-2007M12	CNY	31.2623* (0.0518)	9.84858 (0.9708)	31.7101** (0.0465)	10.1218 (0.9659)	31.6013** (0.0477)	10.0988 (0.9663)
	JPY	13.8624 (0.8374)	7.88401 (0.9926)	13.7552 (0.8427)	7.76052 (0.9933)	13.6580 (0.8474)	7.50054 (0.9947)
	USD	15.8313 (0.7270)	3.60539 (1.0000)	16.1608 (0.7066)	3.82255 (1.0000)	16.1123 (0.7096)	3.69291 (1.0000)
	EUR	21.4926 (0.3687)	13.6643 (0.8471)	21.5861 (0.3664)	13.7937 (0.8408)	21.6758 (0.3584)	13.0942 (0.8733)
2009M7-2018M1	CNY	10.0722 (0.9668)	16.4080 (0.6910)	11.2290 (0.9401)	18.4308 (0.5591)	11.0747 (0.9443)	18.4781 (0.5559)
	JPY	9.25082 (0.9798)	9.99858 (0.9682)	9.62227 (0.9745)	10.6361 (0.9551)	9.57215 (0.9753)	10.6975 (0.9537)
	USD	20.5745 (0.4225)	15.6444 (0.7384)	20.8082 (0.4085)	17.1958 (0.6402)	20.7510 (0.4119)	17.3307 (0.6314)
	EUR	32.9738** (0.0340)	12.5791 (0.8947)	33.3416** (0.0309)	13.5735 (0.8514)	33.2907** (0.0313)	13.7189 (0.8445)

Notes: (1) *** denotes the significance level of 1%, ** significance level of 5% and * significance level of 10%. (2) The whole period and the precrisis period for EUR reference rates starts with January 1996.

Table 7. Results of Fisher PP Tests (Choi Z-Statistic)

Sample	Reference currency	Bartlett Kernel		Parzen Kernel		Quadratic Spectral Kernel	
		Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends	Individual effects	Individual effects and individual linear trends
		Z (p-value)	Z (p-value)	Z (p-value)	Z (p-value)	Z (p-value)	Z (p-value)
1995M1-2018M1	CNY	-2.96619*** (0.0015)	-2.14210** (0.0161)	-3.02963*** (0.0012)	-2.15065** (0.0158)	-2.97089*** (0.0015)	-2.15214** (0.0157)
	JPY	1.03533 (0.8497)	-0.58582 (0.2790)	0.75582 (0.7751)	-0.82958 (0.2034)	0.80799 (0.7905)	-0.79004 (0.2148)
	USD	0.57305 (0.7167)	1.09831 (0.8640)	0.54544 (0.7073)	1.02490 (0.8473)	0.59219 (0.7231)	1.04195 (0.8513)
	EUR	-0.71081 (0.2386)	0.69794 (0.7574)	-0.70344 (0.2409)	0.70402 (0.7593)	-0.66069 (0.2544)	0.70939 (0.7610)
1995M1-2007M12	CNY	-2.10412** (0.0177)	1.23757 (0.8921)	-2.15175** (0.0157)	1.19491 (0.8839)	-2.13704** (0.0163)	1.19362 (0.8837)
	JPY	0.25249 (0.5997)	1.68428 (0.9539)	0.27271 (0.6075)	1.70822 (0.9562)	0.29550 (0.6162)	1.79508 (0.9637)
	USD	0.12679 0.5504	5.39800 1.0000	0.06458 0.5257	5.49808 1.0000	0.07517 0.5300	5.50966 1.0000
	EUR	-0.27488 0.3917	0.64680 0.7411	-0.32068 0.3742	0.53602 0.7040	-0.31023 0.3782	0.65297 0.7431

Table 7. Results of Fisher PP Tests (Choi Z-Statistic) – continuation

2009M7-2018M1	CNY	1.11900 (0.8684)	-0.14094 (0.4440)	0.94840 (0.8285)	-0.50810 (0.3057)	0.99374 (0.8398)	-0.48647 (0.3133)
	JPY	1.37486 (0.9154)	1.54759 (0.9391)	1.29086 (0.9016)	1.37642 (0.9157)	1.30454 (0.9040)	1.41224 (0.9211)
	USD	-0.34027 (0.3668)	0.32645 (0.6280)	-0.40966 (0.3410)	0.06521 (0.5260)	-0.37440 (0.3541)	0.05901 (0.5235)
	EUR	-2.26363** (0.0118)	0.62513 (0.7341)	-2.29837** (0.0108)	0.40582 (0.6576)	-2.29732** (0.0108)	0.37612 (0.6466)

Notes: (1) *** denotes the significance level of 1%, ** significance level of 5% and * significance level of 10%. (2) The whole period and the precrisis period for EUR reference rates starts with January 1996.

criteria applied. Hence, there is evidence in support of PPP when CNY and EUR are considered as reference currencies.

The results of Fisher PP tests are manifested in Table 6 (Maddala and Wu χ^2 statistics) and Table 7 (Choi *Z*-statistics). Examining the whole observed period, the unit root cannot be rejected; consequently, there is no evidence in favour of PPP when JPY, USD, or EUR are reference currencies, regardless of kernel techniques or deterministic specification applied. However, the null can be strongly rejected if CNY is reference currency for all possible test specifications, providing evidence in support of PPP validity.

Considering the precrisis period, the results are similar to the whole period outcomes. There is no evidence what so ever for PPP when JPY, USD, or EUR are reference currencies. As for CNY, the results support the validity of PPP when individual effects are included for all three kernel specifications. In the post-crisis period, the null of a unit root cannot be rejected when CNY, JPY, or USD are considered as base currencies disregarding test specifications. When EUR rates are used, the null can be rejected when individual effects and any of the three kernel techniques are applied. Thus, there is support for PPP theory only in the case of EUR as the reference currency.

Conclusion

The paper formally examines the stationary properties of real exchange rates for ASEAN countries using data series from the beginning of 1995. We found important evidence for the mean reversion of real exchange rates toward PPP in the data sample, although the results reveal some heterogeneity. When we take the whole observed period, the PPP is supported for ASEAN-10 by all the panel unit root tests in the case of CNY values. With respect to the remaining three reference currencies, the relevance of the PPP hypothesis is not unequivocal, but the exchange rate theory is for all base currencies confirmed under at least one panel unit root test. Testing the data sample until the end of 2007 for JPY, USD, and EUR rates produced rather mixed results. In the same period, the PPP proposition holds for the ASEAN group, when China's currency acts as the base for real exchange rates. For the period after the outbreak of the global economic crisis, the results clearly corroborate the PPP proposition for real exchange rates of ASEAN markets when the calculations are performed on euro data. The evidence on PPP-based adjustment of real exchange rates is in the observed Asian economies for the remaining numeraire currencies in the post-crisis time span fairly weak.

The empirical exercise, presented in this paper, brings two important insights. First, the selection and testing of a broader range of numeraire currencies are vital to provide an empirical underpinning for PPP notion. Following the outcome of the present study for ASEAN countries, the PPP holds mostly with respect to CNY rates. Second, when it comes to the parity conditions, the emergence of global economic crisis brought about significant currency shifts in the ASEAN. For the post-financial crisis period, our research proves conclusively that the PPP supposition is predominantly valid between the currencies of the ASEAN countries and the EUR rates.

The evidence on PPP is, in this paper, limited to the ASEAN group. The extension of the presented work can be planned in two directions. First, new empirical findings could be generated by increasing the number of countries that are evaluated for PPP. Second, the application of nonlinear unit root test would further enrich our knowledge about the validity of this exchange rate theory.

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Testiranje hipoteze paritete kupne moči: primer gospodarstev ASEAN

Izvleček

Preverjamo hipotezo paritete kupne moči (PKM) na desetih državah skupine ASEAN. Uporabljen je cel niz panelnih testov enotskega korena na podatkih od januarja 1995 do januarja 2018. Vsi izračuni temeljijo na štirih referenčnih valutah, in sicer CNY, JPY, USD in EUR. Prvič, izhajajoč iz izidov pričujoče študije, PKM pretežno velja, če se kot referenčna valuta pojavlja CNY. Drugič, za pokrizno obdobje naša raziskava prepričljivo pokaže, da je PKM pretežno veljavna za razmerja med valutami držav ASEAN in evrom. Vzorec držav je v raziskavi omejen na skupino ASEAN. Upoštevajoč preučevane paritetne pogoje je nastanek globalne gospodarske krize sprožil pomembne valutne premike v skupini ASEAN. Zajem in testiranje širšega nabora referenčnih valut sta nujno potrebna za empirično podkrepitev ideje o PKM.

Ključne besede: pariteta kupne moči, panelni testi enotskega korena, države ASEAN, devizni trgi