The Changing Dynamics of the East Asian Real Exchange Rates after the Financial Crisis: Further Evidence on Mean Reversion

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May 2006

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by

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3rd Draft
November 2007

Revision (WSU: 6-09-2007)
Revision (CTH: 22-11-2007)

Asian Real Exchange Rates Before and after the 1997 Financial Crises: New Evidence of Purchasing Power Parity

Abstract

Using an improved statistical methodology including tests designed for heterogeneous panels, this paper tests for mean reversion in monthly US Dollar based real exchange rates for nine East Asian countries, including those that were severely affected by the 1997 Asian financial crises. The empirical results reveals mean reversion in real Asian exchange rates is a feature of the post-crises sub-period (1997-2005) but not of the pre-crises sub-period (1981-1996). Additionally, we make a point that a faster speed of convergence to PPP and lower adjustment half-lives for real exchange rates compared to those reported for major industrialized country currencies and especially so for the post-crises period in Asia.

JEL Classification: C12; C23; F31; F40
Keywords: Purchasing power parity; Panel unit root tests; Asian financial crisis

1. Introduction

Purchasing power party (PPP) is one of the oldest and one of the most widely tested hypotheses in economics. This hypothesis states that the price levels in two countries expressed in a common currency, determine the fundamental exchange rate. The hypothesis is of interest to policy makers especially in the emerging economies for at least two reasons. First, PPP becomes a prediction model for exchange rates and a criterion for judging over- and under valuation of currencies (Holmes, 2001; Sarno and Chowdhury, 2003). Second, many exchange rate theories utilize some notion of PPP in constructing their models and a large number of these theoretical and empirical models of exchange rate behavior have been built around PPP. The reliability of the policy advice based on these theories may well depend on the working assumption of PPP (Liu and Burkett, 1995). Therefore, the empirical validity of the hypothesis is of interest to policymakers in both the developed and developing world.

The aim of this paper is to investigate PPP in the East Asian countries and the period of analysis is set from January 1981 to Junes 2005. To this end, we relied on panel, rather than standard bivariate methods since articles by Holmes (2001), Kalyoncu and Kalyoncu (2007) and Alba and Papell (2007), among others, have highlighted the advantages of panel unit root tests in investigating the hypothesis. An important issue that needs to be considered with the application of panel unit root tests to the Asian countries is the impact of the financial turmoil on the nominal exchange rates. In this study, we extend earlier studies by considering the possibility of structural break in the panel data. Recognizing the possibility of a break in the relationship between exchange rate and relative prices, unit root tests based on the division of two sample sub-periods, 1981: 1-1996: 12 and 1997: 1-2005: 6 is considered. Our focus is primarily on the

US dollar rates due to the dollar's role as international currency in the past four decades. The US historically has been an important trading partner of these countries. Most of the East Asian countries examined in this study started to deregulate their financial markets during late 1970s and early 1980s, driven by globalization of financial flows. As these countries continue open up their economy by deregulating their domestic financial markets and capital accounts, we may expect their currencies to resemble those of the developing ones. This also means that national monetary authorities will no longer be able to successful conduct independent monetary policy and simultaneously control the movement of exchange rates.

To preview the findings, we found that the strong form of PPP is violated for the East Asia countries in the pre-crises period (1981-1996) but it seems to hold in the period of 1997 to 2005, when the currencies of these were allowed to float relatively freely compared to the earlier period. We demonstrate that pooling the data across the two exchange rate arrangements bias the tests toward accepting the null of unit roots. By this we mean that the mean reverting behavior of real exchange rates do not show up in the full sample. Interestingly, we observed that the estimated half lives of adjustments to PPP are shorter in the post-crises period and lower in East Asia generally compared to developing countries. The rest of the paper is structure as follows. Section 2 presents the strategies employed in testing the international parity condition. Section 3 provides a brief description of the data and methodology utilized in this paper. Empirical results are presented and discussed in Section 4, and finally Section 5 provides our conclusion remarks.

2. Strategies in Testing PPP

According to the theory of cointegrated processes, if PPP holds the real exchange rate is mean revering and not driven by stochastic trends[1]. It has been widely argued in the recent literature that the observed failure of the PPP relationship is due to the low statistical power of conventional unit root tests in small sample commonly used in earlier studies. Research in this area has progressed by either considering longer data spans or by combining time-series with cross-sectional observations (panel study). For the developing Asian countries in particular, reliable data is mostly unavailable for long periods (over 25 years) and so we have to rely on the latter approach to produce better test results on the hypothesis[2]. As mentioned earlier, this study is not the first to investigate the international parity condition using panel unit root tests. The work of Azali *et al.* (2001), Holmes (2001) and more recently Alba and Papell (2007) are just three examples of the application the panel method to the real exchange rates of the East Asian countries[3]. Azali *et al* (2001) is able to reject the random walk model in favor of the mean reversion for a selected group of East Asian countries using the Japanese yen as the reference currency. Their analysis, however, does not cover the historical episode of the 1997 Asian financial crisis. Meanwhile, Holmes (2001) found that PPP does not hold for most of the major Asian countries (including the ASEAN countries of Malaysia, Thailand, Indonesia, Singapore and the Philippines) using the US dollar as the numeraire currency for the period from 1973 to

[1] Testing for stationarity of real exchange rate assumes a strict proportionality between nominal exchange rate and relative price. The weaker form of the PPP relationship may be tested using a cointegration framework.

[2] Additionally, long span of data may not provide an unambiguous result in favor of PPP as they mix up different exchange rate regimes.

[3] Panel unit root and panel cointegration tests have received great attention in the literature. The approach which exploits cross-section as well as time series variation is much powerful than the traditional uinvariate methods For more discussion on these tests see, for example, Kalyoncu and Kalyoncu (2007), Levin and Lin (1993), Frankel and Rose (1996) and Wu *et al.* (2001) and the articles cited there-in. These studies provide stronger evidence in favor of the hypothesis for the industrialized countries in the current float.

1999. Applying panel unit root tests to 84 countries, Alba and Papell (2007) concludes that PPP holds for the panels for the European and Latin American countries but not for the African and Asian countries. They pointed out that country characteristics (e.g. exchange rate volatility, distance, openness, to name a few) help to explain both the deviation to and adherence form long-run PPP in the high- and low-income Asian countries. Importantly, the empirical evidence in these two papers suggests that the East Asian currencies do not fit the traditional mean reversion literature. The article by Kalyoncu and Kalyoncu (2007) investigated the validity of PPP by using Im, Pesaran and Shin (2003) unit root test for 25 OECD (including Japan and South Korea) countries from 1980-2005 and obtained overwhelming support for PPP.

Given the many studies on the empirical validity of PPP, it is important to asses the contribution made by this research. First, monthly frequency data is utilized in this study and we have extended the articles mentioned above by including data in the post-crisis period that ended in June 2005. Thus, we have a longer data span for post-crises to investigate the impact of the 1997 Asian crises on PPP in East Asia. Second, we did not rely on one or two statistical testing procedures, but instead we examined the same set of data using a range of improved statistical methodologies. Specifically, we test for mean reversion behavior using univariate unit root tests as well as recently developed panel frameworks advocated by Levin-Lin-Chu (2002), Im-Pesaran-Shin (2003), Madalla and Wu (1999) and Breitung (2000) in order to arrive at a conclusion on long-run PPP that is as robust as currently possible. Finally, this paper is also distinct from previous research in that the impact of the crisis on the half-life of PPP in the Asian countries is examined. The purpose is to find out whether grater nominal exchange flexibility promotes real adjustment.

3. Data and Research Design

In this paper, we investigate the PPP hypothesis using monthly data for the period January 1981-June 2005 for nine Asian countries (Malaysia, Thailand, Indonesia, Singapore, the Philippines, South Korea, Hong Kong, Taiwan and Japan). The sample period covers the period of financial deregulation, financial crisis and financial restructuring. Exchange rate and consumer price index data were taken from IMF's International Financial Statistics database. We construct the US dollar monthly bilateral real exchange rates for nine East Asian countries. Several authors have also highlighted the importance of structural breaks like the Asian financial crisis in influencing the assessment of PPP relationship (Chow *et al*., 2007; Zurbruegg and Allsopp, 2004; Fujii 2002). Perhaps, an important conclusion to be drawn from all these studies is that there has been an increased in the number of countries in East Asia that have adopted more flexible exchange rate regime since 1997. In applying unit root and coinegration tests, it is recognized that failure to consider possible breaks can affect the empirical results. In an event that a break is known in the data generating process, a natural approach is to truncate the sampling period divided into sub-periods. To account for the financial crisis and its impact on the sample countries, the monthly data is divided into two sub-periods. These are (i) January 1981- December 1996 which is the period before the Asian financial crisis and coincides with the fast growing phase of the Asian economies; and (ii) January 1997 – June 2005 which constitutes a period of macroeconomic instability and sharp fall in the currencies of crisis-affect countries due to the Asian financial crisis[4]. We also conduct the same panel unit root tests for the full sample period to be used as benchmark.

[4] Scholars attribute the crises to a combination of factors, including a boom in international funding, adverse external shocks, mismanagement of macroeconomic and exchange rate policies, and weak financial sector.

3.1 Univariate Unit Root Tests

All variants of PPP postulate that the real exchange rate reverts to a mean. Evidence of long run PPP can be provided by a test of a unit root in real exchange rates. If the unit root null hypothesis can be rejected in favor of a level stationary alternative, then there is long-run mean reversion and, therefore, long-run PPP holds. On the other hand, if the real exchange rate follows a random walk without reverting back to the constant mean, nominal exchange rates and relative price levels[5] will not converge in the long run and thus PPP will not hold. The real exchange rate is often obtained if we let s_t be the log spot rate, p_t^* and p_t be the log foreign and domestic price levels respectively, and q_t be the (log of the) real exchange rates defined by

$$q_t = s_t + p_t^* - p_t \qquad (1)$$

This estimation of real exchange rate is appropriate for testing PPP as it allows one to compute the half-life of a random disturbance to measure the degree of mean reversion. The common approach in investigating the speed of convergence to PPP employs the following linear autoregressive model of order one, AR (1),

$$q_t = \rho q_{t-1} + \varepsilon_t \qquad (2)$$

where $0 < |\rho| < 1$ and ε_t is a white noise innovation. For annual data, the half-life of deviations from PPP (τ) is the number of years (or months, for monthly data) required for the initial deviation from the long-run level to dissipate by half (with no future shocks). Suppose the long-run PPP level $(E[q_t] = 0)$ as the starting point q_0 with an initial shock $\delta > 0$. Then,

[5] The price level is usually represented by the consumer price index (CPI), the wholesale price index (WPI), or the GDP deflator.

from $\delta/2 = |q_t| = |\rho|^{\tau}\delta$, the half-live is given by $\tau \equiv \ln(1/2)/\ln|\rho|$, where absolute value is introduced to allow oscillation[6]. In practice, the half-lives are estimated by

$$\hat{\tau} = \frac{\ln(1/2)}{\ln|\hat{\rho}|} \qquad (3)$$

where $\hat{\rho}$ is an OLS estimator of ρ in (7). By construction, the speed of adjustment, or the half-life, does not depend on the initial level of real exchange rate q_0 or the size of deviations (δ) in the linear AR (1) model. The time needed for the initial deviation δ to become $\delta/2(\tau)$ is identical to the time for $\delta/2$ to become $\delta/4(\tau')$. However, because arbitrage depends on the relative size of international price differentials and trade costs, the speed of adjustment is likely to be slower when the deviation from PPP is smaller (see Shintani, 2002).

For real exchange series that follow the AR(ρ) process, the model can be re-parameterized as

$$q_t - q_0 = \rho(q_{t-1} - q_0) + \sum_{i=1}^{p-1} a_i \Delta(q_{t-i} - q_0) + \mu_t \qquad (4)$$

with $\rho = \sum_{j=i}^{p} \alpha_j$ and $a_i = -\sum_{j=i+1}^{p} \alpha_j, i = 1,\ldots, p-1$

Eq. (4) can be further derived into the ADF regression to allow for deterministic component (constant, trend) and stochastic component such that

$$\Delta q_t = c + bt + \beta q_{t-1} + \sum_{i=1}^{k} a_i \Delta q_{t-i} + \mu_t, \qquad t = k+2,\ldots,T, \qquad (5)$$

[6] It was noted in Shintani (2002) that since the denominator $\ln|\rho|$ ($\approx |\rho| - 1 = |q_t / q_{t-1}| - 1$ for a small value) can be interpreted as the speed of adjustment (in absolute value), τ becomes greater than unity only if the speed of adjustment is slower than that of the AR (1) model with ρ =0.5. When ρ approaches unity, the speed of adjustment $\ln|\rho|$ approaches zero from the left, and half-life τ approaches infinity, implying the absence of convergence towards PPP.

with $c + bt$ being the deterministic component while $\beta = \rho - 1$ and $\Delta\varepsilon_t = \varepsilon_t - \varepsilon_0$. As such, the AR(ρ) half-life is defined as $h = \frac{\ln(1/2)}{\ln(\beta)}$.

3.2 Panel Based Unit Root Tests

Testing for unit root in time series studies is now a common practice among applied researchers. However, testing for unit roots in panels is relatively recent[7]. The present article incorporates the non-stationary panel unit root tests advocated by Maddala and Wu (1999), Im, Pesaran and Shin (2003, IPS hereafter), Levin-Lin-Chu (2002, LLC hereafter) and Breitung (2000, UB hereafter). The null hypothesis of these tests states that the panel series has a unit root. Rejection of the null hypothesis would imply that real interest exchange rates exhibit mean reverting at level form, which is *I(0)*.

The ADF-Fisher panel test proposed by Maddala and Wu (1999) is nonparametric and allows for different first-order autoregressive coefficients. It pools the p-values of β_i from the ADF distribution for each of the *N* independent ADF regressions in equation (5) for β_i. If we re-define π_i as the p-value from any individual unit root test for cross-section *i*, then under the null of unit root for all *N* cross-sections, we have the asymptotic result that

$$-2\sum_{i=1}^{N}\log(\pi_i) \rightarrow \chi^2_{2N} \qquad (6)$$

[7] See for example Levin and Lin (1993), Im, Pesaran and Shin (1997), Maddala and Wu (1999) and Breitung (2000), among others. Among these, the Levin-Lin test is less preferable as it requires the coefficient (ρ) of the lagged dependent variables to be homogenous across all cross-section unit of the panel which intimate that each series reverts to its respective unconditional mean over time at the same rate. This assumption could be restrictive in applied work. Additionally, O'Connell (1998) found the loss of power in LL test that suffered from significant size distortion in the presence of correlation among contemporaneous cross-sectional error terms.

The χ^2 variables are additive and thus Eq (5) has a χ^2 with $2N$ degrees of freedom. When the series in the panel are not independent, the critical values are no longer valid. To accommodate for contemporaneous correlation in the data, Maddala and Wu (1999) calculate the critical values using the bootstrap method. The procedure requires estimating the parameters of equation (5) using iterative SUR and saving the fitted residual $\hat{\mu}_{it}$. To preserve the contemporaneous correlation among the countries, the fitted residuals $\hat{\mu}_{it}$ are re-sampled over time with a fixed cross-section index to obtain the bootstrap sample of μ_{it}^*. The bootstrap sample q_{it}^* for q_{it} is generated from the following equation (without the deterministic component):

$$\Delta q_{it}^* = \hat{\alpha}_i + \sum_{j=1}^{p} \hat{a}_{ij} \Delta q_{i,t-j} + \mu_{it}^* \qquad (7)$$

where $\hat{\beta}_i$ and $\hat{a}_{ij}$ are the SUR estimates from (5). Following Wu (1996), the initial values for $q_{i,0}^*$ are obtained by randomly resampling a block with replacement after dividing q_{it} into T - p overlapping blocks of length p + 1. The panel unit root tests are then applied to the bootstrap data. The critical values are derived from 2000 replications. In addition, Choi (2001) demonstrates that:

$$Z = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \phi^{-1}(\pi_i) \rightarrow N(0,1) \qquad (8)$$

where ϕ^{-1} is the inverse of the standard normal cumulative distribution function.

By allowing for greater degree of heterogeneity, IPS proposed a testing procedure based on the mean group approach: the *t*-bar statistics and the group mean Lagrange Multiplier test (*LM*-bar). Conceptually, IPS test is a way of combining the evidence on the unit root hypothesis from the N unit tests performed on the N cross-section units. Through Monte Carlo experiments, the average

LM and the *t*-statistics have better finite sample properties than the Levin and Lin (1993) test. Briefly, the test statistics are given by:

$$\Gamma_{\bar{t}} = \frac{\sqrt{N}\left\{\bar{t}_{NT} - E(t_{iT} \mid \beta_i = 0)\right\}}{\sqrt{Var(t_{iT} \mid \beta_i = 0)}} \qquad \Rightarrow \text{N (0,1) where } \bar{t}_{NT} = \frac{1}{N}\sum_{i=1}^{N} t_{iT} \quad (9)$$

and

$$\Gamma_{\overline{LM}} = \frac{\sqrt{N}\left\{\overline{LM}_{NT} - E(LM_{iT} \mid \beta_i = 0)\right\}}{\sqrt{Var(LM_{iT} \mid \beta_i = 0)}} \Rightarrow \text{N (0,1) where } \overline{LM}_{NT} = \frac{1}{N}\sum_{i=1}^{N} LM_{iT} \quad (10)$$

such that $\bar{t}_{NT}$ based on averaging individual ADF test while $\overline{LM}_{NT}$ is average across group. Both means $E(t_{iT} \mid \beta_i = 0)$, $E(LM_{iT} \mid \beta_i = 0)$ and both variances $Var(t_{iT} \mid \beta_i = 0)$, $Var(LM_{iT} \mid \beta_i = 0)$ are obtained from the Monte Carlo simulations with i= 1,2,…,N.

Alternatively, LLC proposed to modify the ADF statistics based on homogenous pooled statistics, which is opposed to the heterogeneous IPS test. An estimate of the coefficient α may be obtained from proxies for Δq_{it} and q_{it} which are standardized and free of autocorrelations and deterministic components, such that:

$$\Delta\tilde{q}_{it} = \alpha\tilde{q}_{it-1} + \eta_t \quad (11)$$

where $\Delta\tilde{q}_{it} = (\Delta\bar{q}_{it} / se_i)$ and , $\tilde{q}_{it-1} = (\bar{q}_{it-1} / se_i)$, with s_i being the estimated standard error from estimating single ADF statistics of the real exchange rate series, q_t . Then, LLC show that under the null, a modified t-statistics for the resulting $\hat{\alpha}$ is asymptotically normally distributed

$$t_{\alpha}^{*} = \frac{t_{\alpha} - (NT)S_N\hat{\alpha}^{-2}se(\hat{\alpha})\mu_{mT}^{*}}{\alpha_{mT}^{*}} \rightarrow N(0,1) \quad (12)$$

where t_{α}^{*} is the standard t-statistics for $\hat{\alpha} = 0$, $\hat{\alpha}^2$ is the estimated variance of the error term η, $se(\hat{\alpha})$ is the standard error of $\hat{\alpha}$, S_N is the mean of the ratios of the long run standard deviation

to the innovation standard deviation for each individual series, which is derived using kernel-based techniques, μ_{mT}^{*} and α_{mT}^{*} are adjustment terms for the mean and standard deviation respectively, and lastly $T = T - (\sum_{i} p_i / N) - 1$.

On the other hand, Breitung (2000) studied the local power of Levin and Lin (1993, LL) and IPS test statistics against a sequence of local alternatives. Breitung found the losses of power due to bias correction in LL and detrending bias in IPS. In consequent, a class of t-statistics (λUB) that do not require bias corrections is propounded. Through the Monte Carlo experiments, the power of UB test is substantially higher than that of LL or the IPS tests. The simulation results indicate that the power of LL and IPS tests is very sensitive to the specification of the determination terms. By defining the T × 1 vectors $Y_i = [\Delta y_{i1},..., \Delta y_{iT}]'$ and $\mathrm{X}_i = [y_{i0},..., y_{i,T-1}]'$ whilst the transformed vectors $Y_i^{*} = Ay_i = [y_{i1}^{*},..., y_{iT}^{*}]'$ and $\mathrm{X}_i^{*} = Bx_i = [x_{i1}^{*},..., x_{iT}^{*}]'$, the UB statistic is in short given by:

$$\lambda_{UB} = \frac{\sum_{i=1}^{N} \sigma_i^{-2} y_i^{*'} x_i^{*}}{\sqrt{\sum_{i=1}^{N} \sigma_i^{-2} x_i^{*'} A' A x_i^{*}}} \qquad \Rightarrow (N,\ T \to \infty)_{seq.} \tag{13}$$

under the assumption of

$$E(y_i^{*'} x_i^{*}) = 0, \qquad \lim_{T\to\infty} E(T^{-1} y_i^{*'} y_i^{*}) > 0, \qquad \lim_{T\to\infty} E(T^{-1} x_i^{*'} A' A x_i^{*}) \tag{14}$$

4. Empirical Results

We begin the analysis with the standard univariate unit root tests for the full sample period for all the nine countries. The results of the empirical analysis appear to suggest that real exchange rates are highly persistent (i.e., they are characterized by a random walk process), except for the Malaysia ringgit and the Singapore dollar as evident by the ADF and KPSS test respectively. We note Bahmani-Oskooee (1993) also reject PPP for 25 LDC based on pure time series method. Authors like Perron (1989) have speculated that in the case of unknown regime changes; say due to financial crisis, unit root tests are likely to be biased towards the null hypothesis of nonstationarity. To account for such a break, we deploy the Zivot and Andrews (1992, ZA) sequential unit root tests, which are robust to (a) an unknown mean, (b) an unknown break in trend, and (c) an unknown break in mean and trend. In our data, the Plaza Accord 1985 as well as the economic recession due to 1985 commodity crash and the 1997/98-currency crises may be considered as potential break points in the real exchange rate series for the nine Asian countries.

[Insert Table 1 about here]

The ZA test results for one-off shift in the process underlying the real exchange rates for the full sample (1985M1-2005M6) are mixed. Five countries have rejected the unit roots but we fail to find evidence of mean reversion in real dollar rates for the Hong Kong dollar, the Singapore dollar, the won, and the peso. The median value of the breaks is 1997 for dollar rates it coincided with the Asian financial crisis. We may interpret the break as changes in exchange rate regime in Asian countries. For Japan, the endogenous single break date is detected in July 1985 and not during the late 1990s, suggesting that the impact of Plaza Accord 1985 - rather than the Asian currency crisis - is more troublesome to the Japanese Yen. All in all, the empirical results

presented in both Table 1 and 2 show that the univariate tests (including the ZA tests) failed to confirm the cohesive supports for real exchange rate stationarity. In other words, evidence from the full sample period is incompatible with the PPP hypothesis as far as the standard unit roots tests are concerned. Such finding has also been recently verified by Zurbruegg and Allsopp (2004).

[Insert Table 2 about here].

To further assess the impact of changes in exchange rate regime due to Asian crisis, all the series were reanalyzed under the pre- and post-crisis episode (see Table 3). In Panel A, the results are evidently not in favor of long-run PPP as the null hypothesis of unit root failed to be rejected for seven countries prior to 1997. However, using the post-1997 data we found more favorable results of mean reversion to support long-run PPP in six cases (Panel B). All the East Asian currencies except the Hong Kong dollar, Taiwan dollar and the Philippine peso are consistent with the parity condition. Taken together, the empirical results so far suggest the PPP is a valid hypothesis in the post-crisis period for six out of the nine Asian countries under investigation.

[Insert Table 3 about here].

Using the ZA tests, we detect a break in the real exchange rate series for most of the East Asian countries. This finding is in line with the empirical evidence reported in two recent studies by Nusair (2004) and Zurbruegg and Allsopp (2004). Indeed, these authors argued that most of the currencies were misaligned (overvalued) prior to the Asian financial crisis. Nonetheless, our findings of univariate tests do not seem to be sufficiently consistent. For instance, Taiwan dollar was reported stationary by the ZA test with a structural break in 1998 but unit root was found in

the sub-period analysis. On the contrary, Singapore dollar and Korea won were reported as mean reverting to support PPP in the post-crisis period but not by the ZA test.

We now proceed with the panel unit root tests. The use of panel data in unit root testing is motivated by the advantage of increased power over the single equation tests. Additionally, the panel approach allows us to focus on relatively short-time span with homogenous exchange rate arrangements. To compare the results with those reported above, Tables 4 shows panel unit root tests using the US dollar as the reference currency. When the panel unit root tests were applied to the full sample period, the strong form of PPP is rejected by all but the BRT (10% significance level). This is consistent with Holmes (2001) and Alba and Papell (2007) who employed panel unit root tests but fail to show the validity of the RIP hypothesis for the Asian countries. Then again, to accommodate the impact of the crisis we divide the sample into sub-periods. This approach was also taken by Holmes (2002) to test for real interest rate parity in EU countries. Interestingly, our results from the all the panel unit root tests failed to reject the null hypothesis of unit root for the 1981-1996 period, except for LLC test[8].

[Insert Table 4 about here].

As reported above, the univariate tests strongly reject the random walk model in the post-1997 period. Likewise, all panel unit root tests (LLC, BRT, IPS and ADF-Fisher tests) reveal that the behavior of real exchange rates after the Asian currencies as a group is noticeably different from the pre-crisis period. Hence, the post-1997 evidence offers a different conclusion on the long-run

[8] Taylor and Sarno (1998) argued that while panel data unit root tests are powerful, they should be treated with care since the rejection of the null hypothesis of joint nonstationarity may be attributed to as few as one of the real exchange rate series under investigation being stationary. Since we did not reject the null we are not concerned with the inclusion of countries like Hong Kong and Thailand in the panel that accept PPP using the univariate tests.

PPP relationship. All of the panel unit root tests find evidence that favor stationarity and so PPP is supported for the post-1997 crises period, possibly as the pegged exchange rate (with US) was abandoned in the aftermath of the speculative attacks in 1997/98[9]. Market adjustments in the post-crisis ear seem to have forced the exchange rates to depreciate to the levels consistent with relative prices.

To sum, the evidence in this paper demonstrates the difficulty of detecting robust evidence in favor, or against the mean reversion property of real exchange rates as suggested by the PPP hypothesis. Overall, the evidence is against PPP as a long run relationship in East Asia during the pre-crisis period. On the other hand, we find sufficient evidence to support PPP for the East Asian countries over the post-crisis period where we observed that most of the countries experience much volatile (flexible) exchange rate movements.

4.1 Half-Lives of PPP deviations

In this section, we present the calculated half-lives. The data from the two sub-periods has the advantage over the full sample period as it does not mix observation from the pre- and post-crisis periods. This is quite the reverse with studies that consider time spans which cut across structural break(s) in the series that might impact any half-life calculations. The single disadvantage, however, is the much shorter time span of data. Estimated half lives (monthly) for the two sub-periods and the overall period are presented in last column of Table 3 and 4. Since panel tests offer more conclusive results, our discussion shall focus on the panel-based half-lives.

[9] Malaysia is the only country in the panel that pegged the ringgit to the US dollar and applied capital controls on 1st in September 1988. Removing Malaysia from the panel seems not to affect the overall results. Zurbrueg and Allsopp (2004) also found that PPP hold for the case of Malaysia in the post crisis period.

Several points about the calculation of the half-life are noteworthy: First, the point estimates of the half-lives for the full sample is roughly 2.7 years (32.85 months) which is slightly less than the range of Rogoff's 3-5 years for the industrialized countries (see also Froot and Rogoff, 1995). Thus, suggesting that the speed of adjustment towards PPP in the Asian countries is faster than the industrialized countries. It is worth mentioning that our panel members include the newly industrialized Asian countries like South Korea, Taiwan, Hong Kong and Singapore. Second, when the half-lives were calculated using data only from the pre-crisis period, the estimates are in the Rogoff's range. Third, using the sample period 1997-2005 generally yields lower half-lives, and the differences in half-lives between the pre-crisis and post-crisis periods are dramatic (6-7 months). Taken together, these findings tend to support the hypothesis that the speed of reversion to parity depends on productivity growth (Balassa-Samuelson effect). The decline in productivity due to the financial crisis in most of the Asian countries leads to lower level of resistant and a faster speed of reversion to parity. We are aware that the sample span (1997-2005) may be to short for computing the half-life during the post-crisis period. Hence, this has to be cautiously interpreted.

In general our estimates are much closer to the periods reported in Papell (1997) and Wu (1996), where they find the half-lives to average 2.5 years for the post-1973 data. Cheung and Lai (2000) using monthly data from 1973:4 to 1996:12 on four US dollar exchange rates: the French franc, German mark, Italian lira and British pound, found the lower bound of the confidence interval for half lives of real exchange rates to be less than 1.5 years. Achy (2003) also found the average half-life is much shorter (about 2 years) for the middle income countries. These half-life

estimates are low enough to be explained by models with nominal rigidities. Summing up, the current exchange regime in East Asian is different from those in the pre-crisis era.

4.2 Discussion and Implications

The results presented here are consistent with a number of other findings related to East Asian exchange rates. First, the exchange rates of the East Asian countries conform to the PPP rates especially in the post-crisis era, indicating that all the East Asian countries are returning to some form of PPP-oriented rule as a basis for their exchange rate policies in order to maintain international competitiveness and to stabilize domestic economies. Supporting this interpretation is the article by Baharumshah *et al.* (2003), which found that the current accounts of the severely affected East Asian countries moved mostly form an unsustainable to a sustainable path following the financial crisis.

Second, one policy implication that arises from this finding is that exchange rates in the East Asian countries may have been misaligned during the pre-crisis period. Barriers that seek to protect the tradable sector may have led to these large deviations from PPP during the pre-crisis period. This also concurs with the view of some scholars that suggest the main caused of the deviation from PPP is due the combination of exchange rate restrictions and government polices aimed at attracting capital inflows (Corsetti *et al.*, 1998). Meanwhile, the mean reverting behavior of these currencies over the post-crisis period suggests that departure from the PPP rates are temporary and indicates that intervention in the currency market to minimize short-term fluctuations may not be harmful. The sub-sample analyses on the PPP relationship reveal an interesting difference. Flexible exchange rate regime allow nominal for a rapid adjustment of nominal exchange rate, such that PPP tends to hold in the long-run. Like earlier studies, we

found that PPP fail to hold over the full sample period. Such a finding is perhaps due to the low power of the panel unit roots in the presence of structural breaks. Furthermore, the fact that PPP holds after the crisis but not before the crisis suggest that the Asian crisis corresponds to the first-generation models which stress on fundamental factors.

Third, we also consider the speed of adjustment of real exchange rates. For monthly data with the CPI series, the average expected half-live for the dollar rates is 2.8 years for the 1981-1997. These estimates are within Wu's (1996) estimates of 2.1-2.7 years for monthly data but well below the typical estimates of 3-5 years suggested in Rogoff (1996). Meanwhile, the estimated half-lives of PPP deviations are shorter for the post-1997 period. Interestingly, this means shocks to parity reversion are overall less persistent (shorter half life) in the post-crisis period compared to the pre-crisis period. It is likely that as the exchange rate of the Asian countries becomes increasingly misaligned with economic fundamentals, one might expect that the pressure to return to fundamental values both from the market and from policy makers would become increasingly stronger.[10] Clearly, our results indicate that the post-crises exchange rate regimes in East Asian countries allow for much greater flexibility in currency values. The empirical evidence also has implication for models of exchange arte: they must be driven by temporary disturbance which slowly dissipate over a period of years.

[10] Emerging theoretical models, suggesting that exchange rate deviations may be governed by nonlinear factors, support this reasoning. The paper by Taylor and Peel (2000) found empirical evidence of nonlinear mean reversion during the post-Bretton Woods period for the currencies of the developed countries. Of course these issues are interesting and worthy of further research.

5.0 Conclusions

The pattern of the Eat Asian currencies has received considerable attention in the past two decades. Prior empirical studies of PPP both in the developed countries and in the developing countries of East Asia have provided mixed results. The literature contends that one reason for these mixed results may be the limited power of the statistical tests used to test for unit roots in real exchange rates. This paper uses improved univariate and multivariate panel unit root tests to test for PPP.

In this article we examine the mean-reversion hypothesis for the real exchange rates in US dollar term of nine Asian countries using a wide range of unit root tests based on data for over a quarter century that includes periods both before and after the late 1990s Asian financial crises. While most unit root tests, including our tests, do not reject the unit root null for the pre-crisis period, our panel unit tests that have power advantage strongly reject unit roots for the post-crises period. Our study finds strong new evidence of mean reversion to supporting PPP for Asian currencies especially for the recent post-crises period.

Further, consistent with changes in Asian exchange regimes resulting from the late 1990s crises, we find that the speed of adjustment by Asian exchange rates towards PPP increased dramatically after the late 1990s Asian crises with average half lives moving from about 3.6 years before the crises to less than year (0.5) after the crises and averaging 2.6 years for the overall period. These half lives are shorter than the 3-5 year half lives reported for developed countries. This finding implies that the shocks to parity reversion are overall less persistent in the post-crisis period.

International economic integration seems to be rising and Asia is becoming an increasingly important part of the world economy. PPP is not only an elegant hypothesis; it is an integral and basic part of international economics with significant and wide ranging implications for individuals, business organizations, and governments responsible for managing the macro-economy. Thus, the results presented in this study provide new results and a fresh perspective on the behavior of exchange rates and should be of much interest not only to managers and investors, but also to policy makers.

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Table 1: Univariate Unit Root Tests of Real Exchange Rates

East Asian	H_0 : Unit Root		H_0 : No Unit Root	
	Lag	ADF	Bandwidth	KPSS
Japan	4	-1.72	14	0.75 ***
Hong Kong	15	-2.30	14	1.31 ***
Singapore	16	-1.57	14	0.34
South Korea	9	-2.48	14	0.46 **
Taiwan	9	-1.64	14	0.47 **
Indonesia	14	-1.84	14	1.45 ***
Malaysia	7	-2.79 *	14	1.71 ***
Philippines	8	-1.74	14	1.03 ***
Thailand	5	-1.62	14	1.41 ***

Notes:
Asterisks *, ** and *** denote rejection of the null hypothesis at 10%, 5% and 1% significant level respectively. For the ADF test, the null hypothesis is series contain unit root whereas for the KPSS (1992) test, the null hypothesis is series without unit root. The optimal lag of the ADF test is determined based on AIC whereas for KPSS, the Newey-West Bandwidth is chosen using the Bartlett Kernel as default Spectral estimation method. The sample period of analysis covers from 1981M1 to 2005M6.

Table 2: Univariate Unit Root Test of Real Exchange Rates with Structural Break

East Asian	Lag	Break Dates	Zivot-Andrew test
Japan	4	1985:M7	-5.45 **
Hong Kong	4	1999:M12	-4.80
Singapore	1	1990:M3	-4.63
South Korea	3	1997:M7	-3.71
Taiwan	2	1998:M7	-5.86 **
Indonesia	7	1997:M11	-5.14 **
Malaysia	1	1997:M7	-5.30 **
Philippines	2	1993:M8	-4.44
Thailand	6	1997:M8	-5.45 **

Notes:
Asterisks * denote rejection of the null hypothesis at 5% significant level. The critical values of structural break unit root test are tabulated as -4.80 (break in intercept), -4.42 (break in slope) and -5.08 (break in both intercept and slope) respectively by Zivot and Andrews (1992). Our estimation considers the breaks in both intercept and slope.

Table 3: Univariate Unit Root Tests of Real Exchange Rates by Sub-period

East Asian	H_0 : Unit Root		H_0 : No Unit Root		Speed of Adjustment	
	Lag	ADF	Bandwidth	KPSS	α - AR(1)	Half-life
			Panel A: 1981M1-1996M12			
Japan	15	-1.70	11	1.33 ***	-	-
Hong Kong	14	-3.25 *	11	0.46 **	-0.04523	14.98
Singapore	1	-1.74	11	0.89 ***	-	-
South Korea	1	-0.95	11	0.85 ***	-	-
Taiwan	4	-2.26	11	0.82 ***	-	-
Indonesia	1	-1.95	11	1.44 ***	-	-
Malaysia	1	-1.62	11	1.42 ***	-	-
Philippines	4	-2.06	11	1.18 ***	-	-
Thailand	4	-2.63 *	11	0.22	-0.04424	15.32
			Panel B: 1997M1-2005M6			
Japan	3	-2.66 *	8	0.10	-0.11390	5.73
Hong Kong	12	-1.37	9	1.10 ***	-	-
Singapore	4	-2.93 **	8	0.27	-0.06033	11.14
South Korea	1	-2.87 *	7	0.20	-0.14549	4.41
Taiwan	1	-2.28	8	1.00 ***	-	-
Indonesia	8	-3.61 ***	8	0.19	-0.24788	2.43
Malaysia	1	-3.20 **	8	0.14	-0.11458	5.70
Philippines	1	-2.15	8	1.07 ***	-	-
Thailand	2	-2.95 **	8	0.17	-0.11408	5.72

Note:
See Table 1 for details. The calculation of half-lives is in monthly basis.

Table 4: Panel Unit Root Tests of Real Exchange Rates

Sample Period	H_0 : Common Unit Root		H_0 : Individual Unit Root		Speed of Adjustment	
	LLC	BRT	IPSW	ADF-Fisher	α - AR(1)	Half-life
1981-1996	-1.55 *	0.05	0.04	16.33	-0.01585	43.38
1997-2005	-3.04 ***	-1.61*	-2.07 **	28.72 **	-0.10396	6.31
1981-2005	-0.76	-1.42 *	-0.23	14.33	-0.02088	32.85

Notes:
Asterisks *, ** and *** denote rejection of the null hypothesis of unit roots at 10%, 5% and 1% significant level respectively. LLC refers to the Levin-Lin-Chu (2002) test; BRT denotes the Breitung (2000) t-statistics; IPSW refers to the Im-Pesaran-Shin (2003) W-statistics whereas ADF-Fisher refers to the Fisher-type test using ADF proposed by Maddala and Wu (1999). The monthly half-lives are estimated based on the LLC test which assume a common unit root process so that ρ is identical across the cross-sections, with α =ρ-1 denoting the autoregressive coefficient of the first order-AR(1) ADF specification.