The models for financial crisis detection in Indonesia based on import, export, and foreign exchange reserves

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Abstract. The severity of the financial crisis that occurred in Indonesia required an early warning system of financial crisis. The financial crisis in Indonesia can be detected based on imports, exports, and foreign exchange reserves. The purpose of the research is to determine an appropriate model to detect the financial crisis in Indonesia based on imports, exports, and foreign exchange reserves. Markov switching is an alternative framework for the approach often used in financial crisis detection. Combined volatility and Markov switching model with three states assumptions can be established if an AR and volatility models have been obtained. Imports, exports, and foreign exchange reserves data from January 1990 to December 2016 have the heteroscedasticity effect so that an ARCH model is used as a volatility model. Research shows that SWARCH(3.1) model is an appropriate model for detecting financial crisis in Indonesia based on imports, exports, and foreign exchange reserves.

1. Introduction

Economic crisis ever hit the countries in Asia, one of Indonesia in 1997-1998. The fall of Thai baht exchange rate in the middle of July 1997 was the beginning of the financial crisis in several countries in Asia, one of them is Indonesia. The IMF stated that a device for early detection systems is needed to detect crisis as early as possible. The early detection system is an order of delivery of predicted information to a threat community before the occurrence of an event that can cause a recipe so as to warn the recipient of information can act immediately according to the conditions and situations.

SWARCH model or Markov switching ARCH model is combined volatility and Markov switching model with ARCH model is a volatility model. Kaminsky et al. [4] states that Markov switching is an alternative framework for the approach often used in early detection systems for economic crisis. There are 15 indicators of crisis including foreign exchange reserves, exports, and imports. According to Pradini and Raharjo [6] exports and imports have an important role in the economy of the country because it can affect the amount of foreign exchange. The detection of the financial crisis in Indonesia has been developed by Hermawan [2] based on the indicator of the amount of import value. From the result of these research the appropriate model to detect the financial crisis in Indonesia based on the import value indicator of SWARCH (2.1) and SWARCH (3.1). This study determines the appropriate model for detecting financial crises in Indonesia based on indicators of import, export, and foreign exchange reserve.
2. Experimental details

2.1. Autoregressive Model

Autoregressive model or AR(p) can be written as

\[ r_t = \phi_0 + \phi_1 r_{t-1} + \phi_2 r_{t-2} + \cdots + \phi_p r_{t-p} + \alpha_t, \tag{1} \]

with \( r_t \) is a transformation data, \( \phi_0 \) is a constant, and \( \phi_p \) are parameter of the autoregressive model (Tsay [7]).

2.2 Volatility Model

Residue of AR model containing heteroscedasticity effect can be modelled using a volatility model.

2.2.1 ARCH Model. Model ARCH(m) can be written as

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

where \( \sigma_t^2 \) is the residual variance to the period-\( t \), \( \alpha_0 \) is a constant, \( \alpha_i \) are parameter of the ARCH model, and \( m \) is an order of ARCH (Tsay [7]).

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

\[ \sigma_t^2 = \alpha_0 + \sum_{i=1}^{m} \alpha_i \sigma_{t-i}^2 + \sum_{j=1}^{s} \beta_j \sigma_{t-j}^2 \tag{3} \]

where \( \beta_j \) are parameters of GARCH model (Tsay [7]).

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

\[ \ln \sigma_t^2 = \alpha_0 + \sum_{i=1}^{m} \alpha_i \left ( \frac{a_{t-i}}{\sigma_{t-i}} \right ) - \frac{2}{\sigma_{t}} + \sum_{j=1}^{s} \beta_j \frac{a_{t-j}}{\sigma_{t-j}} + \sum_{j=1}^{m} \gamma_j \ln \sigma_{t-j}^2, \tag{4} \]

where \( \gamma_j \) are parameter Leverage effect (Tsay [7]).

2.3 SWARCH Model. According to Hamilton and Susmel [1], Markov switching model for the average conditional can be written as

\[ r_t = \mu_{s_t} + \bar{r}_t, \tag{5} \]

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

\[ r_t = \mu_{s_t} + \alpha_t, a_t = \sigma_{t,s_t} \varepsilon_t \tag{6} \]

\[ \sigma_{t,s_t}^2 = \alpha_{0,s_t} + \sum_{i=1}^{m} \alpha_{l,s_t} a_{t-i}^2, \tag{7} \]

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 [5], smoothed probability value is defined as

\[ P(s_t = i | Z^T; \theta) = \sum_{s_{t+1}=1}^{3} P(s_{t+1} = i | Z^T; \theta)P(s_t = i | s_{t+1} = i, Z^T; \theta). \tag{9} \]

Based on Hermosillo and Hesse [3] while the probability of a low-volatility regime has decrease under 0.4 means that the indicator is stabil, 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 import and export from January 1990 to December 2016 were obtained from the International Monetary Fund. While the data of foreign exchange reserve from January 1990 to December 2016 were obtained from Bank Indonesia. These data are used to build the model. The steps of the research are 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 make the AR model. 3) Test the heteroscedasticity effects on the residue of AR model using Lagrange multiplier test. 4) If there are heteroscedasticity effects on the residue of AR model then estimate the parameter of ARCH model. 5) Establish the combination of volatility and Markov switching models with three states assumption. 6) Determine the conditions of crisis based on the smoothed probability.

4. Result and discussion

4.1 Data
Plot data of import, export, and foreign exchange reserve can be seen in Figure 1.

![Figure 1. Plot of (a) import, (b) export, and (c) foreign exchange reserve](image)

Figure 1 indicated that the data are not stationary. Based on the ADF test, the probability values for import, export, and foreign exchange reserve are 0.4446, 0.4622, and 0.5251 respectively. Because the probabilities more than \( \alpha = 0.05 \), so it can be concluded that the data are not stationary. 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 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 import, it was obtained an AR(2) model is \( r_t = -0.52619r_{t-1} - 0.20209r_{t-2} + a_t \). Based on export, it was obtained an AR(2) model is \( r_t = -0.37879r_{t-1} - 0.11493r_{t-2} + a_t \). For the foreign exchange reserve, it obtained an AR(1) model ie \( r_t = 0.16803r_{t-1} + a_t \). Based on Lagrange multiplier test on the residue of model, it were obtained the each probability of import, export, and foreign exchange reserve as 0.00338, 0.0042, and 0.0157. This probability values are less than \( \alpha = 0.05 \) so it can be concluded that there are heteroscedasticity effects on the residue of AR model for import, export, and foreign exchange reserve, so the next step is estimate the parameter of volatility model.

4.3 Establishment of Volatility Model
For import, export, and foreign exchange reserve, the best model is ARCH(1) which can be written as \( \sigma_t^2 = 0.00944 + 0.28387a_{t-1}^2, \quad \sigma_t^2 = 0.00551 + 0.24750a_{t-1}^2, \quad \text{and} \quad \sigma_t^2 = 8.739 \times 10^{-4} + 0.31240a_{t}^2 \) respectively. Based on Kolmogorov-Smirnov test, the probability values of import, export, and foreign exchange reserve are 0.8313, 0.8625, and 0.729 that the probability values are more than \( \alpha = 0.05 \), so it can be concluded that the residue of ARCH model for import, export, and foreign exchange reserve are normally distributed. Based on L-Jung Box test, the probability values for import, export, and foreign exchange reserve are 0.8253, 0.7659, and 0.4944. The probability values are more than \( \alpha = 0.05 \), so it can be concluded that there are no autocorrelation on the residue.
of ARCH model for import, export, and foreign exchange reserve. Based on Lagrange multiplier test, the probability values for import, export, and foreign exchange reserve are 0.9011, 0.2469, and 0.6676 respectively. The probability values are more than $\alpha = 0.05$, so it can be concluded that there are no heteroscedasticity effects on the residue of ARCH model. Based on these tests, it can be concluded that ARCH(1) is the appropriate models for import, export, and foreign exchange reserve.

4.4 Establishment of SWARCH Model

The volatility model combined with Markov switching model with three states assumption for resolve the change condition of crisis, not, crisis, and prone of crisis. The change of condition in Markov switching is an unobserved random variable namely state, where state used id low, high, and medium. 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 import, transition probability matrix can be written as the following

$$P_1 = \begin{bmatrix} 0.31172 & 0.89372 & 0.31492 \\ 0.65723 & 0.00510 & 0.40596 \\ 0.03106 & 0.10118 & 0.27912 \end{bmatrix}$$

Based on $P_1$ obtained that the probability to survive on low volatility state is 0.31172. The transition probability from low to medium volatility state is 0.65723. The transition probability from low to high volatility state is 0.89372. Probability survive in medium volatility state is 0.00510. As well as the transition probability from medium to high volatility state is 0.10118. The transition probability from high to low volatility state is 0.31492. Probability transition state from high to medium volatility state is 0.40596. Probability survive in high volatility state is 0.27912. The matrix of transition probability for export and foreign exchange reserve stated in $P_2$ and $P_3$ as follows

$$P_2 = \begin{bmatrix} 0.70125 & 0.35182 & 0.24608 \\ 0.21744 & 0.47754 & 0.28097 \\ 0.08131 & 0.17064 & 0.47295 \end{bmatrix}, \quad P_3 = \begin{bmatrix} 0.80906 & 0.16466 & 0.00099 \\ 0.19094 & 0.80095 & 0.11560 \\ 0.00033 & 0.03439 & 0.88340 \end{bmatrix}$$

Estimation of parameter SWARCH(3.1) model can be written as

$$\mu_{1,t} = \begin{cases} 0.01623, \text{ state 1} \\ 0.03540, \text{ state 2} \\ -0.20903, \text{ state 3} \end{cases}, \quad \sigma_{1,t}^2 = \begin{cases} 3.194 \times 10^{-5} + 0.03142a_{1,t-1}^2, \text{ state 1} \\ 0.00015 + 0.78234a_{1,t-1}^2, \text{ state 2} \\ 0.04051 + 0.419276a_{1,t-1}^2, \text{ state 3} \end{cases}$$

$$\mu_{2,t} = \begin{cases} 0.00217, \text{ state 1} \\ 0.01219, \text{ state 2} \\ 0.00651, \text{ state 3} \end{cases}, \quad \sigma_{2,t}^2 = \begin{cases} 1.637 \times 10^{-5} + 0.03272a_{1,t-1}^2, \text{ state 2} \\ 0.00489 + 0.47281a_{1,t-1}^2, \text{ state 3} \\ 0.00244 + 0.03119a_{1,t-1}^2, \text{ state 1} \end{cases}$$

$$\mu_{3,t} = \begin{cases} 0.00705, \text{ state 1} \\ 0.01061, \text{ state 2} \\ 0.00955, \text{ state 3} \end{cases}, \quad \sigma_{3,t}^2 = \begin{cases} 2.911 \times 10^{-6} + 0.02593a_{1,t-1}^2, \text{ state 2} \\ 1.085 \times 10^{-6} + 0.00010a_{1,t-1}^2, \text{ state 3} \end{cases}$$

where $\mu_{1,t}$ and $\sigma_{1,t}^2$ is the conditional mean and variance models SWARCH(3.1) for import, $\mu_{2,t}$ and $\sigma_{2,t}^2$ is the conditional mean and variance models SWARCH(3.1) for export, and $\mu_{3,t}$ and $\sigma_{3,t}^2$ is the conditional mean and variance models SWARCH(3.1) for foreign exchange reserve.

4.5 Detection of Crisis

Crisis can be detected with smoothed probability value. Plot of smoothed probability for import, export, and foreign exchange reserve can be seen as Figure 2.
Figure 2. Plot smoothed probability of (a) import, (b) export, and (c) foreign exchange reserve.

Crisis condition signed with value of smoothed probability more than 0.6 for import, export, and foreign exchange reserve as shown in Figure 2. Table 1 showed the crisis period that has been detected on 1997, 1998, and 2008 based on the smoothed probability greater than 0.6 by import, export, and foreign exchange reserve.

| Year | Import       | Export                        | Foreign Exchange Reserve |
|------|--------------|-------------------------------|--------------------------|
| 1997 | February, June, December | November, December            | September, October, November, December |
| 1998 | January, February, November | January, November, December | January, February, March, April |
| 2008 | November, December          | November, December            | October                   |

Table 1. showed that smoothed probability for import, export, and foreign exchange reserve can detect the financial crisis that hit Indonesia in 1997, 1998, and 2008.

5. Conclusion
The result of research showed that SWARCH(3.1) model is an appropriate model for import, export, and foreign exchange reserve that can be used to detect the financial crisis that hit Indonesia in 1997, 1998, and 2008 based on the indicators.

References
[1] Hamilton J D and R Susmel 1994 Autoregressive Conditional Heteroscedasticity and Changes in Regime, Journal of Econometrics 64 307
[2] Hermawan D W 2015 Pendeteksian Krisis Keuangan di Indonesia Menggunakan Gabungan Model Volatilitas dan Markov Switching Berdasarkan Indikator Jumlah Nilai Impor (Solo: Sebelas Maret University)
[3] Hermosillo B G and H Hesse 2009 Global Market Conditions and Systemic Risk, IMF Working Paper 230
[4] Kaminsky G, S Lizondo, and C M Reinhart 1998 Leading Indicators of Currency Crisis, IMF Working Paper 45
[5] Kuan C M 2002 The Markov Switching Model, Journal of Economics Academia Sinica 1 1
[6] Pradini D Y and S Raharjo 2012 Peramalan Nilai Ekspor dan Impor Indonesia ke Jepang menggunakan Model Varima, Journal Online Matematika Universitas Negeri Malang 1 1
[7] Tsay R S 2005 Analysis of Financial Time Series (Canada: John Wiley and Sons)