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Time Series Analysis of LBMA Gold Price and Its Relationship with Stock Price

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Abstract: With the continuous development of modern financial system, the gold market and stock market have gradually become a hot topic of research in the financial field. Many scholars have conducted deep research on gold and stock price. The ARIMA model is used in this paper to investigate the time series of the gold price and its relationship with stock price by using LBMA gold price and S&P 500 Index data between 1980 and 2022. According to the results of research, the gold price shows an upward trend over the entire period and would fluctuate within a certain range in short term. Moreover, gold price is positively related with stock price. And when there is a rise in gold price, there would be a rise in stock price. This study uses newer data to fill the gaps in the field and provide reference for investors and central banks. Finally, this paper has some shortcomings. The study should further discuss the optimality of the model and data.

Keywords: gold price, stock price, ARIMA model

1. Introduction

1.1. Research Background and Significance

Gold occupies an important place among the precious metals. In the early period of human civilization, gold, silver and other precious metals acted as the currency in the transaction. With the continuous development and improvement of the modern financial system, paper money gradually replaced gold as the universal equivalent. Gold has financial properties, gold as one of the important commodities itself has value. In the stock market shock and downturn period, investors would choose to buy gold to hedge the risk and fight against inflation. And according to relevant research, central banks put part of their foreign exchange reserves in gold. In Europe and the United States and other countries, this proportion could reach 30%-75% [1]. Besides, since gold has good corrosion resistance and electric conductivity, it is one of the important raw materials for electron, medical, chemical and other industries. Therefore, gold prices lead a huge influence on our life.

The stock market occupies an essential place among all sorts of financial markets. Investors accumulate wealth by buying and selling shares in the stock market and receiving dividends distributed by companies, while companies raise funds by issuing shares in the stock market. Additionally, a country's economic progress is also strongly impacted by stock market fluctuations.

In recent years, major catastrophic events such as the coronavirus disease 2019 and the Russo-Ukrainian war in 2022 have caused a strong shock to the stock price, and many investors sold their

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stocks and bought gold. According to existing research, the gold market tends to perform sluggishly during a bull market in stocks. And when stock prices fall, gold prices tend to rise [1].

This paper analyzes the gold prices time series to make forecasts of gold price and investigates its relationship with stock prices. As for the theoretical significance of the study, since gold and stock prices are constantly updated, this paper selects the data from 1980 to 2022 for analysis, especially the years after the COVID-19, the Russian-Ukrainian conflict and other major disaster events, which will fill the gaps in the related fields. As for the practical significance of the study, researching the price of gold and its relationship with stock prices could provide reference for investors to invest in gold, and provide suggestions for each country to adjust the structure of foreign exchange reserves.

1.2. Literature Review

On the topic of gold price, a considerable number of scholars have studied it. Livieris et al. analyzed and predicted the gold price by constructing a CNN-LSTM model. They found that this model significantly improved the performance of gold price prediction [2]. A study by Hanen Atri et al. covered the effect of the coronavirus disease 2019 on gold price. They found that these events had a favorable effect on that, and gold could hedge some risks during the pandemic [3]. Saranya P B et al. analyzed and predicted the price of gold in India by using the ARIMA model and concluded that the price of gold would increase in short term [4]. Guo investigated the volatility characteristics of the gold price yields by using the ARMA and GARCH models and concluded that the market is more sensitive to good news about gold. She believes that investors should buy gold in advance to hedge the risk before the expected risk arrives [5]. Li's study analyzes the factors that affect the gold price. She found that different sorts of factors have different degrees of influence on the price. Among them, there is a positive effect of the rate of interest and dollar index on the gold price in long term. By contrast, the inflation has a negative impact on it [6].

In addition, the connection between the price of gold and stock has been the subject of certain studies. Drake conducted deep research on this topic and found that the gold and stock market gains showed a favorable correlation due to stock market volatility during the period of coronavirus disease [7]. The study by Maryam Al-Ameer et al. focused their research on the Der Dax (HDAX) and concluded that the connection between the index and price of gold was basically positive prior to the subprime crisis. By comparison, this relationship turned to negative after the event [8]. Rizwan Ali et al. analyzed the effect of gold price on various factors and concluded that the stock market reacts negatively to gold price volatility in Pakistan [9]. Zhou looked at how the price of gold and crude oil affected the Chinese stock market by using the VECM model. According to his research, the stock market of China is significantly influenced negatively by movements in the price of gold [10]. Both Chai and Huang's studies found that gold futures and gold stocks could influence each other, and gold futures demonstrate a favorable effect on gold-based stocks through a series of transmission mechanisms [11,12].

2. Method

2.1. Data Description

The secondary data that was utilized in this paper was sourced from the London Bullion Market Association (LBMA) (https://www.lbma.org.uk/) and Investing.com (https://cn.investing.com/). In this paper, the missing values were adjusted to be previous period values to eliminate the effect of outliers. For the first part of the time series analysis of gold prices, this study adopted daily LBMA international gold prices for a total of 43 years from 1980 to 2022 to conduct the analysis. For the second part of time series analysis and forecasting of gold prices and stock prices, similarly daily data of LBMA international gold prices and S&P 500 Index from 1980 to 2022 were used to ensure data

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availability and adequacy. This paper used R software (version 4.3.1) to analyze the time series of LBMA gold price and explore its relationship with stock prices.

2.2. ARIMA Models

Except linear regression models, this paper uses the Autoregressive Integrated Moving Average (ARIMA) model to analyze the gold price time series and make forecast to short-term gold price trend. This study also adopts ARIMA model to research the relationship between the price of gold and stock in the subsequent analysis.

ARIMA model is one of the common statistical methods used to analyze and forecast time series. ARIMA model is evolved on the basis of the Auto-Regressive Moving Average (ARMA) model. And the ARMA model consists of two different models: the Auto Regression (AR) model and the Moving Average (MA) model.

The AR model analyzes previous values in the data and makes assumptions about them. The order "p" indicates that the historical values of period "p" are used to predict the current values. A pth-order AR model equation could be written:

$$y_t = \alpha + \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + \cdots + \emptyset_p y_{t-p} + \varepsilon_t \quad (1)$$

Where y_t is the dependent variable at time t, $y_{t-1}, y_{t-2}, \ldots, y_{t-p}$ are the dependent variables at time $t-1, t-2, \ldots, t-p$, respectively. And $\alpha = \mu(1 - \emptyset_1 - \emptyset_2 - \ldots - \emptyset_p), \emptyset_1, \emptyset_2, \ldots, \emptyset_p$ are the auto regressive estimated parameters of the variables on the right side of the equation. And ε_t is the random errorterm which is consistent with white noise at time t.

Similar to the AR model, the MA model reflects pervious random errorterms that are consistent with white noise. "Moving" implies that the process varies with the lag order of time t. "Average" means weighted summation. And the order "q" reflects the degree of moving average. A qth-order MA model equation could be written:

$$y_t = \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q} \quad (2)$$

Where y_t is the dependent variable at time t, $\varepsilon_t, \varepsilon_{t-1}, \ldots, \varepsilon_{t-q}$ are the white noise random error terms at time $t, t-1, \ldots, t-q$, respectively. And $\theta_1, \theta_2, \ldots, \theta_q$ are the estimated parameters.

The ARMA model is obtained by adding the equations of the AR and MA models. The ARMA model could only be used to analyze and forecast stationary time series that are not consistent with white noise. In other words, the original data need to be processed to improve its stationarity before using the ARMA model.

The ARIMA model has a distinct advantage over the ARMA model that it could analyze and predict the non-stationary time series by introducing the integrated term. ARIMA (p,d,q) model could automatically difference the data to make the time series stationary. And the order "d" represents the order of difference. An ARIMA (p,1, q) model could be written:

$$y_t = \beta_0 + \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + \cdots + \emptyset_p y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q} \quad (3)$$

Where y_t is the dependent variable at time t, and $\beta, \emptyset$ and θ are the estimated coefficients.

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3. Results and Discussion

3.1. Gold Price Time Series

Table 1 and Figure 1 are descriptive statistics and time plot for LBMA gold prices, respectively. As shown in the Table 1 and Figure 1, the minimum is 252.8 and the maximum is 2067, which means the range of LMBA gold prices is pretty large from 1980 to 2022. Generally, LMBA gold prices show an increasing trend over the 43 years. And there are some fluctuations between 2014 and 2021 that the LMBA gold prices experience a dramatic fall from 2014 to 2016 while they rise substantially to the original level in about 2021. This is maybe because that the FED implemented the contractionary fiscal policy to reduce inflation in 2014. Because values of the data are quite large, this paper would take logarithm to it in the subsequent analysis.

Table 1: Descriptive statistics of LBMA international gold prices (1980-2022).

Variable	N	Mean	p50	SD	Min	Max
Price	10613	745.5	425	510.5	252.8	2067

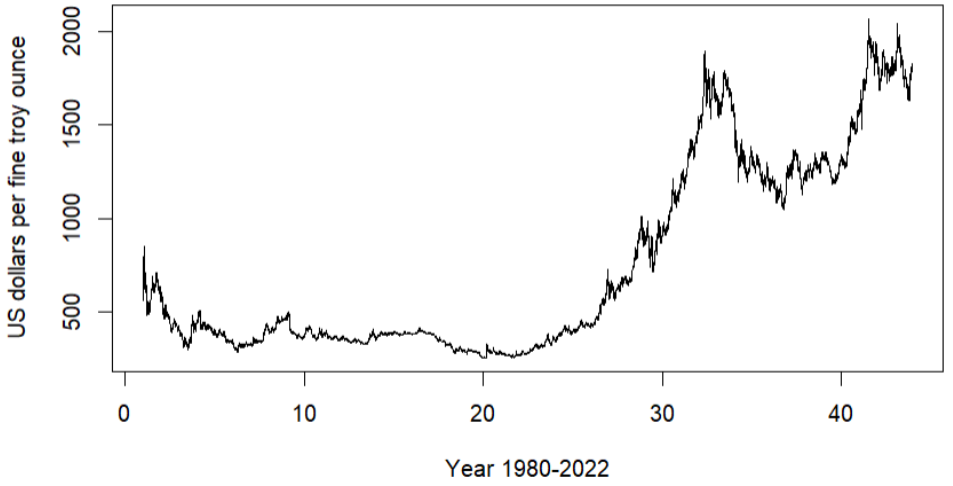
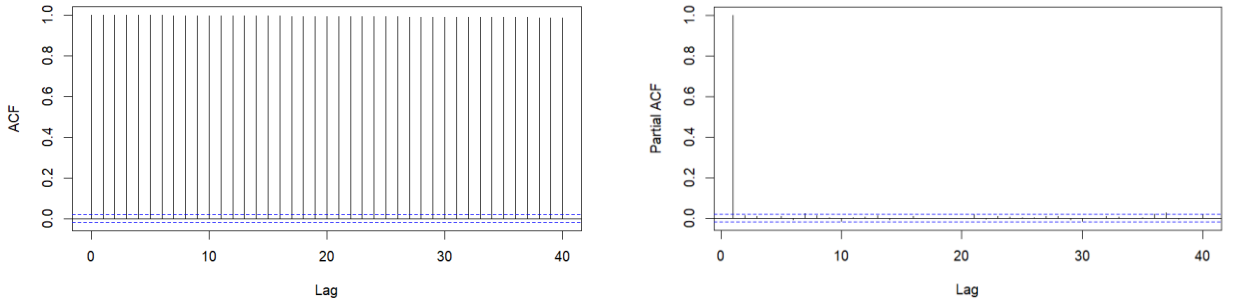


Figure 1: Time series plot of LBMA international gold prices (1980-2022).

Figure 2 shows the ACF and PACF results. As the plot shows, all the coefficients fall outside the critical interval, thus the time series is non-stationary. According to existing studies, there are many measures to make the time series stationary. This paper mainly takes the approach of differencing the data to improve the stationarity of time series.



(1) ACF (2) PACF

Figure 2: ACF and PACF of LBMA gold prices series.

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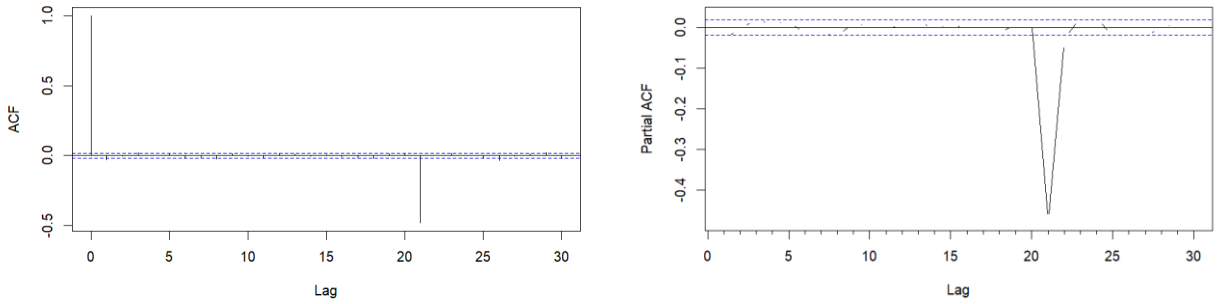
Table 2 shows the result of ADF test for LBMA gold prices series. According to the Table 2, it is also significant evidence of the lack of stationarity of the time series from the perspective of the ADF test. Meanwhile, Table 2 shows the result of ADF test for LBMA gold prices series after log-transformation and taking second difference. As shown in the Table 2, the p-value is 0.01 therefor the time series could be considered stationary. In addition, in the Figure 3 almost all the coefficients fall within the critical values. And it could be concluded that the second difference time series after log-transformation is stationary and therefor suitable to fit into an ARIMA model and estimate its parameters.

Table 2: ADF test results.

Augmented Dickey-Fuller Test	
data: ts.AP	data: diff(diff(log(ts.AP)))
Dickey-Fuller = -2.0977, Lag order = 21, p-value = 0.537	Dickey-Fuller = -37.926, Lag order = 21, p-value = 0.01
alternative hypothesis: stationary	alternative hypothesis: stationary



(1) ACF (2) PACF

Figure 3: ACF and PACF of LBMA gold prices second difference.

Table 3 shows the appropriate ARIMA model for LBMA gold prices time series and after log-transformation. This study uses the code auto.arima to fit ARIMA models automatically with the lowest AIC, ME and other predictive performance models evaluation metrics. According to Table 3, the ideal ARIMA model for both time series and time series after taking logarithm is ARIMA (4,1,0).

Table 3: ARIMA model for LBMA series.

ARIMA (4,1,0)	ARIMA (4,1,0) (log-transformation)
log likelihood = -39707.53	log likelihood = 31978.48
AIC=79425.05; AICc=79425.06 BIC=79461.4	AIC=-63946.95; AICc=-63946.95 BIC=-63910.6
ME=0.1239367; RMSE=10.20392 MAE=5.806143 MPE=0.004215173 MAPE=0.7686461 MASE=0.06217034	ME=0.0001131218; RMSE=0.01188595 MAE=0.00767697 MPE=0.00146348 MAPE=0.1204254 MASE=0.06114753
ACF1=-0.000181549	ACF1=0.0007411441

Table 4 demonstrates the results of Ljung-Box test for ARIMA (4,1,0) models. As shown in the Table 4, the p-values of both time series Ljung-Box tests are less than 0.05. Figure 4 and 5 are residuals from ARIMA (4,1,0) models. As the Figure 4 and 5 show, basically most of the spikes fall within the critical interval, and the residuals follow the normal distribution. This allows the

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conclusion that the time series and after log-transformation are not consistent with white noise and it is feasible to use ARIMA model to make predictions.

Table 4: Ljung-Box test for ARIMA (4,1,0) and ARIMA (4,1,0) (log-transformation).

Ljung-Box test	
data: Residuals from ARIMA (4,1,0)	data: Residuals from ARIMA (4,1,0)
Q* = 1106.6, df = 490, p-value < 2.2e-16	Q* = 766.38, df = 490, p-value = 1.665e-14
Model df: 4. Total lags used: 494	Model df: 4. Total lags used: 494

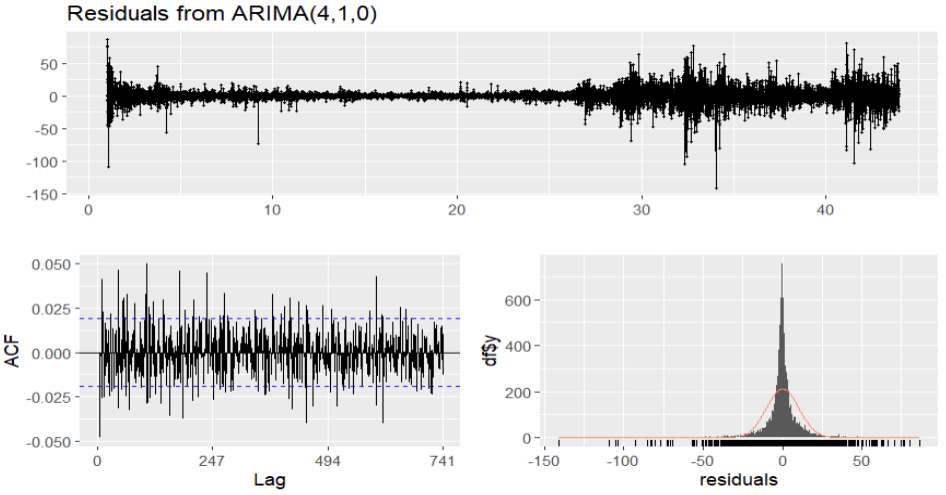

Figure 4: Residual result of ARIMA (4,1,0).

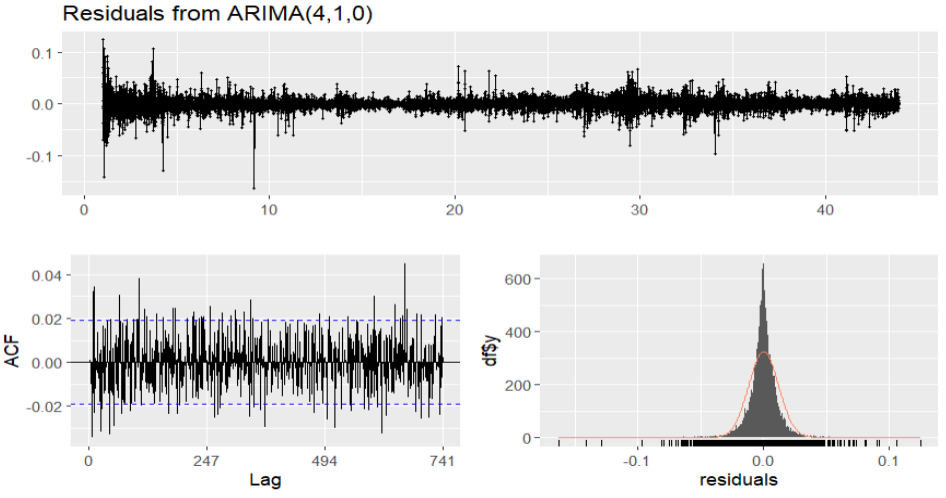

Figure 5: Residual result of ARIMA (4,1,0) (log-transformation).

Figure 6 shows the time plot of real values and forecast from model ARIMA (4,1,0). As shown in the Figure 6, the model fits well and the trend of real values and forecast is generally consistent as time goes on. The plot indicates that the ARIMA (4,1,0) model is an ideal model for forecasting the price of gold.

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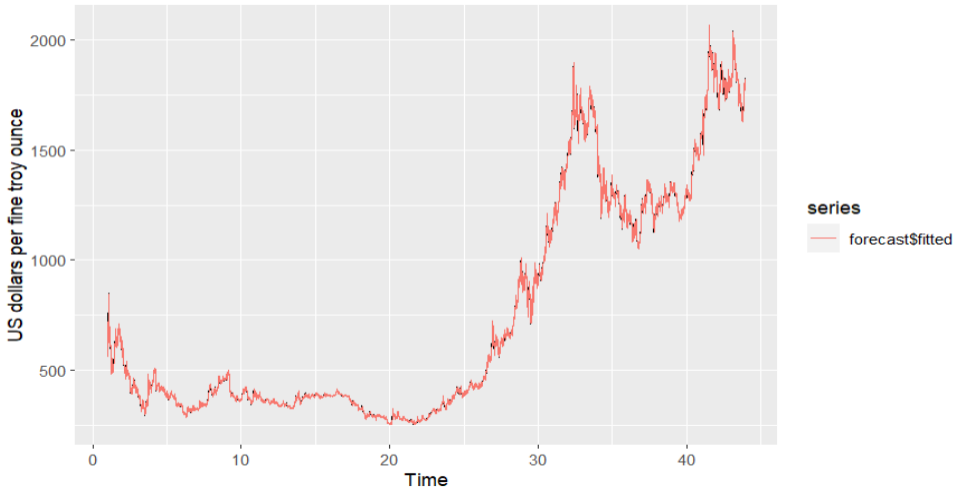

Figure 6: Real values vs. forecast from model ARIMA (4,1,0).

Figure 7 shows the forecast of gold price with ARIMA (4,1,0) model. This paper mainly forecasts the price of gold in short term. As the Figure 7 shows, the gold price would fluctuate within the larger interval (1543.473-2083.351) at the 95% confidence level in the coming year. And at the 80% confidence level the gold price would fluctuate within the smaller interval (1636.909-1989.916) over the next year in the figure.

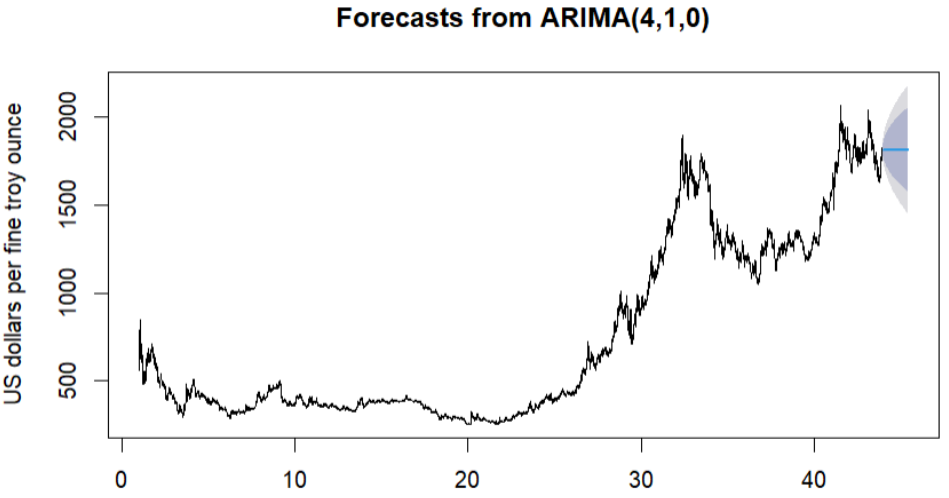

Figure 7: Forecasts of gold price from model ARIMA (4,1,0).

3.2. Relationship between Price of Gold and Stock

Figure 8 is the time plot for S&P 500 Index from 1980 to 2022. As shown in the Figure 8, the S&P 500 Index generally demonstrated an upward trend over the entire period. The subprime crisis that began in 2007 had a dramatic impact on the index, and it slumped from 2008 to 2009. Around 2010 the index experienced a second drastic decline. This may be related to the business cycle.

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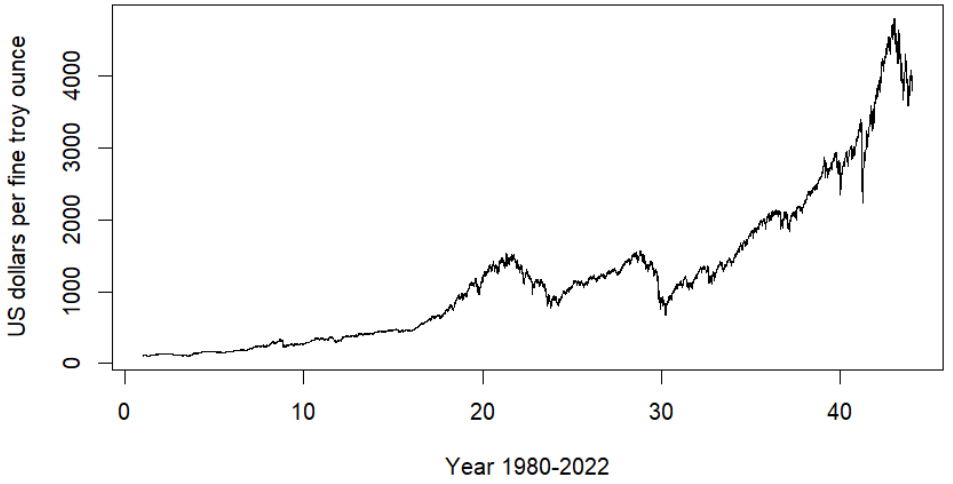

Figure 8: Time series plot of S&P 500 Index (1980-2022).

Table 5 demonstrates the result of regression estimation with ARIMA (5,0,0) model. As a result of large gold and stock price values, this paper uses the data after log-transformation to research the relationship between them with ARIMA model. As shown in the table 5, ARIMA (5,0,0) model is the most optimal model with the lowest AIC, AICc and BIC values to research the relationship between gold and stock price. More importantly, the estimated parameter of the dependent variable is 0.0493. The estimated parameter of the dependent variable is greater than 0 indicating that the gold price is positively correlated with the stock price.

Table 5: Regression estimation with ARIMA (5,0,0) model.

	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	Intercept	Xreg
coefficients	0.5394	0.1340	-0.018	0.1497	0.1630	7.7469	0.0493
S.e.	0.0097	0.0109	0.011	0.0109	0.0097	0.8831	0.1369

4. Conclusion

Gold price and stock price have a huge influence on economic progress and business development. This paper focuses on gold price time series, forecasting gold price and its connection with stock price. The LBMA gold price and S&P 500 Index are proxy variables in study, and the model used is the ARIMA model. Because of the massive value of daily gold price and S&P 500 Index, the data is taken logarithm. And since the time series is non-stationary, this paper differentiates the data to improve the stationarity of the series. Through a series of analysis, it is concluded that it is appropriate to use ARIMA (4,1,0) model as an optimal model to predict gold price. The prediction results show that in the coming year the gold price would fluctuate between 1543.473 and 2083.351 dollars per fine troy ounce at the 95% confidence level. And it would fluctuate between 1636.909 and 1989.916 dollars per fine troy ounce at the 80% confidence level. Besides, by analyzing the relationship between S&P 500 index and LBMA gold price, this paper finds that gold price is positively related with stock price. This study could provide a reference for investors and central banks. Although gold could help investors to hedge risks and fight against the inflation, there is still volatility in the short-term gold price. Paying much attention to the changes in gold market could improve the performance of stock market investors because price fluctuations in gold market could affect the stock market in some degrees. And central banks should decide flexibly the size of gold in their foreign exchange reserves to cope with the risk of exchange rate changes.

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In addition, this paper has some shortcomings. First, this paper only uses the ARIMA model to research the gold price time series and its relationship with stock prices without discussing whether the ARIMA model is the best model to study this topic. Secondly, the LBMA gold price and S&P 500 Index used in this paper are from London and New York respectively, so the findings may have some regional limitations.

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