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Evaluating the Accuracy of ARIMA vs. Holt's Double Exponential Smoothing in Predicting Indonesia's Gold Price Trends

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ABSTRACT

This study investigates the performance of two forecasting techniques — the Autoregressive Integrated Moving Average (ARIMA) model and Holt's Double Exponential Smoothing — in predicting gold prices in Indonesia. The study uses monthly gold prices for PT Aneka Tambang Tbk from January 2021 to December 2025, yielding 60 data points. The analysis in this study employs a time-series framework that incorporates both ARIMA and Holt's Double Exponential Smoothing. The performance of each model is evaluated using Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE). The ARIMA (1,1,6) model outperformed Holt's model in historical prediction accuracy, yielding lower error rates. However, the actual recorded gold prices for January and April 2026 showed that Holt's Double Exponential Smoothing achieved better forecasting accuracy. This finding indicates that the ARIMA model is excellent for predicting historical accuracy; however, for recent data shifts, Holt's model is more advantageous for short-term forecasts. The findings of this study indicated that, to achieve forecasting goals, the choice of forecasting model should be tailored to the specific characteristics of the available data.

Keywords: Forecasting, ARIMA, Holt's Double Exponential Smoothing, Gold Prices, Time Series

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1. INTRODUCTION

Due to its significance and its history as currency and an investment, the metric for gold is important for assessing the economy. Gold is an asset known for its value during an economic crisis (Lastri, 2021). This is also supported by Su (2024), who indicated that gold is resilient and steady during economic downturns. Gold is also liquid, low risk, and a good long-term investment (Sagala et al., 2023). In the long run, gold's value, even during high inflation, is important for assessing its worth, and that is why the public invests in gold (Mulia, 2024).

Investments in gold, particularly in gold bars sold by PT Aneka Tambang Tbk (Antam), are becoming more widespread in Indonesia. Due to their high quality, certified authenticity, and strong market credibility, Antam gold products have become increasingly popular and accepted as a long-term investment option. Kristhy et al. (2022) explain that the high level of interest in gold investment within the population stems from the convenience of conducting buying and selling transactions — either in person or digitally. Additionally, gold is sought after as a long-term investment because it is stable, as noted by Mulia (2024).

The world economy has been all over the place in the last few years, especially since the COVID-19 outbreak began. Because of this, many people looking to invest are considering gold. Gold is an investment because it tends to hold its value and even appreciate when the economy is bad, and prices are rising (Mulia, 2024). Other people have also said that gold is an investment because its value does not change much, it is easy to buy and sell, and it helps protect against inflation, which is when prices rise too fast. So people like to invest in gold for a time (Sagala et al., 2023). Methods exist for forecasting future economic conditions, including the Autoregressive Integrated Moving Average, abbreviated as ARIMA. These methods are good at analyzing past events and using that analysis to predict future outcomes, like the consumer price index ((Djami & Nanlohy, 2022). Other people have also said that when inflation rises and currencies are not worth much, gold prices tend to go up (Lastri, 2021). Gold is also good because it can handle short-term changes in the economy (Su, 2024).

People are becoming more aware of how important it is to invest. So investment trends in Indonesia are also getting bigger. A survey conducted by Jakpat (2024) found that people are still very interested in investing, even when the economy is not doing well. The survey shows that most people already have

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investment instruments, and gold and gold-related products are very popular. This is because people think gold is safer and more stable than other investments.

On the one hand, the price of gold in Indonesia, especially gold made by PT Aneka Tambang Tbk, goes up and down over time. If we look at data from logammulia.com, we can see that gold prices rose significantly from 2021 to 2025. There were also some short-term changes due to developments in global markets, exchange rates, and economic policies. There is a graph of gold prices from January 2021 to December 2025 that shows how gold prices changed.

***source:* [*www.logammulia.com*](http://www.logammulia.com)**

Fig 1. Indonesian Gold Purchase Prices for the 2021–2025 Period

The fluctuations in gold prices exhibit complex behavior in the market, which do not depend solely on local factors but are also affected by the international economy. As such, it is essential to employ a rigorous analytical method that can effectively capture trends in gold prices to forecast outcomes that guide decision-making. Although many studies have been conducted on forecasting gold prices using time-series methods, their results show inconsistent precision rates across the techniques used. The ARIMA model is commonly used in scholarly studies due to its effectiveness in capturing autocorrelation and the correlation between past events in the dataset (Chasanah, 2021; Wibowo et al., 2025). Conversely, the method of exponential smoothing, especially Holt's Double Exponential Smoothing, is considered more appropriate for analyzing data with trends because of its straightforwardness and adaptability (Mandati et al., 2025; Yenkikar et al., 2025).

Nevertheless, past studies indicate that no single approach guarantees the highest accuracy in forecasting. Numerous studies have found that the ARIMA approach is effective for predicting gold prices, as it captures patterns in autocorrelation and correlations within historical data. As illustrated by Wang (2025), the ARIMA method can produce optimal forecasts with relatively low error rates for gold prices. Additionally, some researchers report that the ARIMA method yields the best results among other approaches when applied to certain gold price predictions (Bing & Nor, 2024). At the same time, various studies show that the exponential smoothing method is advantageous for dynamic data with trends. According to Bhattacharya's (2025) research, it was easier to forecast changes in gold prices in an unstable situation using exponential smoothing due to better adaptability, which results in lower rates of errors compared to those created by the ARIMA approach. Although these studies demonstrate the effectiveness of ARIMA and exponential smoothing methods, the reported findings remain inconsistent because the best-performing model varies depending on the characteristics of the dataset and the evaluation approach used.

There is a research gap, and it is getting wider as more people are interested in buying gold, especially gold bullion from PT Aneka Tambang Tbk. The way people invest is changing, and the market is becoming more complex, so we need a way to analyze it. We need to conduct research using the information and compare different methods to determine the best way to predict gold prices.

The results are different. This shows that the performance of forecasting models depends on the type of data used, such as trends and seasonal patterns. Most studies have problems, such as using global or outdated data that do not reflect what is happening in the Indonesian gold market. They also do not use data showing what is happening after the pandemic. We need to compare ARIMA and Holt's Double Exponential Smoothing using recent Indonesian gold price data, as studies specifically focusing on monthly PT Aneka Tambang Tbk gold prices and validating the forecasting results with actual future observations remain limited. Furthermore, previous studies generally selected the best forecasting model based only on statistical error measures, such as MAPE, MAE, and RMSE, while limited attention has been given to

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validating whether the model with the best historical performance also produces the most accurate forecasts when compared with actual future market observations.

Unlike previous studies, this study not only evaluates forecasting performance using statistical error measures such as MAPE, MAE, and RMSE, but also validates the forecasting results using the actual monthly gold prices of PT Aneka Tambang Tbk from January to April 2026. This additional validation provides a more comprehensive assessment of forecasting performance under real market conditions and offers practical insights into selecting an appropriate forecasting model for the Indonesian gold market.

To address these gaps, this study uses monthly gold price data from PT Aneka Tambang Tbk for the 2021–2025 period to compare the forecasting performance of ARIMA and Holt's Double Exponential Smoothing. The forecasting performance is evaluated using MAPE, MAE, and RMSE, followed by validation with actual monthly gold prices from January to April 2026 to provide a forecasting model that is more relevant to current market conditions.

In the situation described, this research aims to to compare the forecasting performance of ARIMA and Holt's Double Exponential Smoothing using monthly gold prices of PT Aneka Tambang Tbk from 2021 to 2025. The forecasting performance is evaluated using MAPE, MAE, and RMSE and further validated against the actual monthly gold prices from January to April 2026. The findings are expected to provide a forecasting model that better reflects current market conditions and supports investment decision-making. In time series forecasting, the ARIMA model is considered an efficient technique due to its ability to model relationships between past and current values using autoregressive (AR), integrated (I), and moving-average (MA) components. The ARIMA model starts by identifying the model, estimating parameters, and testing diagnostics before determining the optimal model (Chasanah, 2021; Wibowo et al., 2025). Moreover, the strength of this model lies in its ability to handle non-stationary data sets by differentiating; therefore, it is commonly used for forecasting economic and financial data.

Conversely, Holt’s Double Exponential Smoothing is used to account for trends in the dataset. This method requires parameters for both the level (α) and the trend (β), thus allowing the model to be flexible with any changes occurring within the dataset. The advantages of this method include its simplicity and effectiveness in providing accurate predictions for datasets with linear trends (Mandati et al., 2025; Yenkikar et al., 2025). The ultimate objective of this study is to formulate a predictive model that aligns well with current market conditions and provides valuable insights for investment decisions.

2. RESEARCH METHOD

A. Type and Research Approach

This study uses a quantitative, time-series approach. The choice of the quantitative approach is based on the nature of the data, which is numerical and is subjected to statistical analysis to develop a forecast model. The process makes it easy to objectively and quantitatively analyze the past data trends and predict the future values (Wibowo et al., 2025; Yenkikar et al., 2025). The use of the time series approach is justified, as the data used in the research consist of numerical gold prices arranged in sequential order, particularly from 2021 to 2025. Time series analysis focuses on recognizing distinct patterns within the data, such as trends and variations, which serve as a foundation for making predictions (Hyndman & Athanasopoulos, 2021).

The techniques used in this research are the ARIMA and Holt's double-exponential smoothing models. They have been selected based on their relevance to analyzing time series and the different approaches used to model the information. While ARIMA focuses on the statistical relationships in past data, the second approach concerns data smoothing and trend adjustment (Wibowo et al., 2025; Yenkikar et al., 2025). This research is quantitative, and its main goal is to develop a forecasting model to accurately predict gold prices in Indonesia using data from PT Aneka Tambang Tbk from 2021 to 2025.

B. Data Sources and Types

The information utilized in this research is secondary, as evidenced by the gold bar prices sourced from PT Aneka Tambang Tbk through the Logam Mulia site. The dataset comprises monthly gold prices ranging from January 2021 to December 2025, featuring a total of 60 observations. The information employed in this study is quantitative, consisting of time-series data organized in sequential order to identify any changes in the trend of gold prices (Chatfield, 2022; Montgomery et al., 2021).

C. Data Collection Techniques

The data collection procedure used in this study is the documentation method, which involves collecting, recording, and managing information that already exists, either in writing or in archival form, from certain sources (Creswell & Creswell, 2022; Sugiyono, 2022). The documentation method is chosen because the information used in this study is in secondary form and has been officially made available to everyone. Data collected includes gold bar prices from PT Aneka Tambang Tbk, through the Logam Mulia website. The procedure that was taken to collect data includes accessing the price data history of gold bars on the website and recording them based on the time period in this study, that is, January 2021 until December 2025. The data used in this study include monthly data collected on the 10th day of each month (Hyndman & Athanasopoulos, 2021).

D. Data Analysis Methods

The methodology used in this study involves adopting a time-series forecasting approach using two models: the Autoregressive Integrated Moving Average (ARIMA) and Holt's Double Exponential Smoothing. The purpose is to determine which of the two methods produces the most accurate forecasts of gold prices in Indonesia. The procedure adopted in this study was to use EViews 12 to analyze the data, including model identification, parameter estimation, diagnostic testing, and forecasting. In this study, time-series analysis was conducted using monthly gold prices in Indonesia from January 2021 to December 2025. Thereafter, a descriptive analysis was conducted to examine the data characteristics.

1) *Autoregressive Integrated Moving Average* (ARIMA) Method

The Autoregressive Integrated Moving Average (ARIMA) model is one of the most commonly used approaches for predicting time-series data, thanks to its ability to detect autocorrelation patterns in historical data and handle non-stationary data through differencing (Bhattacharya, 2025; Wibowo et al., 2025). An ARIMA model is composed of three elements: autoregressive (AR), integrated (I), and moving average (MA). The concept of autoregressive (AR) suggests that the values from earlier periods have an effect on the present value of a variable. Concurrently, moving average (MA) indicates that the present value of a variable is affected by the errors from the preceding period. The ARIMA model is written as ARIMA(p,d,q), where:

- p is the AR order
- d is the difference order
- q is the MA order

For time series that are not stationary, the ARIMA model takes an additional step of differencing to make the series stationary (Chatfield, 2022). In general, the ARIMA model may be expressed as shown below (Hyndman & Athanasopoulos, 2021):

$$\phi(B)(1-B)^d Y_t = \theta(B)\varepsilon_t$$

First-order differencing can be described by the following process (Hyndman & Athanasopoulos, 2021):

$$\Delta Y_t = Y_t - Y_{t-1}$$

Once first-order differencing is completed, the development of the ARMA model can take place into an ARIMA model. The ARIMA model can be described using the following formula for first-order differencing:

$$\Delta Y_t = \phi + \sum_{i=1}^{p} \theta_i \Delta Y_{t-i} + \varepsilon_t - \sum_{i=1}^{q} \lambda_i \varepsilon_{t-i}$$

The approach is used to transform the non-stationary time series data into stationary data through the process of differencing.

From the model stated above, the steps involved in carrying out the ARIMA analysis in this study include:

a. Series Stationarity Test
To determine whether the data on gold prices are stationary, a series stationarity test is conducted. This refers to data which has consistent variance and average at all times. The procedure uses the Augmented Dickey-Fuller (ADF) test, where the data will be considered stationary if the p-value is less than 0.05 (Hyndman & Athanasopoulos, 2021).

b. *Differencing*
If the data is not stable over time, a differencing procedure is applied to eliminate the trend. This is done by taking the current data point and subtracting the value from the earlier period, specifically:$\Delta Y_t = Y_t - Y_{t-1}$
This process can be performed more than once until the data becomes stationary (Hyndman & Athanasopoulos, 2021).

c. Model Identification (ACF and PACF)

Once the data was verified to be stable, the following action was to establish the model by employing Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) diagrams. The ACF diagram helped in recognizing the order of the moving average (q), while the PACF diagram was utilized to ascertain the order of autoregression (p). The *cut-off* and *tailing-off* patterns in the plots were used as the basis for selecting the model (Chatfield, 2022).

d. Determination of the ARIMA (p,d,q) Model
According to the ACF and PACF evaluations, multiple potential ARIMA models, represented as ARIMA(p,d,q), were identified. The model chosen is the one that most accurately aligns with the established data pattern (Montgomery et al., 2021).

e. Parameter Estimation
Parameter estimation was performed to obtain the optimal parameters for the ARIMA model using EViews 12. When the probability value of a parameter, also referred to as the p-value, is less than 0.05, it means that the parameter is statistically significant. When a model has significant parameters, it implies that the variable does impact the model, enabling the model to statistically explain the relationship between the data variables (Hyndman & Athanasopoulos, 2021).
Additionally, selecting the best model depends on the values of the Akaike Information Criteria (AIC) and the Schwarz Criteria (SC). The best model will be the one having the lowest values of both the AIC and SC (Montgomery et al., 2021).

f. Diagnostic Tests
Diagnostic tests were conducted to assess whether the model residuals are white noise and uncorrelated. These assessments were conducted utilizing the residual correlogram (Q-statistics) or the Ljung–Box test, which are formulated to identify the existence of autocorrelation within the residuals. The hypotheses used are as follows:
- H0: the residuals have no autocorrelation (*white noise*)
- H1: The residuals exhibit autocorrelation

A determination is reached according to the probability value (p-value), specifically:
- p-value > 0.05 → the residuals are not *autocorrelated* (the model is suitable for use)
- p-value ≤ 0.05 → the residuals are *autocorrelated* (the model needs to be improved)

Additionally, model stability is assessed via *inverse root* analysis, where the model is deemed stable if all values fall within the permissible range (Montgomery et al., 2021). Should the model fail to satisfy these criteria, the selection process for models will be conducted once again until the model is identified that most appropriately aligns with the characteristics of the data.

2) *Holt's Double Exponential Smoothing* Method

The Double Exponential Smoothing technique proposed by Holt is utilized in this research as a benchmark method against ARIMA for forecasting gold prices in Indonesia. This method is an enhancement of Single Exponential Smoothing, which is capable of capturing trend patterns within data. Consequently, it is deemed suitable for predicting gold price data that exhibits a trend of rising prices and variable patterns. There have been several studies that demonstrate the effectiveness of this method not only in predicting gold prices but also in other goods that exhibit linear trends (Ariffin et al., 2024; Mandati et al., 2025; Zheng, 2025).

This method uses two elements, which are the level element and the trend element. The level element represents the basic value of data during a certain period of time, while the trend element indicates the direction of changes in data for a certain period of time. The combination of both elements enables this method to provide more accurate predictions on data that show linear trends. According to Kahraman (2022), the exponential smoothing method is efficient for predicting the prices of metal commodities due to its adaptive nature to trend changes.

Mathematically, *Holt's Double Exponential Smoothing* model can be written as follows. (Hyndman & Athanasopoulos, 2021):

A. *Level* Equation

$$L_t = \alpha Y_t + (1 - \alpha)(L_{t-1} + T_{t-1})$$

B. *Trend* Equation

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$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1}$$

C. *Forecasting* Equation

$$\hat{Y}_{t+m} = L_t + mT_t$$

where:

- L_t =The *level* component in period t
- T_t = *trend* component in period t
- Y_t = actual data for period t
- α = *level smoothing* parameter ($0 < \alpha \leq 1$)
- β = *trend smoothing* parameter ($0 < \beta \leq 1$)
- $\hat{Y}_{t+m}$ = forecast values for the next m periods

The values of the parameters α and β are crucial for forecasting results, as they control the degree of data smoothing. Optimal parameter values will result in a lower forecasting error rate. According to this model, the steps for analysis employing Holt's Double Exponential Smoothing technique in this research consist of the following:

a. Finding patterns in the data
The first step is to use time-series plots to identify patterns in gold price data. The data demonstrated distinct trend patterns, which made the Holt method appropriate for use (Su, 2024).

b. Calculating the smoothing parameters (α and β)
An ideal model is obtained by determining the smoothing parameters α and β, where α smooths the level component and β smooths the trend component. Parameter determination is performed using *EViews 12* software, which automatically searches for the best parameter combination based on the smallest forecasting error. Determining optimal parameters is crucial because it directly affects forecast accuracy (Zheng, 2025).

c. Determining the trend and level components
The Holt's method is applied to calculate the level and trend components once the parameters have been estimated. The trend component indicates the historical change in the data, while the level component reveals the forecasted base value of the data. These calculations are iteratively repeated for each period to allow the model to adapt to changes in data patterns and produce more accurate predictions (Mandati et al., 2025).

d. *Forecasting* Process
Forecasting is done for the coming period based on the level and trend obtained from the equations. Predictions are made about the price of gold in the near future based on the forecasts. The Holt approach can be used effectively for data showing a linear trend since it is flexible enough to capture any change in patterns (Bhattacharya, 2025).

e. Selection of the Best Model
The model that is chosen should have the minimum forecasting error. The model that uses the Holt's approach with the optimal values of α and β that yield the lowest forecasting error is considered the best model.

The most effective method for predicting the gold price in Indonesia is determined by comparing the forecasting results from the Holt's Double Exponential Smoothing and ARIMA approaches using measures such as MAPE, MAE, and RMSE (Pirmanto, 2024).

E. Measures of Accuracy

The evaluation of forecast inaccuracies takes place after acquiring the best models by utilizing the Autoregressive Integrated Moving Average (ARIMA) and the Double Exponential Smoothing techniques. The purpose of this measurement is to ascertain which approach yields the most precise forecasts. Several error measures (forecast error) are used to compare the forecast values with the actual data in order to do the evaluation. Because they can quantitatively show the model's accuracy, the Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE) are frequently used in forecasting research (Ariffin et al., 2024; Pirmanto, 2024).

a. *Mean Absolute Percentage Error* (MAPE)
The difference in percentages between actual data and forecasted values is measured using the MAPE. The MAPE number makes it simpler to understand by expressing the size of the model's mistake as a percentage. The following is the MAPE formula. (Hyndman & Athanasopoulos, 2021):

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$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{Y_t - \widehat{Y_t}}{Y_t}\right| \times 100\%$$

b. *Mean Absolute Error* (MAE)
The average absolute value of the discrepancy between actual data and anticipated outcomes is measured using MAE. Unlike MSE, which penalizes extreme errors more severely, this indicator accurately depicts the size of prediction errors. MAE is frequently used to compare the accuracy of various forecasting models because it is easier to interpret, as it uses the same units as the original data (Montgomery et al., 2021).
The following is the MAE formula. (Montgomery et al., 2021):

$$MAE = \frac{1}{n}\sum_{t=1}^{n}\left|Y_t - \widehat{Y_t}\right|$$

The smaller the MAE value, the better the forecasting model is considered to be, as it indicates a lower average prediction error.

c. RMSE, or root mean squared error
The level of prediction inaccuracy, expressed in the same units as the original data, is assessed using RMSE, which is derived from the square root of MSE. Since RMSE is presented in the same units as the actual measurements, it is easier to interpret compared to MSE. The RMSE formula is as follows (Chatfield, 2022):

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(Y_t - \widehat{Y_t}\right)^2}$$

A lower RMSE indicates a lower prediction error and better accuracy.

d. Determining the Best Model
The best model in this study was determined based on the smallest MAPE, MAE, and RMSE values. To find out which approach resulted in the lowest forecasting error rate, the ARIMA and Holt's Double Exponential Smoothing models were compared. Because it was thought to have more accurate prediction abilities for predicting gold prices in Indonesia, the model with the lowest error value was chosen as the best model. These results will subsequently form the basis for the research conclusions.

F. Research Flowchart

In order to understand the various stages of research conducted, a research flow chart was formulated. This flow chart shows how the research process was carried out systematically, including gathering data, formulating models using ARIMA and Holt's Double Exponential Smoothing approaches, and choosing the best model through forecasting accuracy.
The following is the flow chart that was used for this research:

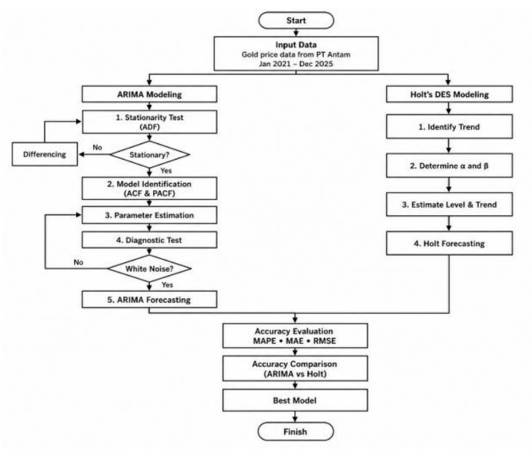

Fig 2. Research *Flowchart*

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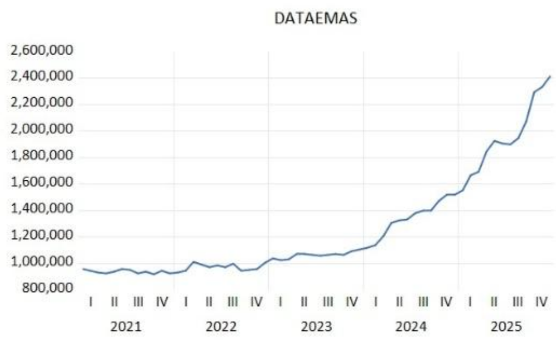
3. RESULTS AND DISCUSSION

A. Description of Research Data

The price of gold from PT Aneka Tambang Tbk (Antam) collected using Logam Mulia from the company's official website serves as the source of the data in this paper. Specifically, the price of gold bars per gram collected monthly, from January 2021 to December 2025, will be analyzed in this research. Monthly data is chosen because it allows for better analysis of trends in gold prices' medium and long-term variations, thus making it more suitable for time series forecasting purposes. The purpose of collecting the data on a specific day each month is to mitigate biases caused by extreme fluctuations in gold prices each day.

To provide an overview of the dataset, descriptive statistics were calculated for the gold price data covering the period from 2021 to 2025. The results show that the mean gold price was **1,255,500**, while the median was **1,063,000**, indicating that the average price was influenced by relatively higher gold prices during the observation period. The gold prices ranged from a minimum value of **914,000** to a maximum value of **2,416,000**, reflecting substantial price variation over the five-year period. Furthermore, the standard deviation of **406,790.1** indicates considerable variability in monthly gold prices, suggesting that the data experienced noticeable fluctuations around the mean.

Based on the results obtained in the time series plot, there are price variations in gold prices that have an upward tendency sometimes. Fluctuations in gold prices are affected by factors such as global interest rates, inflation, rupiah exchange rate, and economic uncertainty (Ariffin et al., 2024; Zheng, 2025). Uncertain economies are likely to increase demand for gold since it acts as a safe haven in case of uncertainties. ARIMA method and Holt's double exponential smoothing are chosen for this research due to the characteristics exhibited by the data, which include pattern and variation.



source : www.logammulia.com

Fig 3. PT Antam Tbk Gold Price Chart for the 2021–2025 Period

B. ARIMA Modeling Results

1) Stationarity Test

In order to check whether the gold prices data fits in the stationarity assumption for the model, the initial step in the ARIMA Modeling is performing a stationarity test. Since ARIMA modeling assumes that the mean and the variance remain constant in time series data, it becomes a basic requirement. For conducting the stationarity test, the Augmented Dickey Fuller (ADF) Test has been performed through the use of the software package, EViews 12. The following theories were proposed:
H0: Non-stationary data
H1: The information is stationary
The probability value (p-value) is used to make the test decision; if the p-value is less than 0.05, the data are deemed stationary.

Table 1. ADF Test Results at the *Level*

		t-statistic	Prob.
Augmented Dickey-Fuller test statistic		5.023249	1.0000
Test critical values:	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

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The ADF test findings at the specified level yielded a probability value of 1.0000, which is greater than 0.05, according to Table 1. This shows that the gold price data still exhibit a unit root and are not stationary at the level. To attain stationarity, a differencing procedure is necessary, as the null hypothesis (H0) is accepted. First-order differencing, or first difference, is used since the data is not stationary at the level. The data is then deemed stationary at the initial difference when the ADF test is performed once again and the results indicate that the probability value is less than 0.05.

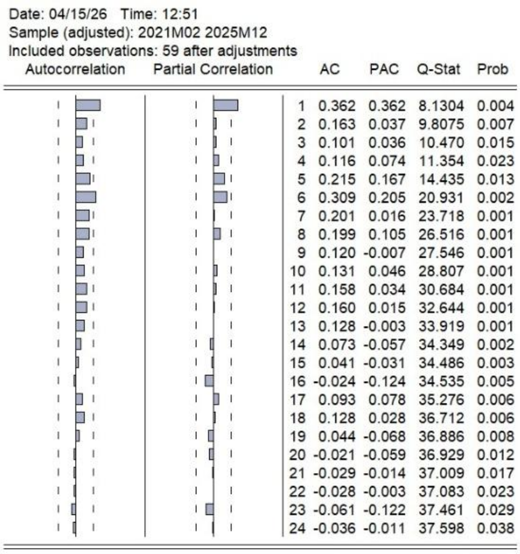
Table 2. ADF Test at the *First Difference*

		t-statistic	Prob.
Augmented Dickey-Fuller test statistic		-5.008320	0.0001
Test critical values:	1% level	-3.548208	
	5% level	-2.912631	
	10% level	-2.594027	

Thus, based on the results in Table 2, the ARIMA model used has a *differencing* value of one, or d = 1.

2) ARIMA Model Identification (ACF and PACF)

Once the data has been established as stationary following the first difference, the subsequent phase involves determining the ARIMA model by utilizing graphical assessments of ACF and PACF.



Date: 04/15/26 Time: 12:51
Sample (adjusted): 2021M02 2025M12
Included observations: 59 after adjustments

Lag	AC	PAC	Q-Stat	Prob
1	0.362	0.362	8.1304	0.004
2	0.163	0.037	9.8075	0.007
3	0.101	0.036	10.470	0.015
4	0.116	0.074	11.354	0.023
5	0.215	0.167	14.435	0.013
6	0.309	0.205	20.931	0.002
7	0.201	0.016	23.718	0.001
8	0.199	0.105	26.516	0.001
9	0.120	-0.007	27.546	0.001
10	0.131	0.046	28.807	0.001
11	0.158	0.034	30.684	0.001
12	0.160	0.015	32.644	0.001
13	0.128	-0.003	33.919	0.001
14	0.073	-0.057	34.349	0.002
15	0.041	-0.031	34.486	0.003
16	-0.024	-0.124	34.535	0.005
17	0.093	0.078	35.276	0.006
18	0.128	0.028	36.712	0.006
19	0.044	-0.068	36.886	0.008
20	-0.021	-0.059	36.929	0.012
21	-0.029	-0.014	37.009	0.017
22	-0.028	-0.003	37.083	0.023
23	-0.061	-0.122	37.461	0.029
24	-0.036	-0.011	37.598	0.038

Fig 4. Results of ACF and PACF Analysis

Additionally, the findings of the ACF and PACF studies in Figure 4 demonstrate that the ACF exhibits prominent values at lags 1 and 6, whereas the PACF has a prominent value at lag 1. Thus, ARIMA(0,1,0), ARIMA(0,1,1), ARIMA(0,1,6), ARIMA(1,1,0), ARIMA(1,1,1), and ARIMA(1,1,6) are the ARIMA model candidates examined in this study. By comparing parameter significance, Akaike Information Criterion (AIC) values, Schwarz Criterion (SC) values, and the outcomes of residual diagnostic tests, the optimal model was chosen. The optimal ARIMA model was determined to have significant parameters, the lowest AIC and SC values, and residuals that met the white noise condition.

3) ARIMA Model Parameter Estimation

The next stage is to estimate the parameters to find the model that best fits the features of the gold price data after identifying a number of candidate ARIMA models. The probability value (p-value) for each parameter is used to test each model. If a parameter's probability value is less than 0.05, it is deemed significant. Furthermore, the model that fits the data better is thought to have lower AIC and SC values.

Table 3. ARIMA Model Parameter Estimation Results

Model	AIC	SC
ARIMA(0,1,0)	24,37068	24,40589
ARIMA(0,1,1)	24,31524	24,42088
ARIMA(0,1,6)	24,27486	24,41571

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ARIMA(1,1,0)	24,2950	24,40064
ARIMA(1,1,1)	24,27387	24,41472
ARIMA(1,1,6)	24,19138	24,36744

The ARIMA(1,1,6) model has the lowest Akaike Information Criterion (AIC) value of 24.19138 and Schwarz Criterion (SC) value of 24.36744 among the candidate models, according to Table 3's estimation results. A better match between the model and the data is shown by smaller AIC and SC values. As a result, the ARIMA(1,1,6) model is chosen as the best option for the time being and will proceed to the residual diagnostic test and parameter significance test.

4) Parameter Significance Test

After the ARIMA(1,1,6) model was selected as the best candidate, the next step was to conduct a parameter significance test to determine whether the model's coefficients had a statistically significant effect. The significance test was conducted by examining the probability value (*p-value*) for each parameter. A parameter was considered significant if the probability value was less than 0.05.

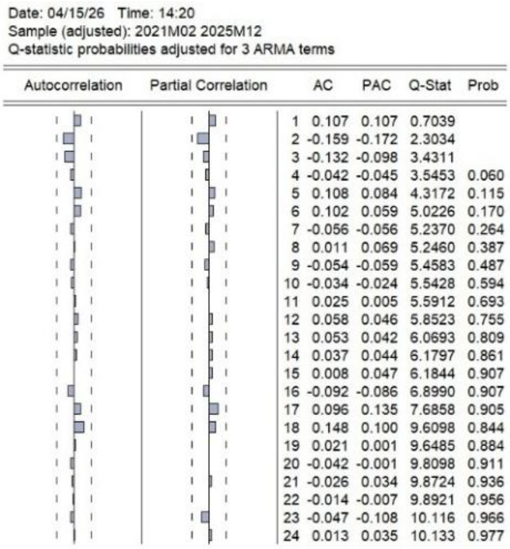
Table 4. ARIMA Model Parameter Estimation Results

Variable	Coefficient	Standard Error	Prob.	Result
C	35376,52	50192,46	0,4840	Not Significant
AR(1)	0,984319	0,041694	0,0000	Significant
MA(1)	-1,060710	0,130107	0,0000	Significant
MA(6)	0,250120	0,163318	0,1315	Not Significant

Table 4 shows that the calculated values for the AR(1) and MA(1) parameters have a probability value of 0.0000, making them significant. In contrast, the MA(6) parameter has a p-value of 0.1315, which is deemed inconsequential because it exceeds 0.05. Furthermore, with a p-value of 0.4840, the model constant is likewise not significant. The ARIMA(1,1,6) model is nevertheless considered despite having one irrelevant parameter because it has more significant parameters than the other candidate models and the lowest AIC and SC values.

5) Residual Diagnostic Tests

To make sure that the model's residuals are random (white noise) and do not show autocorrelation, a residual diagnostic test is then carried out. The Correlogram Q-Statistics (LjungBox Test) is used for this test. If the Q-Statistic probability value is higher than 0.05, the model is considered to meet the white noise assumption.


Date: 04/15/26 Time: 14:20
Sample (adjusted): 2021M02 2025M12
Q-statistic probabilities adjusted for 3 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.107	0.107	0.7039	
		2	-0.159	-0.172	2.3034	
		3	-0.132	-0.098	3.4311	
		4	-0.042	-0.045	3.5453	0.060
		5	0.108	0.084	4.3172	0.115
		6	0.102	0.059	5.0226	0.170
		7	-0.056	-0.056	5.2370	0.264
		8	0.011	0.069	5.2460	0.387
		9	-0.054	-0.059	5.4583	0.487
		10	-0.034	-0.024	5.5428	0.594
		11	0.025	0.005	5.5912	0.693
		12	0.058	0.046	5.8523	0.755
		13	0.053	0.042	6.0693	0.809
		14	0.037	0.044	6.1797	0.861
		15	0.008	0.047	6.1844	0.907
		16	-0.092	-0.086	6.8990	0.907
		17	0.096	0.135	7.6858	0.905
		18	0.148	0.100	9.6098	0.844
		19	0.021	0.001	9.6485	0.884
		20	-0.042	-0.001	9.8098	0.911
		21	-0.026	0.034	9.8724	0.936
		22	-0.014	-0.007	9.8921	0.956
		23	-0.047	-0.108	10.116	0.966
		24	0.013	0.035	10.133	0.977

Fig 5. Results of the ARIMA (1,1,6) Residual Diagnostic Test

The ARIMA(1,1,6) model displays a probability value of 0.06, which is higher than 0.05, according to Figure 5. These findings show that the residuals of the model satisfy the white noise assumption and do not show autocorrelation.

6) ARIMA Model Forecasting

The gold price forecasting procedure is carried out after the ARIMA(1,1,6) model was determined to be the best model based on AIC and SC values, parameter significance tests, and residual diagnostic tests.

Table 5. Gold Price *Forecasting* Results Using ARIMA

Date	Price(Rp/gram)
10/1/2026	2.459.447
10/2/2026	2.397.312
10/3/2026	2.552.297
10/4/2026	2.642.508

The ARIMA(1,1,6) model shows good performance in following the patterns of gold price movement, according to the data in Table 5. However, these forecasting results must be compared with Holt's Double Exponential Smoothing utilizing accuracy metrics like MAPE, MAE, and RMSE in order to identify the more accurate approach.

C. Results of *Holt's Double Exponential Smoothing* Modeling

The next stage is to model using Holt's Double Exponential Smoothing as a comparative approach to predict gold prices in Indonesia, after obtaining the forecasting results from the ARIMA method. This approach is applied to time series data with a trend pattern since the gold price data shows a fluctuating pattern with an increasing tendency. The analysis steps for this method include identifying the data pattern, determining the *smoothing* parameters *alpha* (α) and *beta* (β), calculating *the level* and *trend*, and the *forecasting* process. From the time series graph in Subsection 3.1, it can be observed that the prices of gold have an oscillating pattern with an increasing trend from 2021 to 2025. Hence, it can be inferred that the data is sufficiently trending; thus, the use of Holt's Double Exponential Smoothing method is suitable.

The subsequent phase involves determining the values for the two smoothing factors, alpha (α) and beta (β). The alpha factor is utilized to adjust the level aspect, whereas the beta factor is employed to refine the trend aspect. A better forecasting model requires optimal values for the smoothing constants. In this study, the best results from the Holt model estimation are used to select the alpha and beta parameters. The Holt-Winters No Seasonal model, which is similar to Holt's Double Exponential Smoothing because it considers only the level and trend components without seasonality, was used to determine the smoothing parameters for Holt's Double Exponential Smoothing in EViews 12.

The alpha (α) and beta (β) parameters were found to have a value of 1.0000 and 0.1500, respectively, according to the results of the estimation process. Although the small value of the beta parameter implies that the trend factor will be smoothed continuously, the alpha parameter of value one means that the model responds sensitively to variations in recent data. The technique used to forecast gold prices for January to April 2026 is Holt's Double Exponential Smoothing.

Table 6. Gold Price *Forecasting* Results Using *Holt's Double Exponential Smoothing*

Date	Price(Rp/gram)
10/1/2026	2.490.342
10/2/2026	2.564.685
10/3/2026	2.639.027
10/4/2026	2.713.369

D. Comparison of the Accuracy of the ARIMA Model and Holt's Double Exponential Smoothing

To identify the most effective model for predicting gold prices in Indonesia, a comparison was made between the forecast accuracy of the ARIMA(1,1,6) model and Holt's Double Exponential Smoothing model. Forecasting accuracy comparisons were conducted using forecast error measures: MAPE, MAE, and RMSE. The three measures were used to evaluate the accuracy of the forecasts generated by each model. Those models that had relatively smaller values of MAPE, MAE, and RMSE were regarded as having high accuracy.

Table 7. Comparing the ARIMA and Holt's Double Exponential Smoothing Models' Accuracy

Method	MAPE	MAE	RMSE

ARIMA(1,1,6)	1,98	26,227	37.926,51
Holt DES	2,90	57,438	41.367,74

According to Table 7, the ARIMA(1,1,6) model shows greater accuracy in relation to the Holt's Double Exponential Smoothing approach due to having lesser MAPE, MAE, and RMSE values. The superior performance of the ARIMA(1,1,6) model can be explained by the characteristics of the historical gold price series used in this study. As shown in Figure 1, during the 2021–2025 period, the monthly gold prices of PT Aneka Tambang Tbk generally exhibited an increasing trend, although several temporary fluctuations occurred. After the differencing process, the data became stationary, allowing the ARIMA model to effectively capture the autocorrelation structure and temporal dependence within the historical observations. These characteristics are consistent with the strengths of ARIMA in modelling non-stationary time series after differencing, which contributed to its lower forecasting errors. This finding is consistent with Wang (2025) and Bing and Nor (2024), who reported that ARIMA performs well when historical time series exhibit stable temporal dependence and can be transformed into stationary data through differencing.Therefore, it is clear that the ARIMA model is more accurate, as evidenced by its historical performance. Accuracy of forecasting in this study was verified based on the comparison of forecast values to actual gold price values for the period from January to April 2026, along with the use of accuracy measurements such as MAPE, MAE, and RMSE. As gold prices for January through April 2026 were known, verification was needed to determine which forecasts were most accurate. Forecast values made using both the ARIMA and Holt approaches were compared to actual gold price values from PT Antam Tbk. The one which had the least difference to the actual value was considered the most accurate one for making forecasts about gold prices.

Table 8. Comparison of *Forecasts* and Actual Data for 2026

Month	Actual	ARIMA Forecast	Holt Forecast	Nearest Neighbor Method
January	2.602.000	2.459.447	2.490.342	Holt
February	2.954.000	2.397.312	2.564.685	Holt
March	3.047.000	2.552.297	2.639.027	Holt
April	2.857.000	2.642.508	2.713.369	Holt

As seen in Table 8, the prediction results of the double exponential smoothing Holt approach provide prediction values that are closer to the real value compared to the ARIMA model during the entire observation period. For example, in January 2026, the Holt prediction of Rp2,490,342 is closer to the actual value of Rp2,602,000 than the ARIMA prediction of Rp2,459,447. The same trend also holds for February, March, and April 2026, where the Holt double exponential smoothing predictions show lower differences than the actual values. It is evident that, even though the ARIMA model produces better results in terms of MAPE, MAE, and RMSE on historical data, it is less accurate in validation using recent real values. Holt is more accurate.

The reason for this difference lies in the differences between the two models' data processing methods. ARIMA puts a lot of importance on the analysis of historical trends and autocorrelations within previous data. Hence, the ARIMA algorithm is likely to generate steady predictions but is not sensitive to recent shifts within trends. At the same time, Holt's Double Exponential Smoothing is able to react to the changes in patterns quickly because it assigns more significance to recent data using level (α) and trend (β) parameters. In this research project, the proximity of the α parameter to one suggests that the Holt model can respond to changes within data patterns quickly. Under such circumstances, the changes in gold prices within the most recent period can play a leading role in shaping the forecast's outcome. Therefore, when gold prices rose sharply in early 2026, the Holt approach could detect this change more quickly than the ARIMA model, which was still influenced by historical trends. Overall, the Holt technique produces more precise predictions when data trends shift frequently, whereas ARIMA performs best with historical trends.

4. CONCLUSION

Based on the research, both Holt's Double Exponential Smoothing and ARIMA models can be employed to estimate future gold prices, owing to their ability to identify patterns and fluctuations in historical gold price data. However, the accuracy levels provided by the two methods differ. Forecasting errors are lower when compared to those of Holt's method, which makes the ARIMA(1,1,6) the optimal model, given that the historical performance of the two is used for comparison purposes. However, when validation of predictions using real figures for January–April 2026 is considered, the results indicate that Holt's double exponential smoothing technique provides realistic estimations.

These disparities reveal that the ARIMA forecasting technique is a better tool in estimating past trends than Holt's technique, which is sensitive to recent trend changes and hence suitable for short-term forecasting. Hence, in forecasting, it is advisable to employ techniques based on the aims of the forecasting. Accordingly, this research shows that the ARIMA (1,1,6) technique is the most appropriate when considering past trends, while Double Exponential Smoothing by Holt performs better in short-term forecasting compared with the current actual figures.

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