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The Purchasing Power Parity Puzzle in Indonesia: Insights from ESTAR Model

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Abstrak

Selama beberapa tahun terlihat adanya lonjakan penelitian empiris mengenai validitas dari Purchasing Power Parity (PPP) di dalam dunia nyata. Meskipun demikian, beberapa hasil studi empiris sebelumnya menghasilkan laporan yang mixed, termasuk temuan empiris di Indonesia, yang memunculkan perdebatan diantara para pembuat kebijakan mengenai kegunaan dari temuan empiris. Salah satu penjelasan untuk puzzle dalam temuan empiris pada hipotesis PPP adalah studi-studi sebelumnya umumnya membuat asumsi implisit bahwa perilaku exchange rate adalah pada dasarnya linear. Dengan bukti-bukti yang banyak yang mendukung bahwa non-linearity merupakan gambaran nyata mengenai data exchange rate, seseorang tidak bisa lagi menganggap bahwa pergerakan exchange rate adalah linearly dependent. Paper ini secara empiris menginvestigasi dynamics of adjustment process dari exchange rate Indonesia dari tingkat equilibrium jangka panjang, seperti yang disarankan oleh hipotesis PPP. Untuk melengkapinya, diestimasi standard linearity test statistics seperti yang disarankan Lukhonen, Saikkonen, dan Terasvirta (1998), yang memiliki power dalam mengatasi Exponential Smooth Transition Autoregressive (ESTAR) model. Dengan menggunakan data series quarterly, hasilnya memperlihatkan bahwa bilateral Rupiah-USD (Indonesia Rupiah (IDR)/US Dollar (USD)) mengikuti nonlinearly PPP equilibrium level. Hal lainnya yang menarik dari studi ini adalah hubungan antara adjustment process dan Krisis Finansial di Asia saat ini. Hasilnya menunjukkan bahwa IDR/USD ditandai dengan low speed of adjustment dan hal inilah yang menerangkan kejatuhannya yang luar biasa selama krisis 1997.

Kata Kunci: *Nilai tukar - Paritas daya beli - Model ESTAR - Perekonomian Indonesia*
Key Word: *Exchange rates - Purchasing power parity - Exponential smooth transition autoregressive model - Indonesian economies.*

1. 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 in the short run, deviation of exchange rate from PPP might occur[1], most economic theories suggest that PPP should hold in the long run. According to Ahmad (1999), the origin of PPP can be attributed to the scholars of the Salamanca school in Spain in the sixteenth century. But it is Gustav Cassel, a Swedish economist, who popularized the PPP in the 1920s.

Over the years, there has been an explosion of empirical research on the validity of PPP in the real world. However, previous empirical studies have reported mixed results. For instance, the empirical works of Lee (1976), Glens (1992), Lothian and Taylor (1996), Nagayasu (1998), Coakley and Fuertes (2001), Mohamed *et al*. (2001) and Razzaghipour *et al*. (2001) were supportive of long-run PPP hypothesis, whereas Corbae and Outliaris (1988), Edison and Fisher (1991), Engel *et al*. (1997), O'Connel (1998), Baum *et al*. (1999) and Cuddington and Hong (2000) provided empirical evidence against it.

Even in the empirical work on Indonesia, the results have been mixed, creating a debate among policy makers on the usefulness of the empirical findings. Study by Baharumshah and Ariff (1997) using unit root and Engle and Granger (1987) cointegration approach rejected the PPP proposition for Indonesia. Further analysis using the Johansen and Juselius (1990) multivariate approach also failed to support the PPP hypothesis in this country. Bahmani-Oskooee (1993) who used the Engle and Granger procedure has found weak evidence supporting PPP in Indonesia. On the other hand, a recent study by Bahmani-Oskooee and Mirzai (2000) failed to support the mean reversion in real effective exchange rate for Indonesia using the conventional ADF and KPSS unit root tests. To take into account the presence of structural breaks, Aggarwal *et al*. (2000) employed both the single and multiple breaks unit root tests to test the validity of PPP for ASEAN exchange rate in terms of

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).

the Japanese yen. They found clear and significant evidence in favour of long run PPP for most of the ASEAN currencies, including Indonesia. Another recent study by Mohamed *et al.* (2001) using panel unit root and panel cointegration showed that PPP does hold in the long run between Japan and ASEAN economies.

One possible explanation for the puzzle in the empirical evidence on the PPP hypothesis is that earlier studies generally made an implicit assumption that exchange rate behaviour is linear in nature (Taylor and Peel, 1997). With abounding empirical evidence supporting the presence of non-linearity in exchange rate time series data (Hsieh, 1989; De Grauwe *et al.*, 1993; Steurer, 1995; Brooks, 1996; Mahajan and 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. Taylor and Peel (1997) and Sarno (2000), amongst others, illustrated that the adoption of linear stationarity tests is inappropriate in detecting mean reversion if the true data generating process of exchange rate is in fact a stationary nonlinear 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.

Due to the growing views that the world is non-linearly dynamics (Pesaran and Potter, 1993; Campbell *et al.*, 1997; Barnett and Serletis, 2000), recent works in the PPP literature have attempted to address the issue of non-linearity in mean reversion. 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 investigate are governed by non-linear dynamics. Other studies like Micheal *et al* (1997), Sarno (2000) and Baum *et al.* (2001) employed nonlinear 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 run PPP, in which the real exchange rate adjusts non-linearly towards its equilibrium PPP level.

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

In this study, we employ a version of the well-known linearity test suggested by Lukkonen *et al.* (1988) to investigate the adjustment dynamic of the deviations of Indonesian exchange rate from the long-run equilibrium level suggested by the PPP hypothesis. Another related issue that this study attempts to address is whether the adjustment process has any connection with the recent 1997 Asian Financial Crisis, which has the most negative impact on the Indonesian rupiah (Carbaugh, 2000). The major conclusions drawn from this study are: First, our empirical analysis suggests that the IDR/USD exchange rate under investigate adjust nonlinearly towards its PPP equilibrium level. Second, our empirical results reveal that the impact of the crisis is closely related to the speed of adjustment process. Specifically, exchange rate with a lower speed of adjustment as in the case of IDR/USD was severely affected by the recent Asian Financial Crisis.

This paper proceeds as follows. Section II discusses the rationales on the nonlinear adjustment of exchange rate deviations. This is followed by a brief description of the linearity tests involved. Section IV presents the results as well as the interpretation of our empirical analysis. Finally, concluding remarks are given at the end of the paper.

2. RATIONALES FOR NONLINEAR EXCHANGE RATE ADJUSTMENTS

There are a few theoretical models that provide rationales for the existence of nonlinear adjustment of exchange rate towards its fundamental equilibrium level; see Ma and Kansas (2000a) for a quick review. However, the most widely known model is the target zone model developed in Krugman (1991). Krugman (1991) proposes that given a perfectly credible target zone, the relationship between exchange rate and fundamentals will be nonlinear in nature. His rationale is that exchange rate adjustment differs in magnitude within the zone, in accordance to the changes in fundamentals. For instance, when the exchange rate is near the upper bound of the target zone, a fall in the fundamental will reduce the exchange rate more than a rise in the fundamental will increase the exchange rate. Even though this model is appealing, there is no general consensus on which fundamentals are to be adopted in empirical study. Moreover, Ma and Kansas (2000b) report that most empirical studies have failed to reveal significant nonlinearities in this kind of exchange rate-fundamentals relation.

Taking purchasing power parity as specified fundamental of exchange rate, Dumas (1992) develops the no-arbitrage model to explain the nonlinear behaviour of exchange rate adjustments toward PPP. Dumas (1992) considers the existence of transaction costs to arrive at this model. The presence of transaction costs in international trade implies that deviations from PPP will only be arbitraged away by rational arbitrageurs if the price differentials exceed transaction costs. Thus, there is a band of inaction whereby the marginal profit due to price differential is unable to cover the transaction costs. In other words, exchange rate is left unadjusted if its deviations from the parity are not big enough. As a result, the adjustment process tends to be discrete rather continuous, enabling the modelling of exchange rate dynamics using the nonlinear Threshold Autoregressive (TAR) model. Moreover, beyond the band of inaction, the larger the deviation from equilibrium[2], the stronger is the tendency for the exchange rate to adjust back to equilibrium. Thus, the

[2] Larger deviation implies larger net arbitrage profit and thus the faster will the opportunity be arbitraged away.

speed of adjustment varies with respect to the size of deviation, thereby justifying the nonlinear adjustment of exchange rate towards PPP.

A prominent nonlinear model that is capable of measuring the speed of adjustment is the Exponential Smooth Transition Autoregressive (ESTAR)[3] model due to Granger and Teräsvirta (1993). Taylor and Peel (2000) argue that the STAR model is more appropriate than TAR model in examining the movements of exchange rate based on national price indices involving a range of goods with different costs of arbitrage. Consistent with Taylor and Peel (2000), Baum *et al*. (2001) also postulate that based on observed aggregated process, regime changes may be smooth rather than discrete as long as economic agents do not act simultaneously.

3. LINEARITY TESTS

We employ a version of the linearity test suggested by Lukkonen, Saikkonen and Teräsvirta (1988) that has an auxiliary regression of the form:

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

where α_0, α_i, β_i and δ_i ($i = 1, \ldots, p$) 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 optimal autoregressive lag length whereas d is called the optimal delay parameter.

Under linearity, the null hypothesis of $\beta_{ij} = \delta_{ij} = 0$ for all i and j holds and may be tested by chi-squared (χ^2) distributed test statistic. The linearity test as specified in Equation 1 actually has power against

[3] ESTAR is a version of STAR model capable of characterizing the symmetrical adjustment of exchange rate. Another version of STAR model known as the Logistic STAR (LSTAR) model is less preferred in the modelling of exchange rate; see Granger and Teräsvirta (1993) and Baum *et al*. (2001) for more details on the properties of these models.

ESTAR or Exponential STAR[4], a specification of the general STAR model. 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 nonlinear adjustment process of exchange rate deviations is symmetrical in nature and ESTAR is appropriate in representing this process.

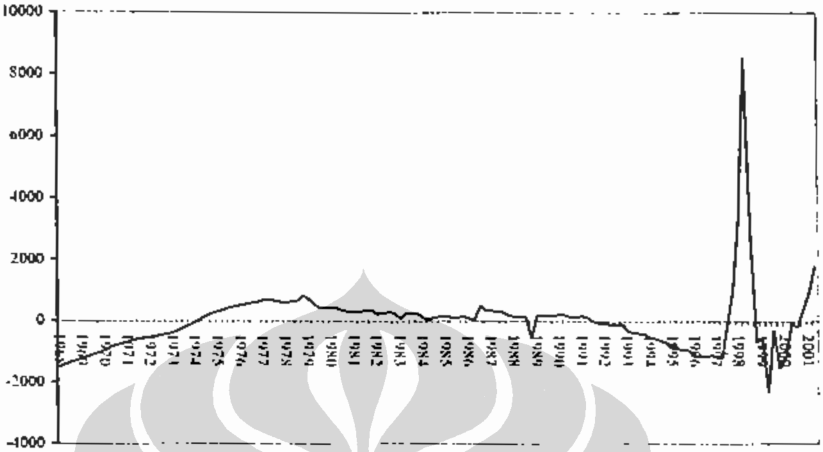
The optimum lag length p and delay parameter d in Equation 1 have to be determined from the data as they are unknown. In the current study, the optimal p of linear AR (p) model is selected from a class of models with no autocorrelation based on the minimum Akaike's biased corrected information criterion (AICC). 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 χ^2 statistic.

4. EMPIRICAL ANALYSIS

This study uses the quarterly end-of-period nominal bilateral Indonesian Rupiah-US Dollar (IDR/USD) and the price index used is the consumer price indices (CPI) of Indonesia and U.S. The data are obtained from various issues of International Financial Statistics published by the International Monetary Funds. Our data spans from the first quarter of year 1968 to the second quarter of year 2001 (1968:1 to 2001:2). Deviations of exchange rates (see Figure 1) are obtained from PPP as estimated by standard Johansen procedure. These deviations series are mean-corrected before they are subjected to 2-steps linearity test procedures.

4 See Lukkonen *et al.*, 1988; Granger and Teräsvirta, 1993 and Teräsvirta, 1994 for a theoretical discussion on this matter.

Figure 1
Deviations of Exchange Rates From PPP Equilibrium
Indonesian rupiah – U.S. dollar



Our analysis starts with estimating the optimum lag length p of the linear autoregressive model for the deviations series, based on the minimum AICC criterion. The estimated results and residual diagnostics are depicted in **Table 1**. The results reveal that the linear AR(p) model for IDR/USD is free from autocorrelation problem at standard significance levels. However, heteroscedasticity are detected in the residuals. Moreover, this fitted linear AR(p) model fails to capture the ARCH and GARCH effects of the deviations. These preliminary estimates suggest that linear autoregressive process is inadequate in characterizing the adjustment dynamic of the IDR/USD exchange rate deviations.

Table 1

Residual Diagnostics For Linear AR (p) Models

Exchange Rate	Optimum p	Marginal Significance Values of Residual Diagnostics					
		Q4	Q12	HET4	HET12	ARCH4	GARCH
IDR/USD	7	0.997	0.956	0.000**	0.000**	0.000**	0.000**

Notes: Q_i and HET_i are, in that order, Ljung-Box Q statistics and Breusch-Pagan-Godfrey test statistics to detect the presence of serial correlation and heteroscedasticity problems, if any, up to the order of i; where i = 4, 12. Q statistic also has the power against the alternative hypothesis that the residuals do not follow independent and identical distribution. $ARCH_4$ and GARCH tests detect the ARCH effects up to 4th and higher order respectively.

** denotes extremely small value.

Rejection of linear process provides us motivation in determining whether the adjustment dynamic could be represented by nonlinear autoregressive process. Thus, we proceed to the second step of our linearity test procedures, that is, to conduct the Lukkonen *et al.* (1988) linearity test. The linearity test results are depicted in **Table 2**. It is obvious from **Table 2** that linearity can be rejected at 5% significance level for the deviation series in favour of the ESTAR model, on the basis of χ^2 statistic.

Table 2

Linearity Test Results

Tests	Delay Length, d											
	1	2	3	4	5	6	7	8	9	10	11	12
	Indonesia rupiah-US dollar (p=7)											
χ^2	58.530	56.927	61.450	40.891	14.046	42.033	32.774	39.108	37.741	25.633	19.171	22.465
Q (20)	0.506	0.557	0.114	0.425	0.453	0.903	0.815	0.998	0.998	0.611	0.999	0.999

Notes: The optimal lag length *p* is determined by the AICC. Q (20) denotes the marginal significance value of the portmanteau Ljung-Box statistic is employed to detect serial correlation up to 20 lag lengths. The bootstrap 1%, 5% and 10% critical values for the rejection of null hypothesis are 66.623, 56.539 and 50.084 respectively.

To sum up, our formal linearity test results strongly suggest that adjustment process of IDR/USD deviations towards the PPP equilibrium follows an ESTAR process which is nonlinear in nature. In particular, this study reveals that the adjustments of Indonesian rupiah follow an ESTAR process of order 7 and a delay lag length of 3.

As the rejection of the null hypothesis of the linearity tests specified in Equation (1) is effectively in favour of the Exponential STAR specification, we proceed to estimate the transition function defined as (Granger and Teräsvirta, 1993)

$$F[z_{t-d}] = 1 - \exp[-\gamma(z_{t-d}^2 / \hat{\sigma}_{z_t}^2)] \quad \text{...} \quad (2)$$

where γ is the scale-free transition parameter, which is standardised by $\hat{\sigma}_{z_t}^2$, the estimated variance of the mean-corrected deviation series, z_t.

This transition function $F[z_{t-d}]$ is estimated for it provides information on the degree of mean-reversion, that is the speed of adjustment of the deviations towards the equilibrium level. The specification of $F[z_{t-d}]$ in the current study differs from that of Granger and Teräsvirta (1993), which includes a threshold parameter to reflect the mean equilibrium level in the transition function. The threshold parameter in our case is assumed to be zero as we are using the mean-corrected series. The estimated scale-free transition parameters, γ, and the residual diagnostics results are summarised in **Table 3**.

The estimated transition parameter as depicted in Table 3 is significantly different from zero at standard significance levels. Moreover, the estimated variances of the nonlinear STAR specification are smaller than those of the linear AR specification. These two findings indicate that linear specification itself is insufficient to represent the exchange rate adjustments.

Residual diagnostics indicate that there is no autocorrelation (from the Q statistic) or heteroscedasticity (from the HET statistic) effect in the remaining residuals at 5% significance level. Moreover, the non-rejection of Q statistics also suggests that the residuals are independently and identically distributed. However, with the Exponential STAR specification, the residual ARCH and GARCH effects due to the linear AR specification cannot be eliminated. It is well known that the Indonesian rupiah has experienced great instability during the 1997 Asian Financial Crisis and the remaining ARCH and GARCH effects in its deviation series may be due to this extraordinary volatility (estimated variance over the sample period is as high as 7203692). It is interesting to know whether the Smooth Transition GARCH model (a variant of STAR model) of Lundbergh and Teräsvirta (1998) is able to fully capture the ARCH and GARCH effects in such case. However, we leave this issue for further research.

Table 3

Estimated Transition Parameters (γ) and Residual Diagnostics

Exchange Rate	γ (Standard Error)	VR	Marginal Significance Values of Residual Diagnostics					
			Q4	Q12	HET4	HET12	ARCH4	GARCH
IDR/USD	0.858 (0.214)*	0.723	0.732	0.454	0.952	0.487	0.012**	0.001**

Notes: VR stands for variance ratio of nonlinear Smooth Transition (STAR) model to linear Autoregressive (AR) model. Q_i and HET_i are, in that order, Ljung-Box Q statistics and Bruesch-Pagan-Godfrey test statistics to detect the presence of serial correlation and heteroscedasticity problems, if any, up to the order of i; where i = 4, 12. Q statistic also has the power against the alternative hypothesis that the residuals do not follow independent and identical distribution. $ARCH_4$ and GARCH tests detect the ARCH effects up to 4th and higher order respectively.

* and ** implies significant at 10% level and 5% level or better.

The transition parameter of Indonesian rupiah is 0.858, implying a slow adjustment process. Interestingly, this speed of adjustment seems to have direct relationship with the 1997 Asian Financial Crisis. Carbaugh (2000) reported that this crisis had the most negative impact on the Indonesian rupiah. Specifically, we find that the Indonesian rupiah plunged more than triple in value during the crisis. One plausible explanation for this phenomenon is that for exchange rate characterized by slow speed of adjustment, as in the case of IDR/USD, most of the deviations are left unadjusted or only partially adjusted because of slow adjustment mechanism. Until at one stage whereby the accumulated deviations are no longer sustainable, tremendous market correction process will be in action, leading to tremendous plunged in value as we observed in the bilateral rate of IDR/USD during the 1997 crisis.

Figure 2 shows the plot of the estimated transition function, F[z_{t-d}] against the corresponding lagged values of the exchange rate deviations from the PPP equilibrium, z_{t-d}. As our series are mean-corrected, the PPP equilibrium level is exactly represented by $z_{t-d} = 0$ in the horizon axis of **Figure 2**. The inverted-bell shaped plot in Figure 2 shows that the adjustment process of the negative and positive deviations are acceptably symmetrical in nature. This finding is in accordance with most literature (Taylor and Peel, 2000; Sarno, 2000; Baum *et. al.*, 2001, among others). To gain an insight on how the adjustments of exchange rate transfer from one regime to the other, we plot the estimated transfer function against time in **Figure 3**. Reveals that IDR/USD tends to remain in the inner regime (F[z_{t-d}] = 0) and it hardly enter the outer regime (F[z_{t-d}] =1). This finding reinforces our conclusion that IDR/USD adjusts slowly towards the equilibrium PPP level.

Figure 2
Estimated Transition Function
Indonesian rupiah – U.S. dollar

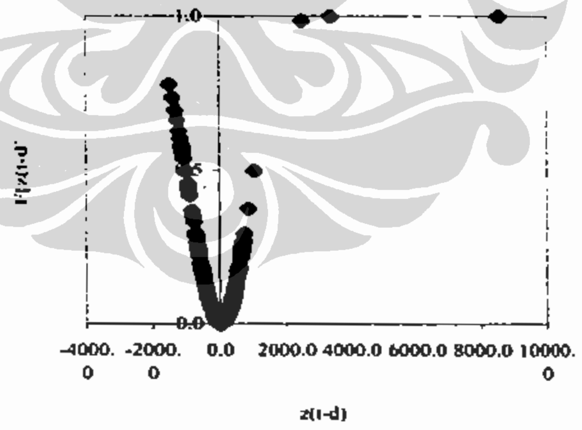
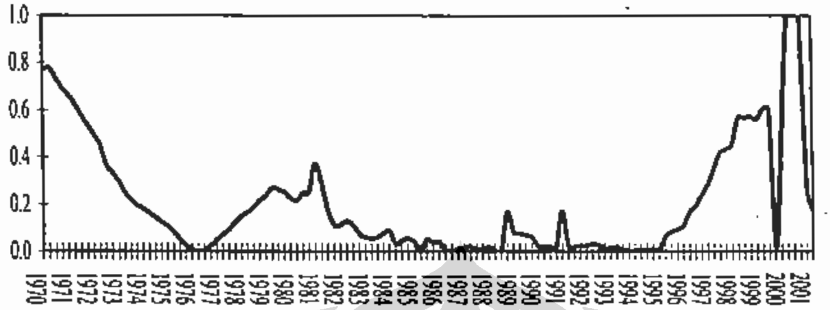


Figure 3
Plot of Transfer Function Against Time
Indonesian Rupiah – US Dollar



5. CONCLUDING REMARKS

The hypothesis that the adjustment dynamic of exchange rate deviations is nonlinear in nature has been widely accepted by most exchange rate researchers. Moreover, there appear many published articles that characterized this nonlinear adjustment process by the Exponential Smooth Transition Autoregressive (ESTAR) model. Following these studies, we utilise the linearity test statistics due to Lukkonen *et al*. (1988) to determine the linearity nature of the adjustment process, in the context of the bilateral IDR/USD exchange rate. We note here that linearity tests have been conducted in developed countries (such as Baum *et al*., 2001) as well as Middle East Countries (Sarno, 2000) but it is not until this current study that similar test is applied in the context of ASEAN countries, specifically Indonesia. Our test statistics verify that the adjustment process towards the purchasing power parity equilibrium is actually nonlinear in nature and could be characterized by an ESTAR process for the bilateral exchange rate under investigate. As such, any estimation of linear exchange rate models for the Indonesian economies may yield unreliable policy conclusion.

Besides, our empirical results reveal that the speed of adjustment seems to have direct relationship with the 1997 Asian Financial Crisis. In particular, exchange rate characterized by low speed of adjustment, as in the case of IDR/USD, is severely affected by the crisis. This is because most of the deviations are left unadjusted or only partially adjusted because of the slow adjustment mechanism. Until at one stage whereby the accumulated deviations are no longer sustainable, tremendous market correction process will be in action, leading to tremendous plunged in value as we observed in the bilateral rate of IDR/USD during the 1997 crisis.

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