The Validity of PPP Revisited: An Application of Non-linear Unit Root Test

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Abstract

To this end, the validity of purchasing power parity (PPP) remains a controversial issue, as empirical evidence is inconclusive. This study provides robust empirical evidence to support the view that negligence of non-linearity may be the culprit of these contrasting findings. This paper demonstrates that the non-linear unit root test proposed by Kapetanois *et al.* [*Journal of Econometrics*, 2003, 112, pp.359-379] is able to reject unit root in 4 out of 5 cases, implying that deviations of exchange rates is mean reverting towards the PPP equilibrium values from the non-linear perspective, whereas the augmented Dickey-Fuller (ADF) test fails in 4 out of 5 cases. Thus, previous conclusions of the invalidity of PPP may be due to misleading results from the ADF test, which has low power against non-linearity.

Keywords: Purchasing power parity; Mean reversion; ASEAN economies; Real exchange rates; Non-linear unit root.

JEL Classifications: F31

I. INTRODUCTION

For the past few decades, the purchasing power parity (PPP) hypothesis has received extensive attention from exchange rate researchers. The PPP, which states that the exchange rate between currencies of two countries should be equal to the relative price of these countries, is one of the most frequently used hypotheses for the determination of exchange rate equilibrium. The issue of whether PPP holds or not has received extensive research in the past several decades. However, to date, previous empirical studies showed contrasting evidence on the validity of PPP. For instance, the empirical works of Lee (1976), Glens (1992), Lothian and Taylor (1996), Nagayasu (1998), Coakley and Fuertes (2001), Azali *et al.* (2001) and Razzaghipour *et al.* (2001) were supportive of long-run PPP hypothesis, whereas Corbae and Outliaris (1988), Edison and Fisher (1991), Engel *et al.* (1997), O'Connel (1998), Cuddington and Hong (2000) and Baum *et al.* (2001) provided empirical evidence against it. Meanwhile, the work of Salehizadeh and Taylor (1999) itself showed inconclusive results. Thus, Rogoff's (1996) verdict that the PPP puzzle is unresolved remains valid.

It is worth pointing out that in the past, exchange rate movement is assumed in *priori* to exhibit linear behaviour. However, there are growing views that the observable world is non-linearly dynamic (Pesaran and Potter, 1993; Campbell *et al.*, 1997; Barnett and Serletis, 2000). Empirically, a number of recent studies have provided strong evidence that exchange rates do exhibit non-linear behaviour (see, for example, Dumas, 1992; Sarno, 2000; Baum *et al.*, 2001; Liew *et al*., 2003). In particular, Dumas (1992) argued, in his "no-arbitrage model", that exchange rate adjusts non-linearly towards its PPP equilibrium value. On the other hands, Sarno (2000), Baum *et al.* (2001), amongst others, showed that the non-linear adjustment of exchange rate towards PPP can best be described by Exponential Smooth Transition Autoregressive (ESTAR) model[1]. More recently, Liew *et al.* (2003) have demonstrated that linear autoregressive model is inadequate in characterizing the Asian (including ASEAN-5) real exchange rates behaviors. Thus, it is reasonable for one to think that the puzzling results of PPP lie in the implicit linear assumption of exchange rate behaviour.

The main objective of this study is to examine the validity of PPP from the non-linear perspective, or more specific, to find out whether exchange rate adjusts non-linearly towards its PPP equilibrium value. Generally, the two widely employed empirical tests for PPP are the unit root methodology and cointegration analysis. A necessary condition for PPP to hold in the long run is that the real exchange rate must be covariance stationary. The standard method for detecting non-stationary behaviour in a time series is to test for the presence of a unit root. Thus, rejection of a unit root in real exchange rate provides evidence supporting PPP. Another stream of literature is based on the cointegration technique. To provide empirical support for PPP, both the bilateral nominal exchange rates and relative prices must form a cointegrated system with parameters [1, −1]. The present study belongs to the first group, which investigates the stationary property of the deviations of U.S. dollar denominated exchange rates of five major ASEAN countries- Indonesia, Malaysia, the Philippines, Singapore and Thailand, from the long-run equilibrium level suggested by the PPP hypothesis. To do that, the newly developed non-linear unit root test proposed by Kapetanois *et al.* (2003) is utilised.

The results of this study suggest that exchange rate adjustment is mean reversion towards PPP equilibrium values, in a non-linear way, thereby providing empirical evidence in favor of long run PPP. More importantly, this study provides empirical evidence against the robustness of standard augmented Dickey-Fuller (ADF) test when the true data generating process of exchange rate is in fact a stationary non-linear process. It is worth pointing out that, the

[1] Teräsvirta (1994) provided theoretical details for ESTAR model, whereas Sarno (2000) and Baum *et al.* (2001) demonstrated the usefulness of this model in characterizing exchange rate adjustment.

current paper is, to date, the first and only one that applies the non-linear unit root test of Kapetanois *et al.* (2003) in examining the mean reversion behaviour of exchange rate adjustment.

This paper proceeds as follows. Section II briefly discusses the contrasting evidence on the validity of PPP whereas the data and methodology of this study is described in Section III. Section IV presents the findings of the study. As usual, concluding remarks are given at the end of the paper.

II. CONTRASTING EVIDENCE ON PPP

Lee (1976) examined the relationship between relative prices and exchange rates dating back to 1900 and concluded that the exchange rates of major currencies tend to assume the equilibrium PPP value in the long run. Glens (1992) also confirmed that the PPP is a long run phenomenon by using annual data of the European Monetary System (EMS), covering the period 1900 to 1987. Lothian and Taylor (1996), in another study, used annual data spanning two centuries for dollar-sterling and franc-sterling exchange rates, beginning in 1791 and ending in 1990, and their findings reinforced the mean reverting behaviour of exchange rates towards the long-run PPP value. The work of Nagayasu (1998) found support for a "semi-strong' version of the long-run PPP hypothesis in a sample of 16 African countries, whereas Coakley and Fuertes (2001) provided strong support for long-run PPP in the context of G-10 plus Switzerland. Salehizadeh and Taylor (1999) applied the standard Johansen cointegration approach to 27 emerging economies and claimed that they have found relatively strong evidence for 14 countries in favour of long-run PPP. In another study, Razzaghipour *et al*. (2001) used statistical analysis to study the mean-reversion towards PPP in the Asian currencies and obtained empirical support for PPP, although not statistically significant. Nevertheless, Azali *et al.* (2001) also found significance evidence that PPP holds between Japan and the Asian economies by using panel cointegration approach.

Even though many empirical findings are consistent with the PPP hypothesis, studies that provide counter empirical evidence against the validity of PPP hypothesis are no lesser. For instance, the results of the standard unit root tests conducted by Corbae and Outliaris (1988) and Edison and Fisher (1991) are not supportive of the PPP hypothesis. Using a different approach, Baum *et al.* (1999) allowed for fractional integrated and structural breaks in testing the mean reversion in the CPI-based rates for seventeen countries and WPI-based rates for twelve countries. Their evidence suggested rejection of the absolute long run PPP during the post-Bretton Woods era. Cuddington and Hong (2000), on the other hand, re-examined the

PPP hypothesis for the dollar-sterling and franc-sterling rates using the data from Lothian and Taylor (1996). Their results rejected the long-run PPP hypothesis by fitting time trends or by considering longer lag length in the augmented Dickey-Fuller (ADF) unit root test. Other evidence against PPP hypothesis are reported in, amongst others, Engel *et al.* (1997) and O'Connel (1998).

As we mentioned earlier, one possible explanation for the inconsistency in the empirical evidence on PPP hypothesis is that earlier studies implicitly assume that exchange rate behaviour is linear in nature. Taylor and Peel (2000) and Sarno (2000), amongst others, illustrated that the adoption of linear stationarity tests is inappropriate in detecting mean reversion if the true data generating process of exchange rate is in fact a stationary non-linear process. Furthermore, the importance of allowing for non-linear adjustment of the exchange rates towards their long-run PPP equilibrium has been stressed in a number of past studies. For instance, Hsieh (1989) observed that exchange rate changes may be non-linearly dependent. Boothe and Glassman (1987) pointed out that exchange rates are not linearly predictable. Sarno (2000) provided strong evidence that real exchange rates of Middle East countries adjust non-linearly towards their long-run PPP equilibrium over the sample period of 1980 to 1997. Mahajan and Wagner (1999) applied the BDS statistic developed by Brock *et al.* (1996) on the daily rates of eleven major countries and concluded that the behaviour of exchange rates are governed by non-linear dynamics, and that innovations in real exchange rates are consistent with a PPP equilibrium. Using a non-parametric cointegration approach in testing the non-linearities in exchange rates adjustment for 18 OECD economies, Coakley and Fuertes (2001) also found significant non-linearities in real exchange rates adjustment to PPP over the 1973 to 1998 period.

These findings of the existence of non-linear relationship between exchange rates and their fundamentals imply that exchange rate researchers could no longer take for granted that exchange rate movements are linearly dependent. In fact, the negligence on the presence of non-linearity in the exchange rate adjustments process has been regarded as a major explanation for the failure of previous linear exchange rate models in explaining the past or forecasting the future movements (Taylor and Peel, 2000). These authors argued that deviations of exchange rate from the equilibrium level may be hard to model using linear methods if they are governed by a non-linear process.

III. DATA AND METHODOLOGY

Data

This study uses the quarterly end-of-period nominal bilateral Indonesian rupiah per U.S. dollar (IDR/USD), Malaysian ringgit per U.S. dollar (MYR/USD), the Philippines peso per U.S. dollar (PHP/USD), Singaporean dollar per U.S. dollar (SGD/USD) and Thai baht per U.S. dollar (THB/USD). The price index used is the consumer price indices (CPI) of Indonesia, Malaysia, the Philippines, Singapore, Thailand and U.S. The data are obtained from various issues of *International Financial Statistics* published by the International Monetary Funds. Our data spans from the first quarter of year 1975 to the second quarter of year 2001 (1975:1 to 2001:2). Deviations of exchange rates are obtained from PPP as estimated by standard Johansen procedure and this is depicted in Figure 1.

These deviations are de-meaned such that the zero-horizontal lines indicate the equilibrium PPP positions of the exchange rates under investigate[2]. A stylised facts depicted in Figure 1 is that the deviations of ASEAN-5 exchange rates from their PPP equilibrium values (shown by the zero-horizontal lines) seem to be persistence throughout the sample period except for few points of time whereby the deviations are zero. However, at this moment, it is inappropriate to conclude that PPP does not hold in this region, with just an informal inspection of graphs. Rather, this study employs the latest econometric technique in analysing the mean reversion behaviour of these deviations. This technique refers to is the non-linear unit root test advanced by Kapetanios *et al*. (2003), henceforth denoted as KSS test.

Non-linear Unit Root Test (KSS Test)

Kapetanios *et al.* (2003) proposed a testing procedure to detect the presence of non-stationarity against non-linear but globally stationary Exponential Smooth Transition Autoregressive (ESTAR) process:

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

[2] Another purpose of de-meaning these series is to suit the nonlinear unit root test procedure that will be discussed shortly.

where y_t is the de-meaned series of interest and $\theta \geq 0$ is known as the transition parameter of the ESTAR model that governs the speed of transition; see Teräsvirta (1994) for more details. As usual, ε_t denotes random errors that are independently and identically distributed (i.i.d.) with zero mean and finite variance.

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 γ is not identified under the null. Thus, Kapetanios *et al.* (2003) reparameterised Equation (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 correlation errors.

In both cases, the null hypothesis to be tested is $H_0 : \delta = 0$ against the alternative $H_1 : \delta > 0$. Kapetanios *et al.* (2003) showed that the *t* statistic of the parameter of interest, that is, δ does not have an asymptotic normal distribution and thus one must resort to simulations for asymptotic critical values. Using stochastic simulations with 5000 replications and 1000 observations, these authors obtained the 1, 5 and 10% asymptotic null critical values of the *t* statistic for both cases as –3.48, –2.93 and –2.66 respectively. For the brevity of reporting, the *t* statistics estimated from Equation (2) and Equation (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}.

IV. EMPIRICAL RESULTS

The unit root tests results are summarised in Table 1. By using conventional augmented Dickey-Fuller (ADF) unit root test, the null of unit root cannot be rejected in 4 out of 5 cases, implying that deviations of exchange rates are not mean reverting towards the PPP equilibrium. In other words, the ADF test results suggest deviations from PPP persist and that PPP is not valid in the ASEAN region, with the exception of only Indonesia.

However, results from both KSS unit root tests are able to reject unit root in 4 out of 5 cases, implying that deviations of exchange rates is mean reverting towards the PPP equilibrium values in the same region. Thus, this study demonstrates that conclusions drawn from linear and non-linear unit root tests may be drastically different. These contrasting conclusions are due to the low power of ADF test against non-linearity (Kapetanios *et al.*, 2003). Hence, it is not unreasonable to expect that previous conclusions of the invalidity of PPP may be due to the misleading results from ADF test, which neglects the presence of non-linearity. As the KSS test is more robust than the ADF test, the conclusion of the current study is that, in general, the long run PPP holds in the ASEAN-5 economies.

Table 1
Unit Root Test Results

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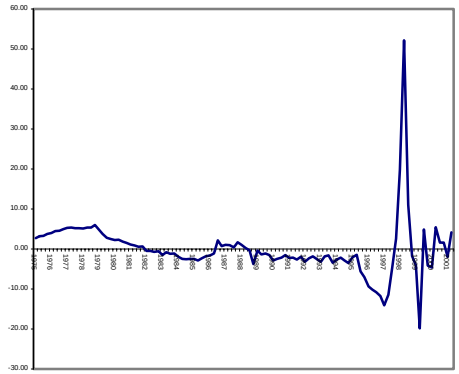
Exchange Rate Deviations	t_{ADF}	t_{KSS1}	t_{KSS2}
IDR/ USD	–4.029***	–7.742***	–9.929***
MYR/USD	–2.021	–3.397**	–3.785***
PHP/USD	–1.893	–0.946	–0.961
SGD/USD	–1.784	–4.608***	–5.128***
THB/USD	– 0.963	–4.074***	–3.967***

Notes: t_{ADF} denotes the conventional ADF test statistics.

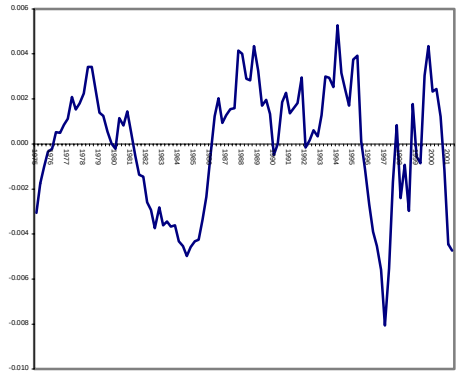
t_{KSS1} and t_{KSS2} represent the *t* statistics estimated from Equation (2) and Equation (3) of this study.

Figure 1
Deviations of ASEAN-5 Exchange Rates

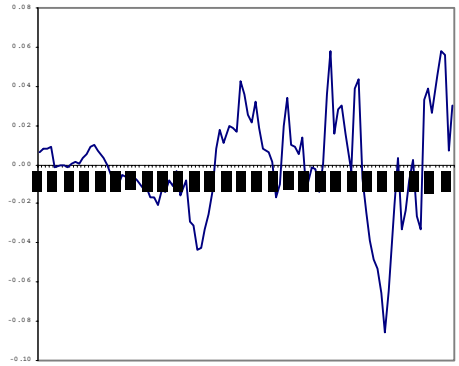
IDR/USD



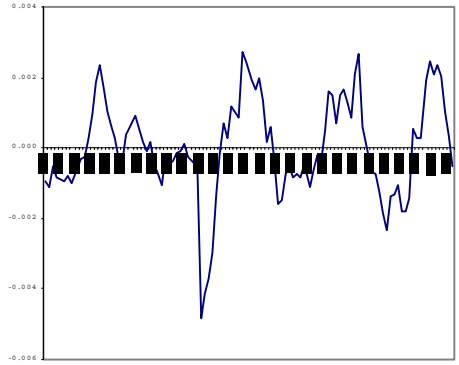
MYR/USD



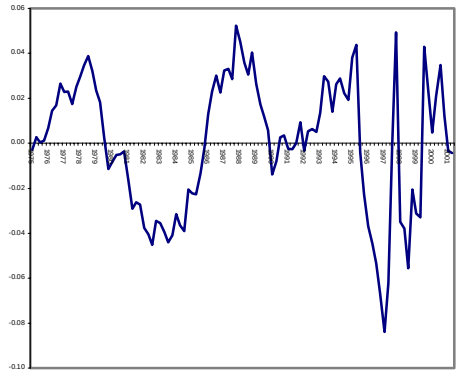
PHP/USD



SGD/USD



THB/USD



V. CONCLUSIONS

Over the years, there has been an explosion of empirical research on the validity of PPP in the real world. While most studies are favorable, the dissenting voices are no lesser. With abounding evidence supporting the presence of non-linearity in exchange rate time series data, coupled with the growing literature suggesting that the adoption of linear stationarity tests is inappropriate in detecting mean reversion if the true data generating process of exchange rate is in fact a stationary non-linear process, this study re-examined the validity of PPP from the non-linear point of view. The findings from this study provide robust empirical evidence supporting the validity of the long-run PPP, suggesting that ASEAN-5 exchange rate adjustment is mean reversion towards PPP equilibrium values in a non-linear way.

The major contributions of this study are twofold. First, it remains the first and only one study insofar that utilised the non-linear unit root test of Kapetanios *et al.* (2003) to verify the validity of PPP. Second, it demonstrates that the contrasting findings of earlier studies based on conventional linear test procedures may be due to the low power of these tests against non-linearity. The last statement is in line with Kapetanios *et al.* (2003).

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