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Summary

Using nonlinear testing procedures relevant to the recent literature, this study provides evidence of nonlinear adjustment of nominal exchange rate towards monetary fundamentals in the context of ASEAN-5 countries. While it supports earlier findings supportive of monetary exchange rate model in this region using the linear testing procedures, this study provides insightful information in explaining why persistent misalignments between nominal exchange rate and monetary fundamentals are often observed in the sample data.

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Introduction

The debate on whether or not nominal exchange rates exhibit long-run relationship with the monetary fundamentals has occupied much of international finance researchers' time ever since the break down of the Bretton-Woods system in the mid-1973. To this end, empirical evidence is not as supportive of the monetary model as the theory suggests (see among others, Meese and Rogoff, 1983; Lyons, 2002; Cheung *et al*. 2005). Recently, there is a growing consensus among researchers that the lack of supportive evidence may largely be associated to the negligence of the nonlinear adjustment of exchange rate towards the equilibrium level suggested by the corresponding monetary fundamentals (Taylor and Taylor, 2004). Nonlinearity in exchange rate adjustment is often attributed to the existence of trading frictions such as transaction costs (Dumas, 1992) and menu costs (Chinn, 2001). These trade frictions resulted in a band of inaction whereby exchange rate misalignments which are not large enough to cover arbitrage profit are left uncorrected within the band. Market players take arbitrage advantage only when the misalignments are outside the band. Eventually, misalignments disappear and exchange rate reverts to its mean position suggested by monetary fundamentals. By this principle, deviations of exchange rate from the monetary fundamentals may apparently behave like a random walk locally within the band of inaction, although it is mean-reverting globally.

Numerous recent studies based on nonlinear consideration have been able to provide evidence supportive of nonlinear adjustment of nominal exchange rate towards its fundamentals. In this regards, using testing procedures in the Smooth Transition Autoregressive (STAR) framework (Luukkonen *et al*. 1988; Granger and Terasvirta, 1993), many studies have documented the nonlinear relationship between nominal exchange rate and fundamentals in the context of developed countries (Micheal *et al*., 1997; Baum *et al*., 2001; Taylor *et al*., 2001), the Middle East (Sarno, 2000), Asian (Liew *et al*.,2003; 2004; 2005), African (Anoruo *et al*., 2005; Bahmani-Oskooee and Gelan, 2006) and Caribbean and Latin American economies (Francis and Iyare, 2006) respectively.

Nonetheless, it should be noted that all the above-mentioned nonlinear studies in exchange rate have insofar been applied to the key building block of monetary model, that is, the purchasing power parity (PPP) model only. Remarkably, STAR framework allows for smooth transition of a time series variable from one regime to another corresponds to the smooth regime changes due to the heterogeneous behavior of exchange rate market players who do not act simultaneously and thus it is a widely accepted framework in exchange rate study related to PPP, in particular. Surprisingly, while this framework is insightful in discovering the nonlinear dynamic between nominal exchange rate and domestic and foreign prices, its application in validating the monetary model is yet to be extended.

Based on the above consideration, the current study thus attempts to fill up the literature gap by examining the long-run relationship between nominal exchange rate and monetary fundamentals using nonlinear approaches in the context of ASEAN-5 economies[1]. Earlier on, Liew *et al*. (2003) have documented the inadequacy of STAR model in characterizing the nonlinear relationship between nominal exchange rate and related price levels in among others, the ASEAN-5 countries. In a follow-up study, Liew *et al*. (2004) provide evidence of STAR-type nonlinear mean-reverting behaviour of ASEAN-5 exchange rates towards the PPP equilibrium levels. In a separate endeavor, Baharumshah and Liew (2005) demonstrate the usefulness of STAR model in predicting the future movement of ASEAN-5 exchange rates based on national price levels. Given the overwhelming evidence of STAR-type nonlinearity in the building block of the monetary exchange rate model, it is natural for one to hypothesize the presence of the same nature of nonlinear relationship among exchange rate and extended set of monetary variables that include domestic and foreign money supplies and aggregate outputs in this region. Thus, this empirical study is under taken to reveal the presence or absence of STAR-type nonlinear relationship among ASEAN-5 exchange rates and the above-mentioned monetary variables.

Empirical Monetary Exchange Rate Model

The following monetary exchange rate model is employed in this study[2].

[1] ASEAN is the acronym of Association of South East Asian Nations, which was formed among the five founding member countries of Indonesia, the Philippines, Malaysia, Singapore and Thailand on 8 August 1967.

$$e_t = \beta_0 + \beta_1 m_t + \beta_2 m_t^* + \beta_3 g_t + \beta_4 g_t^* + \varepsilon_t , \quad (1)$$

where e_t m_t and g_t denote nominal exchange rate, domestic money supply and aggregate output respectively; while foreign variables are marked with asterisks. β's are parameters to be estimated with the expected sign of $\beta_1, \beta_4 > 0$, whereas $\beta_2, \beta_3 < 0$.

Equation (1) is the less restrictive version of the following typical long-run equilibrium exchange rate model resulting from the modern theories of exchange rate determination (Mark and Sul, 2001):

$$e_t = \beta_0 + \beta_1 (m_t - m_t^*) + \beta_2 (g_t - g_t^*) + \varepsilon_t \quad (2)$$

where $(m_t - m_t^*)$ and $(g_t - g_t^*)$ are known as money and output differential respectively. β's are parameters to be estimated. It is expected that β_1=1 (neutrality of money) and $\beta_2 < 0$.

Equation (1) relaxes the assumptions of identical income elasticity for foreign and domestic countries and the neutrality of money inherent in Equation (2), which is also known as forward-looking monetary exchange rate model. Accordingly, Equation (1) is known as the unrestrictive form forward-looking monetary exchange rate model.

It is noteworthy that prior to the adoption of any monetary model, it is required that the nominal exchange rate and all the fundamentals involved must be integrated of the same

order, that is one (Rapach and Wohar, 2002). In the present study, it is found from Ng and Perron (2001) unit root tests that the condition is fulfilled for Equation (2) in the case of Malaysia only. As for the remaining four countries, exchange rate and the money and output differentials are integrated of mixed orders and hence, in the vein of Rapach and Wohar (2002), there is no basis for the validation of forward-looking monetary exchange rate model[3]. In contrast, this study finds that nominal exchange rate, money supplies and aggregate outputs are all integrated of order one for each country under study. As such, there is a possibility that the nominal exchange rate may be cointegrated with the corresponding monetary fundamentals. In the light of this preliminary finding, this study chooses to examine the validity of the more realistic unrestrictive form forward-looking monetary exchange rate model as specified in Equation (1).

Remarkably, the stationarity of the residuals series of Equation (1), ε_t, which represents the deviations (misalignments) of nominal exchange rate from the monetary fundamentals implied by this model, is of interest in this study. In this respect, if the residuals series of this model is stationary, then it can be interpreted as evidence of cointegration relationship between exchange rate and the corresponding monetary fundamentals, henceforth validating this forward-looking monetary exchange rate model. Otherwise, the model is invalid. This method of identifying cointegration relationship in the univariate framework is in the spirit of Engle and Granger (1987) residual-based test for cointegration whereby the conventional Dickey-Fuller types of stationary tests are popularly applied.

[3] All preliminary results of integration test are not shown in this study but are available upon request.

However, it has been pointed out in Liew *et al*. (2003) that the applications of those conventional testing procedures which are built on the basis of the linear framework may be inappropriate in the study of exchange rates behaviour in this region. Therefore, prior to the examination of stationarity, another time series property of the residuals, that is, linearity needs to be predetermined. Conventional testing procedures produce valid inferences only when the deviations series is linear in nature. Otherwise, nonlinear testing procedures are in order.

Testing for Nonlinearity

For the reasons discussed above, this study employs the following linearity test formulated by Luukkonen *et al*. (1988) (*LST*) to determine whether the deviations of ASEAN-5 exchange rates from the corresponding monetary fundamentals are linear or nonlinear in nature in the sample period under study:

$$y_t = a_0 + \left[\sum_{i=1}^{k} a_i y_{t-i} + b_i y_{t-i} y_{t-d}\right] + c y_{t-d}^3 + \xi_t \qquad (3)$$

where y_t is the residuals of the cointegration equation of exchange rate and fundamentals and is essentially the OLS residuals from the regression of e_t on a constant, m_t, g_t, m_t^* and g_t^*, as specified in Equation (1). k and d are the autoregressive and lag order and delay parameter respectively. ξ_t is white noise residuals with zero mean and constant variance under the null hypothesis of linearity.

Under the null hypothesis (H_0: $b_1 = ... = b_k = c = 0$), nonlinearity is absence and the series under study can be adequately characterized by autoregressive process. On the other hand, the alternative hypothesis (H_A: c or/and at least one b is non-zero) postulates the existence of a type of nonlinearity in the series, which can be represented by Smooth Transition Autoregressive (STAR) process. The F test of restriction may be employed to test the null hypothesis against the alternative hypothesis; see Luukkonen *et al*. (1988) and Teräsvirta (1994) for more details.

Note that the true lag length, k and the delay parameter, d are unknown and their optimal values have to be predetermined based on certain considerations. This study employs a computer grid search program that determines the optimal k and d that maximizes the F statistic, for $k, d \in \{1, ..,12\}$.

Testing for Cointegration

It is known from the principle of Engle and Granger (1987) residual-based test for cointegration that if the exchange rate deviation series is stationary, it implies that exchange rate is cointegrated with its underlying fundamentals. However, if a series contains STAR-type nonlinearity, conventional stationarity tests are no more applicable. As such, a nonlinear unit root test developed by Kapetanois *et al*. (2003) (*KSS*) enables us to detect the presence of non-stationarity against nonlinear but globally stationary STAR process is normally applied. This *KSS* test can be represented by:

$$\Delta\tilde{y}_t = \rho\tilde{y}_{t-1}^3 + \mu_t \tag{3}$$

or

$$\Delta\tilde{y}_t = \rho\tilde{y}_{t-1}^3 + \sum_{i=1}^{k}\alpha_i\Delta\tilde{y}_{t-i} + \nu_t \tag{4}$$

where Δ is the first difference operator; $\tilde{y}_t$ may be the demeanded or demeaned and de-trended or the original y_t series, depending on situation; whereas μ_t and υ_t are stochastic error terms each with zero mean and constant variance assumption.

Specifications (3) and (4) correspond to the conventional Dickey-Fuller (*DF*) and augmented Dickey-Fuller (*ADF*) stationary tests with no intercept and trend terms in the nonlinear framework. Results of simulation study show that these nonlinear stationary tests produce robust results if the data generating process of the series under study is in fact nonlinear in nature (Kapetanois *et al*., 2003).

The null hypothesis of $H_0: \rho = 0$ against the alternative of $H_1: \rho < 0$ can be tested using the *t*-statistics. Under the null hypothesis, the exchange rate deviation series is nonlinear and nonstationary, implying the absence of cointegration relationship between exchange rate and its underlying fundamentals. In contrast, the exchange rate deviation series is a stationary STAR process, indicating evidence of nonlinear cointegration relationship between exchange rate and its underlying fundamentals. For the brevity of reporting, the *t*-statistics estimated from Equations (3) and (4) are reported as t_{NDF} and

t_{NADF} respectively in this study. Kapetanois *et al*. (2003) prove that the asymptotically distribution of ρ is non-normal, so the authors simulated and provided the critical values of the statistics involved in the same paper for our convenience. In this paper, Equation (4) is estimated for *k* ranging from 1 to 12 inclusively. The optimal *k* is predetermined based on Akaike Information Criterion (AIC).

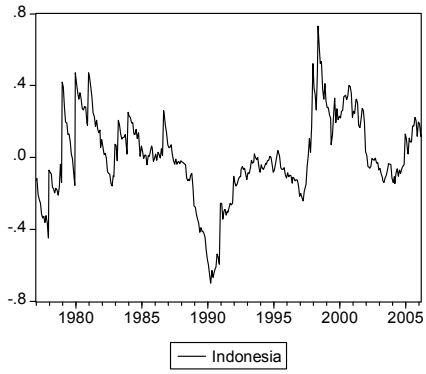
Data

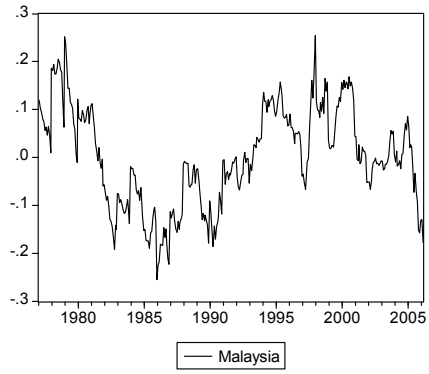
The monthly data of ASEAN-5 countries plus Japan, their major trading partners in this region, as an anchor country for exchange rate are employed in this study. The variables involved are nominal Japanese Yen based exchange rates, aggregate price levels, interest rates, money demands and aggregate output levels. The sample period begins from January 1977 (1977M1) and end at March 2006 (2006M3). In this study Consumer Price Index (CPI), M2 and Gross Domestic Product (GDP) will accordingly serve as measures of aggregate price level, money demand and aggregate output level for all countries. However, as monthly data for GDP is not available for all countries, it has to be interpolated from annually data in the spirit of Bahmani-Oskooee (2002)[4]. As for interest rates, money market rates will be used in all case except Philippines, where there is no report of this data at all. In such case, we follow Alba and Papell (1998) in using the three-month treasury bill rate. The nominal Yen-based exchange rate for each country is the cross-rate of the country's spot U.S. Dollar based exchange rate and the spot Yen/U.S. Dollar exchange rate. The resulting nominal spot exchange rates are the known

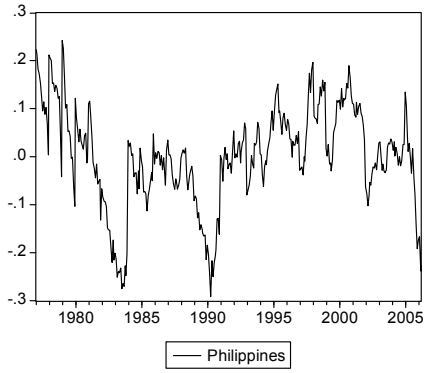
[4] Bahmani-Oskooee (2002) interpolates the quarterly GDP from annually data. Alternatively, we may use quarterly data to derive the required monthly data. However, as the quarterly GDP data for these countries are also either not available or incomplete. Therefore, this study sticks to the former approach.

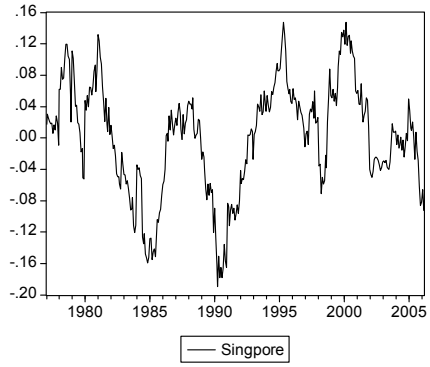
as Rupiah/Yen, Peso/Yen, Ringgit/Yen, Dollar/Yen and Baht/Yen for Indonesia, the Philippines, Malaysia, Singapore and Thailand accordingly. As their names imply, these nominal spot exchange rates are actually the domestic prices of Yen. These data are collected from various monthly and quarterly issues of *International Financial Statistics* (IFS) published by the International Monetary Fund (IMF). All variables will be employed in their logarithmic form. The deviations series are constructed based on the unrestrictive form forward-looking exchange rate monetary model. The resulting deviations for all countries are plotted in Figure 1. Apparently, while the series fluctuate around the zero-mean with no obvious long-term trend in the graphs, coupled with the persistent drift of the deviations from the equilibrium rendering over- or under-valued up to two to three years in many cases, it is quite likely that these series are following nonlinear mean-reverting behaviour. Nonetheless, linearity test and stationarity test are needed to formally analyze whether or not the series are nonlinear as well as mean-reverting.

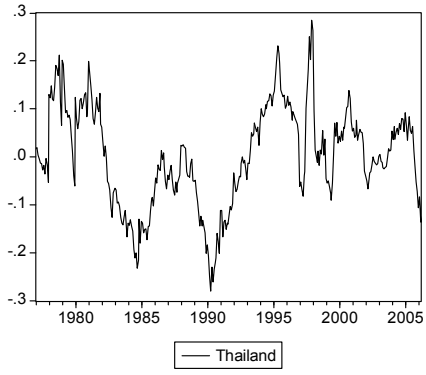
Figure 1: Deviations of exchange rates from monetary fundamentals











Results and Discussion

The formal linearity test results are summarized in Table 1. It clearly shows that the null hypothesis of linear process has been rejected by the *F* statistics for each deviations series, at conventional significant levels, in favor of nonlinear process that can be characterized by the STAR model. This means that the adjustment of ASEAN-5 nominal exchange rate towards the monetary fundamentals is nonlinear in manner, and therefore to certain extend, this finding of nonlinear exchange rate adjustment is supportive of the novel finding of Baharumshah *et al*. (2002), Lee and Azali (2005) and Lee *et al.* (2008), in which evidence of valid monetary models are obtained from linear estimation frameworks. In addition, this fresh evidence also expands the existing literature from the documentation of the nonlinear adjustment between ASEAN-5 nominal exchange rate and relative prices to a broader sense that includes domestic and foreign money supplies and aggregate outputs (Liew *et al*., 2003; 2004).

Table 1: Results of Testing for Nonlinearity.

Country	*k*	*d*	*F*	*msv*
Indonesia	4	3	2.2304*	0.0868
Malaysia	1	1	6.9645**	0.0352
Philippines	10	12	4.0375***	0.0034
Singapore	11	8	1.9152**	0.0172
Thailand	3	4	5.5924***	0.0014

Notes: *msv* denotes on the marginal significance value (*msv*) of the implied *F* statistic, which is computed from 4999 simulated series based on empirical distribution function. ***,** and * indicate significant at 1, 5 and 10% respectively.

Having revealed the nonlinear property of the deviations series, it is interested to know whether these nonlinear series are stationary or not. The corresponding KSS stationary tests are estimated and the results are reported in Table 2. From the t_{NDF}, it is obvious that the null hypothesis of nonstionary may be rejected at 1% significant level in all cases. Moreover, it has been shown that more negative *t* statistics are provided by the t_{NADF}, whereby lagged values of the first differenced deviation series are included in the test to eliminate possible serial correlation problem. All-in-all, the KSS tests results are favouring the monetary exchange rate model under study since stationarity of deviations series implies evidence of long-run relationship between exchange rate and the implied monetary fundamentals. This validation of monetary model provides more insight on the exchange rate adjustment dynamic as compared with previous studies in the same region using the linear frameworks (Baharumshah *et al*., 2002; Lee and Azali, 2005; Lee *et al.*, 2008). Remarkably, the deviations series is mean-reverting in the STAR framework, which means that nominal exchange rate follows the nonlinear path as represented by the STAR process in its adjustment towards the equilibrium position determined by the monetary fundamentals. Based on the discussion earlier, this finding can be interpreted as small deviations remains uncorrected and hence may be persistent in the short-run. However, as time past, deviations which eventually grow into large enough magnitude will be harvested by market players to obtain arbitrage profits. With that, exchange rate will revert to the mean position given by the monetary fundamentals. Such evidence of nonlinear mean-reverting behaviour of exchange rate remains the first in the literature in the context of ASEAN-5 countries. Previous, all we have in the literature in this region is

evidence of nonlinear mean-reverting behaviour of exchange rate towards the PPP equilibrium (Chortareas and Kaprenios 2003; Liew *et al*., 2004).

Table 2: Results of Testing for Stationarity

Country	t_{NDF}	*msv*	t_{NADF}	*msv*	*k*
Indonesia	-2.6521***	0.0084	-2.7917***	0.0002	12
Malaysia	-4.1038***	0.0002	-5.0690***	0.0004	12
Philippines	-2.9516***	0.0034	-3.8749***	0.0002	12
Singapore	-2.8140***	0.0052	-3.3430***	0.0002	12
Thilnd	-3.7320***	0.0002	-4.0980***	0.0004	3

Notes: Notes: t_{NDF} and t_{NADF} correspond to Equations (2) and (3) respectively, which are estimated on the original deviation series, as there is no significant intercept and trend terms in each series. *msv* denotes on the marginal significance value (*msv*) of the implied *t* statistic, which is computed from 4999 simulated series based on empirical distribution function. *** indicates significant at 1% level.

Conclusion

This study employs nonlinear testing procedures to validate the forward-looking monetary exchange rate model, in the context of ASEAN-5 countries. In particular, linearity property of the deviations of yen-based ASEAN-5 exchange rates from the corresponding equilibrium position as determined by the monetary fundamentals is first determined. This is followed by the examination of the stationary property of the above-mentioned deviations series. The testing procedures employed to accomplish these tasks include the linearity test due to Luukkonen *et al*. (1988) and the stationarity test recently developed by (Kapetanois *et al*. 2003). Both testing procedures, which are formulated based on the STAR framework, are adopted in this study based on previous findings of STAR-type nonlinear mean-reverting dynamic in the nominal exchange rate towards equilibrium level in the ASEAN region (Liew *et al*., 2003; 2004; 2005).

It is found that the exchange rate misalignments exhibit nonlinear behaviour in mean-reverting dynamics. Consistent with the theory of band of inaction postulated by Dumas (1992), trading frictions such as transaction costs induced a band of inaction for ASEAN-5 exchange rates, within which exchange rate misalignments are left to drift freely and causing exhibition of persistent misalignments in the short-run. However, misalignments are unsustainable when they surge out of the band, whereby market corrections take place due arbitrage profit reaping activities. Besides, we put forward that it is also plausible that government intervention may occur outside the inaction band whereby the marginal profits (political, economics) exceeds the marginal costs of intervening.

Besides, this study finds that the unrestricted form forward-looking monetary model is suitable for the countries under study. This means that domestic money supply, domestic aggregate output, Japan money supply, Japan aggregate output are the main driving forces the current exchange rate dynamic. As such, in monitoring the movement of exchange rates in these countries, government policy makers could focus on the above-mentioned set of monetary variables, which has been shown well-coordinated with the dynamic of exchange rates in this study.

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