Purchasing power parity in Asian economies: further evidence from rank tests for cointegration

Liew, Venus Khim-Sen and Lee, Hock-Ann and Lim, Kian-Ping

Labuan School of International Business and Finance, Universiti Malaysia Sabah.

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Full title: PURCHASING POWER PARITY IN ASIAN ECONOMIES: FURTHER EVIDENCE FROM RANK TESTS FOR COINTEGRATION

Authors:

VENUS KHIM-SEN LIEW
Labuan School of International Business and Finance
Universiti Malaysia Sabah
Email: liew@mailkal.ums.edu.my, venusliew@yahoo.com

HOCK-ANN LEE
Labuan School of International Business and Finance
Universiti Malaysia Sabah
Email: hockann@ums.edu.my

KIAN_PING LIM
Labuan School of International Business and Finance
Universiti Malaysia Sabah
Email: kianping@ums.edu.my

Abstract:

The finding of nonlinear cointegration between Asian exchange rates with the corresponding relatives prices and aggregate price levels based on Breitung's (2001) nonparametric rank tests reinforces previous validations of Purchasing Power Parity by the parametric testing procedures. Hence, in the long-run Asian exchange rate are in equilibrium with the relevant fundamentals as suggested by the purchasing power parity hypothesis.

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Correspondence to:

VENUS KHIM-SEN LIEW
Labuan School of International Business and Finance,
Universiti Malaysia Sabah,
P.O.Box 80594,
87015 W.P. Labuan, Malaysia.
Email: liew@mailkal.ums.edu.my, venusliew@yahoo.com

PURCHASING POWER PARITY IN ASIAN ECONOMIES: FURTHER EVIDENCE FROM RANK TESTS FOR COINTEGRATION

Abstract

The finding of nonlinear cointegration between Asian exchange rates with the corresponding relatives prices and aggregate price levels based on Breitung's (2001) nonparametric rank tests reinforces previous validations of Purchasing Power Parity by the parametric testing procedures. Hence, in the long-run Asian exchange rate are in equilibrium with the relevant fundamentals as suggested by the purchasing power parity hypothesis.

1. Introduction

Purchasing Power Parity (PPP) remains one of the most debated issues in international financial economics[1]. The validity of PPP has various important implications to decision or policy makers of central banks, multinational firms, and many other exchange rate market participants. In this respect, the if PPP holds, then one may evaluate whether an exchange rate is over- or under-valued based on the equilibrium value as suggested by PPP itself or the more complex monetary exchange rate models, in which PPP serves as the building block. Moreover, PPP and its extended models may also be adopted as reliable predicting tools for future exchange

[1] Taylor (2003), Taylor and Taylor (2004) and Taylor (2006) provide in-depth overview on the conceptual, theoretical and empirical aspects of PPP.

rate movements. An equally important implication of PPP study is that PPP reflects the degree of trade integration and liberalization among countries.

Previous empirical findings on the validity of PPP have been voluminous but puzzling (Rogoff, 1996). One of the reasons for the contrasting results as pointed out by recent studies is the negligence of nonlinear property of exchange rate behavior. Principally, due to market frictions, heterogeneous agents and influence of official intervention in the foreign exchange market, exchange rate adjusts nonlinearly towards its PPP equilibrium value (Taylor, 2006). Empirically, Taylor *et al*. (2001) and Kilian and Taylor (2003), amongst others, showed that the nonlinear adjustment of exchange rate towards PPP can best be described by Exponential Smooth Transition Autoregressive (ESTAR) model[2]. Besides, Liew *et al*. (2003) demonstrated that linear autoregressive model is inadequate in characterizing the Asian (including ASEAN-5) real exchange rates behaviors. More recently, Liew *et al*. (2004a, b) further validated PPP in the nonlinear sense. Thus, it is reasonable for one to think that the puzzling results of PPP lies in the implicit linear assumption of exchange rate behavior.

It is worth pointing out that the above nonlinear evidence adopts the parametric residual based tests for cointegration approach to the testing of PPP hypothesis. This paper differs from the others by providing nonlinear cointegration evidence from the Asian countries based on the nonparametric rank tests recently developed by Breitung (2001), which have power against linear and nonlinear framework, and are applicable to whatever data generating process (DGP) of the variables under tested. In contrast, parametric testing procedures assume the DGP is known in priori, and thus are in

[2] Teräsvirta (1994) provided theoretical details for ESTAR model. See also Taylor (2006) for a concentrated discussion on the usefulness of this model in characterizing exchange rate adjustment.

danger of misspecification if the wrong parametric models are used to characterize the variables of interest[3].

2. Methodology

2.1 Breitung Rank Tests for Cointegration

Breitung (2001) proposes the cointegration test based on rank transformation of the time series, as the alternative to the linear residual-based cointegration tests, which are inconsistent for nonlinear functions. Specifically, to test for (nonlinear) cointegration between two time series y_t and x_t, Breitung (2001), among others, develops the following test statistics:

$$B_1^* = \frac{\sup_{1<t<T} | d_t |}{T\hat{\sigma}_{\Delta d}} \quad \text{and} \quad B_2^* = \frac{\sum_{t=1}^{T} d_t^2}{T^3 \hat{\sigma}_{\Delta d}^2}, \tag{1}$$

where $d_t = R(y_t) - R(x_t)$, for $R(w_t) = \text{Rank of } w_t$ among $(w_1, w_2, ..., w_T)$ where $w = \{y, x\}$. Meanwhile, $\hat{\sigma}_{\Delta d}^2 = T^{-2} \sum_{t=1}^{T} (d_t - d_{t-1})^2$ are used to adjust for possible correlation between the two series of interest.

Breitung (2001) also proposes the following multivariate rank statistic to test cointegration among k+1 variables $y_t, x_{1t}, ..., x_{kt}$:

[3] The Monte Carlo simulations by Breitung show that for a wide range of nonlinear models the rank tests perform better than their parametric competitors. To date, Basher and Haug (2003) remains the sole study that employs these tests to examine the validity of PPP. Based on the monthly data from the post-Bretton Woods era of G-10 countries, they report that there is no nonlinear cointegration relationship in PPP.

$$B_3^*[k] = T^{-3}\sum_{t=1}^{T}(\tilde{u}_t^R)^2 / \hat{\sigma}_{\Delta\tilde{u}}^2 \qquad (2)$$

where $\tilde{u}_t^R = R(y_t) - \sum_{j=1}^{k}\tilde{b}_j R(x_{jt})$, in which $\tilde{b}_1,...,\tilde{b}_k$ are the least squares estimates from a regression of $R(y_t)$ on $R(x_{1t}),...,R(x_{kt})$, and $\tilde{u}_t^R$ are the estimated residuals. Meanwhile, $\hat{\sigma}_{\Delta\tilde{u}}^2 = T^{-2}\sum_{t=2}^{T}(\tilde{u}_t^R - \tilde{u}_{t-1}^R)^2$ are introduced to circumvent the possible correlation among the series.

The basic idea of these rank tests is that the sequences of ranks tend to diverge if there is no cointegration between the time series, whereas under cointegration the sequences of ranks evolve similarly. The null hypothesis of no (nonlinear) cointegration between y_t and x_t is rejected if these tests statistics are smaller than their respective critical values, available in Table 1 of Breitung (2001).

2.2 Breitung Rank Tests for Nonlinearity

To identify the linearity nature of the cointegration relationship found by the above-mentioned rank test, Breitung (2001) further suggests a score test statistic $T \cdot R^2$ computed from the following regression:

$$\tilde{u}_t = c_0 + c_1 x_t + c_2 R(x_t) + e_t \qquad (3)$$

where T is the sample size, R^2 is the coefficient of determination of regression (3), and $\tilde{u}_t$ stands for the residuals of regressing y_t on a constant and x_t. To deal with

plausible serially correlated errors and endogenous regressors, one may obtain $\tilde{u}_t$ from the cointegration regression due to Stock and Watson (1993).

3. The Data

This study applies the Breitung rank tests in testing the validity of PPP in the case of Asian countries, including Indonesia, Korea, Malaysia, Singapore, Thailand and the Philippines. This study uses the quarterly end-of-period yen based nominal bilateral exchange rate and consumer price index (CPI) over the period 1974:1-2004:2. These data are obtained from the International Financial Statistics of the IMF. Meanwhile, relative price is constructed as the ratio of domestic and foreign CPIs. All series are log-transformed.

4. Empirical Results and Conclusion

Results of cointegration test as summarized in Table 1 shows that exchange rate and relative price are cointegrated in all cases except Malaysia based on B_1^* statistic. Meanwhile, B_2^* statistic suggests the validity of PPP in all cases.

[insert Table 1 here]

Turning to the multivariate rank statistic approach, we first compute the $B_3^*[1]$ statistic to determine if each exchange rate is cointegrated with the corresponding relative price, whereas $B_3^*[2]$ statistic is employed to scrutinize the cointegration relationship among exchange rate, domestic price and foreign price. The results strongly reveal that exchange rate is not only cointegrated with relative price but also with domestic

and Japanese CPIs. In sum, results of Table 1 generally suggest the validity of PPP in the six Asian countries under study.

Having determined the cointegration relationship, the next query would the linearity nature of the existing cointegration. In this respect, the rank sum linearity tests results as shown in Table 2 clearly indicate that the existing cointegration relationships are nonlinear in nature in both the bivariate and multivariate cases.

[insert Table 2 here]

To conclude, the finding that Asian exchange rates are nonlinearly cointegrated with their relative price as well as aggregate price levels by the Breitung's (2001) nonparametric tests reinforces the validations of long-run purchasing power parity using the parametric testing procedures in the recent literature. Hence, in the long-run Asian exchange rate are in equilibrium with the relevant fundamentals as suggested by the purchasing power parity hypothesis.

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Table 1
Results of Cointegration Test

Country	Bivariate Rank Test [a] (Autocorrelation Adjusted)		Multivariate Rank Test (Autocorrelation Adjusted)	
	B_1^*	B_2^*	$B_3^*[1]$ [a]	$B_3^*[2]$ [b]
Indonesia	0.0104^{I}	0.0214^{X}	0.0012^{I}	0.0004^{I}
Korea	0.3593^{V}	0.0160^{V}	0.0003^{I}	0.0002^{I}
Malaysia	0.4202	0.0203^{X}	0.0004^{I}	0.0001^{I}
Singapore	0.0031^{I}	0.0000^{I}	0.0002^{I}	0.0002^{I}
Thailand	0.2786^{I}	0.0147^{V}	0.0017^{I}	0.0007^{I}
The Philippines	0.3166^{V}	0.0127^{I}	0.0003^{I}	0.0002^{I}
Critical Value [c]				
10%	0.3941	0.0232	0.0248	0.0197
5%	0.3635	0.0188	0.0197	0.0165
1%	0.3165	0.0130	0.0130	0.0119

Notes: [a] Null Hypothesis: exchange rate and relative price are not cointegrated. Alternative hypothesis: otherwise.
[b] Null Hypothesis: exchange rate, domestic CPI and Japanese CPI are not cointegrated. Alternative hypothesis: otherwise.
[c] Reject the null hypothesis when critical value exceeds test statistic.
Superscripts I, V and X indicate the rejection of null hypothesis of no cointegration at 1, 5 and 10% significance level.

Table 2
Results of Rank Sum Linearity Tests

	Bivariate [a]	Multivariate [b]
Country	$T \cdot R^2$	$T \cdot R^2$
Indonesia	20.943^{I}	8.540^{V}
Korea	5.297^{V}	18.666^{I}
Malaysia	28.028^{I}	35.502^{I}
Singapore	13.063^{I}	12.323^{I}
Thailand	11.211^{I}	27.279^{I}
The Philippines	7.448^{I}	8.539^{V}
Critical Values [c]		
10%	2.71	4.61
5%	3.84	5.99
1%	6.63	9.21

Notes: [a] Null hypothesis: linear relationship exists between exchange rate and the corresponding relative price. Alternative hypothesis: nonlinear relationship exists between exchange rate and the corresponding relative price.
[b] Null hypothesis: linear relationship exists among exchange rate, domestic CPI and Japanese CPI. Alternative hypothesis: nonlinear relationship exists among exchange rate, domestic CPI and Japanese CPI. [c] Reject the null hypothesis if computed $T \cdot R^2$ value exceeds the critical value.
Superscripts I and V indicate the rejection of null hypothesis at 1 and 5% significance level.