Value-at-Risk analysis using ARMAX GARCHX approach for estimating risk of banking subsector stock return’s

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Abstract. Value at Risk (VaR) is one of the statistical methods used to measure market risk by estimating the worst losses in a given time period and level of confidence. The accuracy of this measuring tool is very important in determining the amount of capital that must be provided by the company to cope with possible losses. Because there is a greater losses to be faced with a certain degree of probability by the greater risk. Based on this, VaR calculation analysis is of particular concern to researchers and practitioners of the stock market to be developed, thus getting more accurate measurement estimates. In this research, risk analysis of stocks in four banking sub-sector, Bank Rakyat Indonesia, Bank Mandiri, Bank Central Asia and Bank Negara Indonesia will be done. Stock returns are expected to be influenced by exogenous variables, namely ICI and exchange rate. Therefore, in this research, stock risk estimation are done by using VaR ARMAX-GARCHX method. Calculating the VaR value with the ARMAX-GARCHX approach using window 500 gives more accurate results. Overall, Bank Central Asia is the only bank had the estimated maximum loss in the 5% quantile.

1. Introduction
Value at Risk (VaR) is one of the statistical methods used to measure market risk by estimating the worst losses over time and certain levels of confidence (Messaoud and Aloui, 2015). The accuracy of this measuring tool is very important in determining the amount of capital that must be provided by the company to cope with possible losses. As for users / investors, it is important to determine trust level that reflects the risks to be considered in investment making process. This is because the greater the risk, the greater the losses to be faced with a certain degree of probability (Dharmawan, 2014). Based on this, the VaR calculation analysis is of particular concern to researchers and stock market practitioners to be developed, thus getting more accurate measurement estimates. VaR estimates on the stock market is important to know the risks that will occur in the stock market at the next period. The condition of the stock that fluctuates every day, caused investors need to pay attention and research the past data of a company that will be selected to invest. This is very important for investors to know the future prospects of stock prices in a company. Therefore, stock return forecast for several future period is needed as one step in estimating VaR.

ARIMA is one of many forecasting method, it has the residual assumption of a homogeneous model. However, Donaldson (2015) shows that stock return data is stochastic and stationary also has a volatile nature of non-homogeneous data (heteroscedasticity). So the ARIMA method is less appropriate to use. One method that can be used to analyze non-homogenous data is ARCH, Autoregressive Conditional Heteroscedasticity (Wei, 2006). In 1986, Bollerslev and Taylor developed the ARCH model into a GARCH (Generalized Autoregressive Conditional Heteroscedasticity) model. GARCH model is used to avoid large order in ARCH model.
ARMAX (Autoregressive Moving Average with Exogenous Variable) is the development of ARMA methods used to model and forecast by including exogenous variables therein. In generating better and accurate models and also forecast of non-homogenous stock returns by including exogenous variables, GARCHX (Generalized Autoregressive Conditional Heteroscedasticity with Exogenous Variable) can be used as one of the forecasting method. This research used ARMAX-GARCHX approach, assuming that stock price of a company was not only influenced by stock price in the previous period, but also influenced by exogenous variables namely Indonesia Composite Index (ICI) and exchange rate IDR/USD.

On May 25, 2016, Forbes 2000 The World Biggest Companies listed 2000 lists of the world's largest public companies. There are 6 Indonesian public companies listed on the Forbes 2000 list: Bank Rakyat Indonesia, Bank Mandiri, Bank Central Asia, Telkom Indonesia, Bank Negara Indonesia, and Gudang Garam. It is seen that 4 from 6 entering companies are Banking companies (SahamOK, 2016). Stock return analysis on four banks, namely Bank Rakyat Indonesia, Bank Mandiri, Bank Central Asia, and Bank Negara Indonesia, will be done in this research because these companies were included in Forbes 2000 as the largest company in the world for several times. In addition, those banks are the companies incorporated in the LQ45 index over the last period.

Based on these reviews, VaR analysis to estimate the risk of stock returns in banking sub-sector using Copula ARMAX-GARCHX approach will be done in this research. The ARMAX method is used to estimate the $\mu$ parameter. While GARCHX is used to estimate parameter $\sigma^2$ (because stock data is non-homogenous/heteroscedasticity). So hopefully this research can yield more accurate VaR estimation.

2. Material and Methods

2.1. Material

The data used in this research is secondary data consist of closing price daily, ICI and exchange rate IDR/USD. The closing price and ICI data are sourced from www.finance.yahoo.com. Exchange rate IDR/USD data is sourced from bi.go.id. Period of closing price data of Bank Rakyat Indonesia (Persero) Tbk., Bank Mandiri (Persero) Tbk., Bank Central Asia Tbk., and Bank Negara Indonesia (Persero) Tbk., used is January 1, 2010 until February 28, 2017. Variables used in this research consist of response variables and predictor variables. Response variables are stock return variable at Bank Rakyat Indonesia (Persero) Tbk., Bank Mandiri (Persero) Tbk., Bank Central Asia Tbk., and Bank Negara Indonesia (Persero) Tbk. While the ICI and exchange IDR/USD are predictor variables. The data structure used in this research is presented in Table 1.

| $t$ | Month | Year | Closing Price | ICI | Exchange rate IDR-USD |
|-----|-------|------|--------------|-----|----------------------|
| 1   |       |      | $Y_{1,1}$   | $X_{1,1}$ | $X_{2,1}$ |
| 2   |       |      | $Y_{1,2}$   | $X_{1,2}$ | $X_{2,2}$ |
| 3   | January | 2010 | $Y_{1,3}$   | $X_{1,3}$ | $X_{2,3}$ |
|     |       |      | $Y_{1,28}$  | $X_{1,28}$| $X_{2,28}$ |
| 1770|       |      | $Y_{1,1770}$| $X_{1,1770}$| $X_{2,1770}$ |
| 1771|       |      | $Y_{1,1771}$| $X_{1,1771}$| $X_{2,1771}$ |
| 1772| February | 2017 | $Y_{1,1772}$| $X_{1,1772}$| $X_{2,1772}$ |

Table 1. Data Structure
Stages of the data analysis are described as follows:

a. Identify ARMAX model on stock return BBRI, BMRI, BBCA, and BBNI as a whole.
b. Estimating parameters on the ARMAX model where the predictor variables are IHSG and rupiah exchange rate return against dollar.
c. Testing the significance of ARMAX model parameters.
d. Perform assumption testing on residual which includes white noise assumption and normal distribution on residual data.
e. Choose the best ARMAX model using AIC criteria.
f. Identify ARCH-GARCH effect on error value of ARMAX model formed by using Ljung Box and Lagrange Multiplier test.
g. Identify the GARCHX model.
h. Estimating parameters on the GARCHX model.
i. Conducting a test of significance to GARCHX model parameters.
j. Getting the appropriate ARMAX-GARCHX model.
k. Calculates the VaR value based on ARMAX-GARCHX model parameter estimation

2.2. Autoregressive Moving Average with Exogenous Variables (ARMAX)

ARMAX or Autoregressive Moving Average with Exogenous Variables is the development of ARIMA model by including the exogenous variables into the equation. ARMA model is not only influenced by data of previous period (historical), but also influenced by exogenous variable. The following is a general equation of the ARMAX model as follows (Hyndman, 2010).

\[ Y_t = \sigma_t X_{t,1} + \ldots + \sigma_t X_{t,p} + \phi_1 Y_{t-1} + \ldots + \phi_p Y_{t-p} - \theta a_{t-1} - \ldots - \theta a_{t-q} + a_t \]

\[ Y_t = \sum_{j=1}^{p} \phi_j Y_{t-j} - \sum_{j=1}^{q} \theta a_{t-j} + a_t \]

\( Y_t \) is the response variable at time \( t \), \( X_t \) is the exogenous variable at time \( t \), \( a_t \) is white noise error, and \( (p, q, U) \) indicates the order of the ARMAX model. Based on ARMAX model it can be seen that ARMAX modeling concept is similar as transfer function model, but with condition where \( s \) and \( b \) value equal to 0 and \( r \) value equal to \( p \). So the steps of ARMAX model identification are as follows.

a. Setting order \( (p, q) \), order value \( (p, q) \) on ARMAX model is obtained from ACF and PACF response variable data or \( Y_t \).
b. Assign \( (r, s, b) \), where in the ARMAX model the value of \( r = p \), \( s = 0 \), and \( b = 0 \).
c. Estimate the ARMAX model that has been formed.

2.3. Generalized Autoregressive Conditional Heteroscedasticity with Exogenous Variable (GARCHX)

In generating better and accurate models and forecast of volatility in the time series of financial and economic data, researchers and practitioners often incorporate exogenous predictor variables into data volatility. One method that can be used to overcome this problem is GARCH or Generalized Autoregressive Conditional Heteroscedasticity with Exogenous Variable method. GARCHX was a GARCH model developed by Bollerslev in 1986, by adding exogenous variables into model equations. Where the value of \( Z_t \) in equation is a random variable that identical, independent, and normally distributed (0, 1). Whereas \( \sigma_t^2 \) is a process of volatility that is influenced by exogenous variables i.e.

\[ \sigma_t^2 = \omega + \sum_{j=1}^{r} \varphi_j \varepsilon_{t-j}^2 + \sum_{j=1}^{s} \beta_j \sigma_{t-j}^2 + \sum_{u=1}^{U} \pi_u X_{u,t}^2 \]

Where \( \omega > 0 \), \( \varphi > 0 \), \( \beta > 0 \), and \( \pi > 0 \). The value \( X_t \) represents the exogenous variable, the \( X_t \) value squared to guarantee that \( \sigma_t^2 > 0 \). The addition parameter of \( X_t \) regressor is often used to explain the volatility of stock return, exchange rate returns, or interest rates, and tend to lead to better in-sample and out-sample in forecasting performance. In this case, the exogenous variable is allowed in a
stationary and non-stationary state. However, the intercept parameter $\omega$ is not identifiable when the exogenous variable is not stationary. (Han and Kristensen, 2013).
2.4. Value-at-Risk
The Value-at-Risk (VaR) method is a risk assessment method that summarizes the possible minimum losses for an investor in a portfolio at a certain level of confidence. VaR aims to measure the rate of gain or loss of a stock investment. The amount of profit earned is proportional to the risk obtained. Here is a VaR model based on the return value.

\[
P(R_t < -VaR) = (1 - CI)^\% = \tau
\]

where the value of \( R_t \) denotes the stock return value of the period to-t, \( CI \) is the Confident Interval value, and \( \tau \) is the quantity used to measure the risk level. The greater the VaR the higher the portfolio risk should be considered. The advantage in VaR allows the user to determine trust level that reflects the risk-averseness of the individual. In general, the method for measuring VaR often assumes a portfolio return value following a normal distribution. VaR calculations are generally shown in the following equation.

\[
VaR_t(\tau) = \hat{\mu} + \hat{\sigma}F^{-1}(\tau)
\]

3. Result
Descriptive statistics for stock prices of BRI (BBRI), BCA (BBCA), Bank Mandiri (BMRI), BNI (BBNI), ICI, and exchange rate are presented in Table 2.

| Variable     | Mean   | Variance       | Min  | Max  |
|--------------|--------|----------------|------|------|
| BBRI         | 11,599 | 1,528,194      | 8,300| 15,300|
| BBCA         | 13,324 | 2,283,945      | 11,300| 18,250|
| BMRI         | 10,485 | 1,418,167      | 7,525| 12,900|
| BBNI         | 5,612.9| 603,904.6      | 3,940| 7,275|
| ICI          | 5,081  | 163,731.1      | 3,120.5| 5,829.7|
| Exchange Rate| 13,413 | 142,768        | 12,506| 13,802|

Bank with the highest average stock price is BCA and the lowest is BNI. The highest stock price in a 2.5 years is Rp7,275 and the lowest stock price is Rp3,940.00, the stock price has the lowest price compared to other banks. For ICI in January 2015 to June 2016 has an average of 5,081 with the highest ICI score is 5,829.7 and 3,120.5 is the lowest ICI score. The rupiah-denominated selling rate against the dollar shows an improvement although it is still very volatile. It is known that the average selling rate of rupiah against the dollar in January 2015 to June 2017 was 13,413 with the highest selling rate at 13,802 and the lowest selling rate at 12,506. For the diversity of data in each bank, ICI, and exchange rate IDR/USD can be known very high, it can be known from the high value of variance. The characteristics of stock return can also be seen through the time series plot.
Figure 1 Time Series Plot of BBRI, BBCA, BMRI and BBNI

Figure 1 shows that Bank BCA's stock price from 2015 to June 2017 is higher than other banking stocks, while BNI is the lowest among the three other banks. The four banks have a fluctuating stock value. Competitiveness of stock prices appears in Bank Mandiri and Bank BRI, but Bank BRI is superior in stock price in a longer time than Bank Mandiri.

Characteristics for the exogenous variables of the rupiah exchange rate against the dollar and ICI can be seen in Figure 2.

The movement pattern of the IDR / USD exchange rate from day to day tend to increase, but also decreased in mid 2011 which reached the lowest value of Rp 8,502.00. But since then, the IDR / USD exchange rate has always increased. The drastic increase occurred in mid-2013 to Rp 12.331,00 and the highest IDR / USD rate occurred in mid-2015 reached Rp14.802,00. This phenomenon also coincided with the increase in BI rate to 7.5% which also affected the weakening of ICI at that time, as shown in Figure 2 (b), it appears that when the rupiah weakened in mid-2013 and 2015, the rate of IHSG precisely decrease. The decline of IHSG is affecting the declining value of stocks from several sectors such as property sector. So that the movement rate of IDR / USD and IHSG exchange rate is able to influence the increase and decrease the stock price of a company.

3.1. ARMAX GARCHX Modeling

Analysis of Capital Asset Pricing Model (CAPM) aims to prove the theory about ICI influence. Where the window used 250 days of transactions and generate parameters $\beta_\alpha$. In CAPM analysis between IHSG return with stock return of the four companies, the variable that used as risk free rate is the interest rate. The significance test of $\beta_\alpha$ parameter can be seen in Table 3.

| Return Stock | Window | $\beta_\alpha$ | Pvalue     | Inf.     |
|--------------|--------|----------------|------------|----------|
| BBRI         | 1      | 1.613          | 1.63E-30   | Significant |
| BBCA         | 1      | 1.518          | 1.22E-10   | Significant |
| BMRI         | 1      | 0.832          | 7.04E-11   | Significant |
| BBNI         | 1      | 1.416          | 1.50E-10   | Significant |
| ...          | ...    | ...            | ...        | ...      |
| BBRI         | 1323   | 1.196          | 1.32E-14   | Significant |
| BBCA         | 1323   | 0.927          | 7.49E-17   | Significant |
| BMRI         | 1323   | 0.733          | 7.01E-09   | Significant |
| BBNI         | 1323   | 1.125          | 0.000186   | Significant |

Known from Table 3, at $\alpha = 5\%$ the result of Pvalue $\beta_\alpha$ the five firms in each window have value less than $\alpha$, it can be concluded that the return of IHSG influence significantly to stock return of four company. Thus, the results of this CAPM analysis support the theory that ICI affects individual stocks.
Furthermore, modeling stock prices with ARMAX-GARCHX with exogenous variables are ICI \((X_t)\) and exchange rate IDR / USD. Table 4 is the estimation result of BBRI stock return model.

| Table 4. BBRI Stock Return Model |
| Model | Par. | Estimation | Pvalue |
|-------|------|------------|--------|
| GARCHX (0,1,1) | \(\omega\) | 0.000003 | 0.00 |
|          | \(\beta_1\) | 0.876576 | 0.00 |
|          | \(\pi_1 (X_2)\) | 0.000238 | 0.00 |

Table 4 show that model parameters are significant because each model parameter has \(|t\text{ value}| > |t_{table}|\) amounted to 1.96, so the model formed on stock BBRI is GARCHX (0,1,1) with exogenous variable that is rate of IDR / USD. BBRI stock return model is as follows.

\[
\hat{\sigma}_t^2 = 0.000003 + 0.876576\hat{\sigma}_{t-1}^2 + 0.000238X_{2,t}^2
\]

Table 5 show that model parameters are significant because each model parameter has \(|t\text{ value}| > |t_{table}|\) amounted to 1.96, so the model formed on stock BMRI is GARCHX (0,1,1) with exogenous variable that is rate of IDR / USD. BMRI stock return model is as follows.

\[
\hat{\sigma}_t^2 = 0.000001 + 0.995643\hat{\sigma}_{t-1}^2 + 0.000358X_{2,t}^2
\]

Table 6 is the result of estimation of BBCA return model.

| Table 6. BBCA Stock Return Model |
| Model | Par. | Estimation | Pvalue |
|-------|------|------------|--------|
| ARMAX (1,0,2) | \(\phi_1\) | 0.089 | 0.0002 |
|          | \(\sigma_1 (X_1)\) | 0.987 | 0.0000 |
| GARCHX (1,1,1) | \(\omega\) | 0.000002 | 0.0305 |
|          | \(\beta_1\) | 0.887 | 0.0000 |
|          | \(\pi_1 (X_2)\) | 0.0005 | 0.0306 |

The corresponding model in the stock return of BBCA is ARMAX (1,0,2)-GARCHX (1,1,1), where exogenous variable is significant in ARMAX model that is ICI and IDR / USD rate while in GARCHX model that is IHSG. The LPKR stock return model is as follows.

ARMAX(1,0,2): \(\hat{R}_t = 0.089R_{t-1} + 0.987X_{1,t} - 0.611X_{2,t}\)

GARCHX(1,1,1): \(\hat{\sigma}_t^2 = 0.000002 + 0.020\hat{a}_{t-1} + 0.887\hat{\sigma}_{t-1}^2 + 0.0005X_{1,t}^2\).

| Table 7. Model Return Saham BBNI |
| Model | Par. | Estimation | Pvalue |
|-------|------|------------|--------|
| GARCHX (0,1,1) | \(\omega\) | 0.000009 | 0.00 |
|          | \(\beta_1\) | 0.888899 | 0.00 |
|          | \(\pi_1 (X_2)\) | 0.000913 | 0.00 |

In Table 7, we can obtain the return model of BBNI company’s stock is GARCHX (0,1,1) where the IDR / USD rate as its exogenous variable, with equation that is

\[
\hat{\sigma}_t^2 = 0.000009 + 0.888899\hat{\sigma}_{t-1}^2 + 0.000913X_{2,t}^2
\]

3.2. Value-at Risk

The estimated risk of stock return of the five companies using ARMAX-GARCHX approach. the mean parameter in the VaR model is approximated by the ARMAX model, whereas the variance

\[
\text{VaR}_\alpha = \mu + z_\alpha \sigma
\]

where \(\mu\) is the mean of the return, \(\sigma\) is the standard deviation, and \(z_\alpha\) is the quantile of the standard normal distribution at level \(\alpha\). The VaR model is then used to calculate the Value-at-Risk (VaR) for each company. The VaR is the maximum loss that a portfolio can expect to incur with a given probability level \(\alpha\).

The VaR model is then used to calculate the Value-at-Risk (VaR) for each company. The VaR is the maximum loss that a portfolio can expect to incur with a given probability level \(\alpha\).
parameter is approximated by the GARCHX model. VaR calculations are performed on each window with a total of 250, 375, and 500 days transactions, and 5% quantiles are used.

**Table 8. Risk Estimation with VaR**

|        | 250       | 375       | 500       |
|--------|-----------|-----------|-----------|
| BMRI   | -0.043    | -0.043    | -0.043    |
| BBCA   | -0.050    | -0.050    | -0.051    |
| BMRI   | -0.032    | -0.031    | -0.032    |
| BBNI   | -0.043    | -0.044    | -0.046    |

Based on Table 8 it is known that at the 95% confidence level, the biggest maximum loss value experienced by an investor when investing Rp 1 Billion in BBRI company is Rp 43.000.000,- , BBCA company Rp 51.000.000,- , BMRI Rp 32.000.000,- , BBNI company Rp 46.000.000,- , Also note that the companies that provide the highest and lowest loss rates on the windows 250, 375 and 500 are BBCA. This VaR value estimate applies when the economy is in a normal.

4. **Conclusion**

Banks with the highest average stock price is BCA and the lowest is BBNI. BBRI and BBCA stocks tend to be very volatile but there is an increase. The movement pattern of the exchange rates IDR / USD and ICI is always increasing every year. In CAPM analysis, it is proven that ICI has significant effect on all four stocks. In the VaR estimation, the appropriate model for BBRI is GARCHX (0,1,1) with exogenous variable is IDR / USD rate. The BMRI model is GARCHX (1,0,1) where the exogenous variable is the IDR / USD rate. BBCA model is ARMAX (1,0,2)-GARCHX (1,1,1) with exogenous variable of ARMAX model that is ICI and IDR / USD rate while at GARCHX that is IHSG. The BBNI model is GARCHX (0,1,1) where the IDR / USD rate is the exogenous variable. It is also known that the company that gives the highest and lowest loss rate is BCA. The VaR estimate using the GARCHX approach yields a more accurate VaR score than ARMAX-GARCHX, this is because the ARMAX model is redundant.

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