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

Nonlinear Adjustment of ASEAN−5 Real Exchange Rates: Symmetrical or Asymmetrical?

Venus Khim−Sen Liew
Universiti Putra Malaysia

Abstract

This study examines whether the nonlinear adjustment dynamic of exchange rate to the equilibrium level as documented in Liew et al. (2003, 2004) is symmetrical or asymmetrical. Following the sequential tests as proposed in Teräsvirta and Anderson (1993), this study is able to identify that the US dollar based real exchange rates of Indonesia, Philippines, Singapore and Thailand exhibit LSTAR−type nonlinearity, implying that the real exchange rates of these countries have asymmetrical responds towards appreciation and depreciation. This finding provides useful guidelines in the monitoring and stabilising of ASEAN exchange rates, in order to boost the economy of this region, which has experienced different extends of negative shocks in the past few years.

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1. Introduction

Lately, Liew *et al.* (2003) found strong evidence of nonlinear behaviour of US dollar based Asian real exchange rates, which can be characterised by Smooth Transition Autoregressive (STAR) model, a type of nonlinear time series model that allows the real exchange rate to adjust smoothly every moment in between two regimes, which may either be appreciating and depreciating regimes or undervaluation and overvaluation regimes. Their findings are in line with other studies which provide evidences of nonlinearity in exchange rate movement in other regions; see for example Sarno (2000) Taylor and Peel (2000) and Baum *et al*. (2001). In a separate endeavour Liew *et al.* (2004) further showed that US dollar and Japan yen based Asian real exchange rates are nonlinear stationary, implying the nonlinear adjustment of nominal exchange rates towards the purchasing power parity (PPP) equilibrium level.

To this end, whether the nonlinear adjustment dynamic as documented in Liew *et al.* (2003, 2004) is symmetrical or asymmetrical in nature remains unknown. In this regard, Dumas (1992), Sarno (2000), Taylor and Peel (2000) and Baum *et al*. (2001) contended that exchange rate should exhibit symmetrical adjustment towards stable equilibrium level regardless of whether it is undervalued or overvalued. Moreover, Sarno (2000) postulated that Exponential STAR (ESTAR) model rather than Logistic STAR (LSTAR) model is consistent with the real exchange rate behaviour, whereas Taylor and Peel (2000) and Baum *et al*. (2001) asserted that ESTAR should be used to cater for the symmetrical adjustment of exchange rates positive and negative deviations from equilibrium level. Subsequently, these studies have ruled out the application of LSTAR model in their exchange rate studies[1]. However, it is argued here that to be fair and square, one should let the data to speak for itself regarding the nature of nonlinearities. In particular, given that STAR-type nonlinearity is present in a real exchange rate, one should further identify whether LSTAR or ESTAR model is a better fit of the data. This would allow us to add empirical content to the literature in the understanding of symmetrical or asymmetrical real exchange rate adjustment behaviour. Motivated by the reasons discussed above, the present study addresses the issue of whether real exchange rate adjustment as documented in Liew *et al.* (2003, 2004) follows a LSTAR or ESTAR path. This note reports the empirical results obtained from the 5 major economies in the Association of the South-East Asian Nations (ASEAN-5).

2. STAR Models, Linearity Test and Determination of LSTAR- or ESTAR-Type Nonlinearity

Smooth Transition Autorgressive (STAR) model of order *p*, for a real exchange rate series y_t may be expressed as:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i y_{t-i}) + (\alpha_0^* + \sum_{i=1}^{p} \alpha_i^*) F(y_{t-d}) + \varepsilon_t \qquad (1)$$

where α_0 is the linear intercept term, α_i (i =1, …, p) is the linear autoregressive parameter; α_0^* is the nonlinear intercept term, α_i^*(i =1, …, p) is the nonlinear autoregressive parameter, $F(y_{t-d})$ is the transition function which characterized the

[1] These models will be discussed in the next section.

smooth transition in between 2 regimes, with the speed of transition governed by the lagged term of the real exchange rate, y_{t-d} where d is the delay lag length. ε_t is the white noise residuals with zero mean and constant variance.

Depending on the specification of the transition function, $F(y_{t-d})$, there are variants of STAR model, namely the LSTAR or Logistic STAR and ESTAR or Exponential STAR models. The former has a logistic transition function:

$$F(y_{t-d}) = \left[1 + e^{-\gamma^2(y_{t-d}-\mu)}\right]^{-1} \quad (2)$$

where transition parameter γ^2 is a measure of the speed of transition in between the 2 regimes, and μ is the threshold parameter indicating the mid-way in between the two regimes of real exchange rate.

Meanwhile, the latter has an exponential specification:

$$F(y_{t-d}) = 1 - e^{-\gamma^2(y_{t-d}-\mu)^2} \quad (3)$$

Interested readers may consult Teräsvirta and Anderson (1993) for a throughout discussions, but at this moment it is sufficient to draw our attention to the potential usefulness of these two models. Teräsvirta and Anderson (1993) pointed out that LSTAR model is able to capture the asymmetric behavior of business cycle indicators, where expansion and contraction phases of an economy may have rather different dynamics, and a change in dynamics from one to the other may be smooth. The ESTAR model, on the other hand, can represent an economy which returns from high growth towards normal growth in much the same fashion as it accelerates from low or negative growth towards the normal growth. In other words, ESTAR model implies that contraction and expansion have rather similar adjustment structures. As for the application of these two models, original proposed for the modeling of business cycle, in the field of exchange rate, Sarno (2000) put forward that the transition function (this function will be described later) of ESTAR model symmetrical in shape and so it captures symmetrical adjustment dynamics of exchange rate. As for the LSTAR model, its monotonic increasing transition function implies an asymmetric adjustment towards equilibrium value.

Granger and Teräsvirta (1993) noted that it important to test for linearity prior to estimating any nonlinear model. Liew *et al*. (2003) remarked that the application of any linear model is only appropriate when linearity test has failed to detect any nonlinearity in the time series of interest. In sum, we must conduct linearity test before the selection of linear or nonlinear models.

As in Liew *et al*. (2003), formal linearity test formulated by Luukkonen *et al*. (1988) are deployed to determine whether the ASEAN-5 real exchange rates are linear or nonlinear in nature in the sample period of study:

$$y_t = a_0 + \sum_{i=1}^{p} a_i \; y_{t-i} + \sum_{i=1}^{p}(b_{1i}y_{t-i}y_{t-d} + b_{2i}y_{t-i}y_{t-d}^2 + b_{3i}y_{t-i}y_{t-d}^3) + \xi_t \quad (4)$$

where ξ_t is white noise residuals with zero mean and constant variance under the null hypothesis. Note that the true lag length, p and the delay parameter, d are unknown and their optimal values have to be determined based on certain considerations. Following

Liew *et al*. (2003), this study fixes the optimal p as suggested by partial autocorrelation functions (*PACF*) and the principle of no autocorrelation, whereas d is chosen from 1 to 12 and the one that minimizes the p-value of the *LST* (acronym for Luukkonen-Saikkonen-Teräsvirta) statistics will be selected.

The null hypothesis of (4), $H_0 : b_{11} = \ldots = b_{1p} = b_{21} = \ldots = b_{2p} = b_{31} \ldots = b_{3p} = 0$ is tested against the alternative hypothesis of H_{STAR} : At least one b is not 0, by the *LST* statistics[2]. In our case, the rejection of alternative hypothesis means that the real exchange rate being tested exhibits nonlinearity and this nonlinearity can be characterized by the Smooth Transition Autorgressive (STAR) model. In short, there is evidence of STAR-type nonlinearity in the real exchange rate. However, if the null hypothesis is not rejected, then the real exchange rate behaves in a linear manner.

If linearity has been rejected in favor of STAR model, one may proceed to test the following sequential tests, for the determination of LSTAR- or ESTAR-type nonlinearity (Teräsvirta and Anderson 1993):

$$H_{03} : b_{31} = \ldots = b_{3p} = 0 \mid \text{Reject } H_0 \quad (5)$$

$$H_{02} : b_{21} = \ldots = b_{2p} = 0 \mid \text{Accept } H_{03} \quad (6)$$

$$H_{01} : b_{11} = \ldots = b_{1p} = 0 \mid \text{Accept } H_{02} \quad (7)$$

where in each of the above cases, the alternative hypothesis is H_{Ak} : At least one b_k is non-zero for $k = \{ 1, 2,3\}$. The null hypothesis is tested against the alternative hypothesis by the F-test of restriction (Gujarati 1995, pp. 257 – 259).

The following decision rules are useful in the determination of LSTAR- or ESTAR-type nonlinearity: (i) Rejecting H_{03} implies LSTAR-type nonlinearity. (ii) Accepting H_{03} and rejecting H_{02} implies ESTAR-type nonlinearity. (iii) Accepting both H_{03} and H_{02} and rejecting H_{01} implies LSTAR-type nonlinearity. (iv) Accepting all H_{03}, H_{02} and H_{01} lead to inconclusive determination[3].

3. Data of Study

Five US dollar based ASEAN real exchange rates including the Indonesian rupiah (IDR/USD), Malaysian ringgit (MYR/USD), Philippines peso (PHP/USD), Singaporean dollar (SGD/USD) and Thais baht (THB/USD) are considered in this study. Following Liew *et al*. (2003, 2004), these real exchange rates are derived from the relative form of purchasing power parity (PPP) hypothesis, namely $y_t = s_t + p_t^* - p_t$ 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 (measured by consumer price indices) respectively. The sample period covers 1973Q1 to 1996Q4. A preliminary analysis on the skewness of the returns of these real exchange rates shows that they are asymmetrical in nature, thereby implying that the adjustment dynamic of exchange rate in

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[2] Among others, Liew *et al.* (2003) provides guidelines on the computation of this statistics.

[3] It is argued that once H_0 is rejected indicating that at least one b is non-zero, it is unlikely for one to end up in case (iv).

the appreciating and depreciating regimes are different (results not shown). However, this finding is crude and formal econometric procedures as described in the preceding section is in order.

4. Results and Discussions

The *LST* linearity test results are summarised in Table 1. Table 1 shows that the null of linearity has been rejected at 5% significance level for all real exchange rates for the pre-crisis sample period, with the exception of THB/USD, in which the null can be rejected at 10% significance level only.

Table 1: Linearity Test Results (1973Q1 to 1996Q4)

Real Exchange Rate	*p*	*d*	*LST* statistic	*Bootstrap p* value
IDR/USD	1	2	8.624	0.044
MYR/USD	3	3	19.482	0.008
PHP/USD	2	3	16.264	0.021
SGD/USD	5	9	56.236	0.000
THB/USD	1	3	8.848	0.066

There are several implications of this finding. First, the rejection of the null hypothesis indicates that the non-linear parameters are jointly significant by the *LST* test, thereby suggesting that linear Autoregressive (AR) model is inadequate in characterizing the behaviour of real exchange rates in all the five selected ASEAN economies. The implication of this evidence is that estimating the linear AR exchange rate model disregarding the presence of non-linearity will yield mis-specified model. As such, the results and conclusions from the works of Nguyen and Yao (1989), Gan (1991), Bahmani-Oskooee (1993), Manzur and Ariff (1995), Cao and Ong (1995), Chia and Bauer (1995), Toh and Kendall (1996), Baharumshah and Ariff (1997) and others which studied the exchange rate behaviour in this region but had assumed linearity have to be taken with reservations. Second, in line with the findings of the recent related studies, the rejection of null hypothesis provides empirical evidence that the nonlinear STAR model is the correct specification. Thus, exchange rate forecasters should consider STAR model and its variants as better alternatives to the existing linear forecasting models. Regarding the last statement, we believe that distinguishing between LSTAR-type or ESTAR-type nonlinearity may help maximising the gain of utilising nonlinear models.

The results of sequential tests for LSTAR-type or ESTAR-type nonlinearity are tabulated in Table 2. It is clearly depicted in Table 2 that the null hypothesis H_{03} can be rejected in the case of PHP/USD (at 5% significance level) and SGD/USD (1% level) implying that these two real exchange rates exhibit LSTAR-type nonlinearity. Meanwhile, H_{03} is not reject in the case of MYR/USD but H_{02} can be rejected at 5% significance level, revealing that ESTAR-type nonlinearity is present in MYR/USD. On the other hand, both H_{03} and H_{02} are no rejected for IDR/USD and THB/USD even at 10% significance level. Anyway, H_{01} can be rejected at less than 1% significance level, thereby indicating that the movement of these rates is governed by LSTAR-type nonlinearity.

Table 2: Sequential Tests Results (1973Q1 to 1996Q4)

Real Exchange Rate	F-Test [*p*-value]			Decision on Type of Nonlinearity
	H_{03}	H_{02}	H_{01}	
IDR/USD	1.657[0.201]	0.176[0.677]	14.415[0.000]	LSTAR
MYR/USD	0.657[0.581]	3.605[0.017]	1.469[0.228]	ESTAR
PHP/USD	3.281[0.042]	9.049[0.000]	0.896[0.412]	LSTAR
SGD/USD	4.409[0.002]	0.028[0.868]	6.065[0.000]	LSTAR
THB/USD	0.041[0.839]	2.345[0.129]	21.839[0.000]	LSTAR

The finding of the presence of LSTAR-type nonlinearity in all the ASEAN-5 real exchange rates except MYR/USD is quite striking. It is against the widely-held belief of the symmetrical adjustment dynamics of real exchange rate towards depreciating and appreciating regimes (Sarno, 2000 and Baum *et al*., 2001). Rather, this study finds strong evidence that the homecoming of ASEAN-5 (except MYR/USD) real exchange rates from the positive growth rates (depreciation) to the equilibrium level have rather unalike dynamics as it accelerates from negative growth (appreciation) to the equilibrium level.

Another implication of this finding is that the deviations of nominal exchange rates from the PPP equilibrium levels follow nonlinear path and that the response of market adjustment mechanism towards over-valuation and under-valuation of ASEAN-5 (except MYR/USD) nominal exchange rates are asymmetric in nature. This conclusion is in sharp contrast to Taylor and Peel (2000) and Liew *et al*. (2002) which find ESTAR-type adjustment process of exchange rate deviations towards equilibrium levels. Nonetheless, the results of the current study are more robust than these two studies as they discard LSTAR model in priori and based their analysis solely on ESTAR-type linearity test.

5. Conclusions

This study examines whether the nonlinear adjustment dynamic of exchange rate to the equilibrium level as documented in Liew *et al.* (2003, 2004) is symmetrical or asymmetrical. Following the sequential tests as proposed in Teräsvirta and Anderson (1993), this study is able to identify that the US dollar based real exchange rates of Indonesia, Philippines, Singapore and Thailand exhibit LSTAR-type nonlinearity. This implies that the real exchange rates of these countries have asymmetrical responds towards appreciation and depreciation. Hence, it is argued that foreign exchange market participants should adopt the LSTAR model rather than ESTAR model in their attempt to effectively comprehend the behavior these exchange rates.

The key policy implications of the robust empirical evidence of asymmetrical adjustment dynamics in response of the appreciation and depreciation of real exchange rates and the overvaluation and undervaluation of nominal exchange rates towards the purchasing power parity equilibrium levels are twofold. First, central banks, international financial institutions, multinational corporations and other foreign exchange market players should adopt the LSTAR model rather than ESTAR model in their attempt to comprehend the future behavior these exchange rates as the former is believed a more effective tool. Second, the identification of the correct nonlinearity nature of exchange rate adjustment towards its equilibrium level is important as exchange rate may serve as one of potential intermediate policy tools in boosting the economy of this region, which has experienced different extends of negative shocks such as 1997 Asian Currency Crisis, the 911 incident, the recession of US (ASEAN-5's major trading partner) economy, SARS and the recent Asian birds' flu. It is suggested here that central banks should peruse different policies in their attempt to stabilize their exchange rates movement. In particular, the understandings of the different responds of market adjustment dynamics on the restoration of excessive overvaluation to the equilibrium levels and the bouncing back of excessive undervaluation to the equilibrium levels may be of great help to the central banks in this region in their efforts to improve the measurability and controllability of the exchange rates. In this context, the better the measurability and controllability of an exchange rate (real or nominal), the more potential it is in acting as immediate targeting tool in boosting an economy in this region, which to a large extend depends on international trade and foreign investments.

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