

NON-PARAMETRIC COINTEGRATION ANALYSIS OF ASEAN-5 REAL EXCHANGE RATES

KIAN-PING LIM

HOCK-ANN LEE

*Labuan School of International Business and Finance
Universiti Malaysia Sabah*

ABSTRACT

This study employs the Bierens's (1997) non-parametric cointegration methodology to test the Purchasing Power Parity (PPP) hypothesis for five major ASEAN economies - Indonesia, Malaysia, the Philippines, Singapore and Thailand, with the U.S. and Japan data as base countries. The results provide evidence of mean reversion in dollar denominated real exchange rate for three ASEAN countries - Malaysia, Singapore and Thailand. These findings are in sharp contrast with those earlier studies using Johansen cointegration technique. Consistent with the interpretation of Coakley and Fuertes (2001), the discrepancy between the findings from both approaches is interpreted as a consequence of significant non-linearity in the real exchange rate adjustment to PPP. Further analysis reveals that the evidence of PPP is much stronger with the Japanese yen as the numeraire currency, thus supporting the notion that the choice of numeraire currency can and does matter for testing PPP hypothesis. These results provide strong evidence of the integration between the Japanese economy and those of ASEAN countries, which are closely linked in geographical, economic and trade terms. The increasing role of Japanese yen in the ASEAN region can be taken as providing empirical support for the formation of a yen dominated ASEAN exchange rate system, or a 'yen bloc'.

Keywords: Non-parametric cointegration, Purchasing power parity, ASEAN economies, Non-linearity, EasyReg.

JEL Classifications: C14, F31.

ABSTRAK

Kajian ini menggunakan kaedah kointegrasi tak berparametrik Bierens (1997) untuk menguji hipotesis Pariti Kuasa Beli (PPP) bagi lima buah negara utama

ASEAN- Indonesia, Malaysia, Filipina, Singapura dan Thailand dengan data Amerika Syarikat dan Jepun sebagai negara asas. Hasil kajian ini membuktikan pembalikan min kadar pertukaran benar dalam sebutan 'dolar' bagi tiga buah negara ASEAN-Malaysia, Singapura dan Thailand. Penemuan ini adalah bertentangan dengan kajian-kajian awal yang menggunakan teknik kointegrasi Johansen. Sejajar dengan tafsiran Coakley dan Fuertes (2001), ketidaksamaan penemuan antara kedua-dua kaedah tersebut adalah akibat daripada proses penyesuaian kadar pertukaran benar ke PPP yang bersifat tak-linear. Analisis selanjutnya menunjukkan bukti PPP yang lebih kukuh apabila yen Jepun digunakan sebagai matawang asas, dan keputusan ini menyokong anggapan bahawa pemilihan matawang asas adalah penting dalam ujian hipotesis PPP. Penemuan ini memberikan bukti yang kukuh mengenai integrasi antara ekonomi Jepun dan negara-negara ASEAN yang berkenaan yang sememangnya berhubungan rapat dari segi geografi, ekonomi dan kadar syarat perdagangan. Peningkatan peranan negara Jepun dalam rantau ASEAN boleh diambil sebagai sokongan empirikal untuk membentuk satu sistem kadar pertukaran ASEAN yang dikuasai oleh yen atau dikenali sebagai blok yen.

Kata kunci: Kointegrasi tak berparameter, pariti kuasa beli, ekonomi ASEAN, ketaklinearan, EasyReg.

Klasifikasi JEL : C14, F31.

INTRODUCTION

The oldest method of defining long-term exchange rate equilibrium is the purchasing power parity (PPP). The PPP theory simply states that the exchange rate between currencies of two countries should be equal to the ratio of the countries' price level. Although deviation of exchange rate from PPP might occur in the short run, most economic theories suggest that PPP should hold in the long run. The basic idea of PPP was initially advanced by classical economists like David Ricardo in the 19th century. But it was Gustav Cassel, a Swedish economist, who popularised the PPP in the 1920s.

Over the years, there has been an explosion of empirical research on the validity of PPP hypothesis in the real world. 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 exchange rate and relative prices must form a cointegrated system with parameters [1, -1]. Specifically, if real exchange rates are stationary, the bilateral exchange rate and relative prices should move together one-for-one in the long run.

Generally, empirical studies on PPP have yielded contradictory results. Even in ASEAN countries, which have been the focus of both economic growth and success in the last decade and the recent financial turmoil, the results have been mixed, creating a debate among policy makers on the usefulness of the empirical findings. A study by Baharumshah and Ariff (1997) using the unit root and the Engle and Granger (1987) cointegration approach rejected the PPP proposition for all the five selected ASEAN countries - Indonesia, Malaysia, the Philippines, Singapore and Thailand. Further analysis using the Johansen and Juselius (1990) multivariate approach also failed to support the PPP hypothesis in these countries. Bahmani-Oskooee (1993), who used the Engle and Granger procedure, had found evidence in favour of strong PPP hypothesis in the Philippines and weak form in Indonesia, Malaysia, Singapore and Thailand. On the other hand, a recent study by Bahmani-Oskooee and Mirzai (2000) failed to support the mean reversion in the real effective exchange rate for Indonesia, Malaysia, the Philippines and Thailand by using the conventional ADF and KPSS unit root tests. To take into account the presence of structural breaks, Aggarwal, Montañés and Ponz (2000) employed both the single and multiple breaks unit root tests to test the validity of PPP for ASEAN exchange rates. They found strong evidence of long run PPP hypothesis for most of the ASEAN currencies when the Japanese yen is used as the numeraire currency. However, such evidence of PPP is weaker with the U.S. dollar, German mark and the Australian dollar. Another recent study by Azali, Habibullah and Baharumshah (2001) using panel unit root and panel cointegration showed that PPP does hold in the long run between Japan and ASEAN economies.

The major shortcoming in these earlier studies is that they employed econometric analysis in the linear framework, without realising that the behaviour of exchange rates may follow a non-linear path. Specifically, with abounding empirical evidence supporting the presence of non-linearity in exchange rate time series data (see, for example, Hsieh, 1989; De Grauwe, Dewachter & Embrechts, 1993; Steurer, 1995; Brooks, 1996; Mahajan & Wagner, 1999), many researchers started asking themselves to what extent one should trust the results of linear methods like the conventional unit root tests and cointegration tests if the underlying data generating process is non-linear. Liew, Chong and Lim (2003) demonstrated that estimating the linear model,

implicitly disregarding any possible non-linearity in the series under consideration, can yield a mis-specified model and thereby provide wrong clues in policy matters. Taylor and Peel (1997) and Sarno (2000) 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. On the other hand, the Monte Carlo simulation evidence in Bierens (1997) indicated that the standard linear cointegration framework presents a mis-specification problem when the true nature of the adjustment process is non-linear and the speed of adjustment varies with the magnitude of the disequilibrium. Other related work is provided by Pippenger and Goering (1993) and Balke and Fomby (1997) which suggested a potential loss of power in standard unit root and cointegration tests under threshold autoregressive data generating process.

Due to the growing views that the world is non-linearly dynamic (Pesaran & Potter, 1993; Campbell, Lo & Mckinlay, 1997; Barnett & Serletis, 2000), recent work on non-linear studies has re-energised fresh attention on the PPP hypothesis. Serletis and Gogas (2000) applied non-linear techniques to test for non-linearity in real exchange rate series and found evidence that the behaviour of real exchange rate series under investigation are governed by non-linear dynamics. Other studies like Micheal, Nobay, and Peel (1997), Sarno (2000), Baum, Barkoulas and Caglayan (2001) and Liew, Baharumshah and Lim (2004) employed non-linear models such as the threshold autoregressive (TAR), smooth transition autoregressive (STAR) and exponential smooth transition autoregressive (ESTAR) models to model the behaviour of real exchange rates. All these studies provided strong support for the validity of long term PPP, in which the real exchange rate adjusts non-linearly towards its equilibrium PPP level.

Theoretically, non-linearities in real exchange rate adjustment can be explained by the occurrence of market frictions such as transaction costs. According to Dumas (1992), the presence of transaction costs in international trade implies that deviations from PPP will only be arbitrated away by rational arbitrageurs if the price differentials exceed transaction costs. Thus, there will be persistent behaviour when PPP deviations are within no-arbitrage bands, that is, exchange rate is left unadjusted. However, beyond this band of inaction, there will be mean reversion. Specifically, the larger the deviation, the stronger the tendency for the exchange rate to adjust back to equilibrium. Thus, the speed of adjustment varies with respect to the size of deviation, thereby justifying the nonlinear adjustment of exchange rate towards PPP.

Thus, to obtain more reliable results and policy guidelines, the main objective of this study is to re-examine the PPP hypothesis for the five major economies of ASEAN countries-Indonesia, Malaysia, the Philippines, Singapore, and Thailand, employing the non-parametric cointegration test recently proposed by Bierens (1997) which takes into account the possibility of non-linearity. This concern is well directed as Lim, Azali, Habibullah and Aziz (2002) found that non-linearity plays a significant role in the underlying data generating process of ASEAN-5 exchange rates returns series. Methodologically, the test statistics involved in the Bierens (1997) and Johansen and Juselius (1990) approaches are obtained from the solutions of a generalised eigenvalue problem, but in the Bierens approach a data generating process does not need to be specified and thus this test is completely non-parametric. Therefore, in principle, both approaches should generate a similar outcome. However, the Bierens method is selected in this study due to its potential superiority at detecting cointegration when the error correction mechanism is non-linear (for example, Bierens, 1997; Coakley & Fuertes, 2001), as compared to the standard linear Johansen and Juselius (1990) which assume a constant speed of adjustment.

This paper is organised as follows. Following this introduction, a brief description on the methodology used in this study is given. This is followed in Section III by a discussion on the empirical results. Concluding remarks are given at the end of the paper.

METHODOLOGY

The PPP hypothesis states that the nominal exchange rate (in domestic currency per foreign currency) should be equal to the ratio of domestic to foreign prices as:

$$S_t = \frac{P_t}{P_t^*} \quad (1)$$

where S_t is the domestic currency per unit of foreign currency, P_t and P_t^* are the domestic and foreign price indices respectively. If PPP holds, the deviation from long-run PPP:

$$E_t = S_t \frac{P_t^*}{P_t} \quad \text{where } E_t \text{ is the real}$$

exchange rate, should imply a stationarity process or that shocks have no permanent effect. In the methodology of cointegration, long-run PPP is implied by a cointegration relationship between nominal exchange rate and relative prices, with the cointegrating vector being $[1, -1]$. This study uses the Bierens (1997) non-parametric cointegration test to examine the long-run PPP hypothesis.

The Bierens (1997) Non-parametric Cointegration Test

The Bierens non-parametric cointegration test considers the general framework as:

$$z_t = \pi_0 + \pi_1 t + y_t \quad (2)$$

where $\pi_0 (q \times 1)$ and $\pi_1 (q \times 1)$ are optimal mean and trend terms respectively, and y_t is a zero-mean unobservable process such that Δy_t is stationary and ergodic. The general framework assumes that z_t is an observable q -variate process for $t = 0, 1, 2, \dots, n$.

Apart from some mild regularity conditions, or estimation of structural and/or nuisance parameters, further specification of the data-generating process for y_t are not required and thus this test is completely non-parametric.

The Bierens method is based on the generalised eigenvalues of matrices A_m and $(B_m + n^2 A_m^{-1})$, where A_m and B_m are defined in the following matrices:

$$A_m = \frac{8\pi^2}{n} \sum_{k=1}^m k^2 \left(\frac{1}{n} \sum_{t=1}^n \cos \left(\frac{2k\pi(t-0.5)}{n} \right) z_t \right) \times \left(\frac{1}{n} \sum_{t=1}^n \cos \left(\frac{2k\pi(t-0.5)}{n} \right) z_t \right)'$$

$$B_m = 2n \sum_{k=1}^m \left(\frac{1}{n} \sum_{t=1}^n \cos \left(\frac{2k\pi(t-0.5)}{n} \right) \Delta z_t \right) \times \left(\frac{1}{n} \sum_{t=1}^n \cos \left(\frac{2k\pi(t-0.5)}{n} \right) \Delta z_t \right)' \quad (3)$$

which are computed as sums of outer-products of weighted means of z_t and Δz_t , and n is the sample size. To ensure invariance of the test statistics to drift terms, the weight functions of $\cos \left(\frac{2k\pi(t-0.5)}{n} \right)$

is recommended here. Note that the condition $m \geq q$ must be satisfied and the optimal value of m can be chosen based on Table 1 of Bierens (1997).

Similar to the properties of the Johansen and Juselius likelihood ratio method, the ordered generalised eigenvalues of this non-parametric method are obtained as solution of the problem $\det[P_n - \lambda Q_n] = 0$ when the pair of random matrices $P_n = A_m$ and $Q_n = (B_m + n^2 A_m^{-1})$ are defined. Thus it can be used for testing hypothesis about the cointegration rank r .

To estimate r , two test statistics are proposed by Bierens (1997). First, Bierens (1997) derives the 'lambda-min' ($\hat{\lambda}_{\min}$), $\hat{\lambda}_{n-\eta(n)}$ which corresponds

to the Johansen's maximum likelihood test to test for the null hypothesis of $H_0(r)$ against the alternative hypothesis of $H_1(r+1)$ and tabulates the critical values for this test.

Second, the Bierens approach also provides the $g_m(r)$ which is computed from the Bierens generalised eigenvalues:

$$\begin{aligned} g_m(r) &= \left(\prod_{k=1}^q \lambda_{k,m} \right)^{-1} & \text{if } r = 0, \\ &= \left(\prod_{k=1}^{q-r} \lambda_{k,m} \right)^{-1} \left(n^{2r} \prod_{k=q-r+1}^q \lambda_{k,m} \right) & \text{if } r = 1, \dots, q-1, \\ &= n^{2q} \prod_{k=1}^q \lambda_{k,m} & \text{if } r = q \end{aligned} \quad (4)$$

where m is chosen from Table 1 of Bierens (1997) for $r < q$, and $m = q$ is chosen when $r = q$. It is noted in Bierens (1997) $g_m(r)$ converges in probability to infinity if the true number of cointegrating vector is unequal to r , and $g_m(r) = O_p(1)$ if the true number of cointegrating vector is equal to r . Therefore, we have $\lim_{m \rightarrow \infty} P(r_m = r) = 1$, when $r_m = \arg \min_{1 \leq r \leq q} \{g_m(r)\}$. Thus, this test statistic is useful as a tool to double-check on the determination of r .

Finally, a linear restriction on the cointegrating vectors in the form of $[1, -1]$ is needed to test for long-run PPP. For this purpose, the trace and lambda-max statistics are proposed by Bierens. The critical values of trace ($m = 2q, F_k(x) = \cos(2k\pi x)$) and lambda-max tests ($m = 2q, F_k(x) = 2q, F_k(x) = \cos(2k\pi x)$) are given in Bierens (1997, Tables 3 and 4).

EMPIRICAL RESULTS

Data

The Association of Southeast Asian Nations (ASEAN) comprises of Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam. However, this study focuses only on Indonesia, Malaysia, the Philippines, Singapore, and Thailand (hereafter denoted as ASEAN-5). One main consideration is data availability of the selected member countries.

This study is based on monthly data from 1974.1 to 2002.5 for the countries of ASEAN-5, with the U.S. and Japan data as base countries. The purpose is to find out whether the results of PPP test are invariant to the choice of numeraire currency. The consumer price indices are used to construct the relative price series, which are the ratio of domestic

to foreign prices. The nominal exchange rates are expressed as units of local currency per foreign currency. All the data used in this study are obtained from the *International Financial Statistics* database published by the International Monetary Fund. Both the nominal exchange rates and relative prices are transformed into logarithm form.

Stationarity Tests

It is important to determine the characteristic of the individual series (in this case, the nominal exchange rates and relative prices) before conducting the cointegration analysis. This is due to the fact that only variables of the same order of integration may constitute a potential cointegration relationship. Specifically, cointegration means that the nominal exchange rate and relative price series may be individually non-stationary, but there may exist a linear combination of these two series which is stationary. Thus, in a cointegrated system, the variables involved cannot move 'too far' apart from each other and any short-run deviation from the long-run trend will be corrected.

Table 1
Unit Root Test Results (Series in level)

	Nominal exchange rate		Relative prices	
	Base Country U.S.	Base Country Japan	P / P_{US}	P / P_J
Indonesia	-0.1251 (0.8160)	-0.3743 (0.8230)	0.8875 (0.9720)	0.9978 (0.9730)
Malaysia	-1.6383 (0.7350)	-1.1660 (0.7920)	-3.5615 (0.6610)	1.4366 (1.0000)
Philippines	-0.3673 (0.9010)	-0.6918 (0.8980)	-0.4697 (0.9430)	-0.0912 (0.9770)
Singapore	-2.6778 (0.7020)	-4.7632 (0.4360)	-2.0109 (0.9140)	-13.3099 (0.1410)
Thailand	-0.5455 (0.7620)	-0.9204 (0.8230)	-1.6820 (0.8990)	0.4554 (0.9970)

Note: P_{us} , P_J and P denote U.S. price indices, Japanese price indices and local price indices respectively. * and ** denote significant at the 5% and 1% levels respectively.

This study uses the non-parametric Philips-Perron (PP) (1988) ρ -test to test for non-stationary behaviour in the time series of nominal exchange rates and relative prices. The null hypothesis for the PP is non-stationary. The results of the stationary test on both the nominal exchange rates and relative prices are presented in Table 1 and Table 2.

The results clearly indicate that both variables are not stationary in the level but are able to attain stationary in the first-differences. In other words, all nominal exchange rates and relative prices are integrated of order one, or $I(1)$. These results are consistent with the notion that most macroeconomic variables are non-stationary in levels but become stationary after first differencing (Nelson & Plosser, 1982). With these findings, we can proceed with the Bierens (1997) non-parametric cointegration test to check the validity of the long-run PPP hypothesis.

Table 2
Unit Root Test Results (Series in First-Difference)

	Nominal exchange rate		Relative prices	
	Base Country U.S.	Base Country Japan	P / P_{us}	P / P_j
Indonesia	-272.0997** (0.0090)	-297.0260** (0.0010)	-207.4784** (0.0000)	219.1675** (0.0000)
Malaysia	-319.0172** (0.0010)	-369.0097** (0.0000)	-346.3239** (0.0000)	-364.2003** (0.0000)
Philippines	-430.9464** (0.0000)	-332.2652** (0.0000)	-227.4220** (0.0000)	-252.6315** (0.0000)
Singapore	-320.7142** (0.0000)	-414.3741** (0.0000)	-372.3297** (0.0000)	-412.8025** (0.0000)
Thailand	-236.6784** (0.0010)	-268.8046** (0.0000)	-289.0520** (0.0000)	-543.2005** (0.0000)

Note: See Table 1

The Bierens (1997) Non-parametric Cointegration Test

Further analysis employed the Bierens non-parametric cointegration test in views of its potential superiority over standard linear Johansen and Juselius (1990) method at detecting cointegration when the data generating process is non-linear. Table 3 reports the results of the Bierens test, with the U.S. dollar as the numeraire currency. Clearly, the null of no cointegration cannot be rejected at the 5% level of significance only for Indonesia. However, by imposing the $[1, -1]$ restriction, Malaysia, Singapore and Thailand fail to reject the null hypothesis and hence supporting the long-run PPP hypothesis. The evidence of mean reversion in the dollar denominated real exchange rate for these three ASEAN countries are in sharp contrast with earlier findings reported in Baharumshah and Ariff (1997), Aggarwal *et al.* (2000) and Wang (2000) obtained from the Johansen cointegration technique. These

studies found that the null hypothesis of no cointegration cannot be rejected for all the ASEAN-5.

The conflicting empirical evidence obtained from Johansen approach in those earlier studies and the present Bierens results may be due to the presence of non-linearity in the data generating process. Since the Bierens method has the potential to be superior at detecting cointegration when the error correction mechanism is non-linear, the discrepancy between the findings from both approaches is interpreted as a consequence of significant non-linearity in the real exchange rate adjustment to PPP. This interpretation is consistent with Coakley and Fuertes (2001), who have utilised both the cointegration tests of Johansen and Juselius (1990) and Bierens (1997) to address indirectly the issue of non-linearity in real exchange rate adjustment. To justify for the discrepancy, the authors argued that the nonlinear adjustment process in the real exchange rate would cause the standard linear cointegration approach to present a mis-specification problem. In other words, the failure of Johansen and Juselius method to establish real exchange rate stationarity does not necessarily invalidate the long run PPP. Instead, it is the presence of non-linearity that contributes to its poor performance at detecting cointegration.

The results of the Bierens non-parametric cointegration test with the Japanese yen as numeraire currency are reported in Table 4. There is evidence of cointegration for Malaysia, the Philippines, Singapore and Thailand. Even by imposing the $[1, -1]$ restriction, the null hypothesis cannot be rejected. An important point emerged from the results is that the evidence of PPP is much stronger with the Japanese yen as the numeraire country. This finding is in line with Aggarwal *et al.* (2000) who found strong evidence of long-run PPP hypothesis for most of the ASEAN currencies when the Japanese yen is used as the numeraire currency. However, such evidence of PPP is weaker with the U.S. dollar, German mark and the Australian dollar. In fact, the choice of numeraire currency can and does matter for testing PPP hypothesis, as reported in Papell and Theodoridis (2001). The results for Indonesia are somewhat disappointing. Some authors have shown that the difficulty of finding evidence of PPP for Indonesia is because of the choice of price indexes. For example, Lee (1999) showed that PPP has greater support when CPI is replaced by the wholesale price index (WPI). The favourable results of WPI might be due to its smaller non-traded goods component.

These results provide strong evidence of integration between the Japanese economy and those of ASEAN countries. The increasing role

of Japanese yen in the ASEAN region can be taken as providing empirical support for the formation of a yen dominated ASEAN exchange rate system, or a 'yen bloc', as has been suggested in earlier papers such as Aggarwal and Mougoué (1996, 1998) Tse and Ng (1997); Aggarwal *et al.* (2000) and Azali *et al.* (2001). Several economic explanations have been offered to support the notion of the formation of a yen bloc. Generally, it is well known that Japan and the ASEAN countries have been closely linked in geographical, economic and trade terms. For example, the geographical proximity of ASEAN countries with Japan makes goods arbitrage more effective since transaction costs are low. In addition to that, Japan is the major source of foreign direct investment and loan supplier in this region of ASEAN. In terms of trade, Japan is one of the important trading partners for the ASEAN economies. The statistics for year 2001 provided by the ASEAN secretariat revealed that about 14% of total gross ASEAN exports end up in the Japanese market, while 17% of imports come from Japan.

Table 3
The Bierens Non-Parametric Cointegration Test Results
(Base Country: U.S.)

	$\lambda_{\min}$		$g_m(r_0)$ $r_0 = 0, 1, 2$	β' $H_0: \beta' = [1, -1]$
	$H_0: r = 0$	$H_0: r = 1$		
Indonesia	0.03113	3.52019	93.82913409E-001 99.42319808E+001 14.24222884E+008	-
Malaysia	0.00395*	0.84960	31.45882926E+001 50.90829893E+001 42.47888530E+006	2.40
Philippines	0.00280*	4.57014	23.64402085E+002 23.40867366E-001 56.51898247E+005	12.37*
Singapore	0.00787*	0.30551	54.53836448E+001 22.70930414E+002 24.50267830E+006	1.33
Thailand	0.00227*	0.47225	96.79173390E+001 53.55123598E+001 13.80630294E+006	2.01

Note: * denotes significant at the 5% level.

Table 4
The Bierens Non-Parametric Cointegration Test Results
(Base Country: Japan)

	$\lambda_{\min}$ $H_0: r = 0$	$\lambda_{\min}$ $H_0: r = 1$	$\mathcal{G}_m(r_0)$ $r_0 = 0, 1, 2$	β' $H_0: \beta' = [1, -1]$
Indonesia	0.30552	4.64507	77.18411968E-001 69.41379871E+001 17.31361329E+008	-
Malaysia	0.04083	0.09764	47.54002810E+002 25.50346845E+002 28.10970152E+005	2.93
Philippines	0.02442	1.37183	14.16497832E+006 43.36523347E-004 94.34084327E+001	3.34
Singapore	0.00883*	0.05955	42.69422712E+002 76.34450797E+002 31.30015672E+005	3.80
Thailand	0.00060*	0.05678	16.39282636E+004 21.87161626E+001 81.51956046E+003	3.10

Note: * denotes significant at the 5% level.

CONCLUSIONS

This study employs the Bierens (1997) non-parametric cointegration methodology to test the Purchasing Power Parity (PPP) hypothesis for five major ASEAN economies - Indonesia, Malaysia, the Philippines, Singapore and Thailand, with the U.S. and Japan data as base countries. The Bierens approach is selected in views of its potential superiority over standard linear Johansen and Juselius (1990) method at detecting cointegration when the data generating process is non-linear. The results provide evidence of mean reversion in dollar denominated real exchange rate for three ASEAN countries- Malaysia, Singapore and Thailand. These findings are in sharp contrast with those reported in Baharumshah and Ariff (1997), Aggarwal *et al.* (2000) and Wang (2000), who found that the null hypothesis of no cointegration cannot be rejected by the Johansen cointegration technique for all the ASEAN-5 countries. Consistent with the interpretation of Coakley and Fuertes (2001), the discrepancy between the findings from both approaches is

interpreted as a consequence of significant non-linearity in the real exchange rate adjustment to PPP. To justify for the discrepancy, the authors argued that the non-linear adjustment process in the real exchange rate would cause the standard linear cointegration approach to present a mis-specification problem. In other words, the failure of Johansen and Juselius method to establish real exchange rate stationarity does not necessarily invalidate the long-run PPP. Instead, it is the presence of non-linearity that contributes to its poor performance at detecting cointegration.

Further analysis support the notion that the choice of numeraire currency can and does matter for testing of PPP hypothesis. Specifically, the evidence of PPP is much stronger with the Japanese yen as the numeraire currency. This finding is in line with Aggarwal *et al.* (2000) who found strong evidence of long run PPP hypothesis for most of the ASEAN currencies when the Japanese yen is used as the numeraire currency. However, such evidence of PPP is weaker with the U.S. dollar, German mark and the Australian dollar. These results provide strong evidence of integration between the Japanese economy and those of ASEAN countries, which have been closely linked in geographical, economic and trade terms. The increasing role of Japanese yen in the ASEAN region can be taken as providing empirical support for the formation of a yen dominated ASEAN exchange rate system, or a '*yen bloc*', as has been suggested in earlier papers such as Aggarwal and Mougoué (1996, 1998), Tse and Ng (1997), Aggarwal *et al.* (2000) and Azali *et al.* (2001).

NOTES

1. The deviation can due to factors such as transaction costs, price rigidity, the differential composition of market baskets and prices indices, and imperfect markets (as results of subsidy, taxation, trade barriers, foreign exchange market interventions and the like).
2. Taylor (1995), Rogoff (1996) and Edison, Gagnon and Mellick (1997) have done an excellent survey on the empirical literature of PPP.

REFERENCES

- Aggarwal, R., & Mougoué, M. (1996). Cointegration among Asian currencies: Evidence of the increasing influence of the Japanese

- Yen. *Japan and the World Economy*, 8, 291-308.
- Aggarwal, R., & Mougoué, M. (1998). Common stochastic trends among Asian currencies: Evidence for Japan, ASEAN and Asian Tigers. *Review of Quantitative Finance and Accounting*, 10, 193-206.
- Aggarwal, R., Montañés, A., & Ponz, M. (2000). Evidence of long-run purchasing power parity: Analysis of real Asian exchange rates in terms of the Japanese yen. *Japan and the World Economy*, 12, 351-361.
- Azali, M., Habibullah, M. S., & Baharumshah, A. Z. (2001). Does PPP hold between Asian and Japanese economies? Evidence using panel unit root and panel cointegration. *Japan and the World Economy*, 13, 35-50.
- Baharumshah, A. Z., & Ariff, M. (1997). Purchasing power parity in South East Asian countries economies: A cointegration approach. *Asian Economic Journal*, 11, 141-53.
- Bahmani-Oskooee, M. (1993). Purchasing power parity based on effective exchange rate and cointegration: 25 LDCs' experience with its absolute formulation. *World Development*, 21, 1023-1031.
- Bahmani-Oskooee, M., & Mirzai, A. (2000). Real and nominal effective exchange rates for developing countries: 1973:1 – 1997:3. *Applied Economics*, 32, 411-428.
- Balke, N. S., & Fomby, T. B. (1997). Threshold cointegration. *International Economic Review*, 38, 627-645.
- Barnett, W. A., & Serletis, A. (2000). Martingales, nonlinearity, and chaos. *Journal of Economic Dynamics and Control*, 24, 703-724.
- Baum, C. F., Barkoulas, J. T., & Caglayan, M. (2001). Nonlinear adjustment to purchasing power parity in the post-Bretton woods era. *Journal of International Money and Finance*, 20, 379-399.
- Bierens, H. J. (1997). Nonparametric cointegration analysis. *Journal of Econometrics*, 77, 379-404.
- Brooks, C. (1996). Testing for non-linearity in daily sterling exchange rates. *Applied Financial Economics*, 6, 307-317.
- Campbell, J. Y., Lo, A. W., & MacKinlay, A. C. (1997). *The econometrics of financial markets*. Princeton: Princeton University Press.
- Coakley, J., & Fuertes, A. M. (2001). Nonparametric cointegration analysis of real exchange rates. *Applied Financial Economics*, 11, 1-8.
- De Grauwe, P., Dewachter, H., & Embrechts, M. (1993). *Exchange rate theory: Chaotic models of foreign exchange markets*. Oxford: Blackwell.
- Dumas, B. (1992). Dynamic equilibrium and the real exchange rate in a spatially separated world. *Review of Financial Studies*, 5(2), 153-180.
- Edison, H. J., Gagnon, J. E., & Mellick, W. R. (1997). Understanding the

- empirical literature on purchasing power parity: The post-Bretton woods era. *Journal of International Money and Finance*, 16, 1-18.
- Engle, R. F., & Granger, C. W. J. (1987). Cointegration and error correction: representation, estimation and testing. *Econometrica*, 55, 251-276.
- Hsieh, D. A. (1989). Testing for non-linearity in daily foreign exchange rate changes. *Journal of Business*, 62, 339-368.
- Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52, 169-210.
- Lee, D. Y. (1999). Purchasing power parity and dynamic error correction: Evidence from Asia Pacific economies. *International Review of Economics and Finance*, 8, 199-212.
- Liew, V. K. S., Chong, T. T. L., & Lim, K. P. (2003). The inadequacy of linear autoregressive model for real exchange rates: Empirical evidence from Asian economies. *Applied Economics*, 35, 1387-1392.
- Liew, V. K. S., Baharumshah, A. Z., & Lim, K. P. (2004). On Singapore dollar - U.S. dollar and Purchasing Power Parity. *Singapore Economic Review*, 49(1), 71-84.
- Lim, K. P., Azali, M., Habibullah, M. S., & Aziz, M. A. (2002). Non-linear dependence in ASEAN-5 foreign exchange markets. In M. Azali, M. B. Yusoff, M. S. Habibullah, S. A. Mansor, R. Mustafa, S. Mohamad, Z. Yusop, A. Radam, A. Hassan, & S. Pillai, (Eds.). *Proceedings of the Asia Pacific Economics and Business Conference 2002*, 2, 893-901.
- Mahajan, A., & Wagner, A. J. (1999). Nonlinear dynamics in foreign exchange rates. *Global Finance Journal*, 10, 1-23.
- Micheal, P., Nobay, A. R., & Peel, D. A. (1997). Transactions costs and nonlinear adjustment in real exchange rates: An empirical investigation. *Journal of Political Economy*, 105, 862-879.
- Nelson, C. R., & Plosser, C. I. (1982). Trends and random walks in macroeconomic time series. *Journal of Monetary Economics*, 10, 139-162.
- Papell, D. H., & Theodoridis, H. (2001). The choice of numeraire currency in panel tests of Purchasing Power Parity. *Journal of Money, Credit and Banking*, 33, 790-803.
- Pesaran, M. H., & Potter, S. M. (1993). Nonlinear dynamics, chaos and econometrics: An introduction. In M. H. Pesaran, & S. M. Potter, (Eds.). *Nonlinear dynamics, chaos and econometrics*. New York: John Wiley & Sons, 7-13.
- Phillips, P. C. B., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75, 335-346.
- Pippenger, M. K., & Goering, G. E. (1993). A note on the empirical power

- of unit root tests under threshold processes. *Oxford Bulletin of Economics and Statistics*, 55, 473-481.
- Rogoff, K. (1996). The purchasing power parity puzzle. *Journal of Economic Literature*, 34, 647-668.
- Sarno, L. (2000). Real exchange rate behaviour in high inflation countries: Empirical evidence from Turkey, 1980-1997. *Applied Economics Letters*, 7, 285-291.
- Serletis, A., & Gogas, P. (2000). Purchasing power parity, non-linearity and chaos. *Applied Financial Economics*, 10, 615-622.
- Steurer, E. (1995). Nonlinear modeling of the DEM/USD exchange rate. In A.P. Refenes, (Eds.). *Neural networks in the capital markets*. New York: John Wiley & Sons, 199-211.
- Taylor, M. P. (1995). The economics of exchange rates. *Journal of Economic Literature*, 33, 13-47.
- Taylor, M. P., & Peel, D. A. (1997). Nonlinearities in real exchange rate adjustment during the recent float: Empirical evidence and Monte Carlo analysis. *Discussion Paper*. Institute of Economics and Statistics, University of Oxford.
- Tse, Y. K., & Ng, L. K. (1997). The cointegration of Asian currencies revisited. *Japan and the World Economy*, 9, 109-114.
- Wang, P. (2000). Testing PPP for Asian economies during the recent floating period. *Applied Economics Letters*, 7, 545-548.