Stationarity of Asian-Pacific real exchange rates

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Abstract

This paper examines the stationarity of Asian-Pacific real exchange rates (RERs) using a nonlinear unit root test. The results reject the null hypothesis of nonstationarity in favor of the alternative of nonlinear stationarity for most of US, Australian, or Singapore dollar based RERs, but fail to do so for the majority of Japanese yen based RERs. There is more evidence for level stationarity in the Singapore dollar based rates than in other currency based rates. Many US dollar based Asian-Pacific RERs appear to be trend stationary.

Keywords: Asian-Pacific real exchange rates; Nonlinear stationarity; PPP

JEL classifications: F31; G15

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1. Introduction

Examining the stationarity of real exchange rates (RERs) has been a key issue in empirical international finance because of its importance in validating the purchasing power parity (PPP) hypothesis, an important building block of many international economic models. As the studies using conventional unit root tests, such as the augmented Dickey–Fuller (ADF) tests, based on linear models fail to confirm the validity of PPP (see Sarno, 2005, for a recent survey), several recent studies (e.g., Taylor et al., 2001; Sarno and Taylor, 2002; Sarno et al., 2004; Alba and Park, 2005) have turned to the tests that account for non-linearity in time series movement to examine PPP. These studies reveal the mean-reverting (stationary) properties of RERs for more countries, i.e., more supportive evidence for PPP. Liew et al. (2004) have applied a new nonlinear unit root test developed by Kapetanios, Shin, and Snell (2003, hereafter, KSS) to the bilateral real exchange rates of a group of Asian countries. They found evidence for stationarity for most of US dollar or Japanese yen based RERs.

A concern arising from the results of previous studies is their difference in the test results for the Japanese real exchange rate with US dollar. Applying the same tests to the yen-dollar real exchange rate, Liew et al. (2004) report a rejection of the null of nonstationarity at the 1% significance level, but KSS (2003), with a sample a few years longer than that of Liew et al., do not reject the null at any conventional levels of significance. Such a difference implies a possibility that the results for a stationary yen-dollar real rate might not be sustainable.

A number of studies (e.g., Bahmani-Oskooee and Mirzai, 2000, Taylor, 2002, and Chang et al., 2006) illustrated that reversion in RERs for some countries, especially for developing countries, can be detected more often when using the models allowing for a linear trend in the data. The presence of such a linear trend may reflect the well-known Balassa-Samuelson type effects, resulting from the differential rates of productivity growth in traded and non-traded goods sectors of a country relative to that of the country whose currency is used as a numeraire currency in measuring RER. These studies suggest that it is reasonable to take the possibility of existing a linear trend in the data into account in examining the reversion behavior of RERs.

Papell and Theodoridis (2001) showed that the choice of numeraire currency does matter for PPP. They found that distance between the countries is one of the most important determinants of the results in testing PPP. PPP may hold better for the countries close to each other because the geographical proximity makes goods arbitrage more effective as transaction costs are lower. It is also found in Alba and Papell (2007) that there is stronger evidence of PPP for countries more open to trade, nearer and with similar economic growth to one another. Motivated by these findings, this paper uses alternative currencies, in addition to the commonly used Japan yen and US dollar, as numeraire currencies in the study.

In selecting alternative numeraire currencies, Singapore dollar appears to be a good candidate. Zhou (1996) and Anoruo et al. (2002) indicate that Singapore plays an important role in the Asian region and serves to integrate the regional economies. It is expected that PPP may hold well between Singapore and other Asian countries as they are nearer and well open to each other in trade. Besides, while the Balassa-Samuelson type effects might exist in the RERs of Asian countries versus Japan or the U.S., they are less likely to exist in Singapore dollar based Asian RERs as these countries have experienced similar productivity growth compared with Singapore during the sample periods. It thus seems interesting to examine the convergence toward PPP between Singapore and other Asian countries by testing the stationarity of Singapore dollar based Asian RERs and compare the results with those of major currency based RERs.

In addition, given the existence of close economic relations between Asian and Pacific Rim countries, it is natural to include Australia and New Zealand along with Asian countries for a comprehensive regional study of the behavior of real exchange rates. Australian dollar, as one of widely traded currency (next to Japanese yen and US dollar) compared with other currencies in the sample, is also selected as a numeraire currency for the study.

This paper carries out a more comprehensive investigation than earlier studies on the stationarity of Asian-Pacific RERs by (1) extending the sample period to recent years to detect the sustainability of the results of some earlier studies, (2) taking the possible existence of a linear trend in the data into account in conducting the tests, and (3) examining the stationarity of

Asian-Pacific RERs with not only US dollar and Japanese yen but also Australia and Singapore dollar as numeraire currencies,

2. Empirical tests[1]

The KSS (2003) nonlinear unit root test, utilized in this study, is based on the following exponential smooth transition autoregressive (ESTAR) specification:

$$\Delta y_t = \gamma y_{t-1}[1 - \exp(-\theta y_{t-1}^2)] + \varepsilon_t, \qquad \theta \geq 0 \tag{1}$$

where y_t is the de-meaned or de-trended series of interest, ε_t is an i.i.d. error with zero mean and constant variance, and $[1 - \exp(-\theta y_{t-d}^2)]$ is the exponential transition function adopted in the test to present the nonlinear adjustment. The null hypothesis of a unit root in y_t (i.e., $\Delta y_t = \varepsilon_t$) implies that $\theta = 0$ (thus $[1 - \exp(-\theta y_{t-d}^2)] = 0$), while the alternative of a nonlinear but globally stationary process requires that $\theta > 0$, where θ effectively determines the speed of mean reversion. Stating specifically, for variables containing a nonzero mean or a linear trend in their data and having been de-meaned or de-trended, the alternative hypothesis would be level stationary or trend stationary, respectively.

Because the null hypothesis $\theta = 0$ cannot be directly tested as γ in (1) is not identified under the null, KSS suggest to reparameterize (1) by computing a first-order Taylor series approximation to specification (1) to obtain the auxiliary regression expressed by (2) below:

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

For a more general case where the errors in (2) are serially correlated, regression (2) is extended to

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

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[1] This section draws on KSS (2003).

with the p augmentations to correct for serially correlated errors. The null hypothesis of nonstationarity to be tested with either (2) or (3) is H_0: $\delta = 0$ against the alternative H_1: $\delta < 0$. KSS use the t-statistic for $\delta = 0$ against $\delta < 0$, referred to as the KSS statistic, but show that it does not have an asymptotic standard normal distribution. They tabulate the asymptotic critical values of the KSS statistics via stochastic simulations.

In this paper, both the KSS tests and the conventional ADF tests are applied to the bilateral real exchange rates of 13 Asian-Pacific countries (namely Australia, India, Indonesia, Japan, Korea, Malaysia, Nepal, New Zealand, Pakistan, Philippines, Singapore, Sri Lanka, and Thailand) with US dollar (USD), Australian dollar (AD), Japanese yen (JY), and Singapore dollar (SD) as numeraire currencies. To see the sensitivity of the test results to the number of augmentations p, both ADF and KSS tests are conducted with fixed 8 lags (following Liew et al., 2004) and also with p to be selected using a sequential testing procedure based on the significance of augmentation terms (i.e., insignificant terms are excluded) by setting the maximum number of p to be 8 (as suggested by KSS, 2003).

3. Data and empirical results

Quarterly consumer price indices (CPIs) and end-of-period bilateral nominal exchange rates are obtained from the International Monetary Fund (IMF)'s International Financial Statistics (IFS) online. With the exception of Korea and Nepal, the sample period for the study runs from 1968Q1 to 2005Q4. We start the sample from 1968, the same as the beginning of the sample employed in Liew et al. (2004), in order to make our test results comparable with theirs. The sample periods for Korea and Nepal are 1970Q1-2005Q4 and 1968Q1-2005Q2, respectively, due to the availability of the data in the IFS. Because the maximum number of lag length in equation (3) was set to be 8, the first 9 quarterly observations are used to compute the lagged RER changes for the tests. Thus, the sample period effectively starts from 1972Q2 for Korea and from 1970Q2 for other countries.

The bilateral RERs with USD are constructed by $rer_{i,us} = s_i - p_i + p_{us}$, where s_i is country i's currency price of a USD, p_i and p_{us} are the price indices of country i and the U.S., respectively. Those with AD, JY or SD are $rer_{i,j} = s_i - p_i - s_j + p_j$ where s_j is AD, JY or SD prices of a USD. p_j is the corresponding price index of Australia, Japan or Singapore. All these variables are expressed in logarithm form.

Because the data show the presence of a trend in a number of these RERs, the KSS tests are applied to both de-meaned and de-trended data with the estimated KSS statistics being referred to as KSS1 and KSS2, respectively. Similarly, the conventional ADF tests are conducted using both the model with a constant only and the model with a constant and a time trend, and the corresponding test statistics are denoted as ADF1 and ADF2, respectively. The rejection of the null of nonstationarity by KSS1 and/or ADF1 would be the evidence for level stationarity. Failure to reject the null by KSS1 and/or ADF1 but able to reject it by KSS2 and/or ADF2 would be the evidence for trend stationarity. Note that a level stationary RER is consistent with PPP in a strict form, while a trend stationary RER would be consistent with a modified view of PPP, which allows the long-run (equilibrium) RERs to vary with the changes in important real economic factors such as the Balassa-Samuelson type effects.

Table 1 reports the results of the KSS tests along with those of the standard ADF tests for the bilateral real exchange rates with USD. In this table, ten test statistics are reported. $ADF1_8$ and $ADF1_{Sig}$ are the standard ADF test statistics that only include a constant in the model, with fixed 8 lags and with the lag length selected based on the significance of augmentation terms, respectively. $KSS1_0$, $KSS1_8$, and $KSS1_{Sig}$ are the KSS test statistics for de-meaned data with 0 or 8 augmented terms, or with the number of augmented terms selected based on the significance testing procedure, respectively. The comparable statistics of the ADF tests with trend in the model are $ADF2_8$ and $ADF2_{Sig}$, respectively, and those of the KSS tests for the de-trended data are $KSS2_0$, $KSS2_8$, and $KSS2_{Sig}$, respectively.

Table 1 goes about here

Consistent with the findings of previous studies, the results of the KSS tests reject the null of nonstationarity more often than those of the ADF tests. Whereas the ADF tests reject the null in favor of the alternative of level or trend stationarity for 5 out of 13 USD based RERs at the 10% level of significance, the KSS tests are able to do so for 10 of the 13 RERs.

Comparing the results in Table 1 for USD based Asian RERs with those in Liew et al (2004, p. 315), it is surprising that, with only 18 more quarterly observations of recent years in our sample than that of Liew et al, our test statistics for de-meaned series are quite different from theirs, indicating fewer cases of rejection of the null than theirs. But our results for de-trended series are similar to those in Liew et al. for de-meaned data. In other words, while Liew et al. argue that most of USD based Asian RERs are level stationary, we consider many of them likely to be trend stationary. For the yen-USD RER, the null of nonstationarity was strongly rejected in Liew et al., but is barely rejected at the 10% significance level in our study, implying that the claim of a stationary yen-USD RER in Liew et al. may not hold in the slightly extended sample period.

The results indicate that the KSS test with augmented terms is superior over that with no augmentation, as the former accounts for serial correlation in the error terms and is able to reject the null more often (i.e., has higher test power) than the latter. It is also shown that, for both ADF and KSS, the tests conducted with fixed or selected number of augmentations yield very similar results. To save space, in Table 2 for the RERs with other three numeraire currencies, we report only the test results obtained from the models with selected number of augmentations.[2]

Table 2 goes about here

The results in Table 2 reject the null of nonstationarity for most of AD and SD based RERs, but fail to do so for most of JY based RERs. For de-meaned series, the null is rejected for 9 or 7 out of 13 rates at the 10% or 5% significance level for SD based RERs, but the corresponding figures for USD, AD, and JY based RERs are 6 or 4, 7 or 4, and 4 or 2 out of 13

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[2] Other test statistics based on the models with 0 or 8 augmented terms are available from the author upon request.

cases, respectively. Note that in our summary, a rejection of the null for the RER between two numeraire currencies is counted for both currency based RERs. As the rejection of the null for de-meaned RER series in favor of level stationarity can be viewed as supportive evidence for a strict form of PPP, such PPP seems to hold well between Singapore and other Asian-Pacific countries.

4. Conclusions

Using a nonlinear unit root test, this paper has conducted a relatively comprehensive empirical study for the stationarity of a group of Asian-Pacific real exchange rates with US, Australia, and Singapore dollar as well as Japanese yen as numeraire currencies. The results reject the null hypothesis of nonstationarity in favor of the alternative of nonlinear stationarity for most of US, Australian, or Singapore dollar based RERs, but fail to do so for the majority of Japanese yen based RERs.

It is shown that many US dollar based Asian-Pacific RERs appear to be trend stationary rather than level stationary. There is more evidence for level stationarity in Singapore dollar based rates than in other currency based rates, implying that the choice of numeraire currency does matter in examining the behavior of RERs and indicating steady convergence toward a strict form of PPP between Singapore and other Asian-Pacific countries. These results may reflect the Balassa-Samuelson objection to the pure PPP hypothesis for the US dollar based Asian-Pacific RERs. Yet, the Balassa-Samuelson type effects are less likely to exist in Singapore dollar based Asian RERs due to the fact that many Asian countries have experienced productivity growth similar to that of Singapore during the sample periods. The present study provides additional evidence for the conclusion of Taylor and Taylor (2004, pp.154-155), about the views of the PPP debate, that long-run PPP may hold in the sense that there is significant mean reversion of the real exchange rate, although there may be factors causing the equilibrium real exchange rate to move over time.

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Table 1.
Unit root test results for real exchange rates with US dollar

Country	$ADF1_{Sig}$	$ADF1_8$	$KSS1_0$	$KSS1_{Sig}$	$KSS1_8$	$ADF2_{Sig}$	$ADF2_8$	$KSS2_0$	$KSS2_{Sig}$	$KSS2_8$
Australia	-1.87	-2.43	-1.74	-2.25	-2.26	-3.16^a	-3.44^b	-2.58	-3.27^a	-3.36^a
India	-0.85	-0.76	-1.31	-1.58	-1.56	-2.37	-2.28	-2.25	-3.17^a	-3.17^a
Indonesia	-1.07	-0.84	-3.61^c	-4.22^c	-3.97^c	-2.31	-2.16	-4.72^c	-6.04^c	-5.82^c
Japan	-2.64^a	-2.43	-2.01	-2.02	-1.92	-2.48	-1.88	-2.14	-2.97	-2.60
Korea	-2.29	-2.45	-4.35^c	-3.95^c	-3.91^c	-2.46	-2.69	-4.41^c	-4.10^c	-4.07^c
Malaysia	-0.50	-0.51	-0.91	-1.21	-1.42	-3.00	-3.12	-3.15^a	-3.53^b	-3.76^b
Nepal	-0.83	-0.86	-1.49	-1.37	-1.37	-2.14	-2.14	-3.04	-3.03	-3.03
New Zealand	-3.35^b	-4.16^c	-2.45	-3.97^c	-4.22^c	-3.35^a	-4.24^b	-2.42	-3.83^b	-3.98^c
Pakistan	-1.78	-1.56	-2.90^a	-2.90^a	-2.77^a	-3.38^a	-3.25^a	-2.01	-2.01	-1.97
Philippines	-1.66	-0.96	-1.12	-1.12	-0.70	-3.10	-2.25	-2.88	-3.68^b	-2.81
Singapore	-2.81^a	-2.91^b	-1.93	-4.05^c	-3.92^c	-3.00	-3.06	-1.94	-3.81^b	-3.65^b
Sri Lanka	-2.22	-2.14	-1.46	-1.54	-1.43	-1.09	-1.25	-1.42	-1.18	-1.66
Thailand	-0.84	-0.72	-2.05	-1.86	-1.76	-2.41	-2.28	-4.44^c	-4.67^c	-4.57^c

Notes: ADF1 and ADF2 are the standard ADF test statistics without and with a trend, respectively, in the model for testing. KSS1 and KSS2 are the KSS test statistics for the de-meaned and de-trended data, respectively. Subscript 0 or 8 stands for that the test statistic is obtained using the model with no lag or using the augmented model with fixed lag length of 8. Subscript Sig indicates the selection of the number of augmentations based on significance testing procedure. The 10%, 5%, and 1% asymptotic critical values for ADF1 are -2.57, -2.86, and -3.43, respectively, and those for ADF2 are -3.12, -3.41, and -3.96, respectively. The 10%, 5%, and 1% asymptotic critical values for KSS1 are -2.66, -2.93, and -3.48, respectively, and those for KSS2 are -3.13, -3.40, and -3.93, respectively, taken from Kapetanios et al. (2003, p. 364). [a, b, c] denote rejection of the null hypothesis of nonstationarity at the 10%, 5% and 1% significance levels, respectively.

Table 2.
Unit root test results for real exchange rates with Australian dollar, Japanese yen, or Singapore dollar

Real exchange rate	with Australian dollar				with Japanese yen				with Singapore dollar			
	ADF1	KSS1	ADF2	KSS2	ADF1	KSS1	ADF2	KSS2	ADF1	KSS1	ADF2	KSS2
India	-1.57	-2.08	-2.33	-3.03	-1.75	-1.96	-0.85	-1.22	-1.54	-1.75	-1.41	-1.45
Indonesia	-1.20	-4.85^c	-2.53	-5.69^c	-1.44	-3.28^b	-2.03	-5.65^c	-1.24	-4.39^c	-2.20	-5.29^c
Japan	-1.77	-2.51	-2.59	-1.72	—	—	—	—	—	—	—	—
Korea	-2.96^b	-2.37	-3.72^b	-2.76	-2.19	-4.47^c	-2.47	-2.53	-3.50^c	-5.03^c	-3.43^b	-5.00^c
Malaysia	-1.73	-1.55	-4.04^c	-3.92^b	-1.49	-1.90	-2.73	-3.11	-0.81	-1.81	-2.26	-3.77^b
Nepal	-1.59	-2.13	-2.73	-2.90	-1.91	-2.14	-1.44	-1.60	-1.79	-2.02	-1.28	-1.16
New Zealand	-1.82	-3.76^b	-3.25^a	-4.04^c	-2.09	-2.32	-1.58	-0.97	-4.12^b	-3.60^c	-4.49^c	-4.64^c
Pakistan	-2.55	-2.90^a	-3.46^b	-1.78	-2.30	-2.90^a	-2.67	-2.40	-2.39	-3.27^b	-3.48^b	-3.27^a
Philippines	-2.62^a	-1.78	-2.81	-3.92^b	-1.79	-2.24	-2.22	-2.03	-2.09	-2.86^a	-3.79^b	-2.86^a
Singapore	-2.77	-3.59^c	-3.19^a	-3.01	-2.08	-2.50	-3.07	-2.86	—	—	—	—
Sri Lanka	-2.64^a	-1.55	-2.10	-2.14	-2.52	-1.54	-1.58	-1.68	-2.74^a	-1.51	-1.39	-1.88
Thailand	-2.13	-0.45	-2.80	-3.24^a	-1.79	-2.55	-2.85	-3.21^a	-1.70	-3.11^b	-3.01	-3.88^b

Notes: The test statistics are obtained using the augmented models with the selection of lag length based on the significance of augmentation terms. See rows "Australia", "Japan", and "Singapore" of Table 1 for the test results of the bilateral real exchange rates between the three countries and the U.S. Also see notes to Table 1.