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Comparison of ARIMA and Artificial Neural Network Models for Forecasting Indian Gold Prices

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Abstract: Gold has always been considered to be the safest haven for investment by the Indians. In fact gold is widely regarded as a hedge against adverse financial and economic conditions by the Indians. Thus prior prediction of gold prices assumes great importance as it can aid both the investors and the traders in making intelligent investment decisions in the Gold market. Time Series forecasting has found wide spread applications in varied spheres of business, economics, commerce, production and many others. On the other hand, the past few years have also witnessed rising popularity of Artificial Neural networks for forecasting purposes. This paper compares and analyses the forecasting of the Indian Gold prices using the linear Autoregressive Integrated Moving Average (ARIMA) model and the non linear Artificial Neural Network (ANN) model by developing two models based on these approaches. The relative forecasting efficiencies of the two proposed models is then compared using the statistical measures of performance.

Keywords: Artificial Neural Networks, Autoregressive Integrated Moving Average (ARIMA), Indian Gold Prices, Time Series Forecasting.

I. INTRODUCTION

Gold has always occupied a significant place in the lives of the Indians. Gold is considered more than just a precious metal. It is considered as a symbol of purity, wealth, success, happiness and good luck. The love for the metal and the desire to possess it holds good across people of all sections of the Indian society. Gold forms an important part of a majority of the Indian festivals, ceremonies, functions, customs, marriages etc.

Gold is also considered as a status symbol as is evident from the money spent on gold in the Indian marriages. 35% to 50 % of the budget in an Indian marriage is reserved for purchasing gold. Gold is continuously acquired over the years with the money saved or earned by the Indians. The gold acquired is passed over to successive family generations.

Gold is also considered as the safest form of investment by the Indians. It is used as a hedge in times of difficult economic and financial conditions. This belief was further consolidated in 2009 when inspite of the plunge in the stock prices the world over, gold remained stable and demonstrated better performance. Since gold causes no market risk; it bears "zero beta asset" characteristics [1]. These characteristics of gold make it a very appealing investment option. It is considered as a medium of exchange and a unit of value [2][3].

Thus, with these distinct characteristics and the increasing investments in gold by the Indians, accurate prior forecasting of gold prices would be of great help to the investors and the traders in making intelligent investment decisions. In this context, this study assumes significance as it proposes a model that could accurately forecast the gold prices of the Indian gold market.

Time Series Forecasting has attracted the attention of the researchers in the past few years. Time Series forecasting involves generating future values from the time series of past historical values by prototyping the intrinsic structure of the series [4].

Autoregressive Integrated Moving Average (ARIMA) is one of the most popular time series model [5][6][7]. This model assumes that the considered time series is linear and follows normal distribution of data.

The flexibility to represent several kinds of time series data makes ARIMA model a highly popular model. But it's pre-assumption about the linear form of the time series data makes it inadequate in a number of practical situations. To overcome this limitation, a number of non linear models have been proposed [6] [8] [9]. These models generally lack the simplicity of the ARIMA model.

Artificial Neural networks have attracted lot of attention in the recent years in the sphere of time series forecasting [6] [10] [11]. Unlike the ARIMA model, the ANNs have an inherent capability to model non linear forms of time series data without making any pre-assumption about the statistical distribution of the data.

This makes them very suitable to solve non linear problems of the real world [11]. Zhang et al. presented a review of the research work done on use of Neural Networks for forecasting time series data [12].

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The performance of the ARIMA model and the ANN models for forecasting the Indian Gold prices has been studied in this paper. These models are then compared for their efficiency to predict Indian gold prices.

II. MODELS FOR FORECASTING TIME SERIES DATA

In general, two types of models exist for forecasting time series data. These are linear and non linear models. The conventional statistical time series models like the Moving Average Method, Exponential Moving Average Method, ARIMA model etc are linear models as they assume that the input time series data is linear in nature. But these types of models have not been found to be very efficient in modeling and forecasting time series data of the real world which is generally non linear in nature.

To overcome the limitations of the linear models and to model the real world data, a number of non linear models like Bi-Linear Model [13], Threshold Aggressive Model (TAR) [14], Auto-Regressive Conditional Heteroscedastic (ARCH) [15] were developed. But most of these models were able to capture only some specific types of non linear patterns of the time series data and hence could not be applied to all types of forecasting applications involving real world time series data [16].

Artificial Neural Networks are non linear models which have gained immense popularity because of their ability to model efficiently different types of non linear data without making any pre-assumptions. A number of studies have been carried out which suggest that Artificial Neural networks have better predicting capabilities in different scenarios, compared to the conventional statistical models [17-19].

This section discusses the principles and general structures of ARIMA and the Artificial Neural Networks models for forecasting purposes.

A. Autoregressive Integrated Moving Average (ARIMA) Model

In this model, the future values of a variable can be predicted from the past values of time series data and the past errors. Box and Jenkins [5] developed the ARIMA model. Hence, ARIMA model is also popularly known as the Box Jenkins model. The approach used in this model consists of three iterative steps of model identification, parameter estimation and diagnostic checking. This model assumes that the time series under consideration is stationary. The times series is tested for stationarity in the identification stage. Augmented Dickey- Fuller regression's unit root test is one of the popular methods used for this purpose. To convert a non-stationary times series into a stationary series, the time series is differenced d times.

For estimating parameters of the model, linear optimization procedures are followed.

For diagnostic checking of model adequacy, several diagnostic statistics and plots of the residuals can be used to test the adequacy of the model by checking its goodness of fit of the model to the historical data. If the model is not adequate, a new tentative model could be identified followed by steps of parameter estimation and verification. The above steps are repeated again and again until a satisfactory model is finally selected.

ARIMA (p, d, q) model is obtained by applying ARMA (p, q) to a stationary time series. Here p is the order of auto regression (AR), q is the order of moving-average (MA) and d is the order of differencing. The auto correlation function (ACF) and the partial auto correlation function (PACF) are used to determine the order of the ARIMA model.

Mathematically, the model can be written as:

$$y_t = \theta_0 + \phi_1 y_{t-1} + + \phi_2 y_{t-2} + \ldots\ldots\ldots + \phi_p y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \ldots\ldots - \theta_q \varepsilon_{t-q}$$

Where

y_t is the actual value, ε_t is the random error at time period t.

ϕ_t (i=1,2,3,……..,p) and θ_j (j=0,1,2,3,……..,q) are model parameters.

p, q are integers and referred to as orders of the model.

Random errors ε_t are assumed to have a mean of zero and constant variance of σ^2.

B. Artificial Neural Network Model (ANN)

Artificial Neural Networks were first proposed by Mcculloch and Pitts [10].The architecture of Artificial Neural Networks is based on the working of the human brain. These networks mimic the functioning of the human brain.

The human brain consists of a large network of interconnected neurons. A biological neuron has three components, namely, dendrite, soma and axon. The dendrite accepts signals from other neurons which are electrical impulses transmitted through a synaptic gap with the help of certain chemical processes. A biological network is a collection of many biological neurons.

Similarly, the ANNs consist of a network of interconnected neurons organized in a layered manner. A neuron can have either a single input or multiple inputs. Similarly, it may either have a single output or multiple outputs. The outputs of the neuron are generally a non linear combination of the inputs. These inputs are turn weighted by the synaptic weights which represent the relative importance of the inputs [21]. Weighted sum of the inputs is then obtained. Activation function is then applied on the result obtained. The activation function applied can either be a linear function or a non-linear function. Purelinear, Hyperbolic, Sigmoid and Gaussian functions are some of the activation functions that can be applied.

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Multi Layer Feed Forward Neural Networks (FFNN) have been used in this study for forecasting the Indian Gold prices. FFNNs consist of the input layer, one or more hidden layers and an output layer. These networks process data on a linear way from one layer to the other. The simplicity of the FFNNs makes them highly popular [22].

III.DATA AND METHODOLOGY

The study used historical Indian gold prices from Multi Commodity Exchange of India Ltd (MCX) for developing the ARIMA and the ANN models. Matlab 8.0 was used for developing these models.

The input data used for the study consisted of Indian gold prices covering the period from January 3, 2007 to December 31, 2015 and was downloaded from the MCX website (www.mcxindia.com).

The descriptive statistics for the data under study are as follows:

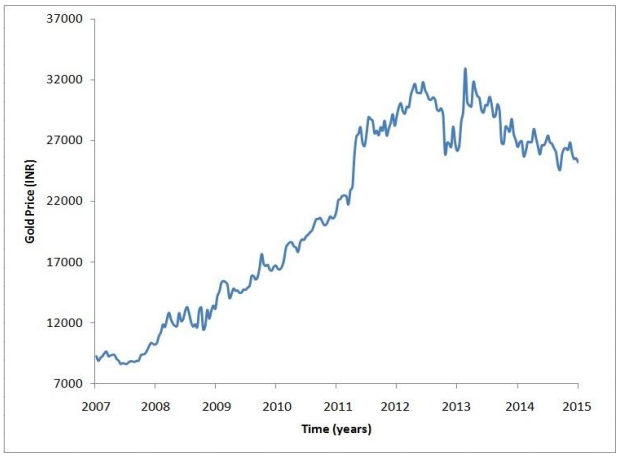

Fig. 1. Variation of Indian Gold prices from 2007-2105.

TABLE I: DESCRIPTIVE STATISTICS OF THE DATA UNDER STUDY

Descriptive Statistics	Value
Average	20971.74
Standard Deviation	7583.54
Skewness	-0.22
Excess-Kurtosis	-1.46
Median	21710
Min Value	8525
Max Value	32943

A. ARIMA(p,d,q) Model for Indian Gold Prices

For constructing the ARIMA model for the Indian Gold Prices, the p and q parameters have to be effectively determined in order to develop an efficient model. The different parameters p and q for the ARIMA model are shown in Table 1. ARIMA (1, 1, 0) model was found to be the best forecasting model for the data under study. ARIMA (1, 1, 0) was found to be the best model.

TABLE II: STATISTICAL RESULTS OF ARIMA MODEL FOR DIFFERENT P AND Q PARAMETERS

ARIMA	Adjusted R^2
(1,0,1)	0.979
(1,0,2)	0.980
(1,0,3)	0.981
(1,1,0)	0.993
(1,1,1)	0.992
(1,1,2)	0.992
(1,1,3)	0.991

B. ANN Model for Indian Gold Prices

This study employed a three-layer (one hidden layer) multilayer perceptron model trained with back-propagation algorithm. This model can be represented in mathematical form as

$$y_t = \alpha_0 + \sum_{j=1}^{q} \alpha_j \, g\left(\beta_{0j} + \sum_{i=1}^{p} \beta_{ij} \, y_{t-i}\right) + \varepsilon_t$$

Where α_j (j=0, 1, 2,…..,q) and
β_{ij} (i=0, 1, 2,……..,p; j=1, 2,3, ……..,q) are model parameters and are known as connection weights .
p= number of input nodes
q= number of hidden nodes

Hidden layer transfer function used is

$$g(x) = \frac{1}{1 + \exp(-x)}$$

(y_{t-1}, y_{t-2},……y_{t-p}) are the inputs corresponding to past observations.

The future value

$$y_t = f(y_{t-1}, y_{t-2} \ldots y_{t-p}, w) + \varepsilon_t$$

Where w is the vector of all parameters and f is a function determined by the network structure and connection weights. The choice of p and q are data dependent. The study used TRAINGDM as the training function, LEARNGDM as the adaptation learning function and TRANSIG as the transfer function for designing the network model.

Using a learning rate of 0.01, momentum of 0.8 and epoch sizes of 1000, 2000 and 5000 different neural network models were developed. A neural network with 25 hidden neurons was found to give the best forecasting performance for all epoch sizes under consideration.

IV. COMPARATIVE ANALYSIS OF FORECASTING PERFORMANCE OF ARIMA AND ANN MODELS

The ARIMA and ANN models were compared for their forecasting capabilities using three performance measures: Coefficient of Determination (R^2), Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE). These error estimates used as performance measures are calculated using the following relations:

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Mean Absolute Deviation (MAD) [23][24][25[26] = $\frac{1}{n}\sum_{t=1}^{n}|e_t|$

Mean Absolute Percentage Error (MAPE) [23][24] = $\frac{1}{n}\sum_{t=1}^{n}\left|\frac{e_t}{y_t}\right| X\ 100$

Root Mean Square Error (RMSE) [25][26] = $\sqrt{\frac{1}{n}\sum_{t=1}^{n} e_t^2}$

Where y_t is the actual value, f_t is the forecasted value, $e_t = y_t - f_t$ is the forecast error and n is the size of the test dataset. The results are depicted in Table 2.

TABLE III: ERROR ESTIMATES OF ARIMA AND ANN MODELS

Model	MAD	RMSE	MAPE
ANN	4.121	5.121	3.212
ARIMA	8.231	13.345	6.527

The results obtained clearly depict that the Artificial Neural Network model supersedes the ARIMA model in terms of forecasting the Indian gold prices.

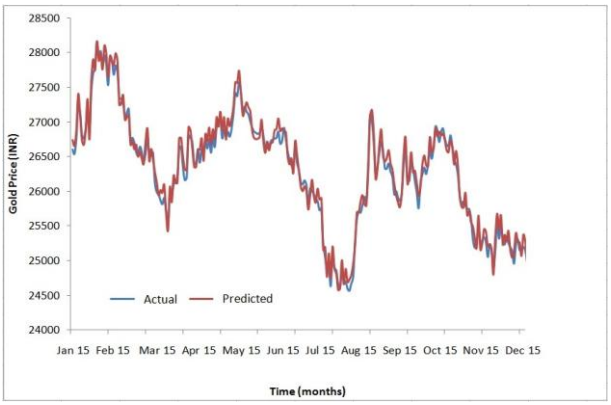

Fig. 2. Forecasted values of Indian Gold prices using ANN

V. CONCLUSION

The results obtained with published data of Indian gold prices on the performance of ARIMA and ANN model to predict the gold prices in the Indian Gold Market have been presented in the paper. The performance of the ANN model developed in this model was compared with the conventional Box-Jenkins ARIMA model. The ANN model demonstrated better performance over the ARIMA model which implies that ANN is better suited for forecasting non linear data patterns.

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