Detection of Financial Crisis in Indonesia based on Import and Yen Exchange Rate to Rupiah Indicators using Combined of Volatility and Markov Switching Models

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Keywords: Crisis, Detection, Import, Yen Exchange Rate to Rupiah, SWARCH.

Abstract: In 1997 and 1998 Indonesia experienced the most severe financial crisis, so early detection is needed to anticipate the impact of the crisis. The financial crisis can be detected by import and yen exchange rate to rupiah indicators. In this paper, it used import and yen exchange rate to rupiah data from January 1990 to December 2016 to form the model, while the data from January until December 2017 were used to validate the model. To overcome the problem of structural change in the data, it is used Markov switching model, while to detect the volatility shift it is used ARCH model and the combination of both models is Markov switching ARCH (SWARCH) model. The aim of this study is to determine the appropriate model and to detect financial crisis based on import and yen exchange rate to rupiah indicators. The results show that the appropriate model for import and yen exchange rate to rupiah data is SWARCH(2,1). Based on the model, it can be predicted that Indonesia will not experience a financial crisis in 2018.

1 INTRODUCTION

The financial crisis in Asia came from the fall in currency values bath in Thailand in 1997. In 1997 and 1998, Indonesia experienced a financial crisis. Currently, global trade is already unavoidable, and the exchange rate affects the economy of a country. For example, when the rupiah becomes more valuable to foreign currencies, the price of imported goods will be cheaper for the Indonesian population and Indonesian export goods are more expensive for foreign countries (Mishkin, 2008). There are 15 indicators that could be used to detect financial crisis for example import, export, price stock, and rupiah exchange rate (Kaminsky et al., 1998).

Engle (1982) uses the Autoregressive Conditional Heteroscedasticity (ARCH) model for resolving the problem of heteroscedasticity. Model ARCH could not be used to cover the data that have structural changes . Therefore, Hamilton (1989) used the Markov switching model for resolving the problem of structural changes on data. However, Markov switching model cannot solve the problem of volatility so Hamilton and Susmel 1994) used the Markov switching ARCH (SWARCH) model to overcome structural changes and volatility of the data. The aim of this paper is to determine the appropriate model of import and yen exchange rate to rupiah data. The model is used to detect the financial crisis in 2018.

2 THEORY

2.1 Autoregressive (AR) and Autoregressive Conditional Heteroscedasticity (ARCH) Model

An AR model is as follows

$$r_t = \phi_1 r_{t-1} + \phi_2 r_{t-2} + \cdots + \phi_p r_{t-p} + a_t, \qquad (1)$$

where r_t is log return in the t^{th} period which is formulated as $r_t = ln\frac{Z_t}{Z_{t-1}}$, ϕ_p is a parameter of AR model at p^{th} time, and a_t is residue at t^{th} time (Tsay, 2005). The next model that we are used is ARCH (p) model. The model could be written as

Zukhronah, E., Sugiyanto, . and Azizah, I.
Detection of Financial Crisis in Indonesia based on Import and Yen Exchange Rate to Rupiah Indicators using Combined of Volatility and Markov Switching Models.
DOI: 10.5220/0008519402050209
In *Proceedings of the International Conference on Mathematics and Islam (ICMIs 2018)*, pages 205-209
ISBN: 978-989-758-407-7

$$\sigma_t^2 = \alpha_0 + \alpha_1 a_{t-1}^2 + .. + \alpha_p a_{t-p}^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i a_{t-i}^2 ,$$

where α_0 is a constant of ARCH model, α_i is a parameter of ARCH model , and $\sigma_t^2$is a variance of residual at t[th] period.

2.2 Cluster Analysis

Cluster analysis is used to group a set of objects into two or more clusters based on the similarity of objects based on various characteristics. One method in cluster analysis is Ward method that based on the sum of square error (SSE), which is defined as

$$SSE_{uv} = \sum_{i=1}^{n_{uv}} (X_i - \bar{X}_{uv})'(X_i - \bar{X}_{uv})$$

where X_i is the i[th] object, $\bar{X}_{uv}$ is the average value of the object in the cluster uv, and n_{uv} is the number of objects on the cluster UV, where $\bar{X}_{uv} = \frac{n_U \bar{X}_U + n_V \bar{X}_v}{n_U + n_V}$ (Rencher, 2003).

2.3 Markov Switching ARCH (SWARCH) Model

Hamilton and Susmel (1994) formulates SWARCH model as below

$$\sigma_{t,st}^2 = \alpha_{0,st} + \sum_{i=1}^{p} \alpha_{i,st}\, a_{t-i}^2$$

where $\sigma_{t,st}^2$ is a variance of residue at i[th] period, a_t is a residue of AR model and conditional variance of $\epsilon_t$is modeled as an ARCH(p) process.

2.4 Smoothed Probability

Smoothed probability is the probability of a state in the t[th] period that based on all observational data which formulated as

$$Pr[S_t = j|\psi_T] = \sum_{k=1}^{M} Pr[S_t = j\ , S_{t+1} = k|\psi_T],$$

where $\psi_T$is a set of data from the past until time T (Hamilton and Susmel, 1994).

2.5 Crisis Detection

Crisis forecasting is determined by the forecasting value of smoothed probability at time (t+1) which is based on smoothed probability at time t, and formulated as follows

$$Pr[S_t = j|\psi_T] = \sum_{k=1}^{M} p_{ij} * Pr[S_{t-1} = i|\psi_{T-1}],$$

where p_{ij} is the probability of transition from state *i* to state j and $Pr[S_{t-1} = i|\psi_{T-1}]$ is smoothed probability at state *i* and time (t-1).

3 RESEARCH METHODS

Data that used in this paper is import and yen exchange rate to rupiah data from January 1990 to December 2016, there are 324 data. The steps of the analysis are as follows.

1. Plot data for knowing the pattern of data. Augmented Dickey-Fuller (ADF) test is used to test the stationary of data. If the data are not stationary, then do transform log return.
2. Analyze the AR model by looking at the plot of PACF then perform a heteroscedasticity effect test using the Lagrange Multiplier test .
3. Identify the volatility model and conduct diagnostic tests.
4. Form the combined of Markov switching and volatility models with the number of states obtained from cluster analysis.
5. Calculate the value of smoothed probability to detect a crisis.

4 RESULTS AND DISCUSSIONS

Figure 1 and 2 are a plot of import and yen exchange rate to rupiah respectively. Figure 1 shows that the import and yen exchange rate to rupiah data have fluctuations and indicate that the data is not stationary. To prove the allegation, the ADF test was carried out and the probability value was 0.4446 for import data and 0.2549 for yen exchange rate to rupiah. Both the probability value is greater than 0.05, it can be concluded that the import and yen exchange rate to rupiah is not stationary. Furthermore, it was done the transformation of log return and based on the ADF test, it is obtained the both probabilities are 0.01 that these are smaller than 0:05, so it can be concluded that the import and yen exchange rate to rupiah were stationary. Furthermore, we estimated the parameter of AR model based on plot of PACF as shown in Table 1.

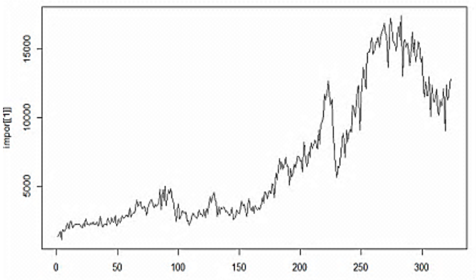

Figure 1: Plot of import data.

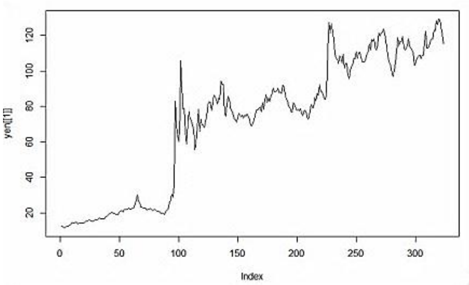

Figure 2: Plot of yen exchange rate to rupiah.

Table 1: Results of estimation of AR model for import and yen exchange rate to rupiah.

AR(2) model for import	$r_t = -0.52619\, r_{t-1} - 0.20209\, r_{t-2} + a_t$
AR(1) model for yen exchange rate to rupiah	$r_t = 1.001141\, r_{t-1} + a_t$

Based on Lagrange Multiplier test, it was obtained the probability value for import data of 0.004175 and for yen exchange rate to rupiah of 0.000016. Because the both probabilities are smaller than 0.05, this shows that the residue of AR model contains the effect of heteroscedasticity. The next step is to estimate the parameter of ARCH model as shown in Table 2.

Table 2: Estimation of the ARCH model for import and yen exchange rate to rupiah.

ARCH(1) model for import	$\sigma_t^2 = 0.009439 + 0.283873\, a_{t-1}^2$
ARCH(1) model yen exchange rate to rupiah	${\sigma_t}^2 = 7.19649 + 1.19417\, a_{t-1}^2.$

The results of the Ljung-Box test, it was obtained the probability value for import data is 0.5344 and for yen exchange rate to rupiah is 0.0912. Both of probabilities are greater than 0.05, it means that the residue of the ARCH model does not contain autocorrelation. Based on the Lagrange Multiplier test , the probability value for import data is 0.333 and 0.1213 for the yen exchange rate to rupiah which is greater than 0.05, it means that the residual of ARCH model does not contain heteroscedasticity effects. Whereas the Kolmogorov Smirnov test, it was obtained the probability value for import data of 0.8 and for the yen exchange rate to rupiah of 0.6 which is greater than 0.05. It can be concluded that the residual of ARCH model is normally distributed.

Then cluster analysis is performed to determine the number of states that can be formed. Based on the cluster analysis, the results show that there are 2 clusters that can be formed, so that there are 2 states in the formation of the SWARCH model. The ARCH(1) model is combined with the Markov switching model 2 state to overcome differences in conditions not crisis and crisis on import data. Transition probability matrix for import data are as follows

$$P_1 = \begin{bmatrix} 0.6669482 & 0.1511154 \\ 0.3330518 & 0.8488846 \end{bmatrix}.$$

In the transition probability matrix P_1, the first column shows that the value of the probability of holding on the low volatility state is 0.6669482 and the probability of change in low to high volatility is 0.3330518 . In the second column, it indicated that the probability of change in high to low volatility is 0.1511154 and the probability of holding on the high volatility state is 0.8488846.

Based on the results of the analysis, the model that full filled the assumption is the ARCH(1) model and there are 2 states so that the SWARCH model that is formed is SWARCH(2,1). Estimation results of the parameter SWARCH(2,1) model for import data is

$$\mu_{s_t} = \begin{cases} -0.0000768044, & for\ state\ 1, \\ 0.0000641941, & for\ state\ 2, \end{cases}$$

where is the average value of the log return data import and the conditional volatility model is

$$\sigma_{t,s_t}^2 = \begin{cases} 0.000100762, & for\ state\ 1 \\ 0.000033454, & for\ state\ 2 \end{cases}.$$

Furthermore, the probability transition matrix for the yen exchange rate to rupiah data is as follows

$$P_2 = \begin{bmatrix} 0.8665379 & 0.02087646 \\ 0.1334621 & 0.97912354 \end{bmatrix}$$

Parameter estimation result of SWARCH(2,1) model for yen exchange rate to rupiah data is

$$\mu_{s_t} = \begin{cases} 0.00005261\,, & for\ state\ 1, \\ 0.21557848\,, & for\ state\ 2, \end{cases}$$

where the conditional variance model is

$$\sigma_{t,S_t}^2 = \begin{cases} 25.247213 , & for\ state\ 1, \\ 19.438948 , & for\ state\ 2. \end{cases}$$

Furthermore, it is calculated the smoothed probability to check the crisis condition. Figure 3 and Figure 4 are the value of smoothed probability for import and yen exchange rate respectively.

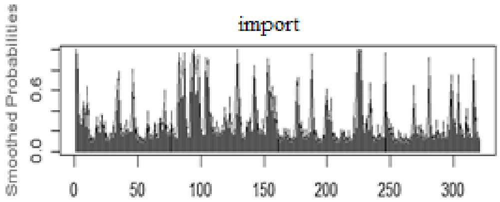

Figure.3: Plot of smoothed probability of import.

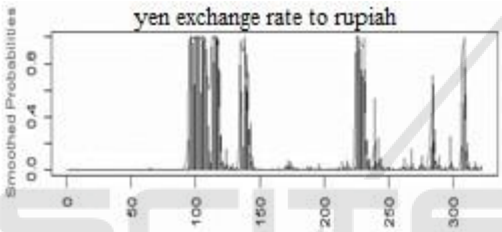

Figure 4: Plot of smoothed probability of yen exchange rate to rupiah.

The results of calculating the crisis limit on the value of smoothed probability, it can be concluded that the value of smoothed probability of import data which more than 0.790915 is in a crisis and of yen exchange rate to rupiah data which more than 0.448561 is in a crisis. Table 3 and Table 4 show the comparison of forecasting and actual smoothed probability value for import and yen exchange rate to rupiah indicators in 2017 respectively.

Based on Table 3, the forecasting smoothed probability value and the actual value do not experience a significant difference, except in June 2017 on import data. This is happened because the value of imports in June declined significantly but the value of yen remained high so that financial conditions in Indonesia were prone to crisis. In the next month the import value rose again and stabilized for the following months so that the SWARCH(2,1) model for import data and yen exchange rate to rupiah could be used to detect financial crises in Indonesia.

Table 3: Forecasting and Actual Smoothed Probability Value for import in 2017.

Period	Import	
	Forecasting	Actual
Jan 2017	0.09058303	0.3051957
Feb 2017	0.08181023	0.4093009
Mar 2017	0.07728494	0.2398876
Apr 2017	0.07495064	0.2612489
May 2017	0.07374653	0.4023360
Jun 2017	0.07312542	0.9373966
Jul 2017	0.07280503	0.4731825
Aug 2017	0.07263976	0.2058910
Sept 2017	0.07255451	0.1341276
Oct 2017	0.07251053	0.1067105
Nov 2017	0.07248785	0.1126172
Dec 2017	0.07247615	0.1352822

Table 4: Forecasting and Actual Smoothed Probability Value for yen exchange rate to rupiah in 2017.

Period	Yen Exchange Rate to Rupiah	
	Forecasting	Actual
Jan 2017	0.0151432	0.04266027
Feb 2017	0.0136995	0.01158024
Mar 2017	0.0124787	0.00366135
Apr 2017	0.0114462	0.00278140
May 2017	0.0105731	0.00735416
Jun 2017	0.0092109	0.00554720
Jul 2017	0.0080589	0.01410902
Aug 2017	0.0070847	0.00645248
Sept 2017	0.0062609	0.00510444
Oct 2017	0.0055642	0.00534139
Nov 2017	0.0049750	0.01698142
Dec 2017	0.0044768	0.02611092

Table 5: Forecasting smoothed probability value in 2018.

Period	Forecasting Smoothed Probability	
	Import	Yen Exchange Rate to Rupiah
Jan 2018	0.07247012	0.00405546
Feb 2018	0.07246699	0.00369915
Mar 2018	0.07246539	0.00339783
Apr 2018	0.07246456	0.00314302
May2018	0.07246413	0.00292754
Jun 2018	0.07246391	0.00274532
Jul 2018	0.07246380	0.00259121
Aug 2018	0.07246374	0.00246090
Sept 2018	0.07246371	0.00235069
Oct 2018	0.07246369	0.00225749
Nov 2018	0.07246369	0.00217868
Dec 2018	0.07246368	0.00211203

Based on Table 4, the forecasting smoothed probability value and the actual value for yen exchange rate to rupiah do not experience a significant difference. The results of forecasting smoothed probability in 2018 are shown in Table 5.

Table 5 shows that the forecasting smoothed probability value on the import data and yen exchange rate to rupiah was below the crisis limit, so that Indonesia was detected not experiencing a financial crisis in 2018.

5 CONCLUSIONS

Based on the results, it was obtained to the conclusion as follows.

1. The appropriate model for import and yen exchange rate to rupiah indicators is SWARCH (2,1).
2. Based on import and yen exchange rate to rupiah indicators, Indonesia was predicted that there is no financial crisis in 2018.

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