Evaluating the stock volatility of service companies in the rise of COVID-19 using ARMAX-GARCHX

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Abstract. This study evaluates the impact of Covid-19 variables which has attracted huge attention from whole countries. The service companies listed in IDX are being the main issue while many are struggling amidst the economy slowdown due to pandemic. By comparing the time series regression (TSR) - GARCHX and ARMAX - GARCHX of stock return of 4 companies listed in service sub-sector since early March 2020, proposed GARCHX models are able to assess the volatility of stock return. As a proxy of the volatility, Value-at-Risk (VAR) is analyzed at 1% and 5% quantiles. It is found that ARMAX-GARCHX is more accurate than TSR-GARCHX in evaluating the volatility in lower risk, particularly that of medical service stock. Through ARMAX-GARCHX model, it is indicated that JCI return and lagged Covid-19 daily death cases have significant impact to the stock volatility, particularly that of transportation and medical service companies.

1. Introduction
Covid-19 has been a major global focus these days since this pandemic broke out in late 2019 in Wuhan, China. The impact attacks various sectors, including the economy. Developed countries, such as the U.S. and Japan, even experienced economic recession, which was caused by the simultaneous decline in consumption, investment, government expenditure, and trade [1]. Foreign capital markets, such as S&P 500, DAX, and Nikkei 225, have also been affected by Covid-19 [2]. In Indonesia, until the end of August 2020, the JCI had also decreased by 16% since the beginning of the year [3].

The weak performance of the stock market indicates that the rate of return is decreasing as well. Consequently, the risk of potential loss that investors face can also increase. Evaluation of stock returns can provide an overview of the impact of such tremendous outbreak on the capital market[1,2]. Evaluation of stock volatility can be carried out using various approaches, one of which is to analyze Value-at-Risk (VaR).

The Covid-19 outbreak, which has surpassed 150,000 positive cases in Indonesia, can affect many sectors on the IDX, including the service sub-sector [4]. These sub-sectors include public transportation, tourism and hospitality services, along with medical facility services. Several companies in the service sub-sector being the interest are PT. Blue Bird Tbk. (BIRD), Garuda Indonesia Tbk. (GIAA), PT. Menteng Heritage Realty Tbk. (HRME), and PT. Mitra Keluarga Karyawan Tbk. (MIKA). Amidst uncertain market due to Covid-19, it is necessary that good risk management is needed through the VaR estimation.
This study proposes the non-economical variables as the covariates, such as lagged Covid-19 daily confirmed cases and lagged Covid-19 daily death cases in Indonesia. Those two variables are exogenous, apart from the return on the Jakarta Composite Index (JCI), which possibly affect the value of service company shares, where the model of stock return produce the non-homegeneous error. VaR estimation is carried out by combining the mean and variance model for errors[5]. Two methods are used to estimate the mean, namely time series regression (TSR) and ARMAX. Then, variance estimation is performed with GARCHX to identify volatility [5]. This study aims to evaluate the volatility of stock returns of service companies in the midst of the Covid-19 pandemic so that it becomes an input for all parties in mitigating more severe risks in the capital market by considering the presence of epidemiological variables.

2. Literature Review and Method

This section briefly explains the concept of Value-at-Risk (VaR) in analyzing volatility along with the statistical model being used.

2.1. Stock return

Stock return (\(y_t\)) is the loss or profit in regular basis experienced by stockholder expressed as,

\[ y_t = \ln P_t - \ln P_{t-1} \]  

with \(y_t\) is stock return at time \(t\), \(\ln\) stands for natural logarithm, \(P_t\) is the daily stock price at time \(t\) and \(P_{t-1}\) is the daily stock price at time \((t-1)\) where \(t = 1, 2, \ldots, n\) [6, 7]. The number of observation of the return \(y_t\) is turned to \((n-1)\) observations.

2.2. Mean models

The mean of stock return is modeled by two methods, namely time series regression (TSR) and Autoregressive Moving Average with Exogeneous (ARMAX). TSR model is multiple regression to analyze the relationship between response \(y_{i,t=1,2,\ldots,n}\) and exogenous \(X_1, X_2, \ldots, X_i\) in terms of stochastic time series [8]. In this study, the exogenous are JCI daily return and epidemiology variables, such as lagged Covid-19 daily confirmed cases and lagged Covid-19 daily death cases. It is shown that the increase in daily confirmed cases and death cases affect the stock performance [9]. Below is the TSR model of a stock return (\(y_t\)) that includes regular and lagged exogenous,

\[ y_t = \beta_0 + \sum_i \beta_i X_{i,t} + \sum_j \gamma_j X_{j,t-1} + a_t. \]  

Based on equation (2), regular exogenous \((X_i)\) is JCI daily return and lagged exogenous \((X_{i,t})\) are Covid-19 daily confirmed cases and Covid-19 daily death cases. The intercept is \(\beta_0\), the parameter of regular exogenous is \(\beta_i\), and the parameter of lagged exogenous is \(\gamma_j\). Those coefficients are estimated by Maximum Likelihood Estimation (MLE).

Furthermore, there is also ARMAX (ARMA with Exogenous) as the development of ARMA model by involving the exogenous \(X_1, X_2, \ldots, X_i\) to model \(y_{i,t=1,2,\ldots,n}\) [10]. Below is the ARMAX model of stock return in this work

\[ y_t = \alpha + \sum_i \beta_i X_{i,t} + \sum_j \gamma_j X_{j,t-1} + \sum_p \phi_p y_{t-p} + \sum_q \theta_q a_{t-q} + a_t. \]  

with \(p\) and \(q\) is the order of AR and MA, respectively.

2.3. Volatility Models

To evaluate volatility using VaR, the residual of TSR and ARMAX are modeled by GARCHX in order that the variance of residual could be fitted. GARCHX (Generalized Autoregressive Conditional
Heteroscedasticity with Exogenous) is the development of GARCH model that take exogenous $X_1, X_2, \ldots, X_k$ into account[11]. GARCHX has shown to be successful in estimating the volatility[11-13]. In GARCHX $(p, q)$ model, for $i = 1,2,\ldots, p$ and $j = 1,2,\ldots, q$, the conditional volatility $h_t$ is expressed as,

$$h_t = \alpha_0 + \sum_{i} \alpha_i^2 a_{i-t}^2 + \sum_{j} \beta_j h_{t-j} + \sum_{k} \gamma_k X_{k,t}^2 + \epsilon_t,$$

(4)

where $\sum_{i} \alpha_i^2 a_{i-t}^2 + \sum_{j} \beta_j h_{t-j} < 1$ in order that return $y_t$ is stationary.

2.4. Value-at-Risk (VaR)

Value-at-Risk (VaR) is estimated by assuming specification for the conditional distribution of stock return[7, 13]. Suppose return $y_t$ is modeled by equation (5)

$$y_t = \mu_i + a_i = \mu_i + \sqrt{h_t} \epsilon_t,$$

(5)

where $\epsilon_t$ is an iid sequence of residual of volatility model. By using normal distribution, the estimation of VaR at time $t$ is as follows,

$$VaR_t^{\alpha} = \hat{\mu}_t + F_{\alpha}^{-1} \sqrt{h_t},$$

(6)

with $\hat{\mu}_t$ modeled by Equation (2) and (3), $\hat{\sigma}$ modeled by Equation (4) , and $F_{\alpha}^{-1}$ the inverse cumulative function of standard normal distribution at $\alpha$ quantile.

One method to evaluating the performance of VaR estimation is backtesting[7, 14]. Below is the function to determine the violation of VaR at time $t$,

$$I_t^\alpha = \begin{cases} 1, & y_t < -VaR_t^{\alpha} \\ 0, & y_t \geq -VaR_t^{\alpha} \\ \end{cases}$$

(7)

The percentage of number of violation of VaR during period $t$ is then compared to probability $\alpha$ to evaluate the risk of stock market and the model accuracy.

3. Data Summary

The data in this study is downloaded from www.finance.yahoo.com for each four companies’ stock price data, while Indonesian Covid-19 data are provided by Ministry of Research and Technology. The stock price and composite index JCI data used in this study is the closing price. Starting from March 2, 2020 till August 19, 2020, it has 112 days of observation in total. Since this study concentrates on stock return, thus the number of observation reduces to 111.

Figure 1. Movement of stock price during Covid-19 outbreak
Figure 1 shows the most stable stock is GIAA since it has the flat pattern as if the aircraft industry didn’t influenced by Covid-19, while BIRD and HRME show that the risk exposed to these companies is arguably high. From beginning of March 2020, they resembles decreasing pattern with the worst impact seems to happen on April - June 2020. It was the period when the government announced the large-scale social restriction to reducing the outbreak spread. In the same time, MIKA began to performed well and improve. The descriptive statistics is summarized in table 1 to explore the characteristic of each stock return.

**Table 1.** Descriptive statistic of return

| Return | Mean  | Variance      | Coef. of Var. | Min.   | Max.   | Median   | Skewness | Kurtosis |
|--------|-------|---------------|---------------|--------|--------|----------|----------|----------|
| BIRD   | -0.0063 | 0.0019        | -699.3        | -0.0844| 0.1330 | -0.0093 | 0.68     | 0.91     |
| GIAA   | -0.0000 | 0.0023        | -2.67x10$^{11}$ | -0.1478| 0.1775 | -0.0073 | 0.67     | 2.31     |
| HRME   | -0.0261 | 0.0020        | -171.0        | -0.0726| 0.1694 | -0.0277 | 1.40     | 3.52     |
| MIKA   | -0.0001 | 0.0016        | -52603.3      | -0.1137| 0.1714 | 0.0000  | 0.57     | 3.39     |

It is shown that GIAA and MIKA had higher average of return. Table 1 also indicates that GIAA is the company with the highest and smallest return. It means the risk and profitability of GIAA is the highest among four companies. It is reflected as well from the its high coefficient of variation. Refer to table 1, the stock return that nearly fits the normal distribution is MIKA since it has mean and median that both close to 0. Its skewness and kurtosis is not far away to 0 and 3, respectively.

![Figure 2](https://via.placeholder.com/150)

**Figure 2.** Relationship between stock return and exogenous

Figure 2 displays the matrix plot of stock return and three exogenous in this study. It is shown that the relationships between each stock return and each exogenous are nearly identical. For the relationship between GIAA return or MIKA return and JCI return, time series regression would be fit to model that alone. That is due to significant correlation among them. Though, ARMAX is possibly more fit to model the stock return had the exogenous were lagged Covid-19 confirmed cases and lagged Covid-19 death cases. The task is to seek for the best model accommodating those three exogenous to the stock volatility.
4. Empirical Analysis

4.1. Unit root test

Unit root test is employed to detect stationarity of stock return. The test is using Augmented Dickey-Fuller (ADF) test with null hypothesis being the series have unit root (non-stationary). Table 2 shows the ADF value with the p-value.

| Stock  | ADF value | p-value | Stock  | ADF value | p-value |
|--------|-----------|---------|--------|-----------|---------|
| BIRD   | -3.585    | 0.038   | HRME   | -4.028    | 0.01    |
| GIAA   | -3.809    | 0.021   | MIKA   | -4.587    | 0.01    |

Based on Table 2, it is concluded that all stock have stationary series of return.

4.2. Mean modeling

Estimation of Value-at-Risk (VaR) needs the mean model in which this study proposes time series regression and ARMAX. Particularly for ARMAX, the order of ARMA is identified first through sample autocorrelation function (ACF) and partial autocorrelation function (PACF) of the stock return. Through the pattern shown by ACF and PACF graph like in Figure 3, the alternative ARMAX models can be evaluated for each stock return.

![Figure 3](image.png)

Figure 3. ACF and PACF of stock return of four companies

Based on Figure 3, the possible order of ARMA for BIRD, GIAA, HRME and MIKA is AR(1), MA(1) or no significant order, MA(1) and AR(1), respectively. As illustration, below is the parameter estimation of both method to model the mean of MIKA return. The significance is at $\alpha = 5\%$.

| Model  | Parameter                  | Estimation | t-value | p-value |
|--------|----------------------------|------------|---------|---------|
| TSR    | Lagged Covid-19 death cases| -0.0003    | 16.48   | 0.000   |
| ARMAX  | AR 1 ( $\phi_1$)           | 0.116      | 4540.26 | 0.000   |
|        | Exogenous                  | Not significant |       |         |

Based on Table 3, after applying stepwise to both mean model in order to obtain significant parameter, it is found that the significant parameter in these two models are different. In TSR, lagged Covid-19 death cases is significant and has negative impact to the stock return.
Meanwhile, in ARMAX, the past of stock return is significant and has positive impact to the current stock return. It is proved by the significance of AR-1 term in the mean model. It is also found that none exogenous is significant to the MIKA return.

4.3. Volatility modeling
The mean model that has been carried out then yield the residual. All series of residual conditional standard deviation are modeled by GARCHX. Alike the mean model, the residuals need to be identified first through Autoregressive Conditional Heteroscedasticity-Lagrange Multiplier (ARCH-LM) test. Table 4 shows the statistical value obtained for both mean models of each stock. The significance is at $\alpha = 5\%$.

| Mean model | Companies | $\chi^2$ value | p-value |
|------------|-----------|----------------|---------|
| TSR       | BIRD      | 14.521         | 0.15    |
|           | GIAA      | 11.57          | 0.32    |
|           | HRME      | 37.21          | 0.00    |
|           | MIKA      | 37.63          | 0.00    |
| ARMAX     | BIRD      | 13.04          | 0.22    |
|           | GIAA      | 11.63          | 0.31    |
|           | HRME      | 26.91          | 0.002   |
|           | MIKA      | 40.49          | 0       |

Table 4 indicates that the residuals of mean model for HRME and MIKA is detected containing ARCH element. However, GARCHX will be carried out as well to evaluate the stock volatility of BIRD and GIAA since it is necessary to evaluate the impact of Covid-19 to the stock market. Then, the subsequent step is to observe the ACF and PACF graph of squared residuals of both mean model. It is to determine the order of GARCH that could be tentative. As illustration, figure 4 provides the ACF and PACF of squared residuals $\varepsilon^2$ of MIKA from TSR and ARMAX mean model.

Figure 4 indicates the squared residuals of both mean models of MIKA return contain the ARCH element or GARCH in general. Figure 4 hints that there should be more than one alternative of GARCH model for MIKA residuals, such as GARCH(1,0), GARCH(1,1), GARCH([6],0), or GARCH([1,6],0). Though figure 4 provides the possibility of complex GARCH model, the parsimony
model is likely selected. When modeling the GARCH model, it is carried out simultaneously with the exogenous and with the mean models as well.

Below is the best TSR-GARCHX model for each stock return of four service companies (BIRD, GIAA, HRME, MIKA).

- **BIRD** is significantly affected by \( x_i \) (JCI return) and follow GARCH(1,0) with JCI return as exogenous
  
  \[
  y_t = 0.437x_{1,t} + a_t
  \]  
  (8)

  and

  \[
  h_t = 0.001 + 0.9a_{t-1}^2 + 0.018x_{3,t}^2 + \epsilon_t
  \]  
  (9)

- **GIAA** is significantly affected by \( x_i \) (JCI return) and follow GARCH with \( x_{3,t-1} \) is lagged Covid-19 death
  
  \[
  y_t = 0.466x_{1,t} + a_t
  \]  
  (10)

  and

  \[
  h_t = 0.001 + 0.9a_{t-1}^2 + \left(8.37 \times 10^{-9}\right)x_{3,t-1}^2 + \epsilon_t
  \]  
  (11)

- **HRME** is significantly affected by lagged Covid-19 confirmed cases and lagged Covid-19 death cases and follow GARCH(2,0) with no significant \( x \)
  
  \[
  y_t = 0.00001x_{2,t-1} - 0.0005x_{3,t-1} + a_t
  \]  
  (12)

  and

  \[
  h_t = 0.0003 + 0.52a_{t-1}^2 + 0.38a_{t-2}^2 + \epsilon_t
  \]  
  (13)

- **MIKA** is significantly affected by lagged Covid-19 death cases and follow GARCH(2,0) with no significant \( x \)
  
  \[
  y_t = -0.00026x_{3,t-1} + a_t
  \]  
  (14)

  And

  \[
  h_t = 0.000003 + 0.33a_{t-1}^2 + 0.66a_{t-2}^2 + \epsilon_t
  \]  
  (15)

Based on weighted ARCH-LM test, it is indicated that there is no significant ARCH on the residuals of those four service companies modeled by TSR-GARCHX. Ljung-Box test also shows that the residuals satisfy the white noise. Then, these are ARMAX-GARCHX models for each stock return of four service companies.

- **BIRD** follows ARMA(1,0) without significant exogenous and follows GARCH(1,1) with lagged Covid-19 death as exogenous
  
  \[
  y_t = 0.234y_{1,t-1} + a_t
  \]  
  (16)

  and

  \[
  h_t = 0.0002 + 0.367a_{t-1}^2 + 0.574h_{t-1} + 0.000001x_{3,t-1}^2 + \epsilon_t
  \]  
  (17)

- **GIAA** follows ARMA(0,1) with JCI return as exogenous and follows GARCH([2],0) without significant exogenous
  
  \[
  y_t = a_t - 0.11a_{t-1} + 0.712x_{i,t}
  \]  
  (18)

  and

  \[
  h_t = 0.001 + 0.648a_{t-2}^2 + \epsilon_t
  \]  
  (19)

- **HRME** follows ARMA(0,1) without significant exogenous and follows GARCH(2,0) with JCI return as exogenous
  
  \[
  y_t = a_t + 0.47a_{t-1}
  \]  
  (20)
\[ h_t = 0.000003 + 0.76a_{t-1}^2 + a_{t-2}^2 + 0.00013x_{1,t} + \varepsilon_t \] (21)

- MIKA follows ARMA(1,0) without significant exogenous and follows GARCH(2,0) with lagged Covid-19 death as exogenous

\[ y_t = 0.116y_{t-1} + a_t \] (22)

and

\[ h_t = 0.000001 + 0.42a_{t-1}^2 + 0.69a_{t-2}^2 + 0.000009x_{3,t-1} + \varepsilon_t \] (23)

Based on weighted ARCH-LM test, it is indicated that there is no significant ARCH on the residuals of those four service companies modeled by ARMAX-GARCHX. Ljung-Box test also shows that the residuals satisfy the white noise.

4.4. Value-at-Risk (VaR) analysis

In this part, VaR as the proxy to evaluate the risk is calculated using equation (6). The VaR calculations are carried out at 1% and 5% quantiles. The descriptive of VaR is summarized on Table 5.

| Company | Statistic | TSR-GARCHX | ARMAX-GARCHX |
|---------|-----------|------------|--------------|
|         | 1% quantile | 5% quantile | 1% quantile | 5% quantile |
| BIRD    | Mean      | -0.1122    | -0.0793      | -0.1014     | -0.0725     |
|         | Variance  | 0.0026     | 0.0013       | 0.0013      | 0.0007      |
| GIAA    | Mean      | -0.1258    | -0.0890      | -0.1053     | -0.0745     |
|         | Variance  | 0.0035     | 0.0018       | 0.0022      | 0.0012      |
| HRME    | Mean      | -0.1100    | -0.0806      | -0.1223     | -0.0889     |
|         | Variance  | 0.0029     | 0.0015       | 0.0072      | 0.0039      |
| MIKA    | Mean      | -0.0912    | -0.0673      | -0.0957     | -0.0677     |
|         | Variance  | 0.0031     | 0.0015       | 0.0033      | 0.0017      |

Based on Table 5, it is GIAA and HRME that could experience the biggest maximum loss according to TSR-GARCHX and ARMAX-GARCHX. It is evidenced at both quantiles. Thus, when a stockholder investing IDR 1 billion in GIAA, the maximum loss that he could experience is IDR 89,000,000 and IDR 125,800,000 at 95% and 99% confidence level, respectively. Table 5 also shows that MIKA is the company service having the smallest maximum loss. It is evidenced at both quantiles that has been modeled by TSR-GARCHX and ARMAX-GARCHX. As an illustration, figure 5 displays the time series plot of MIKA return compared with its VaR at 1% and 5% quantiles.
It is reported that GIAA and MIKA had the highest and smallest return of service companies’ stock, apart from the past.

This research analyzes and evaluates the volatility of service companies enlisted in IDX during the rise of Covid-19. It is reported that GIAA and MIKA had the highest and smallest return simultaneously. The TSR-GARCHX and ARMAX-GARCHX indicated that JCI return and lagged Covid-19 death cases could influence the volatility of service companies’ stock, apart from the past.

Figure 5. MIKA return and VaR estimation

In figure 5, the VaR values are less than the returns of MIKA at both models. It is also indicated that the risk exposed by larger 99% confidence level is greater than 95% level since 99% VaR provides lower values than 95% VaR. Thus, it suggests the high risk might bring the high return even though the current situation is not-normal. Then, table 6 reports the insight of negative violation and positive violation of all stocks yielded by backtesting method.

Table 6. VaR violation of the stock return

| Companies | 1% quantile | 5% quantile |
|-----------|-------------|-------------|
|           | TSR-GARCHX  | ARMAX-GARCHX| TSR-GARCHX | ARMAX-GARCHX |
| BIRD      | NV (%)      | PV (%)      | NV (%)     | PV (%)       |
| GIAA      | 0.90        | 3.60        | 1.80       | 1.80         |
| HRME      | 0.90        | 2.70        | 2.70       | 2.70         |
| MIKA      | 3.60        | 9.91        | 2.70       | 3.60         |

In table 6, the symmetry VaR is proved since many percentages of negative violation and positive violation do not exceed the significance level 1% and 5%. Based on table 6, the percentage of VaR negative violation (unexpected loss) at 1% quantile is slightly rejected at confidence level 99%, except for the VaR of BIRD, GIAA and HRME modeled by TSR-GARCHX. Whilst at 5% quantile, the percentage of VaR negative violation (unexpected loss) is mostly accepted with confidence level 95%.

In average, ARMAX-GARCHX estimates negative violation better than TSR-GARCHX at 5% quantile or at lower risk. Though, it is indicated that TSR-GARCHX performed better than ARMAX-GARCHX when estimating violation, especially the negative one, at 1% quantile or at higher risk. Table 6 also suggests that investing in GIAA and MIKA somehow can bring the unexpected profit (based on positive violation and inline with table 1), though this does not occur every time.

5. Conclusion

This research analyzes and evaluates the volatility of service companies’ stock enlisted in IDX during the rise of Covid-19. It is reported that GIAA and MIKA had the highest and smallest return simultaneously. The TSR-GARCHX and ARMAX-GARCHX indicated that JCI return and lagged Covid-19 death cases could influence the volatility of service companies’ stock, apart from the past.
value of stock return. JCI return showed the positive impact to the stock return, like in BIRD and GIAA. However, lagged Covid-19 death cases had the negative impact to the stock, such as in HRME and MIKA. The result shows GIAA and HRME could experience the biggest maximum loss among four companies during pandemic. It is shown that MIKA is likely the companies with smallest maximum loss. In estimating unexpected loss, ARMAX-GARCHX is better than TSR-GARCHX at 5% quantile. It is recommended that the government and companies should collaborate to make rapid breakthrough to support the industry of transportation and tourism service. It is also necessary to improve the treatment of Covid-19 to reduce the cases since it is evidenced have the impact to the stock volatility. Further research suggests any comparison between volatility before pandemy and during pandemy using various window to simulate many scenarios.

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