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# Are Asian real exchange rates stationary?

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**Abstract**

By applying the newly developed nonlinear stationary test advanced by Kapetanios et al. [Journal of Econometrics 112 (2003) 359] in examining the stationary property of 11 Asian real exchange rates, this paper rejects unit root in 8 US dollar-based and 6 Japanese yen-based rates, whereas the augmented Dickey–Fuller (ADF) test has led to no rejection at all.


*JEL classification:* F31

*Keywords:* Real exchange rates; Asia; Mean reversion; Nonlinear stationary test; ADF test

## 1. Introduction

The stationarity of real exchange rate has been the major concern of exchange rate studies as it has few major implications in the international finance. A nonstationary real exchange rate indicates that there is no long run relationship between nominal exchange rate, domestic and foreign prices, thereby invalidating the purchasing power parity (PPP) hypothesis. As such, PPP cannot be used to determine the equilibrium exchange rate, a position in which most policy makers are interested to know. Invalid PPP also disqualifies the monetary approach to exchange rate determination, which requires PPP to hold true.

Another implication of nonstationarity in real exchange rate is that unbounded gains from arbitrage in traded goods are possible (Kapetanios et al., 2003, henceforth, KSS). In fact, Parikh and Williams (1998)

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have mentioned that a nonstationary real exchange rate can cause severe macroeconomic disequilibrium that would lead to real exchange rate devaluation in order to correct for external imbalances. Empirical evidence on the stationarity of real exchange rates is abundant but inconclusive thus far (Sarno, 2000); see also the work of Sarno and Taylor (2002) who provide details on the theoretical and empirical issues on PPP and the real exchange rate.

Recently, there is a growing consensus that exchange rate exhibits nonlinearities and that a conventional test such as the augmented Dickey–Fuller (ADF) unit root test has low power in detecting its mean reverting tendency (Sarno, 2000; Sarno and Taylor, 2002). Based on linearity tests (Teräsvirta, 1994), a number of studies have provided empirical evidence on the nonlinear adjustment of exchange rates in the developed countries (Baum et al., 2001), the Middle East (Sarno, 2000) and Asian economies (Liew et al., 2002, 2003). However, the finding of nonlinear adjustment does not necessarily imply nonlinear mean reversion (stationary). As such, formal stationary tests based on nonlinear framework must be applied. In this study, our principal objective is to determine whether the Asian real exchange rates are nonlinear stationary, based on a nonlinear stationary test advanced by Kapetanios et al. (2003) (henceforth, KSS test).

The contributions of this paper are twofold. First, while previous empirical studies are able to reject the linearity of exchange rate behaviour based on linearity test, they can draw no conclusion on the nonlinearly stationarity behaviour of these exchange rates. This study fills up this literature gap by formally employing the nonlinear stationary test. Second, this study is to date the first and only study that utilizes the KSS nonlinear stationary test in Asian real exchange rates. We find that the KSS test is able to reject unit root in many of the series under investigation, whereas the linear augmented Dickey–Fuller test has led to no rejection at all.

## 2. Kapetanios et al. nonlinear stationary test

KSS propose a testing procedure to detect the presence of non-stationarity against nonlinear but globally stationary exponential smooth transition autoregressive (ESTAR) process:

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

where $y_t$ is the de-meaned series of interest and $\varepsilon_t$ is an i.i.d. error with zero mean and constant variance. Meanwhile, $\theta \geq 0$ is known as the transition parameter of the ESTAR model that governs the speed of transition.

The null hypothesis of this test procedure is: $H_0$: $\theta = 0$ against the alternative $H_1$: $\theta > 0$. However, testing this null hypothesis directly is not feasible, since $\gamma$ is not identified under the null. Thus, KSS reparameterize (1) based on Taylor series approximation to obtain:

$$\Delta y_t = \delta y_{t-1}^3 + \text{error} \tag{2}$$

or

$$\Delta y_t = \sum_{j=1}^{p} \rho_j y_{t-j} + \delta y_{t-1}^3 + \text{error}, \tag{3}$$

in order to correct for plausible serially correlated errors. Following KSS, we fix $p = 8$ in this study.

In both cases, the null hypothesis to be tested is $H_0$: $\delta = 0$ against the alternative $H_1$: $\delta > 0$. KSS show that the $t$ statistic of the parameter of interest (that is, $\delta$) does not have an asymptotic normal distribution and thus one must resort to simulations for asymptotic critical values. For the brevity of reporting, the $t$ statistics estimated from Eqs. (2) and (3) will be referred to as $t_{KSS1}$ and $t_{KSS2}$, respectively. For the purpose of comparison, we also report the conventional ADF test statistic, denoted by $t_{ADF}$.

## 3. Data of study

The real exchange rates of 11 Asian countries, namely India, Indonesia, Japan, Korea, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka and Thailand, are considered in this study. The real exchange rate, $q_t$, is constructed by $q_t = s_t + p_t^* - p_t$, where $s_t$ is the nominal exchange rate defined as the domestic price of foreign currency, $p_t^*$ and $p_t$ are foreign and domestic price level, respectively, as surrogated by the consumer price indices. All variables are in their logarithmic form.

Quarterly end-of-period nominal bilateral exchange rates over 1968Q1 to 2001Q2, obtained from various issues of International Monetary Fund's International Financial Statistics with US dollar (USD) and Japanese yen (YEN) as numeraire currencies are employed in this study. The resultant real exchange rates series are de-meaned as required by the KSS test procedure.

## 4. Results and conclusions

The unit root tests results are summarized in Table 1.

Table 1 shows that the ADF test fails to reject the null of unit root in all cases, implying that real exchange rates are not mean reverting. However, results from both KSS unit root tests are able to reject unit root in 8 out of 11 USD based real exchange rates, implying that most real exchange rates are mean

Table 1
Linear and nonlinear unit root tests results

| Real exchange rate | US dollar based | | | Japanese yen based | | |
|---|---|---|---|---|---|---|
| | $t_{ADF}$ | $t_{KSS1}$ | $t_{KSS2}$ | $t_{ADF}$ | $t_{KSS1}$ | $t_{KSS2}$ |
| India | −1.77 | −1.90 | −2.92[a] | −1.93 | −0.60 | −1.94 |
| Indonesia | −0.96 | −3.08[b] | −5.41[c] | −1.56 | −2.26 | −2.86[a] |
| Japan | −2.45 | −3.02[b] | −3.88[c] | – | – | – |
| Korea | −2.14 | −2.58 | −3.35[b] | −1.65 | −3.84[c] | −4.25[c] |
| Malaysia | −1.24 | −3.76[c] | −4.74[c] | −2.20 | −2.34 | −2.68[a] |
| Nepal | −2.08 | −1.63 | −2.39 | −2.12 | −0.65 | −1.43 |
| Pakistan | −2.14 | −6.95[c] | −5.39[c] | −3.10 | −6.68[c] | −6.80[c] |
| Philippines | −2.70 | −1.22 | −2.26 | −2.19 | −1.76 | −2.41 |
| Singapore | −0.45 | −2.27 | −3.03[b] | −2.59 | −2.24 | −2.66[a] |
| Sri Lanka | −1.32 | −1.96 | −2.28 | −1.78 | −1.79 | −2.34 |
| Thailand | −0.16 | −4.84[c] | −6.41[c] | −2.52 | −3.07[b] | −2.72[a] |

The 1%, 5% and 10% asymptotic null critical values for ADF test with an intercept term are, in that order, −3.52, −2.90, −2.58. Meanwhile, the 1%, 5% and 10% asymptotic null critical values for both KSS tests are −3.48, −2.93 and −2.66, respectively (Kapetanios et al., 2003). Superscripts [a,b,c] denote significance at 10%, 5% and 1% level, respectively.

reverting and thereby validating the long run PPP hypothesis. This finding demonstrates that the conclusions drawn from linear and nonlinear unit root test may be drastically different.

Few other stylized facts are observed in Table 1. First, based on $t_{KSS1}$, mean reversion is detected in 5 (3) out of 11 (10) USD (YEN) based real exchange rates at standard significance levels. $t_{KSS2}$, on the other hand, is able to uncover more mean reverting rates, with an addition of 3 USD based and 3 YEN based rates. The improvement of $t_{KSS2}$ over $t_{KSS1}$ is due to the fact that the former has accounted for plausible serial correlation. One implication of this finding is that as financial time series are almost always contaminated by serial correlation, it is advisable for us to resort to $t_{KSS2}$ rather than $t_{KSS1}$ for more robust results.

Second, when YEN is the numeraire currency, 60% of the real exchange rates (including four from the ASEAN economies) are stationary. Meanwhile, almost two-thirds of the real exchange rates is stationary with USD as numeraire currency. This finding suggests that price levels in Asian countries adjust slightly more towards US price inflation than Japanese inflation, possibly because of the fact that US is more dominant than Japan in terms of trading partner of these countries. Third, the currencies of the Philippines, Nepal and Sri Lanka are nonstationary even at 10% significance level for both numeraire currencies, implying that arbitrage activities in these countries vis-à-vis US and Japan are profitable (Kapetanios et al., 2003). Nonetheless, while this arbitrage opportunity seems luring, further research is recommended to investigate actual cause of this nonstationarity.

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