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Predicting Gold Price movements using ARIMA Model

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ABSTRACT
Gold is an enticing investment not only for individuals but also for firms and governments around the world. According to International Monetary Fund (IMF) recent reports the central banks around the world hold gold worth US$2 trillion which is accounted for about 16% of world gold reserves. World's largest economies such as USA, Germany, Italy, France and Russian federation are the top five economies with largest percentage of gold reserves. Besides India and China are the top spots for largest retail gold consumers with around 57% demand for the gold jewellery. This inquisitiveness of gold among different sects of the economies is an indication of demand for the gold in various forms. Whether gold as an investment or as a reserve has the power to change an economy's trajectory. Keeping Gold's potential in view the present study is an attempt to forecast future gold prices in India using historical gold prices from November,2020 to April 2024. The forecasted values for the period of May,2024 to April,2025 are an approximate value computed using Auto regressive moving averages (ARIMA) model. The forecasted values indicated stable and cyclical trends which are not too distant from past and present scenarios. The study concluded that the cyclical and stable trends if studies instance to instance wise would generate more accurate and sophisticated forecast values.

Keywords: Forecasting, Gold price, Autoregressive Integrated Moving Average model (ARIMA), Moving average (MA).

I. Introduction
The role of gold and gold reserves is predominant in current scenario as many world economies are moving towards de-dollarization and is increasing their gold reserves rampantly in support of the same. However, the movement of gold prices is so fragile around the world and this fragility is making gold price predication a critical task for investors, economists, and policymakers. Besides, in countries like India Gold is often considered a safe asset that cushions everyone against inflation rates, currency fluctuations, geopolitical events, and market speculation. Since it is considered as a cushion by both investors and economies making accurate forecasts of gold prices can provide invaluable insights for making informed investment decisions thus enabling strategic economic policy framework. Earlier right predicting the gold prices was too herculean because of lack of robust analytical tools however, introduction of time series analysis models has proven to be effective for analysing, forecasting and modelling the gold prices based on historical gold price data. Among wide array of techniques ARIMA- Autoregressive Integrated Moving Average model

stands out due to its flexibility and robustness in handling different types of data. The ARIMA model combines three key elements: autoregression (AR), differencing (I) to test stationarity, and moving average (MA) for smoothening and predicting the future movements based on historical price volume data.

The study aims at leveraging the ARIMA model to right predict gold market trends. The results from the analysis based on the historical gold price data enables the marketers in understanding the underlying gold price movements thus enabling development of more reliable forecasting model. The paper is a humble attempt to present the process of forecasting which involves transforming data to achieve stationarity, selecting the optimal ARIMA parameters and validating the model's accuracy through rigorous testing. The paper is organized in to subsections and it starts with comprehensive review of the relevant literature on gold price forecasting and ARIMA models then methodology of the study followed by ARIMA model to forecast the gold price series. Final section is dedicated to results will be discussed, highlighting the model's predictive performance and potential implications for investors and policymakers. By the end of this study, we aim to provide a clear demonstration of the ARIMA model's capability in forecasting gold prices and offer actionable insights that can aid in strategic decision-making in the gold market.

II. Review of the Literature

The literature on gold price forecasting is extensive reflecting the importance of gold in the global economy and the complexity of predicting its price movements. Various methodologies have been explored ranging from traditional econometric models to advanced machine learning (ML) techniques. The present review focuses on studies that have employed ARIMA model highlighting its effectiveness while comparing ARIMA with other forecasting models available.

Gold price forecasting has been a subject of interest for researchers due to the metal's unique economic properties and its role as a hedge against inflation and currency fluctuations. Early studies such as Ghosh et al. (2004) examined the macroeconomic determinants of gold prices, identifying factors like exchange rates, interest rates, and inflation as key influencers. These studies laid the groundwork for more sophisticated time series analyses. Subsequent researches shifted towards statistical and econometric models to predict gold prices. Blose (2010) demonstrated that gold prices exhibit strong temporal dependencies, making them suitable for time series modelling. Studies like those by Batten et al. (2010) and Wang et al. (2011) employed various econometric techniques, including vector autoregression (VAR) and cointegration models to forecast gold prices yielding mixed results.

The ARIMA model has been widely used in financial time series forecasting due to its ability to capture the underlying patterns in historical data. ARIMA combines autoregressive (AR) and moving average (MA) components along with differencing (I) to achieve stationarity thus making it versatile for modelling various types of time series data. Pioneering work by Box and Jenkins (1976) formalized the ARIMA methodology which has since been applied to numerous financial forecasting problems. In the context of gold price forecasting studies by Shafiee and Topal (2010) showed that ARIMA models could effectively capture the temporal dependencies in gold price data providing accurate short-term forecasts. Patel (2012) compared the forecasting performance of ARIMA with other models, such as exponential smoothing and GARCH, concluding that ARIMA outperformed others in terms of accuracy for short-term predictions. Similarly, Baur and Lucey (2010) demonstrated that ARIMA models could adapt to structural changes in the gold market, enhancing their predictive power.

Despite their vast applicability ARIMA models does suffer some serious limitations such as the assumptions of linearity and ARIMA alone can’t fully capture the complex, nonlinear relationships present in financial time series. To address these limitations hybrid models coupled ARIMA with

machine learning techniques such as artificial neural networks (ANN) and support vector machines (SVM) have been propounded over the last few years. Studies by Khashei, Bijari (2011) and Zhang (2003) highlighted the improved forecasting performance of these hybrid models over standalone ARIMA models.

Recent **c**omparative studies have further explored the strengths and weaknesses of ARIMA models in gold price forecasting. Alqaralleh (2020) compared ARIMA with advanced models like LSTM (Long Short-Term Memory) neural networks and found that while ARIMA performed well for short-term forecasts, LSTM models provided better accuracy for longer horizons due to their ability to capture complex patterns. Additionally, advances in computational power and the availability of high-frequency data have enabled more sophisticated implementations of ARIMA models. The integration of ARIMA with volatility models (such as GARCH) and regime-switching models has shown promise in capturing the dynamic nature of gold prices.

The literature review indicates that ARIMA models have been cornerstone in gold price forecasting due to their simplicity and effectiveness in capturing temporal dependencies. Despite their limitations, ARIMA models remain competitive especially when coupled with hybrid approaches or integrated with more advanced AI/ML based techniques. The ongoing evolution of forecasting methodologies continues to build on the foundational principles established by ARIMA offering new avenues for improving the accuracy and reliability of predictions. The present study aims to contribute to the body of knowledge of price movements or predictions by applying ARIMA to historical gold price data and evaluating its forecasting performance in the current market context.

III. Methodology of the study

This section encompasses the stages and process of data collection to analysis for carrying out the present study. The paper is based on the secondary data pertaining to monthly closing prices of gold from May 2022 to April 2024. The data further analysed as shown in figure 1.

a. Data: Data for the present paper encompasses the monthly closing prices of Gold which is collected from various web sources.

b. Data Sources: Gold monthly closing price data from Sept,2020 to April, 2024 has been collected from web source investing .com.

c. Data Analysis tools: Data collected is used to analyse to compute forecast values for may 2024 to April 2025. The tools used in analysis include Augmented Dickey Fuller (ADF) test, auto regressive integrated moving averages (ARIMA) model to generate predictions for the period of May 2024 to April 2025.

IV. Empirical Analysis and Results

a. Stationarity Property checking- Augmented Dickey Fuller (ADF) test

Data analysis in this paper is carried out keeping the assumptions of ARIMA in view. The data collected is tested for stationarity using augmented dickey fuller (ADF) test. Since the raw closing prices are not stationary and the condition of stationarity is a prerequisite to use ARIMA model to bring stationarity in gold prices the data collected is transformed to lag series using differencing method. The original closing prices of gold for the study duration are plotted in order to inspect the stationarity property.

From figure.2 it is evident that the stationarity property of time series is not satisfied. To prove the same augmented dickey fuller (ADF) test is used and results of the same are presented in table no.2 below. From table no.2 it is evident that the p-value is significantly high (0.993765) indicating that we fail to reject the null hypothesis that the series has a unit root. The test statistic is higher than the critical values at all significance levels reinforcing that the series is non-

stationary. Since the time series is non-stationary, it is recommended to differentiate the series or apply transformations to stabilize the variance before performing further analysis to build forecasting models. Methods such as differencing, logarithmic transformation or seasonal decomposition could be considered to achieve stationarity.

b. Differencing method for stationarity:

Since the time series is not stationary at its original level, we adopted the method of differencing to check the stationarity.

Statistical Measures of Differentiated Series:

The first differenced price data has been used to calculate different statistical measures and the same are presented in table no.4.

From the summary statistics presented in table no.4 the differentiated time series shows that stationarity has been achieved through differencing. The provided graph shows the values of 'Price-difference' over time, with variations that appear to lack an obvious trend or seasonality, which is characteristic of a stationary series**.** Since the data is stationary, we can build a forecasting model using Auto Regressive Integrated Moving Average (ARIMA).

C. ARIMA Model on first differenced data:

The first differenced price data series is used to build ARIMA model for different autoregressive terms, differences for stationarity and number of lagged forecast errors under different information criterion AIC- Akaike Information Criteria, BIC- Bayesian Information Criteria are presented in table no.5 below. Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are both used for model selection. They provide a means to compare different models and select the one that best balances goodness of fit and model complexity.

From the above values of different orders, the best ARIMA model of appropriate order has to be chosen for building right forecasting model.

Order (p, d, q)	AIC	BIC
(1, 1, 1)	741.057	746.1977

From the above the ARIMA model with the order (1, 1, 1) has been identified as the best model based on both AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) criteria. The AIC value for this model is 741.06 and the BIC value is 746.20 which are lesser than other order models, hence indicating ARIMA (1,1,1) being a better fit over others.

D. Forecasted gold prices for next one year using ARIMA (1,1,1):

Using the historical gold price data for the period of Nov,2020 to April, 2024 ARIMA (1,1,1) model is being built and the same model is used to forecast the future gold prices from May,2024 to April,2025. For generating forecasted gold prices using ARIMA (1,1,1) model we used Python programming and the forecasted values are presented in table no.6 below. The forecasted gold prices for the next twelve months starting from May,2024 to April,2025 are relatively stable with a mean value of 70451.82 and a minimal standard deviation of 37.30. The forecasted prices range lies between 70415.33 and 70488.33. Further to better understand the movement of gold prices both historical and forecasted values a line graph is being plotted and the same is presented in figure no.4.

Figure no.4 depicts a sharp increase in the historical data leading up to the forecast period i.e., April 2024 followed by a plateau in the forecasted prices from May 2024 to April 2025. The following inferences can be drawn from the above forecasted values in general.

Stable Prices: The forecasted gold prices fluctuated narrowly between Rs.70,415/- Rs and Rs.70,488/- approximately. This Indicates a stable price trend without significant upward or downward movements in gold prices during the forecasted period.

Cyclical Pattern: Minor cyclical behaviour observed with prices alternating slightly each month on month. This cyclical movements in gold prices indicate seasonal or cyclical trend.

No Significant Trend: No clear upward or downward trend is present in forecasted gold prices which implies the ARIMA model does not anticipate major changes in the gold market over the forecasted period.

Predictability and Model Confidence: The stability and close range of forecasted prices indicate high model confidence since there is a narrow deviation between actual and forecasted values suggesting small residuals (errors) indicating a good fit.

E. Implications of the study:

The results of the study are widely useful to investors, gold consumers, commodity market enthusiasts and economies at large. Every person around the world with disposable income over savings and expenses would be interested in gold and always watch out for its price movements. Since this study focused on observing the future price movements of gold prices using historical price movements it is of at most importance to everyone who is planning to invest in gold either as a commodity or as an investment. For investors, stable prices mean lower risk implying less price volatility thus being attractive for conservative investment strategies. For policymakers, stable prices suggest stability in other economic elements such as inflation, currency values and oil prices as world gold prices and all these elements are interrelated and are the reasons behind growth or depression of any economy.

Conclusion

Thus, from the above study it is evident that the gold prices can be forecasted using historical prices. The forecasted gold prices are an indication of stability, growth or decline in future gold prices which if analysed further instance to instance wise would provide more insights on the direction of the price movements that would assist the investment community in making right investment decision. However, since the above study is conducted using monthly closing prices a more accurate and sophisticated forecasting is possible if the same forecasting using ARIMA model is performed on daily, weekly and structural event-based price data.

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Tables & Graphs

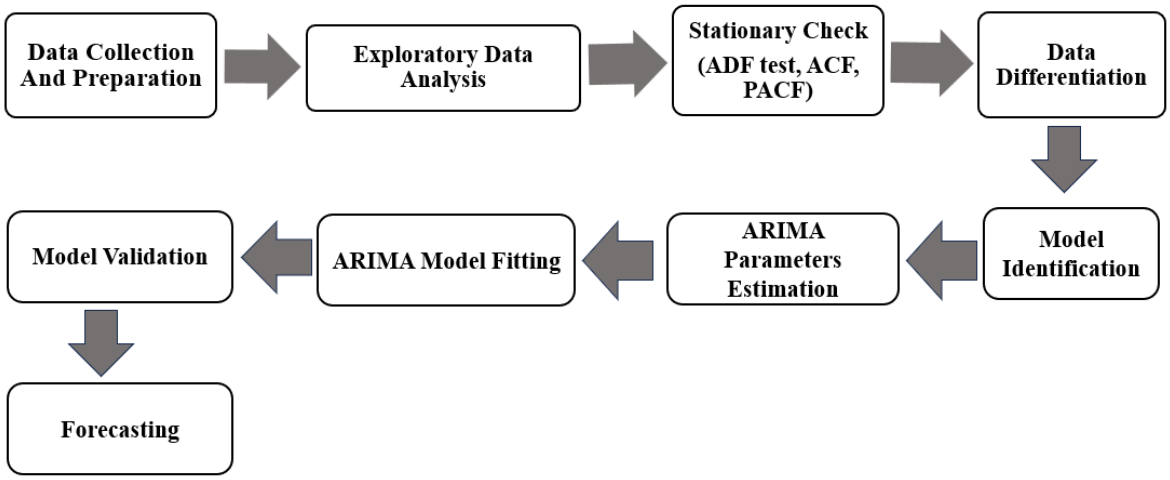

Figure 1 Flow of Data analysis adopted in the research article

Date	Gold prices
01-05-2022	50855
01-06-2022	50517
01-07-2022	51426
01-08-2022	50414
01-09-2022	50094
01-10-2022	50322
01-11-2022	52480
01-12-2022	55017
01-01-2023	57242
01-02-2023	55756
01-03-2023	59402
01-04-2023	59919
01-05-2023	60163
01-06-2023	58211
01-07-2023	59568

01-08-2023	59374
01-09-2023	57105
01-10-2023	60940
01-11-2023	62559
01-12-2023	63203
01-01-2024	62958
01-02-2024	62567
01-03-2024	67677
01-04-2024	70415

Table No.1 Monthly Closing values of Gold

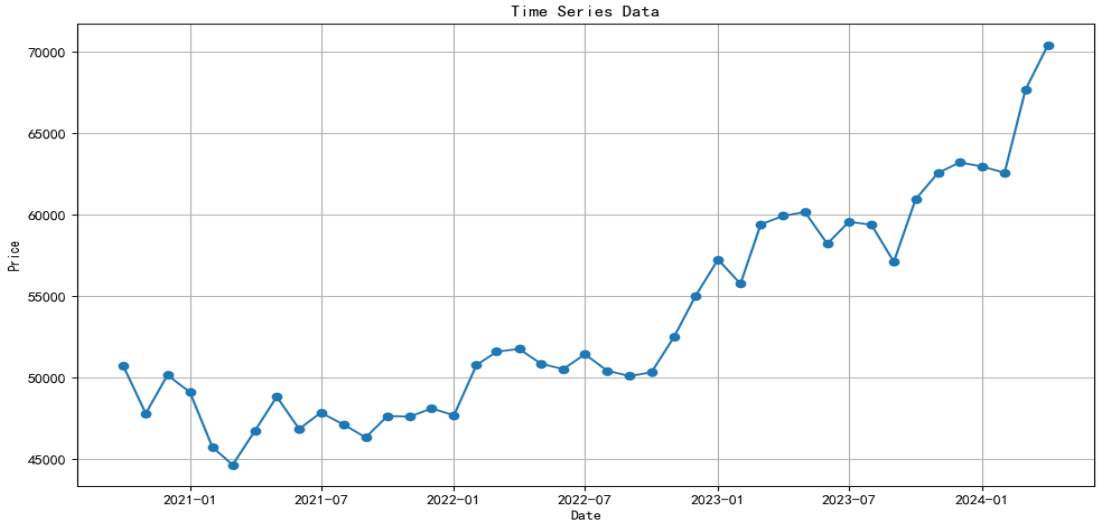

Figure 2. Monthly Closing prices of Gold

Test Statistic	p-value	Lags Used	Number of Observations Used	Critical Value (1%)	Critical Value (5%)	Critical Value (10%)
0.954766	0.9937	0	42	-3.59663	-2.93329	-2.6049

Table no. 2 Augmented Dickey Fuller test results

Sno	Date	Price	Lag1	Lag2	Lag3	Price-difference
1	01-11-2020	47792	50699	50404	51701	-2907
2	01-12-2020	50151	47792	50699	50404	2359
3	01-01-2021	49096	50151	47792	50699	-1055
4	01-02-2021	45736	49096	50151	47792	-3360
5	01-03-2021	44637	45736	49096	50151	-1099
6	01-04-2021	46737	44637	45736	49096	2100
7	01-05-2021	48821	46737	44637	45736	2084
8	01-06-2021	46839	48821	46737	44637	-1982
9	01-07-2021	47846	46839	48821	46737	1007
10	01-08-2021	47120	47846	46839	48821	-726
11	01-09-2021	46323	47120	47846	46839	-797
12	01-10-2021	47635	46323	47120	47846	1312
13	01-11-2021	47606	47635	46323	47120	-29
14	01-12-2021	48099	47606	47635	46323	493

15	01-01-2022	47686	48099	47606	47635	-413
16	01-02-2022	50760	47686	48099	47606	3074
17	01-03-2022	51585	50760	47686	48099	825
18	01-04-2022	51754	51585	50760	47686	169
19	01-05-2022	50855	51754	51585	50760	-899
20	01-06-2022	50517	50855	51754	51585	-338
21	01-07-2022	51426	50517	50855	51754	909
22	01-08-2022	50414	51426	50517	50855	-1012
23	01-09-2022	50094	50414	51426	50517	-320
24	01-10-2022	50322	50094	50414	51426	228
25	01-11-2022	52480	50322	50094	50414	2158
26	01-12-2022	55017	52480	50322	50094	2537
27	01-01-2023	57242	55017	52480	50322	2225
28	01-02-2023	55756	57242	55017	52480	-1486
29	01-03-2023	59402	55756	57242	55017	3646
30	01-04-2023	59919	59402	55756	57242	517
31	01-05-2023	60163	59919	59402	55756	244
32	01-06-2023	58211	60163	59919	59402	-1952
33	01-07-2023	59568	58211	60163	59919	1357
34	01-08-2023	59374	59568	58211	60163	-194
35	01-09-2023	57105	59374	59568	58211	-2269
36	01-10-2023	60940	57105	59374	59568	3835
37	01-11-2023	62559	60940	57105	59374	1619
38	01-12-2023	63203	62559	60940	57105	644
39	01-01-2024	62958	63203	62559	60940	-245
40	01-02-2024	62567	62958	63203	62559	-391
41	01-03-2024	67677	62567	62958	63203	5110
42	01-04-2024	70415	67677	62567	62958	2738

Table no. 3 Differencing series

Mean	Standard Deviation	Minimum	Maximum
469.43	1865.77	-3360.00	5110.00

Table no. 4 Summary statistics of first differenced variable_ Price-difference

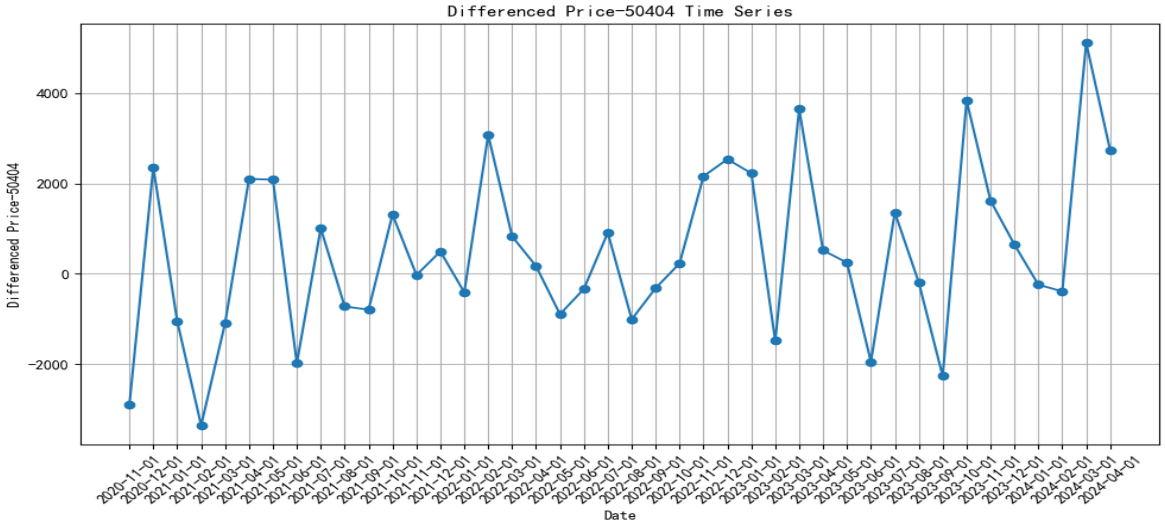

Fig no.3 First difference gold price data

Order(p,d,q)	AIC	BIC
(1, 1, 1)	741.057	746.1977
(1, 1, 2)	742.1495	749.0038
(1, 1, 3)	743.2985	751.8664
(2, 1, 1)	741.3848	748.2391
(2, 1, 2)	743.2344	751.8023
(2, 1, 3)	743.959	754.2404
(3, 1, 1)	743.1791	751.747
(3, 1, 2)	744.9903	755.2718
(3, 1, 3)	744.5811	756.5761

Table no.5 ARIMA Values for different orders

Date	Forecasted prices (Rs)
01-05-2024	70488.33
01-06-2024	70415.33
01-07-2024	70488
01-08-2024	70415.65
01-09-2024	70487.68
01-10-2024	70415.97
01-11-2024	70487.37
01-12-2024	70416.28
01-01-2025	70487.05
01-02-2025	70416.6
01-03-2025	70486.74
01-04-2025	70416.91

Table No.6 Forecasted Gold Prices using ARIMA (1,1,1) model

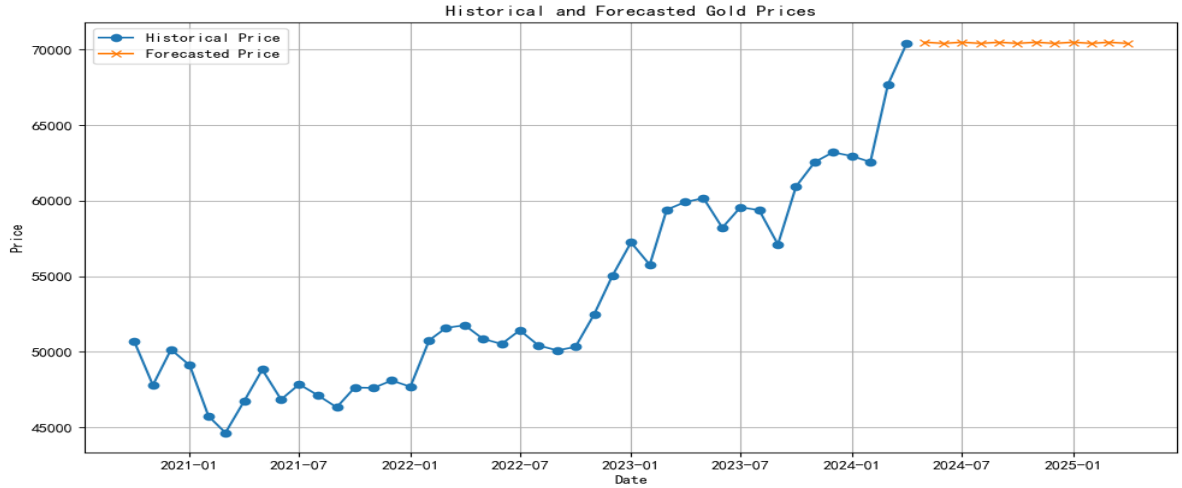

Figure No.4 Historical and Forecasted gold prices from 2020 to 2025