E C O N O M I C S   B U L L E T I N

Exchange Rate – Relative Price Nonlinear Cointegration Relationship in Malaysia

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Abstract

The finding of exchange rate–relative price nonlinear cointegration relationship in Malaysia, among others, suggests that nonlinear Purchasing Power Parity (PPP) equilibrium may be regarded as reference point in judging the short run misalignment of the Ringgit currency and thereby deducing effective policy actions. Moreover, economists who wish to extend the simple PPP exchange rate model into the more complicated monetary exchange models may do so comfortably, at least in the text of Malaysia. Nonetheless, such attempt should be tailored in a nonlinear way to suit the nonlinear characteristic of exchange rate behaviour

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1. Introduction

The relationship between exchange rate and relative price remains one of the most explored topics in the exchange rate literature. Documentation regarding the theoretical discussion and empirical investigation on this relationship, which may be hypothesized as Purchasing Power Parity (PPP), is voluminous. The hypothesis of PPP postulates that nominal exchange rates adjust to reflect differences in price levels across countries. By this hypothesis, the exchange rate between currencies of any two economies should equalize the relative price levels in these economies, provided that the effects of trade barrier and transaction costs are negligible. In reality, the market is not free after all and it has been generally accepted that PPP is not likely to hold true in the short run. Conversely, researchers have not settled on the debate of whether or not PPP is valid in the long run, due to the contradicting empirical evidence thus far. Interested readers are referred to, for instance, Rogoff (1996); Taylor (2002); and Sarno and Taylor (2002) for a comprehensive review on the PPP literature.

The enthusiasm in revealing long-run PPP validity in reality is unsurprising as it has various major implications in the international economics in general and policy decisions in particular. Among others, PPP long run equilibrium is a useful benchmark in the setting of exchange rate parities or in the judging of exchange rate misalignment with fundamental. Moreover, it serves as a basis in determining the international competitiveness of a country's goods and services. PPP is also an indispensable building block of monetary exchange rate models. Once PPP is found invalid, these models simply collapse and no policy suggestion would then be applicable. All in all, the failure of PPP is not just the letdown of the theory *per se* but it has disastrous practical consequences for policy-makers in essence. As such, exchange rate researchers and policy-makers are at all times fascinated by the viability of PPP.

The empirical inconclusiveness of PPP – which is renowned in the literature to an extent that it has been regarded as PPP puzzle by Rogoff (1996) – has motivated many exchange rate researchers back to the examination of the assumptions underlying the theory[1]. Recently, there is a growing consensus that the inconclusiveness of previous studies is methodological. In particular, the conventional unit root tests have been found unreliable in the testing of PPP in the presence of (i) structural break (Corbae and Ouliaris, 1990; Dropsy, 1996 and Sabaté *et al*., 2003) (ii) cross-sectional effect (Mohamed-Azali *et al*., 2001; Holmes, 2001; Chiu, 2002 and Taylor, 2002) and (iii) nonlinearities (Taylor and Peel, 2000; Sarno, 2000; Baum *et al*., 2001). The present study sought to contribute to this literature in examining the validity of PPP in the presence of nonlinearities, which may be induced either through market frictions or structural breaks in the economy. It has the advantage of testing PPP in the univariate framework without resorting to panel data, which has been criticized of assuming homogeneous cointegrating coefficients across countries in the panel procedure (Rapach and Wohar, 2003).

Through extensive review of the literature, Sarno and Taylor (2002) arrive at the main conclusions that exchange rate – relative price relation holds in the long run among major industrialized countries, and that mean reversion in real exchange rates displays significant nonlinearities. This study is interested to examine whether the same conclusion can be extended to small and open developing countries such as Malaysia. To the best of our knowledge, previous related researches that focus solely on Malaysia has been done by Gan (1991) and Goh and Mithani (2000) only. Gan (1991) finds no relationship between real effective exchange rate and relative price of tradable goods. Similar conclusion is arrived in a later study by Goh and Mithani (2000) who find that Malaysian's real exchange rate follow a random walk implying the invalidity of PPP. Others studies in a multi-countries context with the inclusion of Malaysia are also limited. Among others, Manzur and Ariff (1995) find that PPP holds poorly in the short run but quite well in the long run in Malaysia and other four selected South East Asian countries. Bahmani-Oskooee (1993) and Baharumshah and Ariff (1997) also obtain, among other countries,

[1] See Goh and Mithani (2000) and the references therein for an overview in this respect.

a weak evidence of long-run PPP in Malaysia. Their results are in contrary to Kim (1993) who rejects the PPP hypothesis in Malaysia and Singapore using the Johansen and Juselius (1990) method. Recently, Razzaghipour *et al*. (2001) use statistical analysis to study the mean-reversion to PPP in the Asian currencies including Malaysian Ringgit and obtain empirical support for PPP, although not statistically significant. Meanwhile, Mohamed-Azali *et al*. (2001) are able to provide support for PPP between South East Asian countries (including Malaysia) and the Japan using the panel unit root and cointegration approach. One remarkable note is that all methodology adopted in these studies are in the linear framework, which is not reliable in the presence of nonlinearities (Taylor and Peel, 2000; Kapetanios *et al*., 2003; and Liew *et al*., 2003). Indeed, Liew *et al*. (2003) have shown that Malaysia and 10 other Asian real exchange rates exhibit nonlinear behaviour, using linearity test formulated by Luukkonen *et al*. (1988). As such, previous results on Malaysia, in which nonlinearities have not been considered, are no more relevant. It is interesting to know whether the PPP hypothesis receive support or not from the nonlinear perspective point of view. In light of this, the current study adopts the nonlinear unit root test put forward by Kapetanios *et al*. (2003) (henceforth denoted as KSS test). The results of this KSS test suggest that, taken into the consideration of nonlinearity in Malaysian Ringgit – U.S. Dollar (MYR/USD) real exchange rate, the corresponding nominal rate is cointegrated with relative price. It is argued that the current result overrule previous findings including Goh and Mithani (2000)[2], which adopt methodology that has been criticized of malfunctioning in the presence of nonlinearities (Taylor and Peel, 2000; Kapetanios *et al*., 2003).

2. Malaysian Exchange Rate Regime[3]

The currency of Malaysia is regulated by Bank Negara Malaysia (BNM), the Central Bank of Malaysia, which was established on 26 January 1959 with major goals of promoting economic growth, a high level of employment, maintaining price stability and a reasonable balance in country's international payments position, eradicating poverty and restructuring society. The Malayan Dollar (M$) was created on 12 June 1967, replacing the old Sterling-linked Malayan/Straits Dollar[4] but continually tied to Pound Sterling. On 25 June 1972, M$ was linked to U.S. Dollar (USD) with a fluctuating Effective Rate ranging from M$2.76 to M$2.88. On 13 February in the following year, this fluctuation range for M$ Effective Rate was revised as M$2.48 to M$2.60, following the USD devaluation. This Effective Rate was placed under BNM's controlled, on a floating basis on 21 June 1973. BNM set in to intervene to maintain relative stability in the value of M$ and orderly market conditions whenever the currency fluctuated excessively as compared to a basket of Malaysia's trading partners' currencies.

In the year 1975, Malaysia entered a new exchange rate regime. The Malaysian Dollar was officially renamed the Ringgit with its external value determined based on a trade-weighted basket currencies. In 1978, the exchange rates for all other currencies were determined on the basis of Ringgit – U.S. Dollar (MYR/USD) rate and the USD rates for those currencies in the foreign exchange markets. Since then, Malaysian exchange rate was managed within a band of RM2.50 to RM2.70 (Goh and Mithani, 2000). This managed float was sustainable until the mid of 1997, when Ringgit started to depreciate excessively following the outbreak of the Asian Financial Crisis. Within a year, Ringgit plunged over 37% as compared to the USD (Hasan, 2001). Effectively from 2 September 1998, the exchange rate of the Ringgit was no longer

[2] Using ADF test, Goh and Mithani (2000) fail to reject the null of nonstationary in the CPI based and WPI based real exchange rates, implying no cointegration between the nominal MYR/USD rate and relative prices.

[3] The main sources of reference include *Historical Exchange Rate Regime of Asian Countries* [Online, available at http://intl.econ.cuhk.edu.hk/exchange_rate_regime, accessed on 17/5/2003] and Ariff (1991).

[4] Prior to the formation of Malaysia on 16 September 1965, the constituents of Malaysia (Peninsular Malaya and the states of Sawarak and Sabah) were British territories.

determined by demand and supply in foreign exchange market. Malaysia returned to a fixed exchange rate system, pegged at a rate against the USD at RM3.80 per unit USD. This pegged rate is maintained at the time this paper is written.

3. Non-linear Exchange Rate Adjustments

Ma and Kansas (2000) contain a quick review regarding few of the theoretical models put forward by economists to account for the observed nonlinearities in exchange rates. One pertinent model relevant in the current study is the target zone model originally postulated in Krugman (1991) and later refined by Bertola and Svensson (1993)[5]. The target-zone model predicts the existence of nonlinear behaviour in the relationship between the exchange rate and its fundamental determinants. Krugman (1991) argues that given a perfectly credible target zone, exchange rate is allowed to drift in a random manner as long as its deviation from the fundamentals is within a certain tolerance band. However, if the exchange rate becomes increasingly misaligned with its fundamentals, exchange rate will have stronger mean-reversion tendency, with the speed of adjustment varies with respect to the size of deviation, thereby justifying the nonlinear adjustment of exchange rate towards the fundamentals. Such a target zone will allow a government to adopt a relatively loose policy in the present but get stabilizing gains in the exchange rate from the fact that they promise that the band will be defended in the future, if the need arises. This model works in the way that the public believes that the central bank will intervene in the exchange rate *per se*. However, the assumption of perfectly credible may be too harsh in reality. Bertola and Svensson (1993) refine the target zone model by breaking down the change in the exchange rate into expected depreciation of the currency within the band and the expected rate of realignment. This refinement allows for the possibility that nonlinear target-zone effects are significant for parts of the sample period of interest but not necessarily for the full sample period. As the Ringgit is managed within fluctuation bands in the sample period of study, it is not unusual for one to suspect that its behaviour is nonlinearity in nature. In fact nonlinearity has been detected presence in the real Ringgit rate by the formal linearity test of Luukkonen *et al*. (1988). Hence, this study attempts to throw light on the Ringgit and relative price relationship using the nonlinear approach.

4. Data

Through examining the stationary property of the real exchange rate, the current study examines the exchange rate – relative price relationship. The idea is to test whether the real exchange rate is stationary. If the real exchange rate is not stationary, there will be no tendency for the nominal exchange rate to mean-revert to the PPP equilibrium, thereby rejecting the PPP hypothesis (Goh and Mithani, 2000). Following Goh and Mithani (2000), quarterly data of nominal bilateral MYR/USD exchange rate, Consumer Price Index (CPI) and Wholesale Price Index (WPI), covering the period of 1973Q1 to 1997Q2 are employed in this study. This allows us to see whether the PPP hypothesis is sensitive to the use of different price index[6]. These data are collected from various issues of IMF's *International Financial Statistics*.

The real exchange rate is derived from the relative PPP hypothesis:

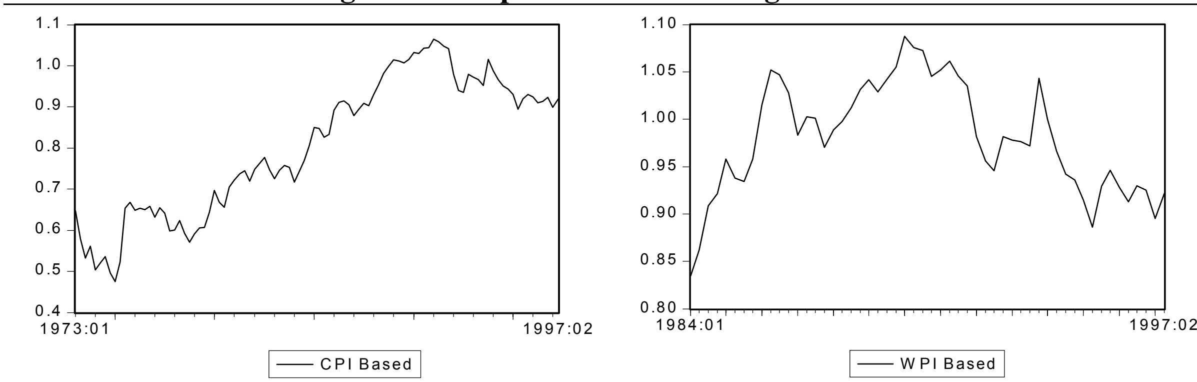
$$y_t = s_t + p_t^* - p_t \tag{1}$$

[5] See Garratt *et al*. (2001) for an empirical assessment of target zone models.

[6] It is widely believe that PPP will hold better when WPI is used as compared to CPI, as the former comprises of a larger component of traded goods. For instance, Maeso-Fernández (1998) finds his results more favourable to PPP when WPI is used. Accordingly, Goh and Mithani (2000) find that price index does matter in testing PPP.

where y_t is the logarithm of nominal exchange rate (domestic price of foreign currency) at time t, and p_t^* and p_t are the logarithms of foreign and domestic price levels respectively. This specification of real exchange rate is effectively the deviation of nominal exchange rate from the PPP equilibrium and thus the mean reversion of real exchange rate may be regarded as the validity of long-run PPP (Peel *et al*. 2001)[7]. With two types of price indices (CPI and WPI) used in this study, we have the resulting CPI and WPI based real exchange rates. These series are plotted in Figure 1. Figure 1 depicts that the real exchange rates behave similarly for different relative price. In particular, there is a long run depreciation tendency in the CPI based real exchange rate for period up to 1991Q1. Since then appreciation is observed until the end of sample period. As for the WPI based real exchange rate, the observed behavior is that it generally depreciates and achieves it lowest value in 1990Q2 and whence it starts to depreciate. Moreover, obvious nonlinear behavior is depicted in both the CPI and WPI based real exchange rate[8]. We shall see shortly from the formal linearity test that the last statement is valid. Further, our stationary test shows that these series are stationary in the nonlinear sense.

Figure 1: Graphs of Real Exchange Rates



5. Methodology

Luukkonen et al. (1988) Linearity Test

To achieve the purpose of validating the PPP hypothesis in our data, in a different perspective from Goh and Mithani (2000) and other similar previous study, that is, using the non-linear approach, the linearity nature of these two series are subjected to a version of linearity test as suggested by Luukkonen *et al*. (1988). This linearity test is an auxiliary regression of the form:

$$z_t = \alpha_0 + \sum_{i=1}^{p} (\alpha_i z_{t-i} + \beta_i z_{t-i} z_{t-d} + \delta_i z_{t-i} z_{t-d}^2) + \omega_t \qquad (2)$$

[7] As real exchange rate is essentially the residuals of cointegration regression of nominal exchange rate on relative price (both in log form), stationarity in real exchange rate by definition implies the residuals of cointegration regression is integrated of order 1, which in turn has implication that nominal exchange rate and relative price are cointegrated (Peel *et al*., 2001).

[8] A drastic jump due to the plunge of nominal rate effected caused by Asian Financial Crisis is observed in all three cases, for sample period beyond this study (not shown), causing even significant nonlinearity if we extend our sample to cover the post-crisis period. However, based on the following consideration, we choose to confine our sample period as it is now: First, to keep our study as comparable as possible to Goh and Mithani (2000), who adopt linear approach in a similar study. Second, to avoid the possible biased result in favour of nonlinearity due to the significant jump, thus ensuring a fair comparison.

where α_0, α_i, β_i and δ_i (i = 1, …, p) are parameters to be estimated and under the null hypothesis, ω_t is white noise with zero mean and constant variance, p stands for the autoregressive lag length whereas d is called the delay parameter.

Under linearity, the null hypothesis of $\beta_i = \delta_i = 0$ for all i holds and may be tested by Lagrange Multiplier (LM) test statistic[9]. The linearity test as specified in (2) actually has power against the alternative hypothesis of Exponential Smooth Transition Autoregressive (ESTAR) model:

$$z_t = \sum_{i=1}^{p} [a_i z_{t-i} + b_i z_{t-i}(1 - e^{-\theta^2 z_{t-d}^2 / \hat{\sigma}_z^2})] + \varepsilon_t \quad (3)$$

where a 's and b 's are linear and non-linear autoregressive parameters respectively. θ^2 is known as the transition parameter and it serves as a measure of the speed of adjustment of the series. $\hat{\sigma}_z^2$ stands for the sample variance of z_t and is used to scale the transition parameter so that comparing speed of adjustment across series is possible[10]. ε_t is the usual white noise with zero mean and constant variance. See Luukkonen *et al*. (1988) and Teräsvirta (1994) for other details.

This version of linearity test is also adopted in Baum *et al*. (2001). It is argued in Baum *et al.* (2001) and many other related studies that the non-linear adjustment process of exchange rate deviations is symmetrical in nature and ESTAR is appropriate in representing this process.

The optimum lag length p and delay parameter d in (2) have to be determined from the data as they are unknown. Following Liew *et al*. (2003), the current study chooses the optimal p of linear AR (p) model based on the sample partial autocorrelation functions (PACFs), with enough additional lags introduced to eliminate remaining autocorrelation when necessary. In order to specify d, linearity tests are performed for the range of values $1 \leq d \leq 12$. Optimal d is chosen from the one that maximises the LM statistic.

If non-linearity has been found present in the two series of interest by this linearity test, non-linear stationary test developed by Kapetanois *et al*. (2003) is then conducted to check the stationarity property of these series.

Kapetanios et al. (2003) Non-linear Stationary Test

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

$$\Delta z_t = \gamma \ z_{t-1}[1 - \exp(-\theta^2 z_{t-1}^2)] + \varepsilon_t \quad (4)$$

where z_t is the de-meaned series of interest and 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: $H_0 : \theta^2 = 0$ against the alternative $H_1 : \theta^2 > 0$. However, testing this null hypothesis directly is not feasible, since γ is not identified under the null. Thus, Kapetanios *et al*. (2003) reparameterised (4) based on Taylor series approximation to obtain:

[9] Effectively, the null hypothesis assumes that linear autoregressive (AR) model is the correct specification for the series being tested.

[10] The larger the θ^2, the faster is the adjustment taking place.

$$\Delta z_t = \delta\ z_{t-1}^3 + \text{error} \tag{5}$$

or

$$\Delta z_t = \sum_{j=1}^{p} \rho_j \Delta z_{t-j} + \delta\ z_{t-1}^3 + \text{error}, \tag{6}$$

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 hence has to be simulated. The simulated 1, 5 and 10% asymptotic null critical values of the *t* statistic for both cases as –3.48, –2.93 and –2.66 respectively. The *t* statistics estimated from (5) and (6) will be reported as *KSS* and *AKSS* respectively. For the purpose of comparison, we also report the conventional augmented Dickey-Fuller test statistic, denoted by *ADF*.

6. Results and Discussions

Linearity and Stationarity Properties of MYR/USD Real Exchange Rate

The results of Luukkonen *et al*. (1988) linearity test and a battery of residual diagnostics test are tabulated in Table 1. Based on the PACFs and the principle of no remaining autocorrelation, the optimum autoregressive order (*p*) for both the CPI based and WPI based exchange rates is 1. Meanwhile, the optimum delay parameter (*d*) that maximizes the *LM* test statistics for both series is 11. The most important information revealed in this table is the rejection of linear behavior in all real exchange rates considered in this study, in favor of the ESTAR-type nonlinearity. This finding is significant at l% level based on the *p*-values of the implied *LM* statistics. Hence, we have enough evidence to propose that the all the three Ringgit real exchange rates exhibit nonlinear movement, which can be appropriately typified by the ESTAR model. This conclusion is trustworthy as there is no sign of mischievous in the residuals of the auxiliary regression of (2) based on a battery of diagnostics (Table 1).

Table 1: Linearity Test and Residuals Diagnostics Results

Real Exchange Rate	Optimum lag *p*	Optimum lag *d*	*LM* Test [*p*-value][a]	Residuals Diagnostics[b] Q_{16}	HET_{16}	$ARCH_{16}$	GARCH
CPI Based	1	11	72.434[0.000]*	0.163	0.607	0.471	0.565
WPI Based	1	11	15.994[0.003]*	0.787	0.669	0.921	0.502

Notes: [a] *LM* test utilised here tests for the null hypothesis of linearity against the alternative hypothesis of ESTAR-type nonlinearity. Asterisk (*) denotes significant at 1% level. [b] Q_{16} and HET_{16} and $ARCH_{16}$ are, in that order, the *p*-value of Ljung-Box Q statistics, Breusch-Pagan-Godfrey test statistics and Lagrange Multiplier test to detect the presence of autocorrelation, heteroscedasticity and ARCH problems, if any, up to the order of 16. Q statistic also has the power against the alternative hypothesis that the residuals do not follow normal distribution. GARCH refers to Lagrange Multiplier test statistic to detect the GARCH effect.

Having revealed the linearity nature, a separate examination of another important statistical property of the real exchange rate series, namely the stationarity is pursued. Two commonly used stationary tests are no other than the well-celebrated augmented Dickey-Fuller (ADF) and the Phillip-Perrons (PP) unit root tests. Note that these tests, which are originally meant for linear series, have been found malfunctioning in the case of nonlinear series (Taylor and Peel, 2000; Sarno, 2000; Baum *et al*., 2001; and Kapetanios *et al*., 2003). Thus, we have ruled out the usefulness of applying of ADF and PP tests in testing the stationary property of the real exchange rates of interest, which have been identified to be nonlinear in nature. Instead, we employ the nonlinear KSS unit root test, which is the extension of ADF test in the nonlinear framework. We nevertheless include the ADF and PP test results for the purpose of comparison.

The results of applying both the linear and nonlinear unit root tests are summarized in Table 2. It is observed in Table 2 that the conventional linear and the contemporary nonlinear unit root tests exhibit contrasting results regarding the stationarity of the real exchange rates. Specifically, there is no sign of stationarity in all the real exchange rates by the linear *ADF* and *PP* test statistics even at 10% significant level[11], whereas the nonlinear *KSS* and *AKSS* test statistics show otherwise. For the reasons stated earlier on, we resort to the nonlinear test results and conclude that these series are stationary – to be precise, nonlinear stationary. One straightforward implication of this finding is that the nominal MYR/USD exchange rate is nonlinear cointegrated with the relative price, thereby validating the PPP hypothesis. With this, we have shown that previous study failed to reveal the cointegration relationship between nominal MYR/USD exchange rate and the relative price due to the inappropriate application of unit root tests. Moreover, we discover no supportive evidence on the claim (Mansur and Ariff, 1995; Goh and Mithani, 2000) that price indices do matter in testing cointegration relationship. This is clear from our finding of nonlinear cointegration regardless of which price indices we adopt.

Table 2: Stationary Tests Results

Real Exchange Rate	Linear Test[a]		Nonlinear Test[b, c]	
	ADF	*PP*	*KSS*	*AKSS*
CPI Based	–2.072	–1.879	–3.462[#]	–3.681[*]
WPI Based	–2.985	–2.956	–2.717[&]	–2.996[#]

Notes: [a] Linear test is performed on the original series. The 1%, 5% and 10% critical values for both *ADF* and *PP* test with intercept and trend are, in that order, –4.06, –3.46, –3.15. [b] Nonlinear test is performed on the de-meaned and de-trended series as required. The 1%, 5% and 10% critical values for both *KSS* and *AKSS* are, –3.48, –2.93, –2.55 respectively. [c] Superscripts *, # and & denotes significant at 1, 5 and 10 percent levels respectively.

Estimated Real Exchange Rate Models

As the linearity test results suggest that the real exchange rates in this study exhibit ESTAR-type nonlinearity, our next exercise is to estimate the ESTAR model for each of these series. The estimated results are summarised in Table 3.

Table 3 shows that in each case, at least one of the nonlinear parameters including the delay parameter is significant at standard significance level. This result reinforces our earlier conclusion that denies the linear behaviour in these real exchange rates. These models are well-specified as there is no significance remaining autocorrelation, ARCH or heteroscedastidy detected in the models' residuals[12]. Note that there is a substantial gain in forecast error of the nonlinear exchange rate models, as the variance ratio of ESTAR model to AR model is less than one in both CPI based (0.620) and WPI based (0.947) cases[13]. To sum up, this findings amount to imply that ringgit real exchange rates are better characterized by ESTAR model.

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[11] These results are consistent with Goh and Mithani (2000), which conclude that the real US Dollar based Ringgit exchange rate follows a random walk movement. It is argued that this conclusion is based on wrong unit root tests and thus should only be regarded indicative rather than implicative.

[12] In this respect, the estimated linear AR models for CPI are contaminated by autocorrelated residuals (results are available upon request from the authors).

[13] A variance ratio of one implies equal forecast error in both competing models.

Table 3: Estimated Models ESTAR Models

CPI Based

$$z_t = 0.009 + 1.012\, z_{t-1} + (0.017 - 0.044\, z_{t-1})(1 - e^{-1.022^2 z_{t-11}^2 / 0.028})$$
$$[0.923]\ [0.000]^{*} \quad [0.867]\ [0.699] \quad [0.043]^{*}$$

sample period: 1973:1 to 1997:2	sample size = 98	
Q_{16} = 26.846 [0.140]	HET_{16} = 21.228 [0.136]	$\bar{R}^2$ = 0.974
GARCH = 1.544 [0.462]	$ARCH_{16}$ =19.951 [0.222]	VR = 0.620

WPI Based

$$z_t = 0.423 + 0.571\, z_{t-1} + [-0.312 + 0.318\, z_{t-1}]\,[1 - e^{-1.933^2 z_{t-11}^2 / 0.003}]$$
$$[0.083]^{\&}\ [0.000]^{*} \quad [0.591]^{*}\ [0.054]^{\#} \quad [0.009]^{*}$$

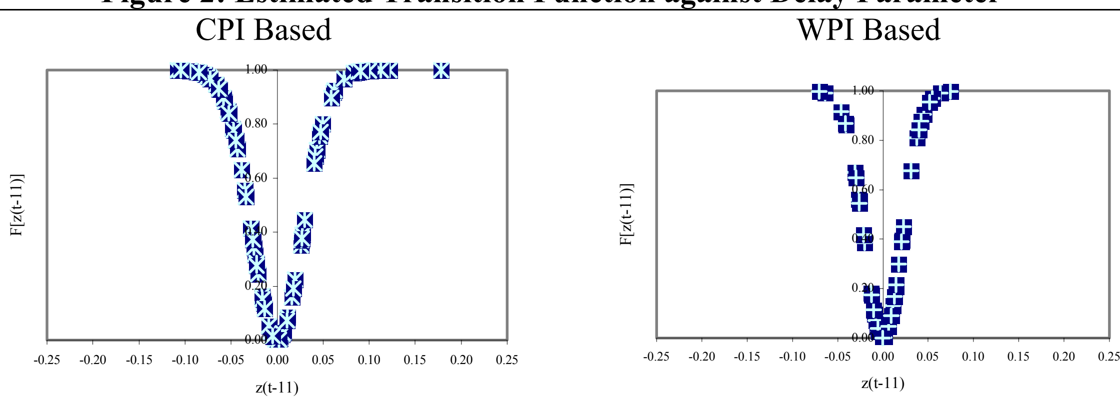
sample period: 1984:1 to 1997:2	sample size = 54	
Q_{16} =12.818 [0.686]	HET_{16} = 8.428 [0.963]	$\bar{R}^2$ = 0.743
GARCH = 1.260 [0.532]	$ARCH_{16}$ =1.800 [0.406]	VR = 0.947

Notes: Marginal significance values of test statistics are given in square brackets. VR denotes the variance ratio of ESTAR to AR models. Superscripts *, # and & denotes significant at 1, 5 and 10 percent levels respectively.

Estimated Transition Functions

Estimated transition functions are capable of throwing light on the adjustment process in our nonlinear models. Hence, it is worth to take a close look at them. Figures 2 and 3 shows the estimated transition functions, $F[z(t-d)]$ against the delay parameters $z(t-d)$ and time respectively.

Figure 2: Estimated Transition Function against Delay Parameter

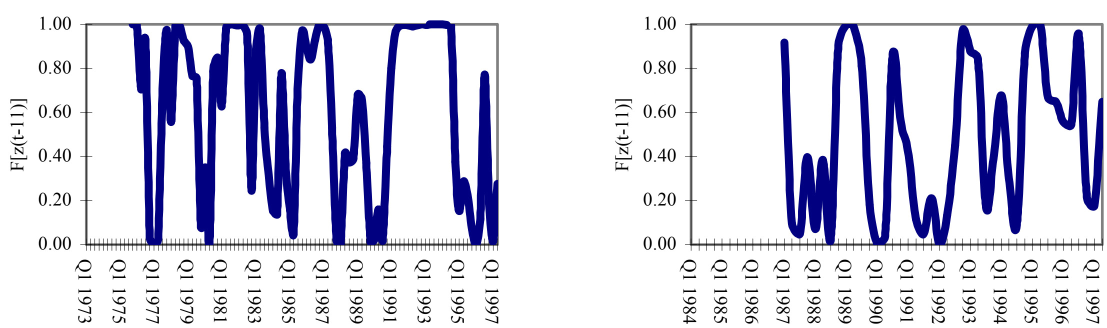


Note: $F[\bullet] = (1 - e^{-\theta^2 z_{t-d}^2 / \hat{\sigma}_z^2})$ is known as the transition function.

It is noticed from Figure 2 that all functions have reasonably symmetry shape, suggesting that the adjustment process are symmetrical regardless of positive or negative deviations. This observation is consistent with Baum *et al*. (2001) and other studies that argue that exchange rate adjustment is a symmetrical process. The slopes of the graphs reveal that the speed of adjustment is faster in the case of WPI based real exchange rate, which has the steeper slope (with a transition parameter of θ =1.933) than the CPI based real exchange rate (θ =1.022). This result is not surprising if we assume that nominal exchange rate adjusts towards the traded goods (as represented by WPI) first, and the effect is then transmitted to traded and nontraded goods (as represented by CPI). Nevertheless, this matter deserved further investigation in future study. As from Figure 3, we can see that the exchange rates adjust constantly between the inner ($F[\bullet] = 0$) and outer ($F[\bullet] = 1$) regimes of the ESTAR model as specified in (3), visualizing the concept that real exchange rates adjust smoothly every moment within the two regimes.

Figure 3: Plots of Transfer Function against Time

CPI Based | WPI Based



Note: F[•] = 0 implies that the series in the inner regime of ESTAR model as specified in (3), whereas F[•] = 1 implies outer regime is attained. First few observations are missing due to lagging.

7. Policy Implications and Conclusions

There are various important policy implications of the validity of PPP in the context of Malaysia and U.S., its major trading partner. First, MYR/USD nominal exchange rate may depart from the PPP equilibrium in the short run within a tolerance band of inaction. However, once the deviations fall outside this band, market correction if not direct market intervention will take place thereby forcing the exchange rate back to the equilibrium position. Further, it is understood from the behaviour of ESTAR model that outside the band of inaction, the larger the magnitude of deviation, the stronger will the force of mean-reverting be. Moreover, PPP holds true regardless of price indices. Second, credit must be given to Bank Negara Malaysia (BNM) in managing the Ringgit in certain fluctuation bands in the sample period of study, with the ultimate purpose of maintaining relative currency stability and orderly market conditions. Our finding of stationary Ringgit real exchange rate indicates that BNM's effort has successfully maintained the country's macroeconomics equilibrium (Parikh and Williams, 1998)[14]. Third, the nonlinear PPP equilibrium serves as a valid reference point for government policy makers in the judging of exchange rate over- or under-valuation and in the decision of policy response[15]. Multinational corporations or traders may also safely resort to this equilibrium in arranging their trading, hedging, arbitraging, and even speculative activities. Fourth, extension of the simple PPP exchange rate model into the more complicated monetary exchange models should be tailored in a nonlinear way to suit the nonlinear characteristic of exchange rate behaviour.

[14] Parikh and Williams (1998) mentioned that nonstationary real exchange rate would result in severe macroeconomic disequilibrium.

[15] In this regard, should the BNM decides that it is time to revalue the Ringgit, which has been pegged to a fix rate of 3.8 ringgit per USD since 2 September 1998, then nonlinear PPP may be employed to estimate the new equilibrium value of ringgit.

To sum, the current study re-examines the exchange rate – relative price relationship in the context of Malaysia and U.S., in which the limited previous evidence are at most inconclusive. To accomplish this task, we follow previous studies such as Goh and Mithani (2000) and resort to test the stationarity property of the relevant real exchange rates, but adopt different unit root test. Following Goh and Mithani (2000), two Ringgit – US Dollar real exchange rates as measured by consumer and wholesale price indices are investigated in this study. As choosing the right unit root test is critical in producing reliable results, we first determine the linearity nature of these real exchange rates. By the Luukkonen *et al*. (1988) *LM* test statistics, we have enough evidence to suggest that various price indices based MYR/USD real exchange rates behave nonlinearly. As such, we resort to the nonlinear unit root test put forward by Kapetanios *et al*. (2003) and our test results strongly suggest that these rates are nonlinear stationary. This finding is in contrast to Goh and Mithani (2000), which report that the MYR/USD real exchange rates follow random walk movement. It is crystal clear that the results in this study overrule previous findings in the context of Malaysia as none of them use acceptable tests that are reflexive of the nonlinear nature of exchange rates.

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