InPrime: Indonesian Journal of Pure and Applied Mathematics
Vol. 6, No. 2 (2024), pp. 158 – 171, doi: 10.15408/inprime.v6i2.40249
p-ISSN 2686-5335, e-ISSN: 2716-2478

A Comparative Analysis of ARCH/GARCH and Decomposition-ARIMA Models for Gold Price Forecasting in Indonesia

Ronald Hutajulu and Neli Agustina*
Department of Statistics, Politeknik Statistika STIS, Jakarta, Indonesia
Email: *neli@stis.ac.id

Abstract

Gold is considered a low-risk investment, serving as a hedge asset and haven against inflation and economic shocks. While gold prices exhibit an increasing trend in the long term, they are subject to short-term fluctuations. Accurate gold price prediction is crucial for investors to maximize returns. This research aims to identify the most suitable method for forecasting gold prices in Indonesia, comparing the decomposition-ARIMA and ARCH-GARCH models. The findings reveal that the decomposition-ARIMA(2,1,2) method surpasses the GARCH(1,0) model in accuracy. The forecasting results indicate an upward trend in gold prices, with an average IDR of 1,209,214.11. This study demonstrates the superior accuracy of the decomposition-ARIMA method for gold price forecasting in Indonesia, offering valuable insights for investors seeking to optimize their investment strategies.
Keywords: ARCH-GARCH model; forecasting; gold; volatility.

Abstrak

Emas dianggap sebagai investasi berisiko rendah, berfungsi sebagai aset hedge dan safe haven yang aman terhadap inflasi dan guncangan ekonomi. Meskipun harga emas menunjukkan tren peningkatan dalam jangka panjang, harga emas juga dapat mengalami fluktuasi dalam jangka pendek. Prediksi harga emas yang akurat sangat penting bagi investor untuk memaksimalkan keuntungan. Penelitian ini bertujuan untuk mengidentifikasi metode yang paling sesuai untuk meramalkan harga emas di Indonesia, dengan membandingkan model dekomposisi-ARIMA dan model ARCH-GARCH. Temuan menunjukkan bahwa metode dekomposisi-ARIMA(2,1,2) melampaui akurasi model GARCH(1,0). Hasil peramalan menunjukkan adanya tren kenaikan harga emas dengan harga rata-rata Rp 1.209.214,11. Kontribusi studi ini terletak pada demonstrasi akurasi metode dekomposisi-ARIMA yang unggul dalam peramalan harga emas di Indonesia, sehingga menawarkan wawasan berharga bagi investor yang ingin mengoptimalkan strategi investasinya.
Kata Kunci: model ARCH-GARCH; prediksi; emas; volatilitas.

2020MSC: 62M10.

1. INTRODUCTION

Investment is defined as a means by which capital/funds can be placed in the hope that these funds will generate positive income and/or maintain or even increase the value [1]. One asset classified as safe or has a low risk to invest in is gold; gold is a type of investment that, in addition to being classified as safe, is also relatively stable in value. Gold is also a promising investment tool for the long term. Gold is used as an investment tool because it is considered a haven product or asset that can maintain its value with a fairly low risk of economic shocks/instability, and its value can even increase during crisis conditions. In addition, gold is also considered a hedge or protector of wealth value from

* Corresponding author
Submitted July 13th, 2024, Revised October 30th, 2024,
Accepted for publication November 3rd, 2024, Published Online November 15th, 2024
©2024 The Author(s). This is an open-access article under CC-BY-SA license (https://creativecommons.org/licence/by-sa/4.0/)

inflation, where inflation can cause the currency to depreciate. The term is pinned because gold can maintain the value of wealth even in uncertain conditions [2].

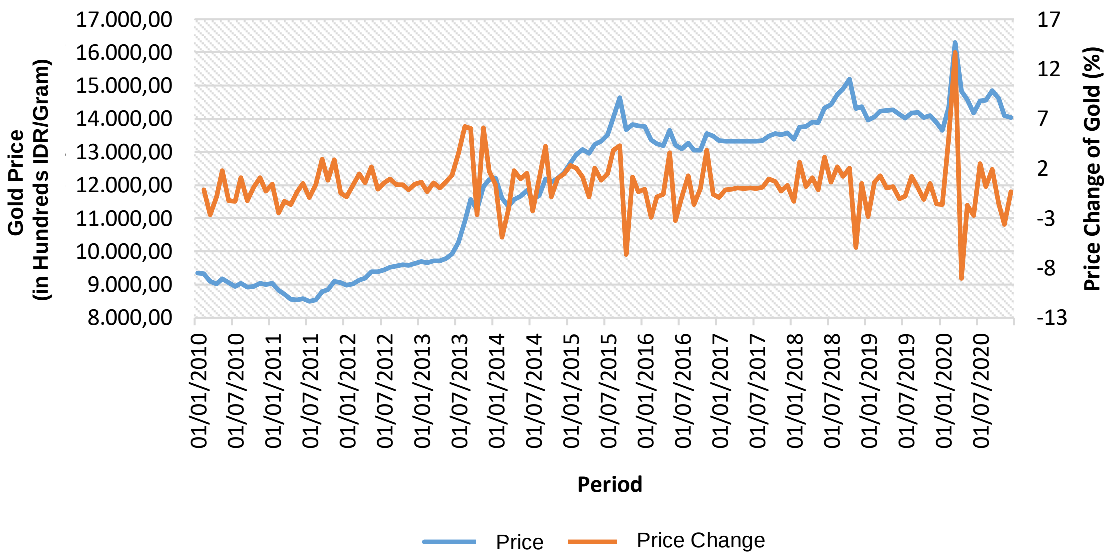

Figure 1. Gold Price and Growth in Indonesia for the Period 2010 – 2020.

Figure 1 shows the fluctuating movement of gold prices. The highest percentage increase in gold prices occurred from early January to February 2020, 13.66 percent. Still, the following month, the sharpest decline in gold occurred in April 2020 to 9.05 percent. The sharpest decline is the impact of the global financial crisis caused by the Covid-19 pandemic. Changes in gold prices that increase and decrease sharply quickly reflect the fluctuating gold price movements. Gold price fluctuations, especially in the short term, make it difficult for investors to choose investment tools. However, in the long run, the price of gold has an upward trend, which makes gold suitable for use as an investment tool.

Future gold price prediction information is needed to maintain investment security and reduce risk. Forecasting is estimating future needs, which includes measures of quantity, quality, time, and location to meet the demand for goods or services. Forecasting is a process for estimating events that will occur in the future to reduce the risk of error. Forecasting is necessary to know when or how an event will occur so that appropriate action can be taken [3]. Forecasting techniques are divided into two main categories, namely quantitative and qualitative methods. One of the quantitative methods is the time series method, using historical gold price data. Patterns in historical data series can be used to forecast the price of Indonesian gold in the next few periods.

One of the time series forecasting methods is the Autoregressive Integrated Moving Average (ARIMA). The ARIMA model is flexible in analyzing various time series and can achieve accurate forecasts. Another advantage is that the ARIMA model uses historical data [4]. In line with this, gold prices follow random movements and have non-stationary characteristics. Therefore, ARIMA has great potential as a forecasting model for gold prices.

As a requirement for ARIMA models, horizontal data patterns are often unmet because real data patterns do not always follow horizontal data patterns but can also follow seasonal, trend, cyclical, or a combination of several existing data patterns. Meanwhile, data analysis that represents a combination of trends and seasonal or cyclical data can be done using decomposition. The decomposition method decomposes (breaking down) time series data into several patterns and identifies each component in the pattern for separate analysis [3]. Component separation occurs to help improve forecasting accuracy and help better understand the behavior of the data series. These components are divided into four components, namely trend (T), seasonal (S), cyclical (C), and random changes (I), where the random component will be forecasted using the ARIMA method so that the decomposition-ARIMA model is obtained.

Although ARIMA is robust and flexible, the model cannot cope with the volatility and nonlinearity present in the data set. The volatile movement of the gold price indicates that the gold price data contains volatility. In addressing this heteroscedasticity problem, several studies have been conducted showing that Autoregressive Conditional Heteroscedasticity (ARCH) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models are used in time series forecasting to address volatility in gold price data. The ARCH-GARCH model captures the ARCH effect in the daily series [5]. Several studies have been conducted on forecasting methods using ARCH-GARCH. Research to forecast Indian gold prices using the Autoregressive Integrated Moving Average (ARIMA) model shows that the ARIMA (0,1,1) model is the most suitable model for forecasting Indian gold prices because it has the smallest MAPE, Max AE, and MAE values of 2.7%, 175.35%, and 19.01%, respectively [6]. Research to forecast Malaysian gold prices by comparing ARIMA and GARCH methods, resulting in the GARCH (1,1,1) model being the best model with the smallest SIC and MAPE, which means the model is most accurate for forecasting Malaysian gold prices [7]. Research to forecast the agricultural sectoral stock index using the ARCH-GARCH method. The results showed that the ARCH(1) model is appropriate for forecasting sectoral stock data. The ARCH (1) model produces a MAPE value of 8.06%, which means that the percentage error in this model is very low and good enough to do forecasting [8]. The forecasting results show that sectoral stock prices experience less significant increases and decreases weekly.

In this research, researchers are interested in comparing the performance of Indonesian gold price forecasting methods using univariate time series. The methods to be used are the decomposition-ARIMA and ARCH-GARCH models. Decomposition-ARIMA is used to forecast gold prices based on components in the time series pattern, such as trend, seasonal, cyclical, and random (error). Meanwhile, the ARCH-GARCH model is used as an approach to forecasting where volatility in the forecast model is suspected. Therefore, the study aims to compare the accuracy of the two methods to forecast the Indonesian gold price. The accuracy of the forecasting results is measured using the Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE) values. The study results are expected to be initial information for people who want to invest in gold to find out information on the movement of gold prices in the future. Gold investment will be better if investors know the right time to buy gold when prices are low and sell gold when prices are high to minimize losses and optimize gold investment profits.

2. METHODS

2.1. Data and Research Variable

The study aims to forecast the price of Indonesian gold 3 months ahead for the period May 1, 2024 - July 31, 2024 (66 days). The data used is secondary data sourced from the TradingView website (www.tradingview.com). This study uses time series data for the daily period, with a period from January 3, 2022, to April 31, 2024. The daily data obtained is the closing price data in the last hour of the day. The accuracy of the forecasting results is required so it is necessary to determine the right forecasting method. Therefore, this research applieds two forecasting methods to see a more precise level of accuracy. The forecasting method used is univariate time series by comparing the decomposition-ARIMA and ARCH-GARCH methods.

In this research the data will be divided into two groups of data, namely in sample (training data) and out sample (testing data). In sample data is used to create a forecasting model that uses the period 3 January 2022 to 29 December 2023 consisting of 520 observations. Out sample data is used to see the accuracy of the model by predicting gold prices in the period 1 January 2024 to 30 April 2024. The results of this forecasting are compared with actual prices to calculate forecast accuracy criteria. After getting a model from each method using data out sample, then calculate the RMSE and MAPE from the two models. A forecasting method is very good if it meets the smaller MAPE criteria from 10%.

2.2. Time Series Model

The ARIMA model does not involve independent variables in its formation; this method is only based on the behaviour of the observed variable data. The autoregressive integrated moving average model is a non-stationary ARMA (p,q) model, so the data is differenced to become stationary. The ARIMA model is denoted by order p,d,q or ARIMA (p,d,q) where d is the number of differencing processes performed. Mathematically, the ARIMA (p,d,q) model is written as follows [9]:

$$\emptyset_p(B)(1-B^d)Y_t = \theta_0 + \theta_q(B)\varepsilon_t. \quad (1)$$

Using the B (backshift) operator, it becomes:

$$(1-B^d)(1-\emptyset_1 B-\emptyset_2 B^2 - \ldots - \emptyset_p B^p)Y_t = (1-\theta_1 B-\theta_2 B^2 - \ldots - \theta_q B^q), \quad (2)$$

$$Y_t - \emptyset_1 Y_{t-1} - \ldots - \emptyset_{p+d} Y_{t-p-d} = \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots + \theta_q, \quad (3)$$

where Y_t is observed value at time-*t*, $(1-B^d)Y_t$ is stationary time series at the d^{th} differencing, $\emptyset$ is AR coefficient, θ is MA coefficient, q is MA order, d is differencing order, p is AR order, and ε_t is white noise error value at time-*t*. ARIMA modelling steps proposed by Box-Jenkins as follows [10]: (1) model-identification is used to determine several alternative models by looking at the patterns of ACF and PACF; (2) parameter estimation of the proposed model, (3) model evaluation determines the model that meets all assumptions, and (4) forecasting data and testing the accuracy of the forecasting results.

The decomposition method assumes that the data pattern consists of trend, seasonal, cyclical, and random components. The basic concept of the decomposition method is to separate the data from seasonal, trend, cyclical, and random components. The random component is identified using the ARIMA model approach. There are two types of decomposition models: additive model and multiplicative model. The additive model is used when the magnitude of the seasonal variation or trend cycle is relatively stable and independent of the level of the series, which can be mathematically written as follows:

$$Y_t = (I_t + T_t + C_t + E_t). \quad (4)$$

Multiplicative models are used when cyclical variations of seasonal or forecast trends change and appear proportional to the level of the time series, which can be written mathematically as follows:

$$Y_t = (I_t * T_t * C_t * E_t), \quad (5)$$

where Y_t is actual data, I_t is seasonal component, T_t is trend component, C_t is cycle component, and E_t is random component.

Volatility in time series refers to the condition that the conditional variance of the time series varies across time [11]. In other words, there is a heteroscedasticity problem in the conditional variance. The Autoregressive Conditional Heteroscedasticity (ARCH) or Generalized Autoregressive Conditional Heteroscedasticity (GARCH) method can overcome this problem. A hybrid model is a model that combines a nonlinear model and a linear model of the data. In the GARCH model, it is assumed that the conditional mean of a time series is zero. However, under more general conditions, the conditional mean can be modelled with an ARMA(p,q) model, and then the white noise component of the ARMA(p,q) model is modelled with a GARCH(p,q) model. Suppose (Y_t) is an ARMA (p,q) process with the following equation form.

$$Y_t = \emptyset_1 Y_{t-1} + \ldots + \emptyset_p Y_{t-p}\theta_0 + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \ldots + \theta_q \varepsilon_{t-q}, \quad (6)$$

$$\varepsilon_t = \sigma_{t|t-1} v_t, \quad (7)$$

$$\sigma^2_{t|t-1} = \omega + \alpha_1 \varepsilon^2_{t-1} + \ldots + \alpha_p \varepsilon^2_{t-p} + \beta_1 \sigma^2_{t-1|t-2} + \ldots + \beta_q \sigma^2_{t-q|t-q-1}. \quad (8)$$

The ARMA parameters' orders can be traced based on the time series of {Yt}. Meanwhile, the order of the GARCH model parameters can be observed based on the squared residuals of the ARMA model estimation results.

Model Accuracy

Model evaluation is used to select the best model from several possible time series models obtained. Measures that can be used for model evaluation in forecasting are Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE). RMSE is the magnitude of the prediction error rate, where the smaller (closer to 0) the RMSE value, the more accurate the prediction results will be. The RMSE calculation is as follows.

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(Y_t - \hat{Y}_t)^2}{n}}, \quad (9)$$

where *n* is the sample size, Y_t is the actual data value, $\hat{Y}_t$ is the forecasted data value [9].

MAPE is a measure of relative error. This evaluation is conducted to ascertain whether the model obtained is suitable for forecasting in the next period. This accuracy measurement was chosen because this measurement tool is a percentage that is easy to interpret; the smaller the percentage of MAPE, the model is said to be because the actual data and forecasting have the slightest possible difference. The smaller the difference, the more accurate it is. MAPE can be calculated based on the following equation [12].

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{Y_t - \hat{Y}_t}{Y_t}\right| x\ 100\%. \quad (10)$$

3. RESULTS

General View of Indonesian Gold Prices

The movement of gold prices in Indonesia generally fluctuates and tends to experience an upward trend. During the period January 2022 to December 2023, the largest percentage increase in gold prices occurred from January 28 to March 8, 2022, amounting to 14.55 percent. Meanwhile, a significant decline in gold prices occurred from March 8 to September 26, which was the lowest price, amounting to -12.17 percent.

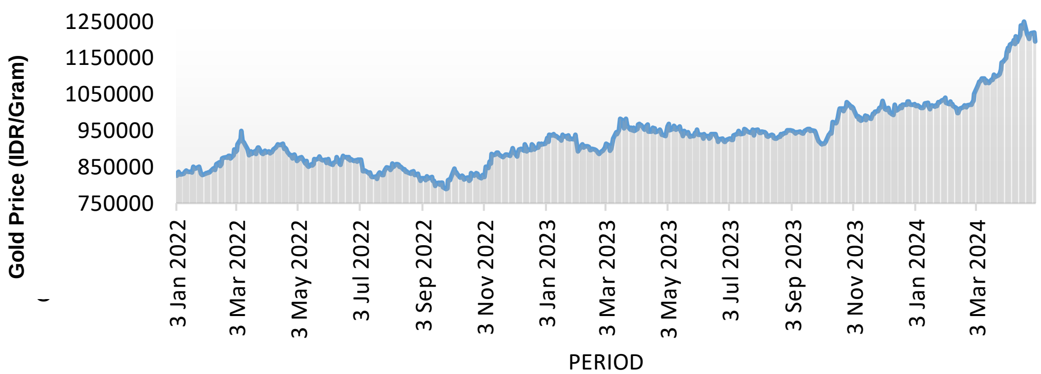

Figure 2. Indonesia Gold Price in 2020 – 2024.

Figure 2 shows that the price of gold in Indonesia always fluctuates in the short term and there are several shocks in its development, including in 2020 the Covid-19 pandemic which resulted in a world economic crisis such as recession in various countries. Therefore, many investors are looking for assets with low risk (safe haven) to secure their wealth. A global phenomenon also occurred towards the end of 2022 which caused many commodities to rise including world gold due to Russia's invasion of Ukraine so that low-risk commodities became favored by investors. This was also the case with the continued rise in 2022 supported by the Fed's interest rate policy which continued to increase from May 2022 to 2023, and the weakening of the Chinese economy with the devaluation of the Yuan.

ARCH/GARCH Model

ARIMA modeling requires data stationarity. Therefore, the first step in modeling is to test the stationarity of the data. Stationarity testing is done using the ADF Unit Root Test on the Indonesian gold price variable. Based on Table 1, the t-statistic value of the random variable is -1.0226. This value is still greater than the Dickey-Fuller critical value at the 5% significance level (-3.4173) and the p-value of both variables is greater than the significance level (5%) so there is not enough evidence to reject the null hypothesis, meaning that the data is not yet stationary at the level. After differencing at the first order, the random data has been stationary with the respective t-count value of -19.2595 smaller than the 5% critical value (-3.4173) and p-value < 5%. So, reject H_0 which means the data is stationary at the first differencing.

Furthermore, the ARIMA model identification process is carried out by looking at the ACF and PACF patterns through the first difference correlogram to determine the order of p dan q of ARIMA models. Based on the correlogram results, it shows that the ARIMA model is lagging at the 2nd and

4th orders. After identifying the order of the ARIMA model, the next step is parameter estimation to select the best model. ARIMA parameter estimation is done using Generalized Least Square (GLS) to select the best model. The best ARIMA model is selected based on the smallest AIC and SC values and significant parameters. Based on the parameter estimation results, the ARIMA (2,1,2) model has a larger Adjusted R-squared value, the smallest Akaike Information Criterion (AIC) and Schwarz Criterion (SC) values and the parameters in the model are also significant, seen from the p-value < 5%. The ARIMA(2,1,2) model was chosen as the best model. The parameter estimation results of the ARIMA model can be seen in Table 2.

Table 1. Stationarity Test at Level and First Difference

Variable	t-statistic	t-table	p-value	Decision about H_0
GOLD	-1.0226	-3.4173	0.9388	Accept H_0
D(GOLD)	-19.2595		0.0000	Reject H_0

Table 2. Parameter Estimation of ARIMA Model

Model	Variable	Coefficient	p-value	Adjusted R-Squared	SC	AIC
ARIMA (2,1,2)	Constant	375.15	0.2361	0.0521	20.8560	22.8150
	AR (1)	0.4740	<0.001			
	AR (2)	-0.8720	<0.001			
	MA (1)	-0.5716	<0.001			
	MA (2)	0.8353	<0.001			

The ARIMA (2,1,2) model can be written in the following equation:

$$\widehat{GOLD}_t = 375.15 + 1.474GOLD_{t-1} - 1.346GOLD_{t-2} + 0.8720GOLD_{t-3} -0.5716\varepsilon_{t-1} + 0.8353\varepsilon_{t-2} + \varepsilon_t. \quad (11)$$

Residual diagnostic testing is performed after testing the significance of the ARIMA model parameters. This test is carried out to prove the adequacy of the model. Residual diagnostic checks include white noise and normally distributed assumption tests. White noise is a process where there is no correlation in the residual series [9]. The classical assumption test on the ARIMA model is the white noise test using the Ljung-Box, the residual normality test using the Kolmogorov-Smirnov test, and the homoscedasticity test using the ARCH-LM test. The summary of the residual diagnostic test can be seen in Table 3.

Table 3. Result of Residual Diagnostic Test

Testing Type	t-statistic	t-table	p-value	Descision about H_0
Ljung-Box	0.0133	0.0435	0.9388	Accept H_0
Kolmogorov Smirnov	0.0533	0.0592	0.1050	Accept H_0
ARCH-LM	3.6394	1.7144	0.0064	Reject H_0

Based on Table 3, the results of classical assumption testing on the ARIMA(2,1,2) model meet the white noise requirements but do not meet the assumption of homoscedasticity, which means that the residual variance of the model is not constant. Therefore, to overcome the volatility stemming from these violated assumptions, the ARCH-GARCH model is the recommended model. The next step is to tentatively determine the best ARCH-GARCH model. The criteria for the best model is the significance of the estimated parameters, as well as the criteria for the smallest AIC and SC values [13]. The summary of the ARCH-GARCH model parameter estimation can be seen in Table 4.

Table 4. Parameter Estimation of ARCH-GARCH Model

Model	Variable	Coefficient	p-value	SC	AIC
GARCH (1,0)	Constant	308.4748	0.2266	20.9020	20.8445
	AR (1)	0.4610	<0.001		
	AR (2)	-0.8074	< 0.001		
	MA (1)	-0.5880	< 0.001		
	MA (2)	0.7827	< 0.001		
	RESID (-1)	0.1714	< 0.001		
GARCH (0,1)	Constant	346.4149	0.1493	20.9217	20.8642
	AR (1)	0.3803	< 0.001		
	AR (2)	-0.7590	< 0.001		
	MA (1)	-0.4890	< 0.001		
	MA (2)	0.6021	< 0.001		
	GARCH (-1)	0.1714	0.9411		
GARCH (1,1)	Constant	324.7305	0.3635	20.9396	20.8738
	AR (1)	-0.0439	0.9169		
	AR (2)	-0.1525	0.6012		
	MA (1)	-0.0416	0.9216		
	MA (2)	0.0381	0.9014		
	RESID (-1)	-0.0167	0.3610		
	GARCH (-1)	0.4332	0.6474		

The GARCH (1,0) model is obtained as the best model because it has the smallest AIC and SC values and significant mean and variance model parameters. Model evaluation is conducted to check whether the model does not have elements of heteroscedasticity, using the ARCH-LM test. The results show that the F-Statistic value of 0.2405 is greater than the critical point value of $\chi^2_{(0,05;1;519)}$ = 3,8875, and the p-value of 0.6224 is greater than the 5% significance level. Thus, we fail to reject H_0, which means that the residual variance of the model is homoskedastic.

Decomposition-ARIMA Model

The decomposition method is used to forecast the seasonal and trend components of the Indonesian gold price data. The random component is forecasted using the ARIMA method. The results of the decomposition method and the ARIMA method are combined to obtain gold price forecasting results. The first stage is to determine the trend equation which is determined directly from the actual data. The linear trend equation is determined using the least squares method, so the trend equation is obtained as follows:

$$\widehat{Trend} = 827519 + 298.17t \tag{12}$$

The next step is to determine the seasonal index, using the moving average method. The results of the seasonal index calculation can be seen in Table 5.

Table 5. Seasonal Index

Day	Period (t)	Seasonal Index (I_t)
Monday	1	0.9993
Tuesday	2	0.9998
Wednesday	3	1.0004
Thursday	4	1.0001
Friday	5	1.0005

The gold price pattern has an upward trend with a relatively constant variance, so the decomposition method used is additive. The random component is obtained by subtracting the actual data with the seasonal index and trend component, namely $Y_t - I_t - T_t = E_t$. After obtaining the random component (E_t), the next step is to do forecasting for the random component using the ARIMA model.

Table 6. Unit Root Test Results of Random Data with ADF at Level and First Difference

Variable	t-statistic	Critical Value	*p-value*	Conclusion
random	-1.0225	-3.4173	0.9388	Not Stationary
D(random)	-19.2595		< 0.0001	Stationary

Table 6 shows the unit root test results of the random component, obtained that the t-value of -1.0225 is greater than the MacKinnon critical value at the 5% significance level (-3.4173). So there is not enough evidence to reject H_0, meaning that the data is not yet stationary at the level. After differencing at the first order, the random data has been stationary with the respective t-statistic value of -19.2595 smaller than the 5% critical value (-3.4173) and p-value < 5%. So reject the null hypothesis which means the data is stationary at first differencing. Next, identify alternative models based on ACF and PACF correlogram plots. The correlogram plot can be seen in Figure 3.

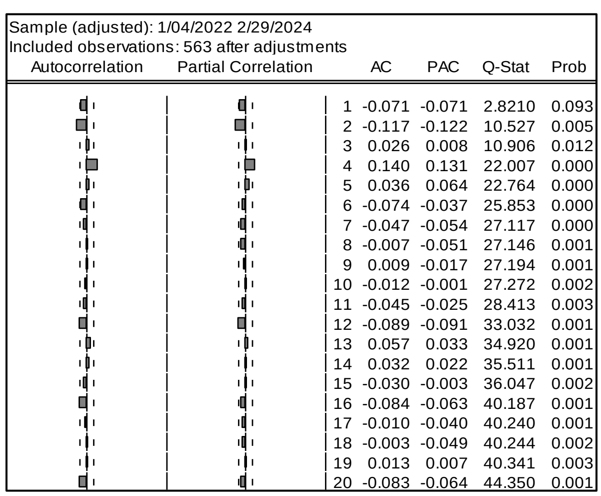

Figure 3. Correlogram on First Difference Random Data

Based on the correlogram of the differencing random data in Figure 3, there are ACF and PACF values that cross the bartlet line at the 2nd and 4th lags. Therefore, there are several alternative choices of ARIMA models at the 2nd and 4th orders. The best ARIMA model is selected based on the smallest AIC and SC values and significant parameters. The best ARIMA model selected based on the estimation results is ARIMA(2,1,2). The parameter estimation results of the ARIMA(2,1,2) model can be seen in Table 7.

Table 7. Estimation of ARIMA Model on Random Data

Model	Parameter	Coeffisient	p-value	*Adjusted R-Squared*	SC	AIC
ARIMA(2,1,2)	AR(1)	0.4598	0.000	0.0397	20.8288	20.7826
	AR(2)	-0.8570	0.000			
	MA(1)	-0.5560	0.000			
	MA(2)	0.8163	0.000			

Based on Table 7, the ARIMA(2,1,2) model has the largest Adjusted R-Squared value and the smallest AIC and SC values among other alternative models. The parameters in this model are also significant as seen from the p-value < 5% so that it is chosen to be the best model. By using the ARIMA (2,1,2) model, the random component is forecasted. The last stage of the ARIMA model formation is the residual assumption test which consists of a white noise test and a normal distribution test.

Based on the two forecasting methods, the best models for forecasting Indonesian gold prices are Decomposition-ARIMA(2,1,2) and GARCH(1,0) models. Measurement of the accuracy of forecasting results from both models using RMSE and MAPE. Table 9 displays the accuracy test results of the ARIMA(2,1,2) and GARCH(1,0) Decomposition models, using out sample data (testing data). Based on the accuracy test results, the Decomposition-ARIMA(2,1,2) and GARCH(1,0) models have a MAPE below 10%, which means that both forecasting methods are very good at forecasting gold prices, and can be used to forecast future periods. However, based on the MAPE value, the accuracy of gold price forecasting with the Decomposition-ARIMA(2,1,2) method is more accurate than the GARCH(1,0) model.

Table 8. Model Accuracy of Decomposition-ARIMA(2,1,2) and GARCH(1,0)

Model	RMSE	MAPE
Decomposition-ARIMA(2,1,2)	10156.85	0.679%
GARCH(1,0)	10189.74	0.682%

Using the decomposition-ARIMA(2,1,2) method, forecasting will be done for the next 3 months from May 1, 2024 to July 31, 2024. The average price of Indonesian gold is IDR 1,209,214.11. Based on the forecasting results, it can be seen that the price of Indonesian gold is experiencing an upward trend, as can be seen in Figure 4. This is in accordance with research conducted by [14],[15]. which shows that gold is a safe haven asset and hedging against economic turmoil. Therefore, investors may choose gold as a hedge for their assets..

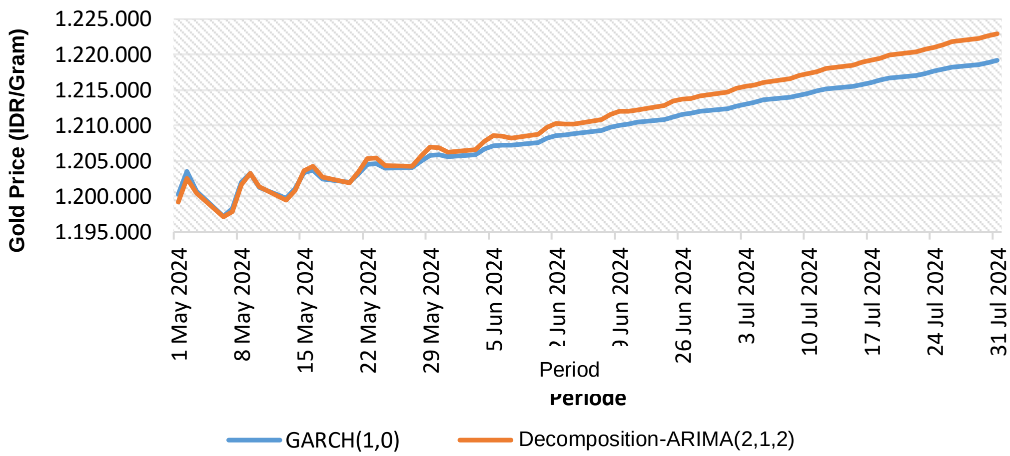

Figure 4. Forecasting Results of Indonesian Gold Price of May 1, 2024 - July 31, 2024

4. DISCUSSION

In general, the movement of Indonesian gold prices experienced an upward trend from the beginning of January 2022 to the end of April 2024, with around IDR 930,778.92 per gram. Indonesian gold prices tend to fluctuate in the short term, while in the long term, they tend to increase monthly. The volatility of gold prices will profoundly affect the investment decisions of individuals, enterprises and countries [16]. So, investors want to know predictions of future gold price trends, which is a hot conversation topic. The price of gold has fluctuated rapidly over the last few months [17], partly due to the exchange rate of the rupiah against the US dollar. The exchange rate influences the price of Indonesian gold, so when the rupiah weakens against the US dollar, the price of gold will increase.

Gold price forecasting is a significant financial problem for many people because gold is considered an investment asset. Therefore, accurate forecasting techniques must be applied to predict gold prices. A better investment in gold can only be made if we estimate its price carefully. This research focuses on forecasting Indonesian gold prices by implementing the decomposition-ARIMA model and the ARCH/GARCH model, which is used to accommodate volatility in gold prices.

The decomposition-ARIMA method combines the decomposition method with the ARIMA model. ARIMA model estimates the value of random components whose patterns are challenging. It is hoped that the forecasting results by decomposing the gold price data components will produce more accurate results. This is in line with previous research that used the decomposition-ARIMA model, which made forecasts with a very high level of accuracy [18],[19]. The best model for predicting the random component from several alternative ARIMA models is ARIMA (2,1,2). This model has the most considerable Adjusted R-squared value and the smallest AIC and SC values among other alternative models. Forecasting Indonesian gold price data using the decomposition-ARIMA(2,1,2) model has a MAPE below 10%. The forecast results using in-sample data resemble the Indonesian gold price data on the investing.com website. So, it can be said that this forecasting method can be used to predict the price of Indonesian gold for the coming period. The results of forecasting Indonesian gold prices have an upward trend. The results of this research are in line with previous studies using the ARIMA model [20], [21], and research that predicts Indonesian gold prices using the fuzzy time series method [22].

Gold price data contains volatility, as shown by the results of heteroscedasticity testing using the ARCH-LM test. The test results concluded that the residual variance of the model was not constant, so the ARCH/GARCH model was used to overcome volatility. This aligns with previous research that used the ARCH/GARCH model [23],[24] to overcome the volatility problem. Of several alternative ARCH/GARCH models, the GARCH(1,0) model was chosen as the best model because it has the smallest AIC and average model parameters -The mean and variance are significant. The GARCH(1,0) model has a MAPE below 10%, meaning this method is very good for forecasting the future period. This result aligns with research that predicts world gold prices with volatility, which shows the GARCH model is appropriate [25].

The results of forecasting Indonesian gold prices using both the decomposition-ARIMA(2,1,2) model and the GARCH(1,0) model produce an accuracy level of less than 10%. The forecasting accuracy rate is 0.679% for decomposition-ARIMA(2,1,2) and 0.682% for GARCH(1,0). These results show that the decomposition-ARIMA(2,1,2) model is more accurate than the GARCH(1,0) model. More accurate gold price forecasting results are obtained by decomposing gold price data into its components.

Using the selected model, namely the decomposition-ARIMA(2,1,2) model, the forecast results for Indonesian gold prices in May 2024 - July 2024 tend to experience an upward trend, with an average price of IDR 1,209,214.11 per gram. Knowing Indonesian gold prices' price estimates and patterns will provide additional information for investors to determine investment choices. Gold is a prevalent and attractive metal investment because the price of the gold commodity has been proven to increase continuously [26]. Apart from that, gold investment can be a haven and hedging asset to protect the value of wealth from global economic turmoil [27].

5. CONCLUSSION

Indonesian gold prices have demonstrated an upward trend from January 2022 to April 2024 despite short-term fluctuations influenced by global economic conditions and events such as the COVID-19 pandemic and geopolitical tensions. The study reinforces the perception of gold as a haven and a hedge against financial instability and inflation. This characteristic of gold supports its attractiveness as a stable investment option during economic uncertainty. This research highlights the importance of using robust and accurate forecasting models for financial investments, i.e., the GARCH and decomposition-ARIMA models. The superior performance of the decomposition-ARIMA model offers valuable insights for investors looking to enhance their portfolio strategies by leveraging precise gold price predictions. The decomposition-ARIMA (2,1,2) method integrates the decomposition of time series data into trend, seasonal, cyclical, and random components with ARIMA for the random component, which is identified as more accurate than the GARCH(1,0) model. The decomposition-ARIMA model provides a MAPE of 0.679%, slightly better than the GARCH model's 0.682%.

REFERENCES

[1] S. B. Smart, L. J. Gitman, and M. D. Joehnk, *Fundamentals of Investing Thirteenth Edition*, Harlow : Pearson Education Limited, 2017.

[2] Y. Zhu, J. Fan, and J. Tucker, "The impact of monetary policy on gold price dynamics," *Res. Int. Bus. Financ.*, vol. 44, pp. 319–331, Apr. 2018, doi: 10.1016/j.ribaf.2017.07.100.

[3] S. Makridakis, S. C. Wheelwright, R.J. Hyndman, *Forecasting: Methods and Application (3rd ed).* New York: John Wiley & Sons Inc, 1997.

[4] Ď. Peter and P. Silvia, "ARIMA vs. ARIMAX-which approach is better to analyze and forecast macroeconomic time series?", *Proceedings of 30th International Conference Mathematical Methods in Economics*, pp. 136-140, 2012.

[5] W. Wang, P. H. a. J. M. Van Gelder, J. K. Vrijling, and J. Ma, "Testing and modelling autoregressive conditional heteroskedasticity of streamflow processes," *Nonlinear Processes in Geophysics*, vol. 12, no. 1, pp. 55–66, Jan. 2005, doi: 10.5194/npg-12-55-2005.

[6] N. Tripathy, "Forecasting Gold Price with Auto Regressive Integrated Moving Average (ARIMA) model," *Int. J. Econ. Financ.* Issues, vol. 7, no. 4, pp. 324–329, 2017.

[7] P. Y. Ping, N. H. Miswan, and M. H. Ahmad, "Forecasting malaysian gold using GARCH model," *Appl. Math. Sci.*, vol. 7, no. 57–60, pp. 2879–2884, 2013, doi: 10.12988/ams.2013.13255.

[8] A. P. Desvina and N. Rahmah, "Penerapan Metode ARCH / GARCH dalam Peramalan Indeks Harga Saham Sektoral," *J. Sains Mat. dan Stat.*, vol. 2, no. I, pp. 1–10, 2016.

[9] W. W. S. Wei, *Time Series Analysis Univariate and Multivariate Methods Second Edition*, Pearson Addison Wesley. ISBN:0-321-32216-9. 2005.

[10] D. N. Gujarati and D. C. Porter, *Basic Econometrics Fifth Edition*, NewYork: McGraw-Hill, 2009.

[11] J. D. Cryer and K-S. Chan, *Time Series Analysis with Applications in R Second Edition*, New York: Springer, 2008.

[12] D. C. Montgomery, C. L. Jennings, and M. Kulachi, *Introduction to Time Series and Analysis and Forecasting*, Canada: John Wiley and Sons, 2008.

[13] B. Juanda and Junaidi, *Ekonometrika Deret Waktu Teori dan Aplikasi*, Bogor : IPB Press, 2015

[14] D. G. Baur and T. K. McDermott, "Is gold a safe haven? International evidence," *Journal of Banking & Finance*, vol. 34, no. 8, pp. 1886–1898, Aug. 2010, doi: 10.1016/j.jbankfin.2009.12.008.

[15] G. Tkacs, "Gold prices and inflation", *Bank of Canada Working Paper* Series, vol. 36, June 2007.

[16] X. Yang, X. Jiaotong and X. Suzhou, " The prediction of gold price using ARIMA model", *Advances in Social Science, Education and Humanities Research,* Vo. 196, 2018.

[17] A. Ali, et al, " Forecasting of daily gold price by using Box-Jenkins methodology", *International Journal of Asian Socila Science*, 6(11): 614-624, 2016.

[18] M. R. Ramadhan, J. Nugraha, "Analisis peramalan jumlah kedatangan pesawat international di Bandar Udara Soekarno-Hatta dengan menggunakan metode dekomposisi-ARIMA", *Emerging Statistics and Data Science Journal.* Vol 1, No. 1, 2023.

[19] Aswi, I. Rahma. I & M. Fahmuddin, " Penerapan metode hybrid dekomposisi-ARIMA dalam peramalan jumlah wisatawan mabcanegara", *Inferensia*, Vol. 7, March 2024.

[20] R. Elizabeth, S. Sitorus, " Gold price forecasting using autoregressive integrated moving average (ARIMA) method", *Journal of Mathematics Technology and Education,* Vol. 1, No. 1, 2021.

[21] J. P. Sagala, E.D Tarigan, "Analisis peramalan harga emas antam menggunakan ARIMA", *SeminarNasional Teknologi Informasi dan Matematika,* Vol.2, No. 1, Hal. 77-84, 2023.

[22] F. Aditya, D. Devianto, M. Maiyastri, " Peramalan harga emas Indonesia menggunakan metode fuzzy time series klasik", *Jurnal Matematika*, July 2019. DOI: 10.25077/jmu.8.2.45-52.2019

[23] D. AL-Najjar, "Modelling and estimation of volatility using ARCH/GARCH models in Jordan's stock market", *in Asian Journal of Finance & Accounting*, May 2016. DOI: 10.5296/ajfa.v8i1.9129

[24] S. Somarajan, M. Shankar, T. Sharma, and R. Jeyanthi, "Modelling and analysis of volatility in time series data", *Proceedings of ICSCSP*, January 2019. DOI: 10.1007/978-981-13-3393-4_62

[25] T. Bunnag, " The importance of gold's effect on investment and predicting the world gold price usng the ARIMA and ARIMA-GARCH", in *Ekonomikalia Journal of Economics*, April 2024

[26] I. Henriques and P. Sadorsky, "Can bitcoin replace gold in an invesment portfolio?", *Journal of Risk and Financial Management*, Vol. 11(3), 2018. https://doi.org/10.3390/jrfm11030048

[27] Y. Zhu, J. Fan, J. Tucker, "The impact of monetary policy on gold price dynamics", *Research in International Business and Finance*, Vol. 44, pages 319-331, April 2018. https://doi.org/10.1016/j.ribaf.2017.07.100.