Forecasting of Daily Prices of Gold in India using ARIMA and FFNN Models

K Murali Krishna, N Konda Reddy, M Raghavendra Sharma

Abstract: ***The present paper is aimed to develop a forecasting model to predict the daily gold prices in India with high accuracy. The historical prices of gold were collected from 1st January, 2014 to 24th July, 2018 and the same is divided into training sample and out-of-sample. The forecasting models were developed using auto regressive integrated moving average (ARIMA) and artificial neural networks (ANN) for the daily gold prices in India. The performance of the forecasting model was evaluated using mean absolute error (MAE), mean absolute percentage error (MAPE) and root mean square error (RMSE). The results show that, the feed forward neural networks (FFNN) model outperforming the traditional ARIMA model.***

Index Terms**:** ***Gold Prices, ARIMA, FFNN, MAE, MAPE and RMSE.***

I. INTRODUCTION

Gold is one of the precious metal and which is also classified as commodity and a monetary asset. It is only the metal retains its value during all the periods of crisis – savings, financial, Investment or political. From the economic point of view and financial point of view, the fluctuations in price of gold are both interesting and important [Ref.12].

People investing in gold have mainly two objectives, one being it is a hedge against inflation as over a period of time, the return on gold investment is in line with the rate of inflations, next to mix your investment basket and hence diversity the risk and will help you to reduce the overall volatility of your portfolio with status. Investing in gold have evolved over a period of time for traditional ways by buying jewelleries or by modern way as purchasing gold coins and bonds or by investing in gold exchange traded fund (Gold ETF). In present situation gold become the medium of security for loan funds. Importance of the gold metal has changed over a period of time. In India, few thousands of years ago, countless kings and emperors, then rulers of land in different parts of the country having different monetary system, but only gold was treated as common exchange commodity [Ref.3].

In recent years, the global price trend has attracted a lot of attention and price of gold has a frightening spike compared to historical data. Consumer choice depends upon the prevailing price in the market, hence the forecasting of the prices of gold plays a vital role in the consumer perceptions and purchasing behaviours [Ref.15].

The time series is the fundamental object of the study in various sectors of research. Conventionally, time series modelling has a tacit assumption that there is a linear underlying relationship among the past and future values of the series. Forecast modelling of non-stationary and complex time series is a huge challenge in the area of scientific statistical analysis. During the study daily gold prices in India are forecasted using artificial neural networks and then compared with standard ARIMA model. The subsequent section presents the results supported Box-Jenkins methodology and Artificial Neural Networks.

II. REVIEW OF FORCASTING METHODS

A.Box-Jenkins Methodology

In this section, the modelling of gold prices in India per 10gm using Box-Jenkins methodology is discussed. The Box-Jenkins procedure is concerned with the fitting of an ARIMA model of the following form for the a given set of data $\{Z_t : t=1, 2, \ldots\ldots n\}$ and the general form of ARIMA (p, d, q) model is given by

$$\emptyset(B)\nabla^d Z_t = \theta(B)a_t$$

Where

$$\emptyset(B) = 1 - \emptyset_1 B - \emptyset_2 B^2 - - - - - - \emptyset_p B^p$$

$$\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - - - - \theta_q B^q$$

and $\nabla^d = (1 - B)^d$

where $B^K Z_t = Z_{t-k}$ *and* a_t is a white noise process with zero mean and variance σ_a^2. The Box-Jenkins procedure consists of the following four stages. (i) Model Identification, where the orders d, p, q are determined by observing the behavior of the corresponding autocorrelation function (ACF) and partial autocorrelation function (PACF). (ii) Estimation, where the parameters of the model are estimated by the maximum likelihood method. (iii) Diagnostic checking by the "Portmanteau Test", where the adequacy of the fitted model is checked by the LJung-Box statistic, applied to the residual of the model. (iv) Forecast is obtained from an adequate model using minimum mean squared error method. If the model is judged to be inadequate, stages 1-3 are repeated with different values of d, p, and q until an adequate model is obtained (Box et al., 1994)[Ref.1], (L Jung G.M. et al., 1979) [Ref.7].

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B. Neural Network Model

An artificial neural networks (ANN) is a mathematical model which is inspired by the structure and functional aspects of biological neural networks is a powerful forecasting model.

Its consists of an interconnected group of artificial neurons, and it processes information using a approximate approach to computation. In this sections we develop a feed forward neural networks (FFNN) model for fore casting daily prices of gold in India. Feed Forward neural network (FFNN) structure is a three layer network and it consists of an input layer, a hidden layer and an output layer. Total number of input neurons needed in this model is one, and it depresenting the values of lag1 (previous day gold price). In this model only one output unit is needed and it indicates the forecasts of gold price for 10gm in India. The following table displays information about the neural networks model, including the dependent variable, number of input and output units, rescaling method, number of hidden layers and units and activation functions.

Network Information

Input Layer	Covariates	1	Lag1
	Number of units [a]		1
	Rescaling method of covariates		Adjusted normalized
Hidden Layer(s)	Number of Hidden Layers		1
	Number of units in Hidden Layer 1[a]		3
	Activation Function		Hyperbolic Tangent
Output Layer	Dependent Variables	1	Price per 10gm of gold
	Number of Units		1
	Rescaling method for scale Dependents.		Standardized
	Activation Function		Identity
	Error Function		Sum of Squares

a. Excluding the bias unit.

Back propagation Theorem is used in learning of the network. The network is trained using back propagation algorithm until the sum of squares of error is small for the training set (Haykin, 1999, Rama Krishna et al., 2013), [Ref 5 and 14].

Data source:-

The historical prices of gold were collected from 1st January, 2014 to 24th July, 2018 from www.goldpricesindia.com and the same is divided into training sample (till 30th June, 2018) and out-of-sample (from 1st July, 2018 to 24th July, 2018). The ARIMA and ANN models fitted to the training sample and validated on the out of sample. The actual time series data was plotted in Figure-1 and it shows more fluctuations in the gold prices over a period of time.

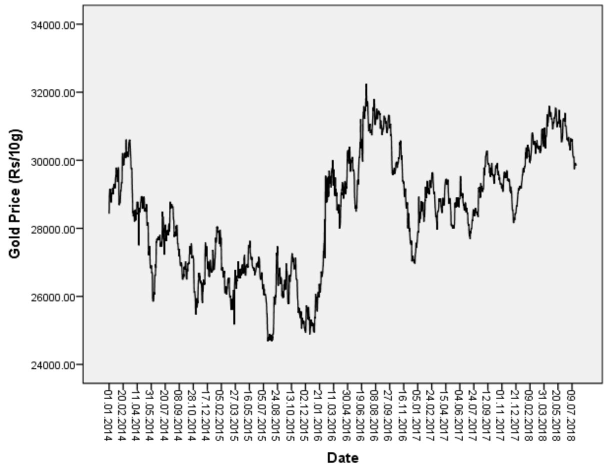

Figure 1 : Time plot of Gold Prices in India

Figure-1 reveals that, the daily gold prices of data are non-stationary. Non-Stationary series in mean is corrected through appropriate differencing of the data.

Table 1 : Monthly characteristics of the Gold Prices.

	Gold Price (Rs/10g)				
Month	Min	Percentile 25	Median	Percentile 75	Max
Jan	24966	26852	28380	29216	30361
Feb	26050	27945	29330	29940	30801
Mar	25175	28385	29036	30204	30927
Apr	26454	28246	28882	29409	31597
May	26623	27465	28635	30034	31526
Jun	25852	26897	28734	30545	31586
Jul	24677	27584	28234	30545	32251
Aug	24680	27609	28616	30262	31800
Sep	25835	26653	28726	30541	31334
Oct	25776	26954	28369	29679	30747
Nov	24983	25747	27589	29398	30562
Dec	24882	25940	27072	28252	29209

From the above table, it was observed that, the gold prices were high in February and March, whereas it was very low in December month in a year. The reason behind these high and low prices of gold may be due to the demand in the beginning of auspicious days.

The estimated auto correlation and the partial auto correlation functions (ACF and PACF) for the gold prices in India are given below.

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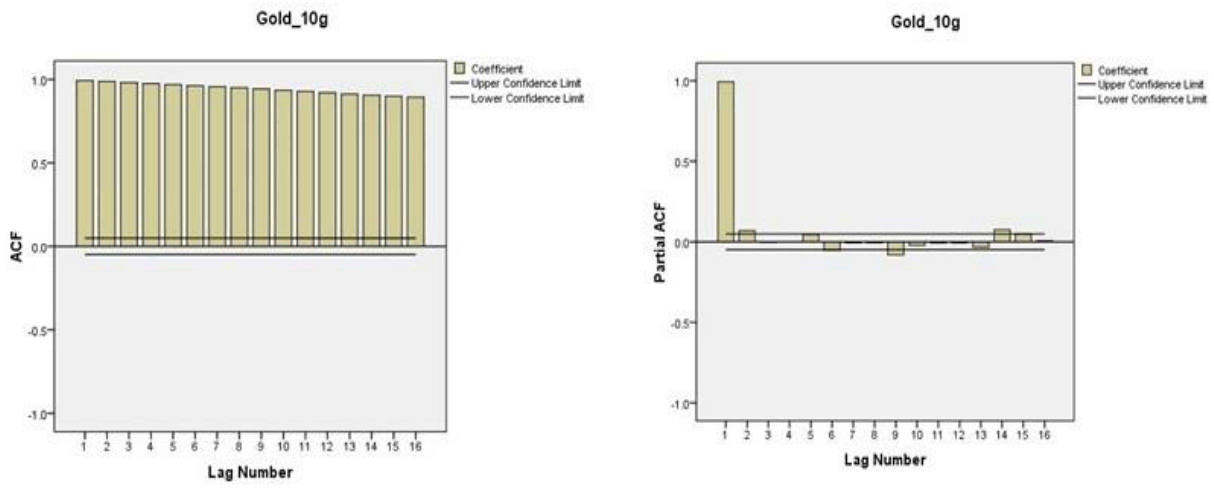

Figure 2: ACF and PACF of gold prices in India

From Figure 2, the ACF confirms that daily gold prices data is non-stationary as this function is does not die quickly for higher lags.Then the differencing of order 1(d=1) applied to convert the non-stationary series into a stationary series and examine the following ACF and PACF for the possible values of p and q series in the model.

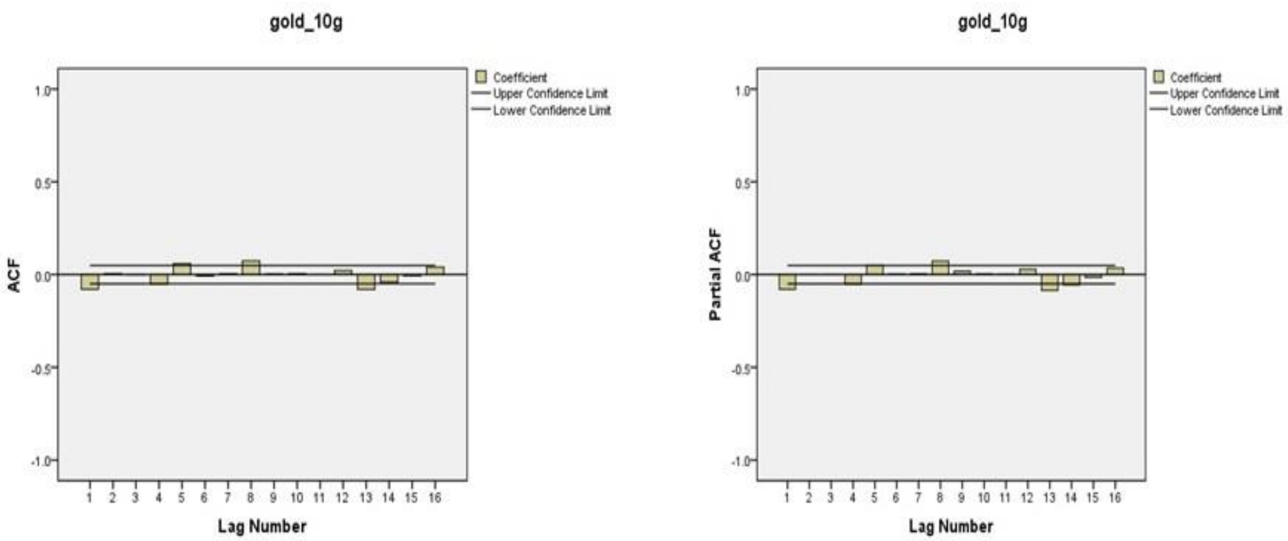

Figure 3 : ACF & PACF of transformed series of gold prices.

In this case, difference of order 1(d=1) is sufficient to achieve stationary in Mean (Figure 3) as ACF dies quickly for higher lags. The significant spikes in PACF were observed at 1, 8 and 13 lags where as in ACF also it was 1, 8, 13 lags. The maximum values of p and q were 13.

ARIMA model building:

The daily gold prices data was analysed using the Box-Jenkins methodology on the training sample and the forecasts are tested with the out-of-sample set. The gold prices are observed to be non-stationary (fig 1) and a single successive differencing (d=1) with no transformation is sufficient to convert the non-stationary series into the stationary series. The parameters of the ARIMA model was obtained using ACF and PACF plots. The ACF and PACF plots suggest the p value at most 13 and the q value is also at most 13. All the tentative models are estimated and tested for the adequacy of the model. The model parameters were presented in the following table.

Table 2 : ARIMA Model Parameters

Transformation	Parameters		Estimate	SE	t	p-value
No Transformation	Difference		1			
	MA	Lag 1	0.079	0.025	3.216	0.001
		Lag 5	-0.07	0.025	-2.866	0.004
		Lag 8	-0.083	0.024	-3.38	0.001

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Then the resulting forecasting model is $Z_t = a_t - 0.079a_{t-1} + 0.07a_{t-5} + 0.083a_{t-8}$

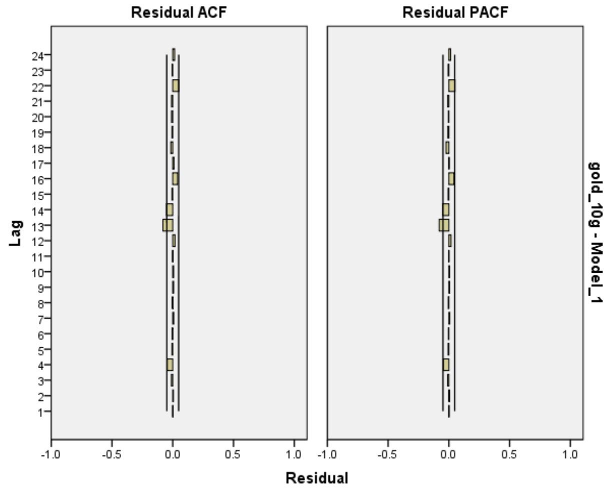

Figure 4 : Residual ACF and PACF of gold prices in India.

Diagnostic checking is done through examining the auto correlations and partial auto correlations of the residual of various orders. As the results indicate, none of these auto correlations is significantly different from zero at the level 0.05. This proves that the model is an appropriate model. The adequacy of the model is tested using LJung-box Q-Test statistic (Ljung and Box 1979)[Ref.7], LJung-Box statistic value is 23.133 for 15 d.f. and the significant probability value corresponding to LJung-Box Q-Statistic is 0.081 which is greater than 0.05. Therefore, null hypothesis of model adequacy is accepted and it is concluded that the selected ARIMA (0,1, 8) model is an adequate model for the given time series.

Then forecasts are generated using minimum mean square error method. The error measures are tabulated below.

Table 3 : Model Performance

Sample	MAE	MAPE	RMSE
Training-sample	128.71	0.46	203.32
Out-of-sample	313.36	1.04	369.09

The fitted model showing lower error measures in the training sample and relatively higher error measures observed in the out-of-sample. The ARIMA forecasts have at least one percentage point error and also having average absolute difference of Rs. 313. The forecasts from this model will be constant after eight terms, however the confidence band increases over the time.

FFNN Model

The Neural Networks model is developed by considering the lag1 value of daily gold prices to forecast the future prices using a feed forward neural networks (FFNN) model. The FFNN model is a three-layer model consists a hidden layer with three hidden neurons in addition to the input and output layers. The hyperbolic tangent function is taken as an activation function under the back-propagation algorithm. The FFNN model was trained till the testing sample error is smaller than the training sample. The layout of the FFNN Model is given below.

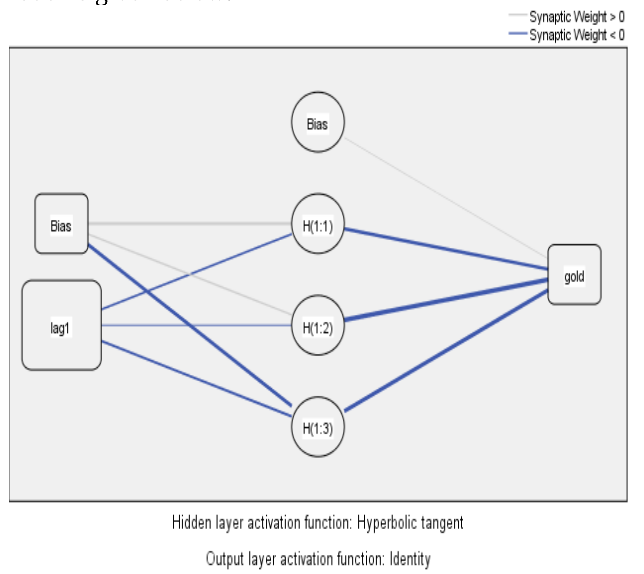

Figure 5 : FFNN model for prediction of daily gold prices.

The model was developed on SPSS Software and the model parameters are presented in the following table.

Table 4 : Parameter Estimates

Predictor		Predicted: Hidden Layer 1 H(1:1)	Hidden Layer 1 H(1:2)	Hidden Layer 1 H(1:3)	Output Layer gold
Input Layer	(Bias)	.712	.416	-.898	
	lag1	-.490	-.336	-.576	
Hidden Layer 1	(Bias)				.258
	H(1:1)				-.873
	H(1:2)				-1.399
	H(1:3)				-1.153

and the FFNN model is

$$h_1 = \tanh[(0.712 - 0.49\left(Z_{t-1} - 28425.37\right)/1728.02)]$$

$$h_2 = \tanh[(0.416 - 0.336\left(Z_{t-1} - 28425.37\right)/1728.02)]$$

$$h_3 = \tanh[(-0.898 - 0..576\left(Z_{t-1} - 28425.37\right)/1728.02)]$$

$$o_t = 0.258 - 0.873h_1 - 1.399h_2 - 1.153h_3$$

$$Z_t = 28426.6 + 1728.21a_t$$

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The forecasting performance of FFNN model is given below.

Table 5 : Model Performance

Sample	MAE	MAPE	RMSE
Training-sample	127.04	0.45	204.63
Out-of-sample	73.26	0.24	113.09

The FFNN model has lower error measures in the out-of-sample as compared with the training sample.

Comparison Forecasting models for Gold Prices in India

The forecasts from ARIMA and FFNN models were presented below.

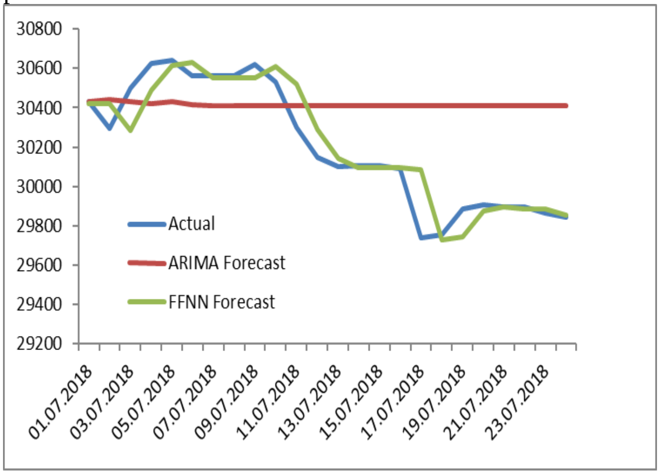

Figure 6 : Comparison of forecasts using ARIMA & FFNN models.

The out-of-sample performance of two model shows a huge difference in the error measures. The FFNN model has lowest error measures as compared to the ARIMA model (Table-6). Therefore, the FFNN model forecasts better than the ARIMA forecasts.

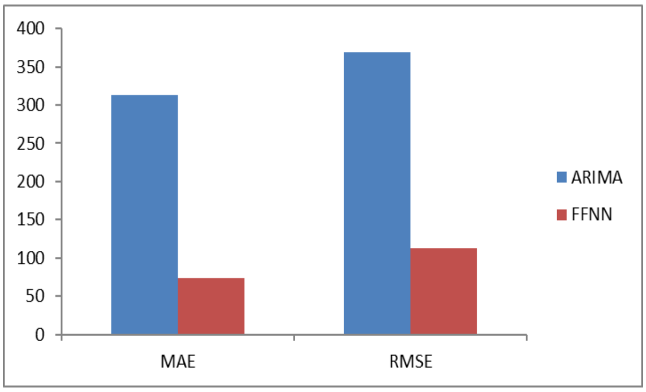

Figure-6 : MAE and RMSE values using ARIMA and FFNN.

Table 6 : Comparison of ARIMA &FFNN models

Model	ARIMA		FFNN		PB
	RMSE	MAE	RMSE	MAE	
Training Samples	203.32	128.71	204.63	127.04	2%
Out of the Samples	369.09	313.36	113.09	73.26	77%

From the above table, It was observed that, the FFNN model has minimum RMSE and MAE in both the modelling and forecasting stages than that of the ARIMA model. FFNN model 2% better than the ARIMA model in in-Sample forecasts. FFNN model 77% better than the ARIMA model in out-of-Sample forecasts.

III. CONCLUSION

From the above study, it was observed that FFNN model is giving better forecasts than out of the ARIMA model in forecasting of gold prices in India. Hence, it was concluded that FFNN model is better than the ARIMA model for forecasting daily gold prices in India.

APPENDIX

Forecasts using ARIMA and FFNN Models

Date	Actual	ARIMA Forecast	FFNN Forecast
01.07.2018	30432	30428.68	30422.38
02.07.2018	30293	30439.59	30422.38
03.07.2018	30497	30430.24	30283.81
04.07.2018	30623	30419.95	30487.01
05.07.2018	30641	30431.02	30611.91
06.07.2018	30561	30415.88	30629.71
07.07.2018	30560	30411.33	30550.52
08.07.2018	30560	30410.73	30549.53
09.07.2018	30619	30410.73	30549.53
10.07.2018	30530	30410.73	30607.96
11.07.2018	30299	30410.73	30519.78
12.07.2018	30150	30410.73	30289.8
13.07.2018	30102	30410.73	30140.9
14.07.2018	30105	30410.73	30092.87
15.07.2018	30105	30410.73	30095.87
16.07.2018	30092	30410.73	30095.87
17.07.2018	29739	30410.73	30082.86
18.07.2018	29755	30410.73	29729.4
19.07.2018	29883	30410.73	29745.41
20.07.2018	29904	30410.73	29873.58
21.07.2018	29895	30410.73	29894.61
22.07.2018	29895	30410.73	29885.6
23.07.2018	29863	30410.73	29885.6
24.07.2018	29843	30410.73	29853.55

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