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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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 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

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

where \( r_t \) is log return in the \( t \)th period which is formulated as \( r_t = \ln \frac{Z_t}{Z_{t-1}} \), \( \phi_p \) is a parameter of AR model at \( p \)th time, and \( \alpha_t \) 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
\[ \sigma_t^2 = \alpha_0 + \alpha_1 \sigma_{t-1}^2 + \ldots + \alpha_p \sigma_{t-p}^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \sigma_{t-i}^2, \]

where \( \alpha_0 \) is a constant of ARCH model, \( \alpha_i \) is a parameter of ARCH model, and \( \sigma_t^2 \) is a variance of residual at \( t \) 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

\[ \bar{X}_{uv} = \frac{n_{uv} X_{uv} + n_{uv} \bar{X}_v}{n_{uv} + n_v} \] (Rencher, 2003).

### 2.3 Markov Switching ARCH (SWARCH) Model

Hamilton and Susmel (1994) formulates SWARCH model as below

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

where \( \sigma_{t, st}^2 \) is a variance of residue at \( i \)th period, \( \alpha_i \) is a residue of AR model and conditional variance of \( \epsilon_i \) is modeled as an AR(t) 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.
Based on 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

\[
\mu_{st} = \begin{cases}
-0.0000768044, & \text{for state 1}, \\
0.0000641941, & \text{for state 2},
\end{cases}
\]

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

\[
\sigma_{st}^2 = \begin{cases}
0.000100762, & \text{for state 1}, \\
0.000334545, & \text{for state 2},
\end{cases}
\]

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

\[
\mu_{st} = \begin{cases}
0.00005261, & \text{for state 1}, \\
0.21557848, & \text{for state 2},
\end{cases}
\]
where the conditional variance model is
\[
\sigma_t^2 = \begin{cases} 
25.247213, & \text{for state 1}, \\
19.438948, & \text{for state 2}.
\end{cases}
\]
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.](image)

![Figure 4: Plot of smoothed probability of yen exchange rate to rupiah.](image)

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.

Based on Table 3, 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 3: Forecasting and Actual Smoothed Probability Value for import in 2017.](image)

<table>
<thead>
<tr>
<th>Period</th>
<th>Forecasting</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2017</td>
<td>0.09058303</td>
<td>0.3051957</td>
</tr>
<tr>
<td>Feb 2017</td>
<td>0.08181023</td>
<td>0.4093009</td>
</tr>
<tr>
<td>Mar 2017</td>
<td>0.07726494</td>
<td>0.2398876</td>
</tr>
<tr>
<td>Apr 2017</td>
<td>0.07495064</td>
<td>0.2612489</td>
</tr>
<tr>
<td>May 2017</td>
<td>0.0734653</td>
<td>0.4023360</td>
</tr>
<tr>
<td>Jun 2017</td>
<td>0.07312542</td>
<td>0.9373966</td>
</tr>
<tr>
<td>Jul 2017</td>
<td>0.07280503</td>
<td>0.4731825</td>
</tr>
<tr>
<td>Aug 2017</td>
<td>0.07263976</td>
<td>0.2058910</td>
</tr>
<tr>
<td>Sept 2017</td>
<td>0.07255451</td>
<td>0.1341276</td>
</tr>
<tr>
<td>Oct 2017</td>
<td>0.07251053</td>
<td>0.1067105</td>
</tr>
<tr>
<td>Nov 2017</td>
<td>0.07248785</td>
<td>0.1126172</td>
</tr>
<tr>
<td>Dec 2017</td>
<td>0.07247615</td>
<td>0.1352822</td>
</tr>
</tbody>
</table>

![Table 4: Forecasting and Actual Smoothed Probability Value for yen exchange rate to rupiah in 2017.](image)

<table>
<thead>
<tr>
<th>Period</th>
<th>Forecasting</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2017</td>
<td>0.0151432</td>
<td>0.04266027</td>
</tr>
<tr>
<td>Feb 2017</td>
<td>0.0136995</td>
<td>0.01158024</td>
</tr>
<tr>
<td>Mar 2017</td>
<td>0.0124787</td>
<td>0.00366135</td>
</tr>
<tr>
<td>Apr 2017</td>
<td>0.0114462</td>
<td>0.00278140</td>
</tr>
<tr>
<td>May 2017</td>
<td>0.0105731</td>
<td>0.00735416</td>
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<tr>
<td>Jun 2017</td>
<td>0.0092109</td>
<td>0.00554720</td>
</tr>
<tr>
<td>Jul 2017</td>
<td>0.0080589</td>
<td>0.00140902</td>
</tr>
<tr>
<td>Aug 2017</td>
<td>0.0070847</td>
<td>0.00645248</td>
</tr>
<tr>
<td>Sept 2017</td>
<td>0.0062609</td>
<td>0.00310444</td>
</tr>
<tr>
<td>Oct 2017</td>
<td>0.0055642</td>
<td>0.00534139</td>
</tr>
<tr>
<td>Nov 2017</td>
<td>0.0049750</td>
<td>0.01698142</td>
</tr>
<tr>
<td>Dec 2017</td>
<td>0.0044768</td>
<td>0.02611092</td>
</tr>
</tbody>
</table>

![Table 5: Forecasting smoothed probability value in 2018.](image)

<table>
<thead>
<tr>
<th>Period</th>
<th>Forecasting Smoothed Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2018</td>
<td>0.07247012</td>
</tr>
<tr>
<td>Feb 2018</td>
<td>0.07246699</td>
</tr>
<tr>
<td>Mar 2018</td>
<td>0.07246539</td>
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<td>Apr 2018</td>
<td>0.07246456</td>
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<td>May 2018</td>
<td>0.07246413</td>
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<tr>
<td>Jun 2018</td>
<td>0.07246391</td>
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<tr>
<td>Jul 2018</td>
<td>0.07246380</td>
</tr>
<tr>
<td>Aug 2018</td>
<td>0.07246374</td>
</tr>
<tr>
<td>Sept 2018</td>
<td>0.07246371</td>
</tr>
<tr>
<td>Oct 2018</td>
<td>0.07246369</td>
</tr>
<tr>
<td>Nov 2018</td>
<td>0.07246369</td>
</tr>
<tr>
<td>Dec 2018</td>
<td>0.07246368</td>
</tr>
</tbody>
</table>

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.

REFERENCES


