Models for financial crisis detection in Indonesia based on M1, M2 per foreign exchange reverse, and M2 multiplier indicators

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Abstract. Indonesia has been hit by financial crisis in the middle of 1997. The financial crisis that has occurred gives a severe impact to the economy of Indonesia resulting the needs for a detection system of financial crisis. Crisis can be detected based on several indicators such as M1, M2 per foreign exchange reserves, and M2 multiplier. These three indicators can affect the exchange rate stability and may further affect the financial stability so that it can be one of the causes of the financial crisis. This research aims to determine the appropriate model that can detect the financial crisis in Indonesia. Markov switching is an alternative model that can be approach and used often for detecting financial crisis. We can determine the combination of volatility and Markov switching model with AR and volatility model are determined first. The results of this research are that M1 can be modelled by SWARCH (3, 1) while M2 per foreign research exchange reserves and M2 multiplier can be modelled by SWARCH(3,2).

1. Introduction
A country will face the financial crisis if the country’s financial system is disrupted then the system may not function efficiently. Financial crisis consists 3 types, one of them is currency crisis. Currency crisis is a situation that there are doubts whether the central bank of a country has sufficient foreign exchange reserves to maintain a country’s exchange rate. Currency crisis often leads to the weakening of currency values as a sign of the financial crisis. Financial crisis that hit Asia on the middle of 1997 is begun by the falling of Baht Thailand. The crisis is also happened in Indonesia that has serious effect on the economic stability. After the financial crisis in 1997, International Monetary Fund (IMF) stated the importance of financial crisis detection system [1]. Detection system is a development model by observing the selected economic indicators. According to Kaminsky et al. [2], there are 15 indicators that can be used to detect the crisis; three of them are M1, M2 per foreign exchange reserves, and M2 multiplier. These three indicators can affect the exchange rate stability and may further affect the financial stability so that it can be one of the causes of the financial crisis. Monthly data of M1, M2 per foreign exchange reserves, and M2 multiplier are time series data that are indicated having heteroscedasticity and condition changes. To overcome this condition, SWARCH model is introduced by Hamilton and Susmel [3] on 1994. Some researchers have conducted research
on the detection of financial crisis that occurred in a country using the combination of volatility and Markov switching models. Chang et al. [4] used SWARCH model to identify the stock volatility foreign and global financial crisis in Korea based on real exchange rate on the period of January 4th 2000 to March 31st 2010. In this study, it will determine the appropriate model for detecting financial crisis in Indonesia based on M1, M2 per foreign exchange reserves, and M2 Multiplier.

2. Experimental Details

2.1. Autoregressive (AR) Model

AR model is usually used as a linear time series models. AR model has an order called p that can be determined by partial autocorrelation function (PACF) plot. Model AR (p) can be written as

\[ r_t = \phi_1 r_{t-1} + \phi_2 r_{t-2} + \cdots + \phi_p r_{t-p} + \epsilon_t, \]

(1)

Where \( r_t \) log return series is at time-t, \( \phi_p \) is parameter of AR model (Tsay [7]).

2.2. Volatility Model

2.2.1. ARCH Model. Residue of AR model containing heteroscedasticity effect can be modelled using a volatility model where the residue can be expressed as

\[ \epsilon_t = \sigma_t \epsilon_t \quad \text{for} \quad \epsilon_t \sim N(0,1) \quad \text{and} \quad \epsilon_t | F_{t-1} \sim N(0, \sigma_t^2), \]

(2)

Where \( F_{t-1} \) is set of all the information in time, \( t - 1 \). Model ARCH (m) can be written as

\[ \sigma_t^2 = \alpha_0 + \sum_{i=1}^{m} \alpha_i \epsilon_{t-i}^2, \]

(3)

Where m is the order of ARCH model, \( \alpha_0 \) is a constant, \( \alpha_i \) is a parameter of the ARCH model, and \( \sigma_t^2 \) is the residual variance to the time-t \([5]\).

2.2.2. GARCH Model. High order of ARCH model can be overcome using a GARCH(m, s) which can be written as

\[ \sigma_t^2 = \alpha_0 + \sum_{i=1}^{m} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{s} \beta_j \sigma_{t-j}^2, \]

(4)

Where \( \beta_j \) is parameter of GARCH model \([5]\).

2.2.3. EGARCH Model. Leverage problem on GARCH effect can be overcome by the model EGARCH (m, s) which can be written as

\[ \ln \sigma_t^2 = \alpha_0 + \sum_{i=1}^{m} \alpha_i \left( \frac{\epsilon_{t-i}}{\sigma_{t-i}} \right)^{2} + \sum_{i=1}^{s} \gamma_i \epsilon_{t-i} \left( \frac{\sigma_{t-i}}{\epsilon_{t-i}} \right) + \sum_{j=1}^{s} \beta_j \ln \sigma_{t-j}^2, \]

(5)

Where \( \gamma \) is a parameter Leverage effect \([5]\).

2.3. SWARCH Model

According to Hamilton and Susmel \([3]\), Markov switching model for the average conditional can be written as

\[ r_t = \mu_{s_t} + \hat{\epsilon}_t \]

(6)

where \( r_t \) is the log return at time \( t \), \( \hat{\epsilon}_t \) is following the process of AR (p) with an average of zero, and \( \mu_{s_t} \) is the average of state at time \( t \). While SWARCH model can be written as

\[ r_t = \mu_{s_t} + a_r, \quad a_r = \sigma_r \epsilon_t \]

(7)

\[ \sigma_{t,s_t}^2 = \alpha_{0,s_t} + \sum_{i=1}^{m} \alpha_{i,s_t} \epsilon_i^{2}, \]

(8)

Where \( \mu_{s_t} \) is the conditional average on a state and \( \sigma_{t,s_t}^2 \) is a variance of residue in a state at time \( t \).

2.4. Smoothed Probability

According to Kuan \([6]\), smoothed probability value is defined as
\[ P(s_t = i|Z^T; \theta) = \sum_{a} P(s_{t+1} = i|Z^T; \theta)P(s_t = i|s_{t+1} = i, Z^T; \theta) \]  

(9)

Based on Hermosillo and Hesse [7] while the probability of a low-volatility regime has decreased under 0.4 means that the indicator is stable, the probability of a medium-volatility regime (though declining) still remains at around 0.4-0.6 means that the indicators are prone condition, and if the probability of a high-volatility regime has increased to over 0.6 means that the indicators on a crisis condition.

3. Method
The research used data of M1, M2 per foreign exchange reserves, and M2 multiplier from January 1990 to December 2015 that were obtained from Bank Indonesia and World Bank. The steps of the research are as follows. 1) Create a data plot and then test the stationary of data. If the data are not stationary then transform the data using log return. 2) Make a plot of partial autocorrelation function (PACF) of log return data then form the AR model. 3) Test the effects of heteroscedasticity on the residue of AR model using Lagrange multiplier test. 4) If there is the effects of heteroscedasticity on the residue of AR model, estimates the parameter of ARCH model. 5) Establish the combination of volatility and Markov switching models with the assumption of a three states. 6) Determine the conditions of the crisis based on the smoothed probability.

4. Results and discussion
4.1. Data
Plot data of M1, M2 per foreign exchange reserves, and M2 multiplier can be seen in Figure 1.

![Figure 1](image1.png)

Figure 1. (a) M1 Indicator (b) M2 Per Foreign Exchange Reserves Indicator (c) M2 Multiplier Indicator

Figure 1 indicates that the data are not stationary in mean and variance. It is proven by ADF test with probability value for each data is 0.99, 0.5091, and 0.09072 respectively. Then, the data were transformed using log return. Based on ADF test for log return data, the probability values are 0.01 where the probability values are less than \( \alpha = 0.05 \) so it can be concluded that the data are stationary. The next step is to form an AR model.

4.2. Establishment of AR Model
AR model can be identified from PACF plot of log return data. Based on M1, it was obtained an AR (1) model i.e. \( r_t = -0.179548 + 0.015227 + \alpha_t \). Meanwhile for M2 per foreign exchange, it was obtained an AR (1) model i.e. \( r_t = 0.15626r_{t-1} + \alpha_t \) and for M2 multiplier, it was obtained an AR (2) model i.e. \( r_t = -0.38173r_{t-1} - 0.21282r_{t-2} + \alpha_t \).

Based on Lagrange multiplier test on the residue of model, it was obtained the each probability of M1, M2 per foreign exchange reserves, and M2 multiplier as 2.853 \( \times \times \times \times 10^{-6} \), 5.317 \( \times \times \times \times 10^{-6} \), and 0.00575 respectively. All of probability values are less than 0.05, it means that there are the effect of heteroscedasticity on the residue. To overcome this condition, it was used ARCH model

4.3. Establishment of ARCH Model
For M1, the best model is ARCH (1) which can be written as
\[ \sigma_t^2 = 8.483 \times 10^{-4} + 0.2128 \alpha_{t-1}^2. \]
Meanwhile, the best model for M2 per foreign exchange reserves is ARCH (2) which can be written as
\[ \sigma_t^2 = 0.0009494 + 1.1485267 \sigma_{t-1}^2 + 0.1648690 \sigma_{t-2}^2, \]
and the best model for M2 multiplier is ARCH(2) which can be written as
\[ \sigma_t^2 = 0.0020978 + 0.1821516 \sigma_{t-1}^2 + 0.0696154 \sigma_{t-1}^2. \]

Ljung-Box test results the probability values each of M1, M2 per foreign, and M2 multiplier as 0.4703, 0.6893, and 0.7382 respectively. These values are more than 0.05, so it can be concluded that the residue of ARCH models do not contain autocorrelation. Based on the Kolmogorov Smirnov test, the probability values of each indicators are 0.9255, 0.947, and 0.9625. These values are more than 0.05, so it can be concluded that the residue of ARCH models are normally distributed. Based on Lagrange multiplier test, the probability values of each indicators are 0.1612, 0.7343, and 0.8241. These values are more than 0.05, so it can be concluded that the residue of ARCH models do not contain the effect of heteroscedasticity. Based on these tests, it can be concluded that the ARCH models are the appropriate models. To model the changes of condition, it is used Markov switching model.

4.4. Establishment of SWARCH Model

The condition changes in Markov switching model are called states. The condition of intended in this research is low, medium and high volatility. States can be formed by transition probability. The transition probability can be formed as a matrix notation and usually called as matrix of transition probability, for M1 indicator transition probability matrix can be written as the following

\[ P_1 = \begin{bmatrix}
0.07676399 & 0.28453180 & 0.6986911025 \\
0.38344527 & 0.53779923 & 0.3011849593 \\
0.53979073 & 0.17766900 & 0.0001239382 \\
\end{bmatrix}. \]

Based on \( P_1 \) obtained that the probability to survive on low volatility state is 0.07676399. Probability changes from low to medium volatility state is 0.28453180. Probability changes from low to high volatility state is 0.6986911025. Probability changes from medium to low volatility state is 0.38344527. Probability survive in medium volatility state is 0.53779923. As well as the probability changes from medium to high volatility state is 0.3011849593. Probability changes from high to low volatility state is 0.53979073. Probability changes state from high to medium volatility state is 0.17766900. Probability survive in high volatility state is 0.0001239382. The matrix of transition probability for M2 per foreign exchange reserves and M2 multiplier stated in \( P_2 \) and \( P_3 \) as follows

\[ P_2 = \begin{bmatrix}
0.3296875 & 0.29289357 & 0.5331779 \\
0.5149849 & 0.67176968 & 0.1895393 \\
0.1553276 & 0.03533675 & 0.2772827 \\
\end{bmatrix} \]

and

\[ P_3 = \begin{bmatrix}
0.0004510231 & 0.4594832 & 0.3716147 \\
0.7649777181 & 0.4446863 & 0.2884468 \\
0.2345712588 & 0.0958305 & 0.3399384 \\
\end{bmatrix}. \]

Based on \( P_1 \), the parameter estimates of SWARCH(3,1) model for M1 can be written as follows

\[
\begin{aligned}
\mu_t &= \begin{cases}
0.029641, \text{state 1} \\
0.013654, \text{state 2} \\
-0.009820, \text{state 3}
\end{cases}, \\
\sigma_t^2 &= \begin{cases}
0.000077 + 0.359388 a_{t-1}^2, \text{state 1} \\
0.000192 + 0.019840 a_{t-1}^2, \text{state 2} \\
0.000008 + 0.280558 a_{t-1}^2, \text{state 3}
\end{cases},
\end{aligned}
\]
Based on $P_3$, the parameter estimates of SWARCH(3,2) model for M2 per foreign exchange reserves can be written as follows

$$\begin{align*}
\mu_t & \begin{cases} -0.018669, & \text{state 1,} \\ 0.001943, & \text{state 2,} \\ -0.022587, & \text{state 3,} \end{cases} \\
\sigma_t^2 & \begin{cases} 0.00000004 + 0.02538471a_{t-1}^2 + 0.04343017a_{t-2}^2, & \text{state 1,} \\ 0.00000003 + 0.00526216a_{t-1}^2 + 0.00178388a_{t-2}^2, & \text{state 2,} \\ 0.00006397 + 0.30972356a_{t-1}^2 + 0.05636983a_{t-2}^2, & \text{state 3.} \end{cases}
\end{align*}$$

Based on $P_3$, the parameter estimates of SWARCH(3,2) model for M2 multiplier can be written as follows

$$\begin{align*}
\mu_t & \begin{cases} 0.01936, & \text{state 1,} \\ -0.00300, & \text{state 2,} \\ -0.02996, & \text{state 3,} \end{cases} \\
\sigma_t^2 & \begin{cases} 0.000047 + 0.059475a_{t-1}^2 + 0.078826a_{t-2}^2, & \text{state 1,} \\ 0.000001 + 0.116317a_{t-1}^2 + 0.015176a_{t-2}^2, & \text{state 2,} \\ 0.000116 + 0.169118a_{t-1}^2 + 0.000192a_{t-2}^2, & \text{state 3.} \end{cases}
\end{align*}$$

where $\mu_t$ and $\sigma_t^2$ is the conditional mean and variance of SWARCH models.

4.5. Crisis Detection

Crisis detection using SWARCH(3,1) and SWARCH(3,2) can be seen by value of smoothed probability. Figure 2 show the smoothed probability plots of SWARCH (3.1) modeled by M1 and SWARCH(3,2) modeled by M2 per foreign exchange reserves and M2 multiplier.

![Figure 2](image_url)

**Figure 2.** (a) Smoothed Probability of M1 (b) Smoothed Probability of M2 per Foreign Exchange Reserves (c) Smoothed Probability of M2 Multiplier.

Crisis condition signed with value of smoothed probability that greater than 0.6 for each indicators as shown in Figure 2. Table 1 showed the crisis period that has been detected on 1997, 1998, and 2008 based on the value of the smoothed probability that greater than 0.6 by M1, M2 per foreign exchange reserves, and M2 multiplier.
Table 1. The crisis detection based on smoothed probability

| Year | M1          | M2 per Foreign Exchange Reserves | M2 Multiplier          |
|------|-------------|----------------------------------|-----------------------|
| 1997 | July        | September                        | August, October,      |
|      |             |                                  | December              |
| 1998 | April, July | January, May, June, October      | March, June           |
| 2008 | January, October, December | November | September, October |

Table 1 showed that smoothed probability for M1, M2 per foreign exchange reserves, and M2 multiplier can detect the financial crisis that hit Indonesia in 1997, 1998, and 2008.

5. Conclusion
The results of this research are M1 can be modelled by SWARCH(3,1) while M2 per foreign exchange reserves and M2 multiplier can be modelled by SWARCH(3,2) that can be used to detect the financial crisis in Indonesia in 1997, 1998, and 2008.

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