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STOCK PRICE FORECASTING USING THE *HYBRID* ARIMA-GARCH MODEL

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ABSTRACT

In the current era, many people have made investments, namely capital investment activities within a certain period to seek and get profits. One of the most popular investment instruments in the capital market is stocks, which consist of conventional stocks and Islamic stocks. Conventional stocks are shares traded on the stock market without adhering to Sharia principles. In contrast, Sharia-compliant stocks meet Islamic principles and are traded in the sharia capital market. One form of development of the Islamic capital market in Indonesia is the existence of the Indonesian Sharia Stock Index (ISSI), which projects the movement of all Islamic stocks on the Indonesia Stock Exchange (IDX). Stock prices change every day so modeling is needed that can be used by investors to determine decisions. The Autoregressive Integrated Moving Average (ARIMA) model is one of the forecasting models that is applicable. Stock prices have volatility that tends to be high, this results in variance that is not constant or there is a heteroscedasticity problem, at the same time the ARIMA model must fulfill the assumption of homoscedasticity. Therefore, it is necessary to combine the ARIMA model with a model that can overcome the problem of heteroscedasticity, namely the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model. This research aims to get the best hybrid ARIMA-GARCH model that will be used to forecast the stock price of the ISSI. The daily closing data of the ISSI stock price from May 4, 2020, to January 13, 2023, is the data that was used. The study's findings suggest that ARIMA (0,1,3)-GARCH (2,0) is the best model among all possible models for ISSI stock price forecasting. By evaluating the predictive accuracy of the model using Mean Absolute Percentage Error (MAPE), the forecasting result for ISSI stock prices using the best model, ARIMA(0,1,3)-GARCH(2,0) at 0,6092%, shows a forecasting that is close to the actual data, which means that the model used is highly effective at forecasting stock priced.

Keywords: *ARIMA-GARCH Model, Forecasting, ISSI Stock Price, Heteroskedasticity*

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INTRODUCTION

One of the activities of investing capital into a project or company for a certain period that can be undertaken by the public with the aim of generating profits is investment (Azmi & Syaifudin, 2020). Stocks are one of the most widely used investment products in the capital market. Stocks are proof of ownership of a portion of capital that grants rights to dividends and other rights based on the amount of capital invested (Zili et al., 2022). The Islamic capital market is a capital market that operates based on Sharia principles, which means all its transactions comply with Islamic law (Kalimah & Khoirunnisa, 2019). The Indonesia Sharia Stock Index (ISSI), issued on May 12, 2011, by the Indonesia Stock Exchange (IDX), is one form of development in the Islamic capital market in Indonesia. ISSI is a Sharia stock index that projects the movement of all Sharia-compliant stocks listed on the IDX.

Investors planning to invest in the capital market have an important principle, which is to observe stock price index movements. An instrument useful for observing stock price movements is the stock price index. Changes in market conditions will be indicated by stock index movements. If the stock index rises, it means active transactions are occurring in the market. The market is stable if the stock index remains steady, while if the stock index declines, the market is weak (Agestiani & Sutanto, 2019). A company's performance can be measured by its stock price; if the stock price is high, its value to investors will also be high, and vice versa. Investment activities promise profits, but they also carry risks. In the capital market, an investor may face the risk of a decline in stock prices, which could result in losses for the investor. Similarly, with ISSI, the effort that can be made before making investment decisions such as selling, buying, or holding stocks is to use models to forecast future stock prices (Azmi & Syaifudin, 2020).

In statistics, many models can be utilized to predict future data. One of the most popular forecasting models, as it uses past data as a reference to predict the future, is time series analysis (Cryer & Chan, 2008). Time series forecasting has several models, including Auto-Regressive (AR), Moving Average (MA), Auto Regressive Integrated Moving Average (ARIMA), Exponential Smoothing, Autoregressive Conditional Heteroscedasticity (ARCH), and Generalized Autoregressive Conditional Heteroscedasticity (GARCH), among others. There are also forecasting models that use artificial intelligence such as Neural Networks, Genetic Algorithms, and hybrid time series models.

The ARIMA (Autoregressive Integrated Moving Average) method is one of the time series forecasting techniques widely used in time series data analysis. ARIMA combines three main concepts into one model: autoregression (AR), differencing (I for integrated), and moving average (MA). The GARCH model is an extension of the ARCH model, where volatility depends on the previous day's value as well as the previous volatility value. By combining the ARIMA model with the GARCH model, a new model called the ARIMA-GARCH hybrid model is created, which combines the two models to compensate for each other's shortcomings (Zili et al., 2022).

This research uses ISSI stocks, which tend to have high volatility meaning their prices rise and fall rapidly. This results in non-constant variance or heteroscedasticity issues, while the ARIMA model residuals must meet the homoscedasticity assumption (Putri et al., 2021). Therefore, it is necessary to combine the ARIMA model with a model that can address heteroscedasticity issues (Putri et al., 2021). A model that can be used to model residual heteroscedasticity is the Generalized Autoregressive Conditional Heteroscedasticity (GARCH). Combining the ARIMA and GARCH models is expected to produce forecasts with smaller residuals.

The study using the hybrid ARIMA-GARCH model, as conducted by (Melana & Suwanda, 2023), aimed to forecast JISDOR exchange rate data and found that the best model was the hybrid ARIMA(0,1,1)-GARCH(1,1), which achieved an AIC value of -8.68 and a MAPE of 1.80. Another study (Trimono et al., 2021) predicted the profits and losses in agricultural commodity prices using the ARIMA-GARCH and VaR models. The results showed that the best model for predicting the profits of onions and red chilies was the hybrid ARIMA-GARCH, which produced a low MSE value.

Based on the explanation above, this study aims to obtain a hybrid ARIMA-GARCH model that will be used to predict stock prices in the Indonesia Sharia Stock Index (ISSI). The difference between this study and previous studies lies in the object and research period. In this study, the research uses ISSI stocks with the period from May 4, 2020, to January 13, 2023.

MATERIALS AND METHODS

This research investigates the closing price data of the Indonesian Sharia Stock Index (ISSI) for the period from May 4, 2020, to January 13, 2023 sourced from the website https://id.investing.com/, aiming to forecast stock prices using the hybrid ARIMA-GARCH model. The research process begins with separating the data into in-sample and out-of-sample datasets. This research uses 660 observations of ISSI daily closing stock prices. The data period used for the in-sample consists of 650 observations from May 4, 2020, to December 30, 2022, while the out-sample data includes 10 observations from January 2, 2023, to January 13, 2023. A line plot or graph is then used to identify patterns in the in-sample data.

Next, a Box-Cox test is performed to assess variance stationarity, and the Augmented Dickey-Fuller (ADF) test is used to test mean stationarity. The Box-Cox transformation can be employed to assess variance stationarity. According to (Wei, 2006), data is considered stationary in variance if the lambda (λ) value approaches or equals 1; otherwise, transformation is necessary (Lestari et al., 2018). To address the non-stationarity of data variance, the Box-Cox transformation is applied usi (1) following formula (Wei, 2006):

$$Y_t^{(\lambda)} = \begin{cases} \frac{Y_t^{(\lambda)} - 1}{\lambda}; & \lambda \neq 0 \\ \ln Y_t & ; \lambda = 0 \end{cases}$$

with $Y_t^{(\lambda)}$ representing the data at the time t, where λ is the transformation parameter.

The following step involves identifying the ARIMA model for stationary data by examining the ACF and PACF plots. The parameters of the ARIMA model are estimated using the maximum likelihood estimation (MLE) method. The best ARIMA model is determined by considering the significance of parameter estimates and the lowest Akaike Information Criterion (AIC) value. The ARIMA model formula is as follows:

$$\phi_p(B)(1-B)^d Y_t = \mu + \theta_q(B)\varepsilon_t \quad (2)$$

Where Y_t is the data at time t, μ is a constant, $\phi_p(B)$ is $1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$, $(1-B)^d$ is the differencing process with order d, B is the backward shift operator, $\theta_q(B)$ is $1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_p B^p$, and ε_t is the error or residual at time t.

After identifying the best ARIMA model, diagnostic testing and the ARCH-LM test are conducted to assess whether there is heteroscedasticity in the model's residuals. The hypotheses used are as follows (Asmarita et al., 2022):

H_0: $\alpha_1 = \alpha_2 = \alpha_m = 0$ (no ARCH/GARCH effect (homoskedasticity))
H_1: minimal ada satu $\alpha_m \neq 0$ (there is ARCH/GARCH effect (heteroskedasticity))
the ARCH-LM test statistic is defined as follows:

$$LM = nR^2 \quad (3)$$

If the LM statistic is greater than $X^2_{(\alpha,m)}$ or the p-value is less than α = 0,05 reject H_0.

If heteroscedasticity is found in the residuals, GARCH modeling is applied. The ACF and PACF plots of the squared residuals of the ARIMA model are used to identify the GARCH model. The parameters of the GARCH model are then estimated, and the best GARCH model is selected based on the smallest AIC value and parameter significance. The GARCH model formula is as follows:

$$\sigma_t^2 = \mu + \sum_{i=1}^{u} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{v} \beta_j \sigma_{t-j}^2 \quad (4)$$

Where σ_t^2 represents the residual variance, μ is the constant, α_i is the ARCH parameter (u), β_j is the GARCH parameter (v), ε_{t-i}^2 is the squared residual of the previous period in the ARCH term, and σ_{t-j}^2 is the squared residual variance of the previous period in the GARCH term.

The model used in this research is a combination of the ARIMA and GARCH models. The errors from the ARIMA model forecasts, which have been previously developed, are used to form the GARCH model. Once the ARIMA-GARCH hybrid model is obtained the best ARIMA-GARCH model is evaluated using the out-of-sample data. If the model proves to be highly accurate in forecasting stock prices, as evidenced by a low Mean Absolute Percentage Error (MAPE) value, the ISSI stock prices are then predicted for the next 11 days, namely the period January 16, 2023 to January 31, 2023. Additionally, this study focuses on forecasting the ISSI stock prices only, without predicting their returns.

RESULTS AND DISCUSSION

Data Description

Daily closing prices of ISSI stocks were utilized in this study, comprising a total of 660 observations. Changes in ISSI stock prices can be observed in the data plot in Figure 1.

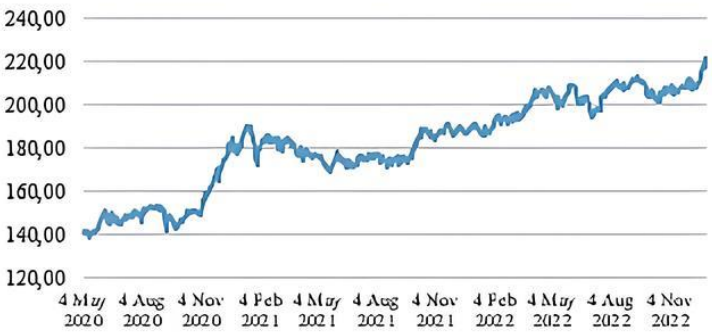

Figure 1. Plot of ISSI Stock Prices

Figure 1 depicts the movement of ISSI stock prices from May 4, 2020, to December 30, 2022, showing a trend pattern or fluctuation where there are daily increases or decreases. Due to the data forming a trend pattern, it indicates that the ISSI data is non-stationary. The ISSI stock prices also do not exhibit stationary patterns in both mean and variance because the data movements do not cluster around a constant mean value. The volatility of ISSI stocks is notably high, with significant fluctuations occurring over short periods of time. The highest stock price recorded was 222.00 on December 22, 2022, while the lowest was 138.80 on May 14, 2020. In early 2020, the COVID-19 outbreak significantly impacted stock movements, causing prices to decline and leading to investor panic in Sharia stocks investments. Despite Indonesia's overall economic downturn during the pandemic, ISSI stock returns showed a slight increase. The ISSI stocks began recovering in mid-2020, continuing through the post-pandemic period. This can be observed in the plot where there is an upward trend towards the end of 2020 and early 2021.

Stationary Test

a. Box-Cox Transformation

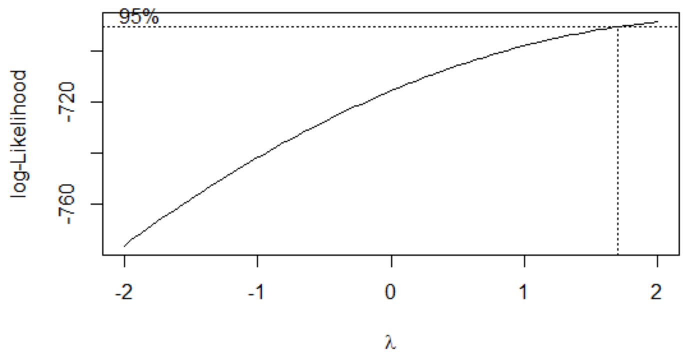

Figure 2. Box-Cox Plot of ISSI Stocks

Based on Figure 2, it can be seen that the dashed vertical line represents the estimated parameter λ with a 95% confidence interval, which does not include or approach 1, as evidenced by the software results showing a λ value of 2. Therefore, a transformation of the data is necessary, and after the transformation, the Box-Cox plot is displayed in Figure 3.

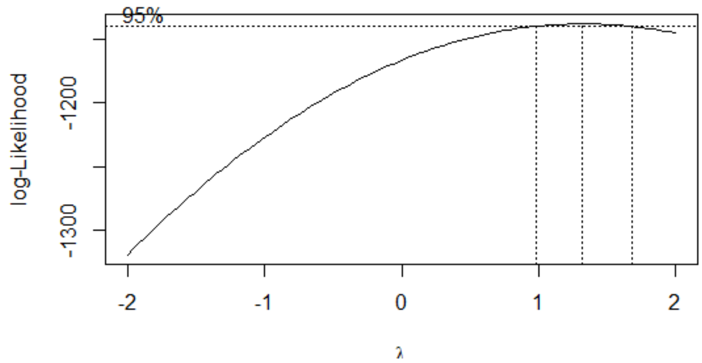

Figure 3. Plot After Box-Cox Transformation

In Figure 3, after the Box-Cox transformation, it can be seen that the value has approached 1, with the lambda value obtained from the software being 1.31. This indicates that the ISSI stock data is now stationary in variance.

b. Augmented Dickey-Fuller Test

The stationarity of data in terms of mean is determined by conducting the ADF test. If the probability value is less than the significance level of $\alpha = 0.05$, then differencing is not required because the data is already stationary in mean. The ADF test results indicate that the data is non-stationary because the p-value is greater than 0.05, specifically 0.2618, and the Augmented Dickey-Fuller value is -2.7478. Therefore, differencing is necessary, and after differencing, the ADF test is performed again.

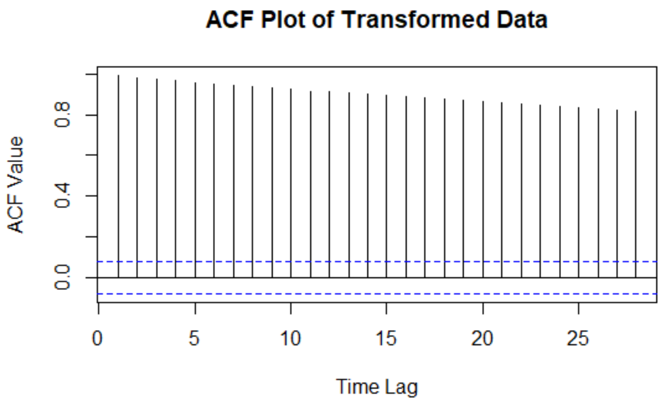

Figure 4. ACF Plot of Transformed Data

From Figure 4, it is known that the ACF plot of the transformed data shows autocorrelation function values that exceed the interval lines, indicating that the data can be considered non-stationary in mean. After differencing, the data achieves stationarity in mean with a p-value of 0.01, which is now less than 0.05, and an Augmented Dickey-Fuller value of -9.0308. Below is the plot demonstrating the data's stationarity.

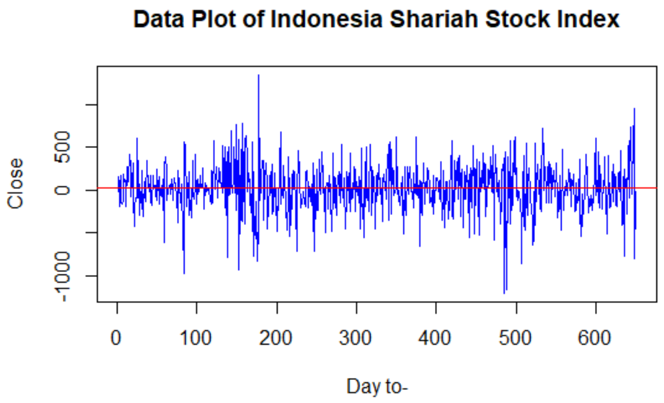

Figure 5. Stationary Plot

Based on Figure 5, the data is already around its mean value, which is zero. This means that the ISSI stock data is already stationary.

ARIMA Modeling

a. Model Identification

ARIMA model identification is determined from the ACF and PACF plots when the data is stationary. The order *p* can be identified from the PACF plot where it cuts off, while the order *q* can be identified from the ACF plot where it cuts off. The order *d* depends on the number of differencing operations performed.

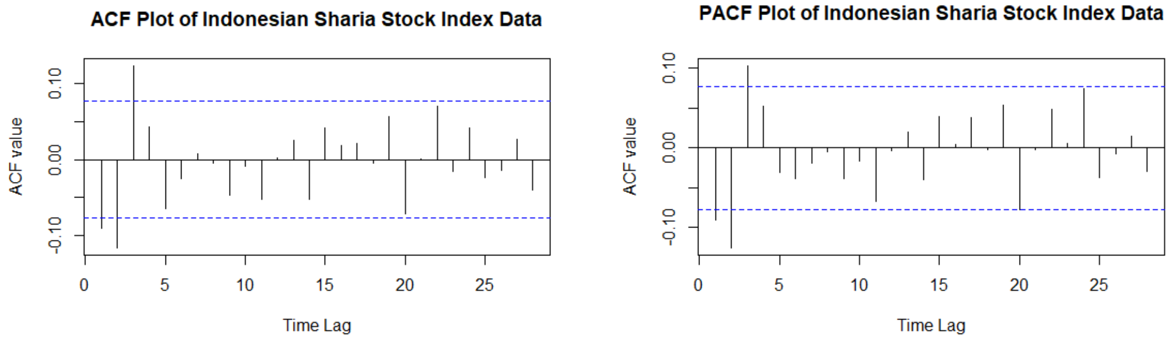

Figure 6. ACF and PACF Plot of ISSI Stock Data

Based on Figure 6, it is observed that both the ACF and PACF plots cut off at lag 1, 2, and 3. Therefore, the orders *p* and *q* are determined to be 1, 2, and 3. It was previously noted that the data underwent differencing once, hence the order *d* is 1. The following is the potential ARIMA model:

Table 1. Possible ARIMA Models

ARIMA (1,1,0)	ARIMA (2,1,0)	ARIMA (3,1,0)
ARIMA (1,1,1)	ARIMA (2,1,1)	ARIMA (3,1,1)
ARIMA (1,1,2)	ARIMA (2,1,2)	ARIMA (3,1,2)
ARIMA (1,1,3)	ARIMA (2,1,3)	ARIMA (3,1,3)
ARIMA (0,1,1)	ARIMA (0,1,2)	ARIMA (0,1,3)

Table 1 presents several potential models that could be formed by observing the ACF and PACF plots. All of these models will then undergo parameter estimation to determine the best model.

b. Parameter Estimation

To test all possible ARIMA models, parameter estimation was conducted to identify significant models. Out of 15 potential models, only five were found to be significant. The parameter estimation results for these significant models are presented below.

Table 2. Results of ARIMA Model Parameter Estimation

Model	**Parameter**	**Parameter Value**	***p-value***	**AIC Value**
ARIMA (1,1,0)*	AR(1) = $\emptyset_1$	-0,0779	0,0463	2461,78
ARIMA (2,1,0)*	AR(1) = $\emptyset_1$	-0,0884	0,0231	2451,87
	AR(2) = $\emptyset_2$	-0,1348	0,0005	
ARIMA (2,1,1)*	AR(1) = $\emptyset_1$	-0,4312	0,0089	2450,14
	AR(2) = $\emptyset_2$	-0,1714	0,0000	
	MA(1) = θ_1	0,3505	0,0334	
ARIMA (0,1,1)*	MA(1) = θ_1	-0,1004	0,0195	2460,54
ARIMA (0,1,3)**	MA(1) = θ_1	-0,0860	0,0270	2447,08
	MA(2) = θ_2	-0,0987	0,0085	
	MA(3) = θ_3	0,1288	0,0010	

*Significant Models
**Best ARIMA Model (Selected Model)

From the parameter estimation results in Table 2, only five models were found to be significant with p-values less than the significance level of 0.05. Therefore, the next step is to select the best ARIMA model, which is ARIMA (0,1,3), as it has the lowest AIC value of 2447.08.

c. Diagnostic Test

Diagnostic testing of residuals ensures that they satisfy the assumptions of independence (white noise) and normal distribution. ACF plot of residuals can be used to test the independence of residuals, where all lags are within the significance bounds. Alternatively, the Q-Ljung Box test can also be conducted, where if the p-value exceeds 0.05, it indicates that the residuals are independent. To assess the normal distribution of residuals, one can examine a normality plot of residuals.

From the Q-Ljung Box test results, the p-value for the ARIMA (0,1,3) model is 0.6427, which is greater than 0.05, indicating that the residuals pass the test for independence.

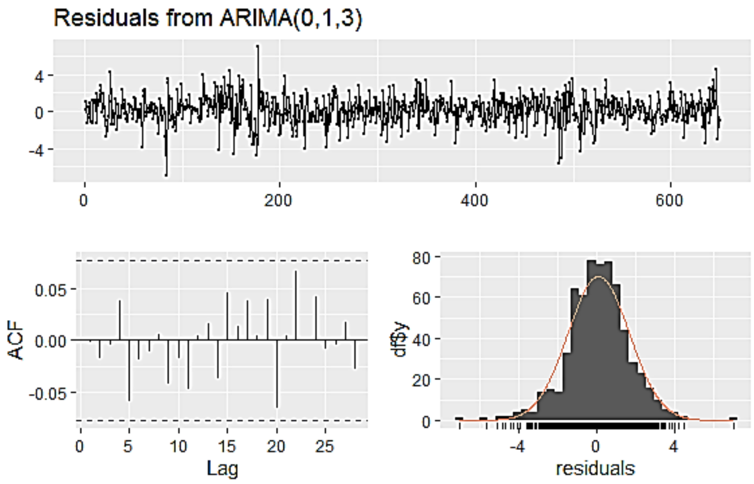

Figure 7. Residuals Plot

Based on the residuals plot in Figure 7, the ACF plot of the ARIMA (0,1,3) model shows that all lags are within the significance bounds, indicating that the assumption of residual independence is satisfied. Additionally, the residual plot of the ARIMA (0,1,3) model forms a bell-shaped curve, suggesting that the residuals are normally distributed there is no enough evidence to reject null hypothesis (Ho: Data are normally distributed) since p-value 0.3352 is larger than alpha 0.05. The data residuals is already around its mean value, which is zero. Therefore, the white noise assumption is fulfilled.

ARCH-LM Test

Next, the ARCH-LM test is conducted to detect whether there is ARCH effect in the residuals of the ARIMA (0,1,3) model. The p-value of the ARCH-LM test is 0.0056, which is less than 0.05. This indicates that H0 is rejected, confirming the presence of ARCH effect (heteroskedasticity) in the data. Additionally, as shown in Figure 1, the data exhibits high volatility, suggesting non-constant variance or heteroskedasticity issues. Therefore, the next step is to estimate a model using GARCH.

ARIMA-GARCH Modeling

a. Model Identification

The ACF and PACF plots of the squared residuals from the ARIMA model are used to identify the GARCH model. The PACF plot is used to determine the order of the ARCH model, while for the GARCH model, the order is determined based on the ACF plot.

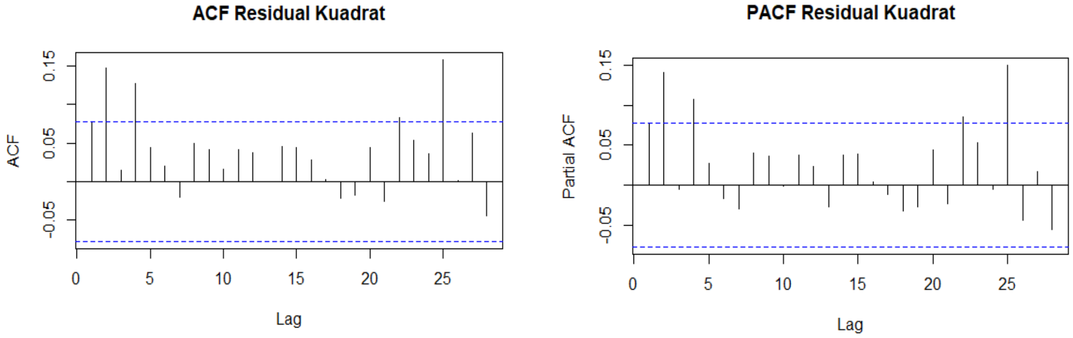

Figure 8. ACF and PACF Plot of Quadratic Residuals

Figure 8 shows that the second lag in both the ACF and PACF plots is the longest one that exceeds the significance bounds. Therefore, the GARCH models to consider are GARCH (2,0), GARCH (0,2), and GARCH (2,2).

b. Parameter Estimation

Next, we estimate the parameters of the ARIMA-GARCH model to determine the best model by looking at the significance and AIC value.

Table 3. Parameter Estimation of ARIMA-GARCH

Model	Parameter	Parameter Value	Prob	AIC Value
ARIMA (0,1,3)-GARCH (0,2)	c	0,2576	0,9540	3,7845
	β_1	0,2277	0,9941	
	β_2	0,6725	0,9814	
ARIMA (0,1,3)-GARCH (2,0)*	c	1,8899	0,0000	3,7515
	α_1	0,1245	0,0023	
	α_2	0,1391	0,0008	
ARIMA (0,1,3)-GARCH (2,2)	c	0,7849	0,0105	3,7474
	α_1	0,0774	0,0141	
	α_2	0,1277	0,0016	
	β_1	-0,0802	0,5936	
	β_2	0,5701	0,0015	

* Best Model

In Table 3, only one significant model was obtained, which is the ARIMA (0,1,3)-GARCH (2,0) model with an AIC value of 3.7515. Therefore, the ARIMA (0,1,3)-GARCH (2,0) model is considered the best model. The equation formed by the ARIMA (0,1,3)-GARCH (2,0) model is as follows:

ARIMA Equation:

$$\phi_p(B)(1-B)^d Y_t = \theta_P(B)\varepsilon_t$$
$$Y_t = \varepsilon_t - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} - \theta_3\varepsilon_{t-3} + Y_{t-1}$$
$$Y_t = \varepsilon_t - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} - \theta_3\varepsilon_{t-3} + Y_{t-1}$$
$$Y_t - Y_{t-1} = \varepsilon_t - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} - \theta_3\varepsilon_{t-3}$$
$$Y_t - Y_{t-1} = \varepsilon_t + 0{,}0860\varepsilon_{t-1} + 0{,}0987\varepsilon_{t-2} - 0{,}1288\varepsilon_{t-3}$$

GARCH Equation:

$$\sigma_t^2 = \mu + \sum_{i=1}^{u} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{v} \beta_j \sigma_{t-j}^2$$
$$\sigma_t^2 = 1{,}8899 + 0{,}1245\varepsilon_{t-1}^2 + 0{,}1391\varepsilon_{t-2}^2$$

c. ARCH-LM Test

The next step involves conducting the ARCH-LM test again to determine if there is still heteroskedasticity in the ARIMA (0,1,3)-GARCH (2,0) model. The test result yielded a p-value of 0.8186, indicating that H0 is accepted because it is greater than α. Therefore, the ARIMA (0,1,3)-GARCH (2,0) model no longer exhibits heteroskedasticity issues.

Evaluation of ARIMA-GARCH Model

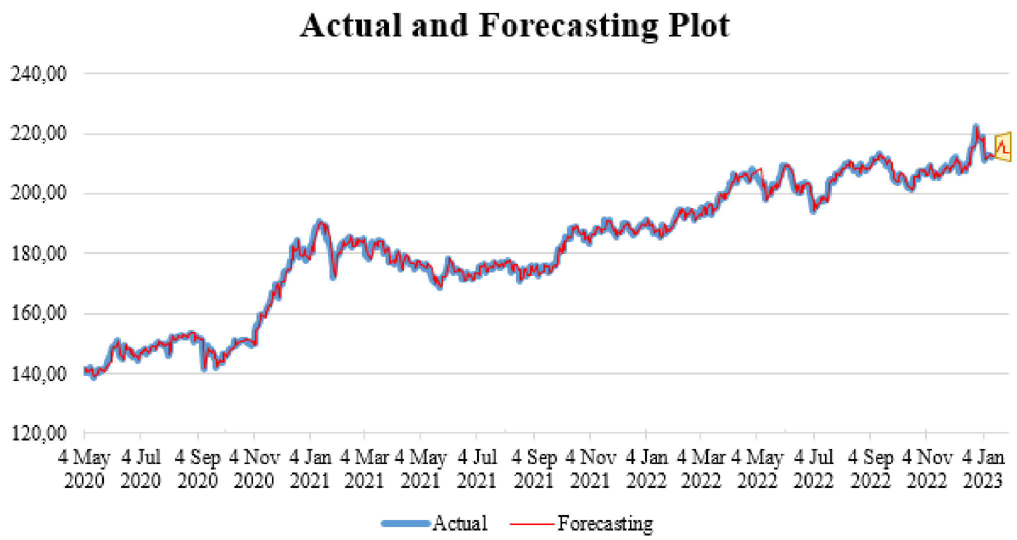

Figure 9. ARIMA-GARCH Model Evaluation Plot

Figure 9 shows that the pattern of ISSI stock data movement from May 4, 2020, to December 30, 2022, closely aligns with the forecasted data using the best-fit ARIMA (0,1,3)-GARCH (2,0) model. This is further supported by the very low MAPE value of the in-sample data, which is 0.6741%, indicating that the ARIMA (0,1,3)-GARCH (2,0) model is highly accurate in estimating ISSI stock data.

After obtaining the best model, ARIMA (0,1,3)-GARCH (2,0), the model is evaluated by comparing the forecasted results with the actual or out-of-sample data from January 2, 2023, to January 13, 2023., followed by calculating its MAPE (Mean Absolute Percentage Error).

After obtaining the forecast results in Figure 9, it is observed that the forecasted prices of ISSI stock using the ARIMA (0,1,3)-GARCH (2,0) model closely match the actual data. Based on calculations, a very low MAPE value of 0.6092% indicates that the forecasting results are highly accurate.

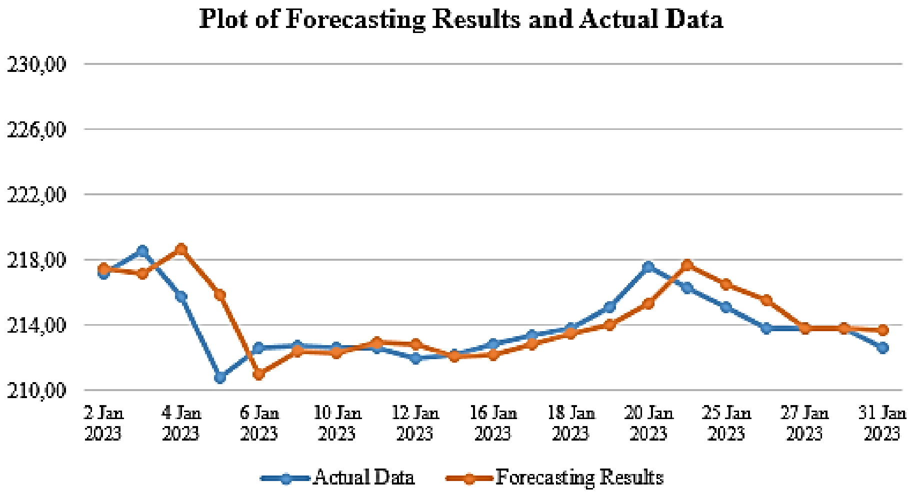

Figure 10. Comparison Plot of Forecasting and Actual Data

In Figure 10, the forecast plot using the ARIMA (0,1,3)-GARCH (2,0) model is also displayed. The period from January 2 to January 13, 2023, represents the out-of-sample data, while January 16 to January 31, 2023, represents the forecasted results. The plot indicates that the forecasted data for January 2023 closely aligns with the actual data, demonstrating that the model obtained can provide accurate forecasts.

Forecasting with the ARIMA-GARCH Model

The results of ISSI stock price forecasting for the next 11 days, namely the period January 16, 2023, to January 31, 2023, are shown in Table 4.

Table 4. 11-Day ISSI Stock Forecasting Results

Date	Actual Data	Forecasting Results
January 16, 2023	212,85	212,23
January 17, 2023	213,35	212,88
January 18, 2023	213,82	213,47
January 19, 2023	215,14	214,00
January 20, 2023	217,57	215,31
January 24, 2023	216,28	217,72
January 25, 2023	215,15	216,51
January 26, 2023	213,79	215,50
January 27, 2023	213,82	213,76
January 30, 2023	213,79	213,80
January 31, 2023	212,64	213,73

Based on Table 4, the forecasted prices of ISSI stock for the period from January 16, 2023, to January 31, 2023, exhibit minor fluctuations. This indicates that ISSI stock maintains a relatively stable price, as there are no significant differences observed from day to day.

CONCLUSION

Based on the results of the analysis conducted, the following conclusions To forecast the closing prices of ISSI stocks, the ARIMA (0,1,3)-GARCH (2,0) model was selected as the best model. The model equations are as follows:

$$Y_t = Y_{t-1} + \varepsilon_t + 0{,}0860\varepsilon_{t-1} + 0{,}0987\varepsilon_{t-2} - 0{,}1288\varepsilon_{t-3}$$
$$\sigma_t^2 = 1{,}8899 + 0{,}1245\varepsilon_{t-1}^2 + 0{,}1391\varepsilon_{t-2}^2$$

The forecast using the ARIMA (0,1,3)-GARCH (2,0) model obtained a Mean Absolute Percentage Error (MAPE) of 0.6092%, indicating that the forecasted ISSI stock prices for the period from January 2, 2023, to January 13, 2023, are classified as very good as they closely approximate the actual data. Furthermore, the forecasted ISSI stock prices for the next 11 days, from January 16, 2023, to January 31, 2023, are expected to range between 212.23 and 217.72. During this period, ISSI stock prices are anticipated to fluctuate, albeit not significantly.

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