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**RESEARCH ARTICLE**

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# PREDICTION OF GOLD PRICES USING TIME SERIES ANALYSIS

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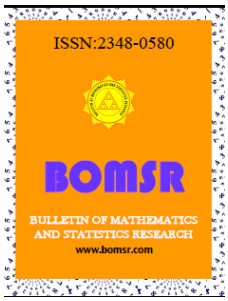


**ABSTRACT**

In this article, we give an ARMA model to forecast the future average monthly gold prices. This study gives the application of ARMA (Autoregressive moving average) time series model to forecast the future gold prices per 10 grams in Indian currency. The data analysis is done by the ITSM (Interactive Time Series Modelling) software. The suitable ARMA model is chosen by the least value of AICC (Akai Information Corrected Criterion) and BIC (Bayesian information criterion).

**Keywords:** Gold Price, ARMA, AICC, BIC, ACF, PACF, Forecasting.



## 1 INTRODUCTION

In the whole world, gold is very valuable and precious metal and in particular Indians are very attracted towards gold and collect it as a sign of wealth. In India the demand of gold is mostly for the jewellery fabrications and the production of gold in India is very limited that makes India in the list of top imports of gold. Investing in gold is nowadays changing from jewellery to gold coins, bars which is commonly available in scheduled banks. Forecasting the price of gold is an interest area for financial analysts and investors. Nowadays, investors give importance to gain profit by investing in gold, so it has necessary to predict accurate future price of gold by suitable method. The analysis of time series is used for prediction and determining models from past data. There are several methods for statistical forecasting such as regression analysis, in this study we use the Autoregressive Moving Average (ARMA) Models. We applied this method to average monthly gold prices data. We used ITSM Software for constructing and forecasting the model and best choice were chosen by least value of AICC (Akai Information Corrected Criterion) and BIC (Bayesian Information Criterion).

Many researchers have used time series methods for forecasting the time series data. Javier Contreras et al. [1] use ARIMA model to predict next day electricity prices and given the result that estimated values are very accurate for other forecasted days. Forecasting gold bullion coin prices through ARIMA model by Abdullah Lazim [2] had suggested that the gold bullion coins are upward trends and could be considered investment is worthy. Uma Devi et al. [3] studied time series analysis for stock trend for Midcap-50 by using ARIMA model and predict the future Midcap-50 trend based on minimum error percentage. Davis et al. [4] studied time series data of gold prices on financial markets for modelling and forecasting using ARIMA models gives the 66.67% correct forecasting. Guha and Bandyopadhyay [5] studied the forecasting the gold price by using ARIMA(1, 1, 1) model and is helpful for predicting the future values of gold Data. Jha et al. [6], studied the time series application on traffic forecasting in India by using the ARIMA and GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model and shown that the time series model gives better result than GARCH.

***Definition 1.1 :*** A time series is a set of observations $\{X_t\}$, each one being recorded at specific time t.

***Definition 1.2*** : Let $\{ X_t \}$ be a time series with $E(X_t) < \infty$. The Mean function of $\{X_t\}$ is

$$\mu_X(t) = E(X_t)$$

***Definition 1.3 :*** The covariance function of $\{\mathbf{X_t}\}$ is,

$$\gamma_X(r, s) = Cov(X_r, X_s) = E[(X_r - \mu_X(r))(X_s - \mu_X(s))] \text{ , for all integers r and s.}$$

***Definition 1.4 :*** The time series$\{X_t\}$ is Stationary process if,

(i) $\mu_X(t)$ is independent of t.

(ii) $\gamma_X(t + h, t)$ is independent of t for each h.

***Definition 1.5 :*** Let $\{X_t\}$ be a stationary time series. The Auto covariance function (ACVF) of $\{X_t\}$ at lag h is,

$$\gamma_X(h) = Cov(X_{t+h}, X_t).$$

***Definition 1.6 :*** The Autocorrelation function (ACF) of $\{X_t\}$ at lag h is

$$\rho_X(h) = \frac{\gamma_X(h)}{\gamma_X(0)} = Corr(X_{t+h}, X_t).$$

***Definition 1.7:*** The time series $\{X_t\}$ is an ARMA (p, q) process if $\{X_t\}$ is stationary and if for every t,

$$X_t - \phi_1 X_{t-1} - \ldots - \phi_p X_{t-p} = Z_t + \theta_1 Z_{t-1} + \ldots + \theta_q Z_{t-q}$$

where, $\{Z_t\} \sim WN(0, \sigma^2)$ and the polynomials $( 1 - \phi_1 z - \ldots - \phi_p z^p)$ , $( 1 + \theta_1 z + \ldots + \theta_q z^q)$ have no common factors.

***Definition 1.8 :*** A Time series model for the observed data $\{X_t\}$ is a specification of the joint distributions (or possibly only the means and covariance) of a sequence of random variables $\{X_t\}$ of which $\{X_t\}$ is postulated to be a realization.

## 2 Data Analysis by Time Series

An average monthly data of gold prices from April 2007 to March 2016 (108 values) are used for the analysis. The data is taken from the website of Reserve Bank of India (RBI). The time series plot of average monthly gold prices represented graphically in Figure 1 below.

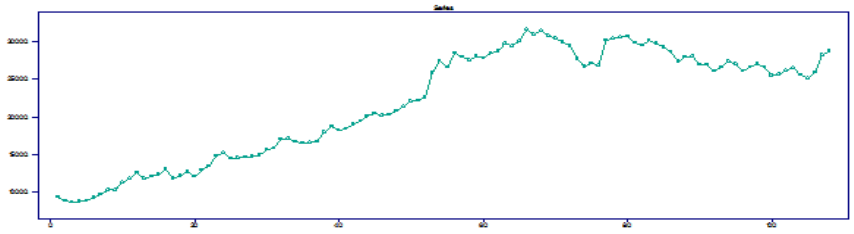

**Figure 1:** Average Monthly Gold Prices

By looking at the plot, there is an increasing trend in the gold prices. By taking logarithms of the data we observe that there was seasonality and trend. We remove seasonality and trend by method of differencing. The stationary time series after removal of trend and seasonality is shown in Figure2.

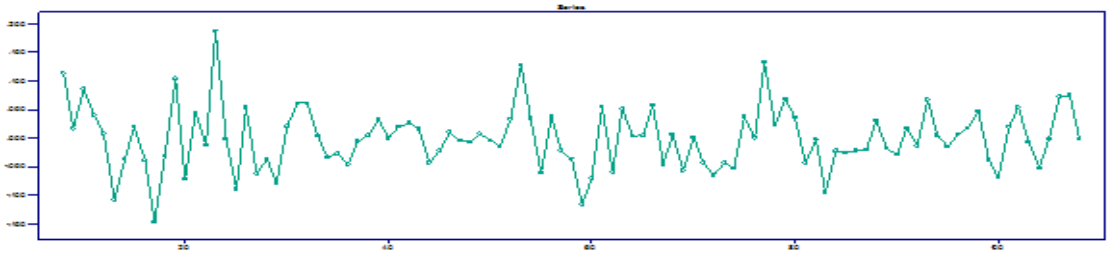

**Figure 2:** The Stationary Series of the Gold Prices

## 3 Model Specification

The sample ACF and sample PACF for the stationary series of gold prices are shown in Figure 3 below.

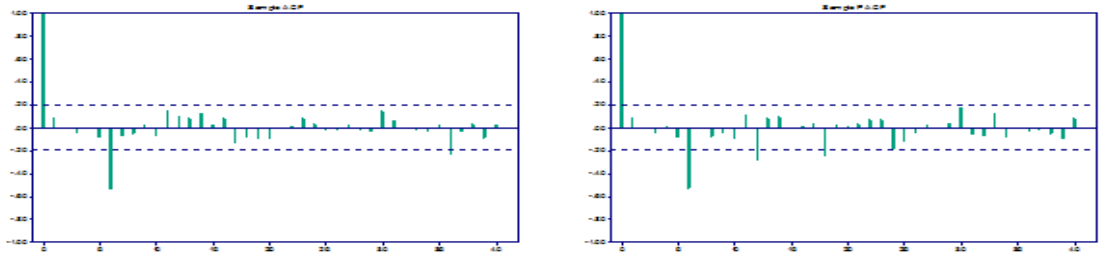

**Figure 3:** The sample ACF and sample PACF

The sample ACF suggests ARMA(0, 6) model and sample PACF gives strong evidence to support ARMA(18, 0) model. We use ITSM software to fit these models. After fitting these models, the ARMA(0, 6) model gives the least value of AICC (Akaike's Information Corrected Criterion) which is -346.482 and least value of BIC (Bayesian Information Criterion) which is -351.979 and hence consider this model as the best model for the stationary series of the gold prices. Using the maximum likelihood estimation method for the parameters, we get the following model for the gold prices.

$$X_t = Z_t - 0.008396\, Z_{t-1} + 0.1005\, Z_{t-2} + 0.03065\, Z_{t-3} + 0.07643\, Z_{t-4} + 0.07218\, Z_{t-5} - 0.9104\, Z_{t-6}$$

## 4 Model Diagnostics

To check whether the fitted model is good for our data, we take the Q-Q plot of the residuals in Figure 4 with $R^2$ value 0.9782 which shows the normality assumption is satisfied. There is no significant autocorrelation and partial autocorrelation in the residuals except at lag 36 in Figure 5. The p-values of the Ljung - Box statistic test, McLeod - Li statistic test, Turning point test, Difference sign test and Rank test are greater than 0.05. Therefore this model is well fits to our data. We can therefore proceed to use model for forecasting.

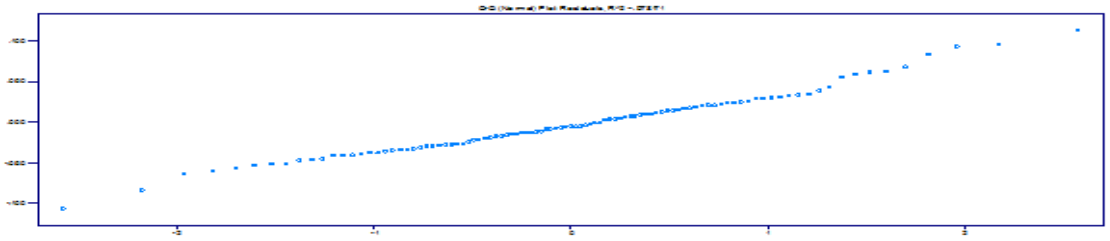

**Figure 4 :** Q-Q plot for Residuals

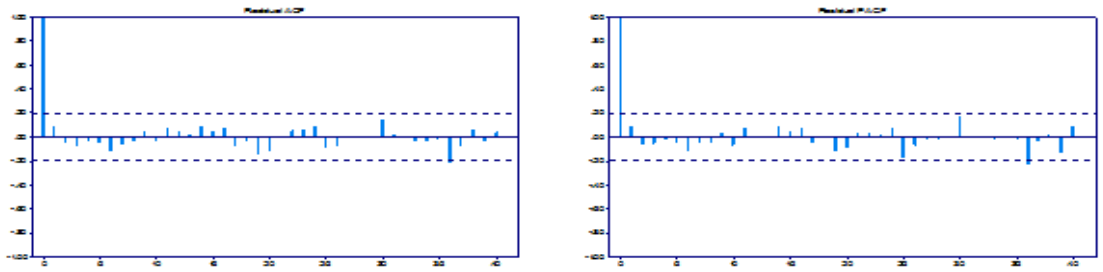

**Figure 5 :** Residual ACF and Residual PACF

## 5 Forecasting

The fitted ARMA(0, 6) model is used to forecast next 36 values, that is for next 3 years average monthly gold prices. The graph of future average monthly gold prices shown in Figure 6 and future average monthly gold prices along with approximate 95% are shown in table 1.

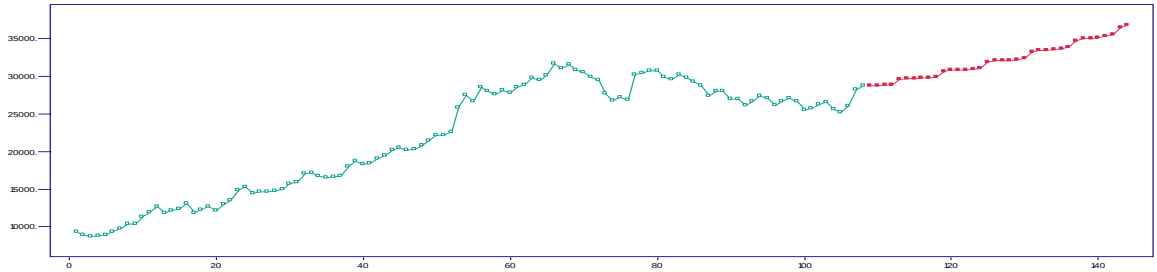


**Figure 6:** Forecasting of Average Monthly Gold Prices

**Table 1 :** Forecasting of average monthly Gold Prices with approximate 95% bounds

| Sr. No | Predicted Gold Prices | Approximate 95 percent prediction Bound | |
|---|---|---|---|
| | (in Rupees) | Lower | Upper |
| 1 | 28767 | 26714 | 30979 |
| 2 | 28773 | 25923 | 31936 |
| 3 | 28822 | 25258 | 32889 |
| 4 | 28882 | 24710 | 33758 |
| 5 | 29577 | 24717 | 35393 |
| 6 | 29757 | 24297 | 36443 |
| 7 | 29744 | 23719 | 37301 |
| 8 | 29766 | 23238 | 38127 |
| 9 | 29833 | 22775 | 39077 |
| 10 | 29910 | 22349 | 40031 |
| 11 | 30647 | 22399 | 41932 |
| 12 | 30849 | 22045 | 43169 |
| 13 | 30853 | 21538 | 44196 |
| 14 | 30892 | 21102 | 45225 |
| 15 | 30978 | 20679 | 46404 |
| 16 | 31075 | 20283 | 47608 |
| 17 | 31857 | 20319 | 49946 |
| 18 | 32084 | 19987 | 51505 |

| Sr. No | Predicted Gold Prices | Approximate 95 percent prediction Bound | |
|---|---|---|---|
| | (in Rupees) | Lower | Upper |
| 19 | 32106 | 19516 | 52817 |
| 20 | 32163 | 19103 | 54152 |
| 21 | 32269 | 18705 | 55669 |
| 22 | 32388 | 18330 | 57228 |
| 23 | 33221 | 18345 | 60158 |
| 24 | 33476 | 18028 | 62159 |
| 25 | 33516 | 17588 | 63868 |
| 26 | 33594 | 17198 | 65620 |
| 27 | 33723 | 16824 | 67596 |
| 28 | 33865 | 16469 | 69635 |
| 29 | 34754 | 16466 | 73353 |
| 30 | 35039 | 16166 | 75949 |
| 31 | 35100 | 15756 | 78193 |
| 32 | 35200 | 15390 | 80509 |
| 33 | 35354 | 15040 | 83105 |
| 34 | 35522 | 14708 | 85790 |
| 35 | 36474 | 14691 | 90557 |
| 36 | 36793 | 14409 | 93953 |

## 6 Discussion and Conclusion

The purpose of this paper was to find a suitable ARMA model for the average monthly gold prices. ARMA(0, 6) model help us to predicting future gold prices. This model gives minimum values of AICC (Akai Information Corrected Criterion) and BIC (Bayesian Information Criterion). The chosen model satisfies all the criteria to fit statistics. By using this model we forecast future gold prices from April 2016 to March 2019 with approximate 95% bounds. This model can also be used for further forecasting.

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