
Bulletin of Indonesian Economic Studies

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cbie20

# Real Exchange Rate Misalignment and Currency Crises

**Unggul Heriqbaldi , Wahyu Widodo & Dian Ekowati**

Routledge
Taylor & Francis Group

*Bulletin of Indonesian Economic Studies*, Vol. 56, No. 3, 2020: 345–362

# REAL EXCHANGE RATE MISALIGNMENT AND CURRENCY CRISES

Unggul Heriqbaldi*
*Airlangga University*

Wahyu Widodo
*Diponegoro University*

Dian Ekowati
*Airlangga University*

This article calculates the real exchange rate misalignment (RERM) of the rupiah to examine the role of misalignment in exchange rate crises in Indonesia. The article does this by employing an autoregressive regime-switching model and behavioural equilibrium exchange rate (BEER) approach. The findings are as follows. First, net foreign assets and the relative productivity differential between sectors significantly influence the equilibrium exchange rate, indicating that external and internal balance determine the behaviour of the rupiah in the long run. Second, the BEER approach can properly predict misalignment of the rupiah, especially through explaining the overvaluation periods of the rupiah before the Asian financial crisis. The regime-switching model performs well in identifying episodes of stability and volatility in the rupiah. Third, of the 17 crisis episodes experienced in Indonesia in 1981–2012, 10 were preceded by high RERM.

Keywords: *real exchange rate misalignment, currency crises, balance of payments, regime switching, behavioural equilibrium exchange rate*

*JEL* classifications: F30, F31, F41

## INTRODUCTION

Real exchange rate misalignment (RERM) refers to situations in which the actual real exchange rate (RER) differs significantly from its long-run equilibrium value. The study of RERM has evolved since the Asian financial crisis (AFC) in 1997–98. In addition to examining how the RER behaves, various studies have investigated how RERM impacts the economy. Initially, empirical research on exchange rates used the purchasing power parity (PPP) approach, where, under the assumption of free trade, the exchange rate between two countries is equal to the ratio of the countries' price levels. Newer approaches—such as the fundamental equilibrium exchange rate (FEER) and behavioural equilibrium exchange rate (BEER)—have analysed exchange rate behaviour. The BEER approach focuses on the dynamic behaviour of the exchange rate over the short run and the deviation of the actual

* Corresponding author's email: u.heriqbaldi@feb.unair.ac.id

ISSN 0007-4918 print/ISSN 1472-7234 online/18/000345-362

http://dx.doi.org/10.1080/00074918.2019.1662885

exchange rate (the current market value of a currency) from its long-term value, using macroeconomic variables as determinants (Aliyu 2009).

Most research on RERM has dealt with macroeconomic performance. Various studies have shown that RERM affects economic growth (Akram and Rath 2017; Ribeiro, McCombie and Lima 2019; Wong 2019). Others have shown how RERM influences export competitiveness and private investment (Jongwanich 2009; Nouira and Sekkat 2015; Razmi, Rapetti and Skott 2012; Sekkat 2016; Sekkat and Varoudakis 2000). Some research has explored how RERM can predict currency crises in particular countries (Holtemöller and Mallick 2013; Jongwanich 2008; Kemme and Roy 2006; Stein and Paladino 1999). So far, however, the relationship between RERM and the 1997–98 exchange rate crisis in Indonesia has not been widely discussed, possibly because it is difficult to identify. Understanding the relationship between RERM and currency crises is crucial for developing early warning systems that can anticipate financial crises, especially in Indonesia. This article aims to fill the gap in knowledge about this relationship.

Theoretically, the relationship between exchange rate misalignment and exchange rate crises can be formulated in second-generation models of currency crises. First-generation models see currency crises as resulting from inconsistent stances on macroeconomic policy (Agénor, Bhandari and Flood 1992; Feridun 2009; Ford, Santoso and Horsewood 2007; Heriqbaldi et al. 2014; Krugman 1979; Sachs, Tornell and Velasco 1996). Second-generation models, however, assert that speculative attacks can give rise to a crisis, even in cases where the stance on monetary and fiscal policy is consistent with the exchange rate regime (Heriqbaldi et al. 2014).

Although theory and policy broadly acknowledge RERM as an important issue, less attention has been paid to the relationship between RERM and currency crises, especially in the context of the Indonesian economy. One question, for example, is whether overvaluation of the rupiah could prelude a currency crisis in Indonesia.

This article calculates the RERM in the rupiah and examines whether misalignment can help to explain episodes of exchange rate volatility. Our research differs from earlier research in two main ways. First, it identifies currency crisis episodes by employing a regime-switching model. Second, it uses the BEER approach in estimating RERM.

## A BRIEF REVIEW OF THE LITERATURE

### The Literature on Currency Crises

Theoretically, views on the causes of currency crises are informed by first-, second- and third-generation models of crises. The first-generation models assert that fundamentally flawed or inconsistent macroeconomic policies are the main sources of speculative attacks, which can result in exchange rate crises (Chui 2003).

The second-generation models assert that speculative attacks can occur even when the fundamental factors that influence internal and external balance are in good condition. According to these models, circumstances in which an exchange rate is overvalued encourage economic actors to expect market corrections. If speculative attacks eventuate, an exchange rate crisis becomes more likely. This is known as a self-fulfilling attack. If the market attacks, a currency crisis occurs; if it does not attack, the crisis does not occur. This has implications for the emergence of multiple equilibria.

An exchange rate crisis, as understood in second-generation models, occurred in several Southeast Asian countries during the AFC. High economic growth, relatively low unemployment and trade balance surplus were present in Asian countries such as Indonesia, Thailand, Malaysia and South Korea before the crisis. However, the crisis still spread very quickly in the region (Ford, Santoso and Horsewood 2007).

In the third-generation models, the emergence of an exchange rate crisis is associated with a crisis in the banking system caused by moral hazard and poor supervision. Large capital inflows to a country encourage excessive lending to the private sector, whose assets tend to become overvalued. This creates bad loans (Goldstein, Kaminsky and Reinhart 2000). These bad loans lead to a drastic decline in the value of assets, which causes panic in the market, resulting in speculative attacks that end with sudden capital outflows, reduced foreign exchange reserves and depreciation pressures.

As the objectives of studies on exchange rate crises have varied, so too have the approaches to research and modelling (Cerra and Saxena 2002; Ford, Santoso and Horsewood 2007; Frankel and Rose 1996; Hernández and Montiel 2003; Kaminsky, Lizondo and Reinhart 1998; Kumah 2011; Liu 2009). Some researchers have used probit or logit models to estimate the probability of a crisis (Cipollini and Kapetanios 2009; Moreno 1999). Some have focused on early warning systems, using arbitrary thresholds as indicators of crises (Abiad 2003; Arias and Erlandsson 2004). Others have studied determinants of crises, using structural approaches such as vector auto regression (VAR), vector error correction (VEC) and regime switching (Feridun 2009; Sachs, Tornell and Velasco 1996).

The emergence of second-generation models has changed how studies of crises are carried out. The characteristics of multiple equilibria and self-fulfilling attacks mean that linear structural models such as VAR and VEC models cannot accommodate changes in the equilibrium. Kaminsky (2003) states that to understand an exchange rate crisis involving multiple equilibria, a regime-switching approach is needed. One of the frontier approaches is Markov regime switching (MRS).

**The Literature on the Behavioural Equilibrium Exchange Rate (BEER)**

The inability of ‘traditional’ approaches such as the PPP approach, monetary models and the theory of uncovered interest parity to explain the behaviour of the exchange rate has led to the development of new approaches. These approaches include the fundamental equilibrium exchange rate (FEER) and behavioural equilibrium exchange rate (BEER) approaches.

FEER, as advocated by Williamson (1994), can be defined as the exchange rate level that is consistent with simultaneous internal and external balance over the medium term (Lòpez-Villavicencio, Mazier and Saadaoui 2012). Internal balance refers to a condition in which the level of output is consistent with a state of full employment and stable inflation. External balance refers to a situation in which the current account balance is not only sustainable (not too far in surplus or deficit) but also in line with the exchange rate movement.

Several studies have used the FEER approach to identify RERM (Jeong, Mazier and Saadaoui 2010; Lòpez-Villavicencio, Mazier and Saadaoui 2012; Saadaoui, Mazier and Aflouk 2013; You and Sarantis 2012). The balance principle of the FEER approach is used for other approaches, such as the natural real exchange rate (NATREX) approach (Stein 1993) and the debt-adjusted real exchange rate (DARER) approach (Fabella 1996).

The FEER approach tends to be normative, especially in identifying the medium-term current account equilibrium. It is difficult to determine the equilibrium level because there is no reference to ideal conditions in the current account, given the macroeconomic differences between countries. The BEER approach builds on the FEER approach by focusing on the actual value of the exchange rate rather than the medium-term equilibrium. The principle of macroeconomic balance is not applied in the BEER approach.

Popularised by Clark and MacDonald (1999), BEER is an empirical approach to estimating the equilibrium exchange rate based on the long-term econometric relationship between the RER and the fundamental factors that influence it. When identifying the fundamental factors, some studies refer to the stock-flow approach developed by Alberola et al. (1999) and Alberola (2003).

The BEER approach typically estimates RERM in two stages. In the first stage, the long-run relationship between the RER and the fundamental factors influencing it is estimated. The equilibrium exchange rate is then obtained using the values of all the explanatory variables in the long-term equation. In the second stage, the RERM is obtained by calculating the difference between the actual and fitted values of the RER. For this study, the BEER approach is best suited to calculating the misalignment of the rupiah in relation to the US dollar.

Several studies have used the BEER approach—combined with the balance-of-payments approach (Frenkel and Mussa 1985) or the Balassa–Samuelson effect (Balassa 1964; Samuelson 1964)—to observe exchange rate behaviour. While the balance-of-payments approach considers that accumulated current account balances can explain the behaviour of the RER, the Balassa–Samuelson hypothesis considers that the differences in productivity growth between countries and between sectors in a country are the major determinants of the behaviour of the RER in the long run. Studies on RERM that use the BEER approach include those by Cheung et al. (2019); Wong (2019); Adu, Litsios and Baimbridge (2019); Allegret and Sallenave (2014); Baak (2012); Couharde and Sallenave (2013); Coulibaly and Gnimassoun (2013); Holtemöller and Mallick (2013); Schröder (2013); and Terra and Valladares (2010). In the Indonesian context, several studies show that BEER estimations are quite robust statistically (Bénassy-Quéré, Béreau and Mignon 2009; Lòpez-Villavicencio, Mazier and Saadaoui 2012).

One research gap in the study of Indonesian RERM concerns whether misalignment is likely to precede an exchange rate crisis. The second-generation model of exchange rate crises suggests that RERM can affect the expectations of economic agents. Real exchange rate overvaluation can lead to downward pressure on the currency, which can result in an exchange rate crisis if a speculative attack is successful. This article studies the relationship between RERM and exchange rate crises in Indonesia.

## METHODOLGY AND DATA

### Vector Error Correction and Regime Switching

This article uses VEC and regime-switching models. The regime-switching model is used to identify episodes of exchange rate crisis in Indonesia during the observation period (1981–2012), while the VEC model is used to estimate the equilibrium RER. Using the VEC model, we can identify the relationship between the RER and its fundamental influences. The estimation results from these two models are used to determine whether RERM always precedes an exchange rate crisis.

Before the VEC model estimation is made, certain econometric procedures need to be employed. First, standard unit root tests need to be done for all the variables to determine the order of integration. If all variables are of the same order, then the second step is to conduct a Johansen test to determine if cointegration relationships exist among the variables.

In the third step, the VEC model is estimated to obtain short-term and long-term coefficients for all the variables. The VEC estimation results are used to calculate the equilibrium RER by obtaining the fitted value. The difference between the actual value and the fitted value is the RERM, where a positive value shows overvaluation and a negative value refers to undervaluation. This misalignment can be categorised as either short-run or long-run RERM (Clark and MacDonald 1999).

**Markov-Switching Autoregressive Methodology**

The most common way to determine the statistical dating of crises is to identify changes in exchange rates, reserves and interest rates; determine the weights for these three variables; and combine these data into an index of exchange market pressure. The next step is to determine the time span of the crisis and then to identify the crisis episode based on whether the index exceeds a selected threshold (Abiad 2003). This approach has several disadvantages. First, the choice of thresholds for identifying a crisis is often arbitrary. For example, some studies use 1.5 × σ as the threshold (Aziz, Caramazza and Salgado 2000), while others use 2.5 × σ (Edison 2003) or 3 × σ (Kaminsky, Lizondo and Reinhart 1998). These different thresholds can lead to different crisis dates. Second, the results from calculating a threshold using a specific time sample indicate that future data affect the identification of past crisis times.[1] Edison (2003) noted that crisis episodes could be 'lost' if a threshold that accommodated events such as the AFC was used. Since the threshold calculation involves an element of standard deviation, a high standard deviation of the RER during the AFC will result in a high threshold. This threshold would cause certain crisis periods, especially those occurring outside the AFC period, to be classified as non-crisis episodes. Third, ad hoc adjustments to the binary crisis variable can cause artificial serial correlation. Fourth, transforming continuous variables into binary variables can cause loss of information, especially regarding the dynamics of the dependent variable.

To avoid these problems, this article uses a regime-switching model to determine the statistical dating of crises, using RER as the main variable. This model has several advantages. First, it does not require a priori dating of crises. The regime-switching model identifies endogenous crisis episodes that are estimated

1. To calculate the standard deviation of the RER, one should involve the whole observation of the RER at each point in time to get a certain threshold, such as 1.5 mean × σ. One can then determine whether the RER in a quarter is below or above the threshold. This means that the future conditions will determine whether this point in time (in the past) is defined as a crisis period.

simultaneously with the forecast probabilities for crises, within the framework of the maximum likelihood estimation. Second, information loss does not occur, because the regime-switching model does not transform continuous dependent variables into binary variables.

The Markov-switching autoregressive model was first developed by Hamilton (1989). He used the fourth-order model, in which the mean of the process switches between two regimes, to classify the US economic cycle into periods of recession or growth.

$$y_t = \mu(s_t) + \left[ \sum_{i=1}^{4} \alpha_i \left( y_{t-i} - \mu(s_{t-i}) \right) \right] + u_t, \; u_t \mid s_t \sim NID\left(0, \sigma^2\right) and\; s_t = 1, 2 \tag{1}$$

Based on equation 1, the two regimes are distinguished in terms of the mean parameter, $\mu$. Krolzig (1998) classifies this as the Markov-switching mean autoregressive model: MSM(2)–AR(4). As the data-generating process is determined by the autoregressive model, the next step in the Markov-switching methodology is to identify the regime-generating process. Under this regime-generating process, the unobserved state, $s_t$, is assumed to follow the first-order Markov process. This means that the current regime, $s_t$, depends only on the regime of one period before, $s_{t-1}$. The transition probability is as follows:

$$P\{s_t = j \mid s_{t-1} = i, s_{t-2} = k, \ldots\} = P\{s_t = j \mid s_{t-1} = i\} = p_{ij}, \; \sum_{j=1}^{M} p_{ij} = 1 \; \forall i, j \in \{1, \ldots, M\} \tag{2}$$

where $p_{ij}$ is the probability of being in regime $j$ in period $t$ if regime $i$ occurs in period $t$-$1$.

The Markovian transition matrix, $P^*$, can be summarised as follows:

$$P^* = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1M} \\ p_{21} & p_{22} & \cdots & p_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ p_{M1} & p_{M2} & \cdots & p_{MM} \end{bmatrix} \tag{3}$$

The univariate exchange rate model is as follows:

$$q_t = \alpha_0(s_t) + \sum_{i=1}^{p_0} \alpha_i q_{t-i} + \varepsilon_t, \; \varepsilon_t \sim IID\left(0, \sigma^2(s_t)\right) \tag{4}$$

Based on the Markov-switching model classification (Krolzig 1998), the above model falls into the Markov-switching intercept autoregressive heteroscedastic specification. This model is used to identify states of stability or volatility in the

TABLE 1 *Unit Root Test*

| | Level | | First difference | |
|---|---|---|---|---|
| | Adjusted *t*-statistic | Probability | Adjusted *t*-statistic | Probability |
| *q* | –3.173 | 0.0017 | –6.632 | 0.0000 |
| *f* | 0.318 | 0.9986 | –3.674 | 0.0276 |
| *a* | 0.382 | 0.9815 | –3.076 | 0.0310 |

*Notes: q* is the real exchange rate; *f* is the ratio of net foreign assets to GDP; and *a* is the relative sectoral productivity differential. All series are non-stationary at level, except for *q*; at first difference, all series are stationary.

exchange rate. A state of volatility represents a crisis episode. The autoregressive model is employed as a data-generating process to accommodate the inertia factor, while the heteroscedastic specification is used to allow the disturbances to be different in each state.

### Data

The empirical analysis of the RER of the rupiah uses quarterly data from the first quarter of 1980 to the fourth quarter of 2012. All data are from the IMF's International Financial Statistics data set or from Statistics Indonesia (BPS). Three variables are considered in the estimation: the RER (*q*); the ratio of net foreign assets to GDP (*f*); and the relative sectoral productivity differential (*a*).

The RER is calculated in stages. First, the natural logarithm of the average exchange rate of rupiah to the US dollar is calculated and then multiplied by the ratio of the US consumer price index (CPI) to the Indonesian CPI. The net foreign assets of Indonesia's central bank are calculated as the difference between the bank's foreign assets and its liabilities to non-residents. This series is expressed as a share of GDP. To measure relative sectoral productivity, this article uses average labour productivity as a proxy, calculated as the ratio of GDP to total employment.

An augmented Dickey–Fuller test is conducted on all series to test for a unit root. Table 1 presents the results of the unit root test, which indicates that at a critical value of 5% all of the series are non-stationary at level, except for *q*.

Table 2 shows the results of the Johansen cointegration test. The results from the maximum eigenvalue test as well as the trace test show at least one cointegration relationship in the chosen set of variables.

## RESULTS

### Equilibrium Exchange Rate and Misalignment

*Long-run and Short-run Estimations*

Since the $\lambda_{trace}$ and $\lambda_{max}$ statistics indicate the presence of one cointegrating vector among the variables, the short- and long-run equations can be estimated. The estimation results are shown in table 3.

In the long-run equation, the *t*-statistics show that all of the estimates are significantly different from zero at the 5% significance level. While the estimated

TABLE 2 *Johansen Cointegration Test*

| | | Trace test | | Maximum eigenvalue test | |
|---|---|---|---|---|---|
| Rank | Eigenvalue | λtrace | *p*-value | λmax | *p*-value |
| $r = 0$ | 0.179 | 30.29 | 0.04** | 25.04 | 0.01** |
| $r \leq 1$ | 0.004 | 5.25 | 0.78 | 5.02 | 0.74 |
| $r \leq 2$ | 0.002 | 0.22 | 0.63 | 0.23 | 0.64 |

*Notes:* ** signifies the rejection of the null hypothesis at the 5% critical value; *r* refers to the cointegration relationship between variables or series.

TABLE 3 *Estimation of the Short- and Long-run Coefficients*

| | Long run | | | Short run | |
|---|---|---|---|---|---|
| | Coefficient | *t*-statistic | | Coefficient | *t*-statistic |
| *f* | –99.293000 | –5.76 | $ect_{t-1}$ | –0.001 | –4.27 |
| *a* | 00.000001 | 2.14 | $q_{t-1}$ | 0.272 | 2.89 |
| *c* | 94.147000 | | $q_{t-2}$ | –0.103 | –1.19 |
| | | | $\Delta f_{t-1}$ | 0.160 | 2.98 |
| | | | $\Delta f_{t-2}$ | 0.017 | 0.34 |
| | | | $\Delta a_{t-1}$ | 6.6e-08 | 0.87 |
| | | | $\Delta a_{t-2}$ | –8.57e-08 | –1.12 |
| | | | *c* | –0.072 | –3.89 |

*Notes: f* is net foreign assets; *a* is labour productivity; and *c* is the intercept. All coefficients in the long-run equation are significantly different from zero (at the 5% significance level).

coefficient value for labour productivity (*a*) has a positive sign, as predicted by the Balassa–Samuelson hypothesis, net foreign assets (*f*) appear to have a negative relationship with the RER. This negative relationship is consistent with previous findings (Alberola and Navia 2008; Alper and Civcir 2012).

The results also show that the adjustment coefficient, or the coefficient of the error correction term, is estimated as –0.001 and its *t*-statistic as –4.27, indicating that it is significant at the 1% level. This result also confirms the existence of a cointegrating vector, as was indicated by the Johansen cointegration test.

*Measuring Misalignment*

The behavioural equilibrium exchange rate (BEER)—or the long-run relationship between the RER, net foreign assets and productivity—is illustrated in figure 1, along with the RER. The current misalignments are computed using the difference between the BEER and the RER after they are estimated using a Hodrick–Prescott filter—similar methodology was used by Baffes, O'Connell and Elbadawi (1999);

FIGURE 1 *Long-run BEER and Actual RER*

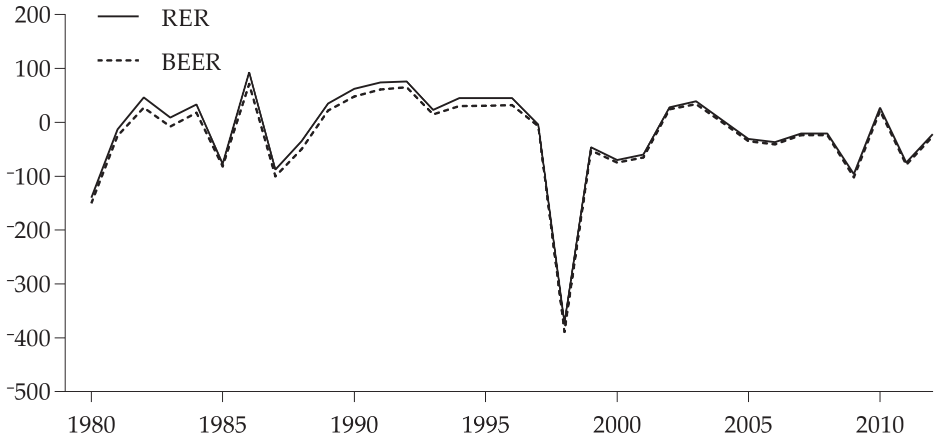
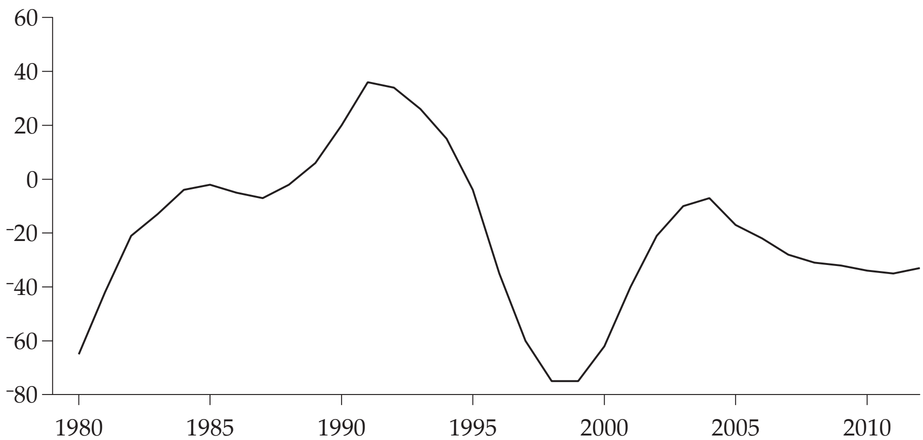



FIGURE 2 *Degree of Misalignment*




Clark and MacDonald (1999); Iossifov and Loukoianova (2007); and Dufrenot and Yehoue (2005). The current misalignments are illustrated in figures 1 and 2.

The $y$-axes show the sum of squared deviations of the RER when compared with its long-run value (BEER). It appears that although the BEER and RER move in the same pattern, there is a gap between them at any point in time. This gap is called a cyclical component or misalignment (deviation of the RER from the BEER).

**Estimation of Exchange Rate Crises**

*Diagnostic Tests*

The results of the diagnostic tests are shown in table 4. An autoregressive conditional heteroscedasticity (ARCH) test is conducted to assess the existence of heteroscedasticity in the residual. The null hypothesis is that the residual exhibits

TABLE 4 *Diagnostic Tests for the Regime-Switching Model*

| Type of test | |
|---|---|
| No. of observations | 128 |
| No. of parameters | 11 |
| Akaike information criterion | –1.28030205 |
| Log likelihood test | 92.93933110 |
| Linearity LR test ($Chi^2(17)$) | 110.93000000 |
| | (0.00000000)* |
| Normality test ($Chi^2(2)$) | 2.53180000 |
| | (0.28200000) |
| ARCH 1-1 test: $F(1,115)$ | 1.37900000 |
| | (0.24270000) |
| Portmanteau (12): Chi^2(11) | 9.00310000 |
| | (0.62160000) |

*Note:* * The LR test of linearity rejects the linear model, which means that the regime-switching specification is better in explaining the movement of the real exchange rate in the long run.

no heteroscedasticity. The ARCH statistic (with this null hypothesis) shows that the regime-switching model is sufficient to capture the ARCH process in RER movement. There is no evidence of heteroscedasticity. The portmanteau test confirms that the null hypothesis cannot be rejected, which means that there is no autocorrelation. The residual is also tested using the normality test developed by Doornik and Hansen (2008). The test shows that the null hypothesis (normal distribution) cannot be rejected.

*Regime Characterisation*

A diagnostic test was also used to assess the robustness of the regime-switching model. A likelihood ratio test was conducted to compare the linear model with the regime-switching model. The null hypothesis of the test was that the linear model was the appropriate specification, while the alternative hypothesis was that the regime-switching model was more representative. The chi-square value shows that the null hypothesis can be rejected, as the regime-switching specification fits the data better than the linear specification.

The regime-switching estimates show that the period of interest can be divided into two types of exchange rate regime: stable and volatile. Probability smoothing shows that periods of volatility rarely occur. These periods are concentrated in the middle of the sample period—in mid-1980, mid-1997, 1998, early 1999 and early 2001. The volatility in 1997 coincided with the AFC, while the high pressures in 2001 corresponded to the Latin America debt crisis. Periods of stability dominate the picture and tend to last longer than periods of volatility. Furthermore, the estimation result for the endogenous regime, calculated by employing the Markov-switching model, shows that the model can accurately predict volatile and stable periods, especially during the financial crisis of the late 1990s.

*Regime Shift*
Estimated transition probabilities are presented in the matrix *P* below:

$$P = \begin{bmatrix} 0.50 & 0.18 \\ 0.49 & 0.82 \end{bmatrix}$$

The estimated transition probabilities in the matrix indicate that neither stability nor volatility is permanent, but stability is more persistent. For example, there is a 50% probability of remaining in a state of volatility but an 82% probability of remaining in a state of stability. It is therefore much harder to transition out of a stable state, with a probability of 18%, than it is to transition from volatility to stability (49%).

Moreover, the estimated ergodic probabilities (the probabilities derived from the whole random sample process) indicate that Indonesia experienced periods of stability 74% of the time, with an average duration of 5.28 quarters, and periods of volatility 26% of the time, with an average duration of 1.94 quarters (table 5). Thus, there were only a few episodes of currency crisis in Indonesia during 1980–2012. In addition, table 5 shows that the estimated model can accurately detect the currency crisis in late 1997. This is indicated not only by a high RER but also by a high average probability. Therefore, the inferred probabilities of volatility are highly useful for understanding the Asian currency crisis of 1997.

*Autoregressive Model Estimation Results*
Table 6 shows the results of the regime-switching autoregressive model estimation. The intercept is characterised as regime-dependent. The parameter estimates on the lag of the RER indicate that the current value of the RER is strongly influenced by its lags. In the case of lag one and lag two of the RER, the regression results show that they are also regime-dependent. This suggests inertia, where the RER in the previous period influences the expectations of economic agents regarding the RER at the present time. The results also show that the degree of uncertainty in the RER is higher during periods of volatility than during periods of stability, as shown by the variance of the volatile state ($\Sigma(0)$), which is 5.8 times higher than variance of the stable state ($\Sigma(1)$).

## RERM AND EXCHANGE RATE CRISES

Table 7 summarises the relationship between RERM and exchange rate crises in Indonesia. From the table, it can be seen that of the 17 episodes of crisis, 10 were preceded by a quarter of high RERM, compared with the five-year average of misalignment.

The worst currency crisis in Indonesia occured during the late 1990s. Based on the regime classification shown in table 7, it started in the fourth quarter of 1997 and ended in the first quarter of 1999. Under further review, the high pressure on the rupiah can be seen to have begun in 1996, when the rupiah was misaligned by about 23%. The degree of misalignment then grew to reach 68% in the third quarter of 1997, before the year ended with an exchange rate crisis in the fourth quarter.

TABLE 5 *Currency Crisis Episodes*

| | No. of quarters | Average probability |
|---|---|---|
| Regime 0: volatility | | |
| 1981 (Q3)–1981 (Q3) | 1 | 0.886 |
| 1982 (Q1)–1982 (Q2) | 2 | 1.000 |
| 1982 (Q4)–1984 (Q1) | 6 | 0.986 |
| 1985 (Q2)–1985 (Q3) | 2 | 0.742 |
| 1986 (Q1)–1986 (Q1) | 1 | 0.987 |
| 1987 (Q4)–1987 (Q4) | 1 | 1.000 |
| 1990 (Q2)–1990 (Q3) | 2 | 0.752 |
| 1991 (Q2)–1991 (Q3) | 2 | 0.935 |
| 1993 (Q1)–1993 (Q1) | 1 | 1.000 |
| 1994 (Q1)–1994 (Q1) | 1 | 0.988 |
| 1994 (Q3)–1994 (Q3) | 1 | 0.541 |
| 1995 (Q1)–1995 (Q2) | 2 | 0.603 |
| 1996 (Q1)–1996 (Q2) | 2 | 0.890 |
| 1997 (Q4)–1999 (Q1) | 6 | 0.946 |
| 2001 (Q3)–2001 (Q3) | 1 | 1.000 |
| 2002 (Q1)–2002 (Q1) | 1 | 0.986 |
| 2005 (Q4)–2005 (Q4) | 1 | |
| Total: 33 quarters (25.78%) with average duration of 1.94 quarters | | |
| Regime 1: stability | | |
| 1981 (Q1)–1981 (Q2) | 2 | 0.866 |
| 1981 (Q4)–1981 (Q4) | 1 | 0.655 |
| 1982 (Q3)–1982 (Q3) | 1 | 0.683 |
| 1984 (Q2)–1985 (Q1) | 4 | 0.873 |
| 1985 (Q4)–1985 (Q4) | 1 | 0.565 |
| 1986 (Q2)–1987 (Q3) | 6 | 0.891 |
| 1988 (Q1)–1990 (Q1) | 9 | 0.937 |
| 1990 (Q4)–1991 (Q1) | 2 | 0.861 |
| 1991 (Q4)–1992 (Q4) | 5 | 0.902 |
| 1993 (Q2)–1993 (Q4) | 3 | 0.873 |
| 1994 (Q2)–1994 (Q2) | 1 | 0.807 |
| 1994 (Q4)–1994 (Q4) | 1 | 0.592 |
| 1995 (Q3)–1995 (Q4) | 2 | 0.851 |
| 1996 (Q3)–1997 (Q3) | 5 | 0.907 |
| 1999 (Q2)–2001 (Q2) | 9 | 0.928 |
| 2001 (Q4)–2001 (Q4) | 1 | 0.761 |
| 2002 (Q2)–2005 (Q3) | 14 | 0.969 |
| 2006 (Q1)–2012 (Q4) | 28 | 0.976 |
| Total: 95 quarters (74.22%) with average duration of 5.28 quarters | | |

*Notes:* We analysed a total of 128 quarters in this study. Our estimation shows that Indonesia experienced stability in 74.22% of all quarters and volatility in 25.78% of quarters. The duration of volatility varied from 1 to 6 quarters and the longest episode of stability was 28 quarters. The average probability that an episode will be volatile or stable varies between 0 (low probability) and 1 (high probability).

TABLE 6 *Estimation Results*

| | Coefficient | *t*-value | *t*-probability |
|---|---|---|---|
| **Regime-dependent intercept** | | | |
| C(0) | –0.3772430 | –1.66 | 0.099 |
| C(1) | –0.0303671 | –2.46 | 0.015 |
| **Coefficient** | | | |
| RER_3 | 0.1612830 | 2.22 | 0.028 |
| RER_1(0) | 1.3534300 | 8.13 | 0.000 |
| RER_1(1) | 1.2539400 | 19.1 | 0.000 |
| RER_2(0) | –0.4971710 | –2.50 | 0.014 |
| RER_2(1) | –0.4150250 | –5.16 | 0.000 |
| Σ(0) | 0.2891550 | 7.28 | 0.000 |
| Σ(1) | 0.0513628 | 5.00 | 0.000 |
| $p$_{0\|0} | 0.5015110 | 3.00 | 0.000 |
| $p$_{0\|1} | 0.1828800 | 3.12 | 0.002 |

*Notes:* C(0) shows the intercept in the volatile state; C(1) refers to the intercept in the stable state. Both coefficients are statistically significant. This confirms that the autoregressive regime-switching specification is robust. The specification is supported by the coefficients of the lag of the RER in both regimes. For example, the coefficient of the first lag of the RER (RER_1) is statistically significant, in the case of both the volatile state (RER_1(0)) and the stable state (RER_1(0)). Similar conclusions apply to the coefficient of RER_2. Σ shows the variance in each state; $p$ shows the transition probability between states.

TABLE 7 *Relationship between Crisis Episodes and RERM*

| Period | Duration of crisis (quarters) | Probability of crisis | Degree of misalignment one quarter before (%) | Five-year average of misalignment (%) |
|---|---|---|---|---|
| 1981 (Q3)–1981 (Q3) | 1 | 0.886 | 35.26* | 20.13 |
| 1982 (Q1)–1982 (Q2) | 2 | 1.000 | 25.93* | |
| 1982 (Q4)–1984 (Q1) | 6 | 0.986 | 15.45 | |
| 1985 (Q2)–1985 (Q3) | 2 | 0.742 | 3.07 | |
| 1986 (Q1)–1986 (Q1) | 1 | 0.987 | 3.39 | 6.74 |
| 1987 (Q4)–1987 (Q4) | 1 | 1.000 | 5.73 | |
| 1990 (Q2)–1990 (Q3) | 2 | 0.752 | 22.23* | |
| 1991 (Q2)–1991 (Q3) | 2 | 0.935 | 30.39* | 15.99 |
| 1993 (Q1)–1993 (Q1) | 1 | 1.000 | 28.39* | |
| 1994 (Q1)–1994 (Q1) | 1 | 0.988 | 18.49* | |
| 1994 (Q3)–1994 (Q3) | 1 | 0.541 | 10.99 | |
| 1995 (Q1)–1995 (Q2) | 2 | 0.603 | 1.59 | |
| 1996 (Q1)–1996 (Q2) | 2 | 0.890 | 22.74 | 59.49 |
| 1997 (Q4)–1999 (Q1) | 6 | 0.946 | 67.60* | |
| 2001 (Q3)–2001 (Q3) | 1 | 1.000 | 32.12* | 15.58 |
| 2002 (Q1)–2002 (Q1) | 1 | 0.986 | 22.67* | |
| 2005 (Q4)–2005 (Q4) | 1 | | 16.87* | |

*Notes:* * Degree of misalignment exceeds the five-year average.

## CONCLUSIONS

This article has measured the RERM of the rupiah and assessed its connection with the currency crises in Indonesia between 1980 and 2012. The misalignment was estimated using a BEER approach, while the currency crisis episodes were estimated using a regime-switching model.

We find that currency crisis episodes in Indonesia are almost always preceded by an overvalued exchange rate. Several episodes of crisis were preceded by a high misalignment of the rupiah compared with the US dollar, especially during the AFC in late 1997. Our calculations show that 10 of 17 currency crises were preceded by a highly misaligned rupiah. Conversely, low misalignment was strongly associated with stable exchange rate episodes, as shown after 2005.

In terms of economic policy, our findings suggest several important recommendations for Indonesia. First, the government should ensure realignment and consistency of macroeconomic policies, such as fiscal and monetary policies. This will help to encourage clear signals in the financial market that would reduce speculation. Second, the government should guarantee the sustainability of the balance of payments in the long run. This means that Indonesia must be able to increase the growth of exports from the manufacturing industry to compensate for the decline in commodity exports due to declining world prices, and to reduce its dependence on short-term capital flows to cover the current account deficit. Third, Indonesia will need to improve the supply side of the economy to increase economic growth and economic diversification. This will require investing in the infrastructure sector, both economically and socially, to reduce logistical and transportation costs and increase labour productivity. Improving the supply side will also require deregulation and de-bureaucratisation to encourage direct investment.

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