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DETECTION OF ACCURACY POWER OF GOLD PRICES IN INDIA USING TIME SERIES ANALYSIS

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Abstract:

This paper discussed for developing forecasting models used to predict the time series elements in gold prices in India. In this study, the forecasted models are ARIMA (Auto Regressive Integrated Moving Average) and FFNN (Feed Forward Neural Network) models for forecast the next 30 days on daily gold prices in India. The model separated two sets training data set and a testing data set. The model development on training data sets and performance of the model is used test data set based on minimum error measures using the mean absolute percentage error, root mean square error and mean absolute error. The results give the Feed Forward Neural Network (FFNN) model is performing good result than the ARIMA model.

Key Words: ARIMA, FFNN, MAPE, RMSE, MSE.

1. Introduction:

The gold metals are a better investment for middle class people in India for the reason that, in a middle-class family, a single earner can slightly bear to place assets into properties, so pick out gold as a mission. Most of the humans in India are like gold jewellery for home appliances. India has typically been where people have terrific affection for vast gold metals. When it comes to embellishments and metal expenditures, gold has always been a popular choice among all precious metals because it has the advantage of being more affordable. A respectable market exists with reasonable value, transparency, and prudent liquidity. Due to this, this priceless metal is a good speculative asset for investors. The data of daily gold prices in India collected from goldpricesindia.com from 01st January 2017 to 30th October 2022 (containing 2128 observations) have been utilised to forecast future gold prices in India. The objective of this paper is to analyse the gold prices and develop a better model to forecast the daily gold prices in India.

2. Materials and Methods

The historical data of gold prices in India is collected from goldpricesindia.com from 01st January 2017 to 30th October 2022 (containing a total 2128 observations). The auto-regressive integrated moving average and feed-forward neural network models are used to predict the daily gold prices in India and find the adequacy of the models. Ms-Excel and R-Software are used to create charts and models.

2.1 ARIMA Model

The Box-Jenkins technique uses an auto-regressive integrated moving average model to analyse historical data series and choose an optimum model. This methodology has various benefits, including a minimum number of auto-regressive and moving average parameters, such as p and q, and the ability to check the data for seasonality and non-seasonality, and stationary and non-stationary data patterns. The four steps of the Box-Jenkins technique are used to create the model. Identification, estimate, diagnostic evaluation, and forecast Using the ACF and PACF plots for the stationary data series, model identification is the process of obtaining the model parameters p and q. In the ACF plot, the ACF dies out for more lags and q spikes; this is parameter q; in the PACF plot, the PACF dies out for more lags and p spikes; this is parameter p. The Ljung-Box Q statistics test is used to confirm the model's suitability, and the assumption that the mistakes are random is checked. The Ljung-Box test is useful for determining whether the residuals are random. Check the parameters' adequacy and relevance; if not, repeat the process, create some tentative models, and determine the model's adequacy. The best model for predicting the daily gold prices in India, was chosen after a number of models were tested using the provided training data set. Error measures like mean absolute error (MAE), mean absolute percentage error (MAPE), and root mean square error (RMSE) are used to verify a good model based on minimum error values.

2.2 FFNN (Feed Forward Neural Network) model

The FFNN models are biological neural networks stimulated. The nodes that make up neural networks are interconnected. The architecture of the feed-forward neural network is depicted in the following figure

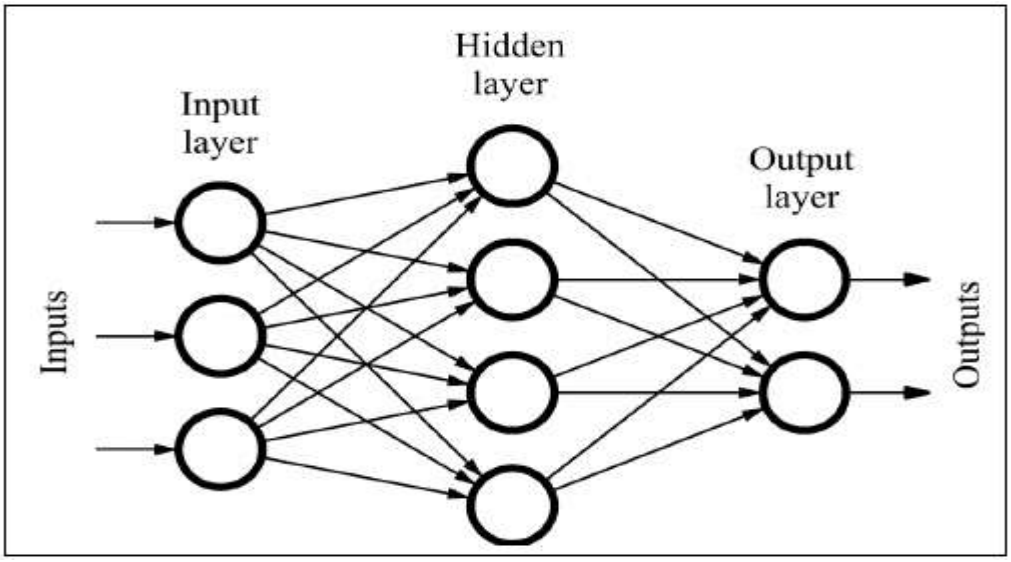

Figure 2.2.1: Feed Forward Neural Network diagram.

There are three layers that make up the architecture of the feed-forward neural network model. It has an output layer, a hidden layer, and one input layer. Data is first transformed at the input layer, then at the hidden layer, and finally at the output layer. The input of the following layer is the output of the node in the previous layer. Lag1 is the final model data for neurons in this projected model. Information about the network is provided in the table below.

Table 2.2.1: Neural Network Layer Information

Input Layer	Covariates 1	Lag1
	Number of Units	1 Normalized
	Rescaling method of covariates	
Hidden Layer	Number of hidden layers	1
	Number of units in the hidden layers 1	4
	Activation functions	Hyperbolic Tangent
Output Layer	Number of units	1

	Rescaling method of scale dependent	Normalized
	Activation functions	Identity
	Error functions	Sum of squares

3 Results and Discussion

The time series plot of daily prices of gold collected from Indiagoldprices.com from 1st January 2017 to 30th October 2022 .The entire data set is separated into two sets, such as training and testing data sets. The training data set contains (1st January 2017 to 30th September 2022) for model building and testing data set contains (1st October 2022 to 30th October 2022) for model performance.

3.1 ARIMA (Auto Regressive Integrated Moving Average) Model

The auto correlation (ACF) and partial auto correlation (PACF) functions are used to test the model's stationary behaviour. The correlation functions are shown in the following graph.

Figure 3.1.1: Daily gold prices in India(10 grms)

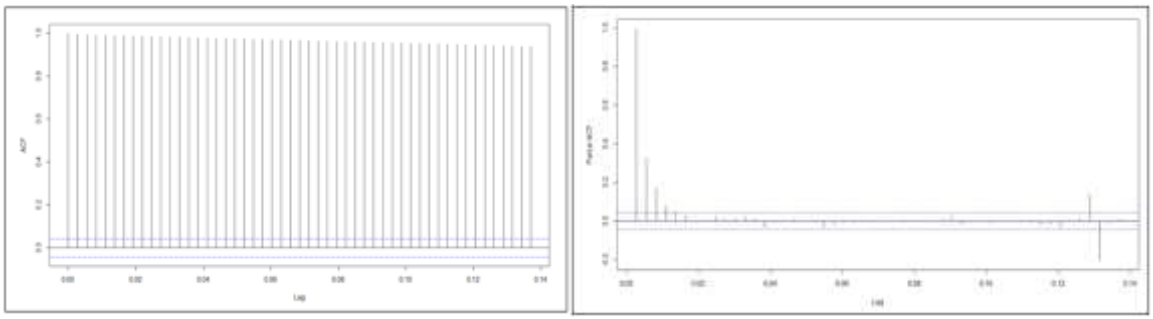

Figure 3.1.2: ACF and PACF plots for the gold prices in India (10 gm)

The temporal plot of gold prices shows an upward trend over time with seasonal variation; see figures 3.1.1 and 3.1.2 above. From July 2020 to September 2020, gold prices are raised and decreased in September 2020. From January 2021 onwards, the prices of gold are normalised within the range of Rs. 44,000 to Rs. 48,000 up to October 2022. The time plot demonstrates that the series is non-stationary with a variable mean. Additionally, the data is non-stationary and requires the creation of ACF and PACF plots since in ACF the dies are not out for longer delays.

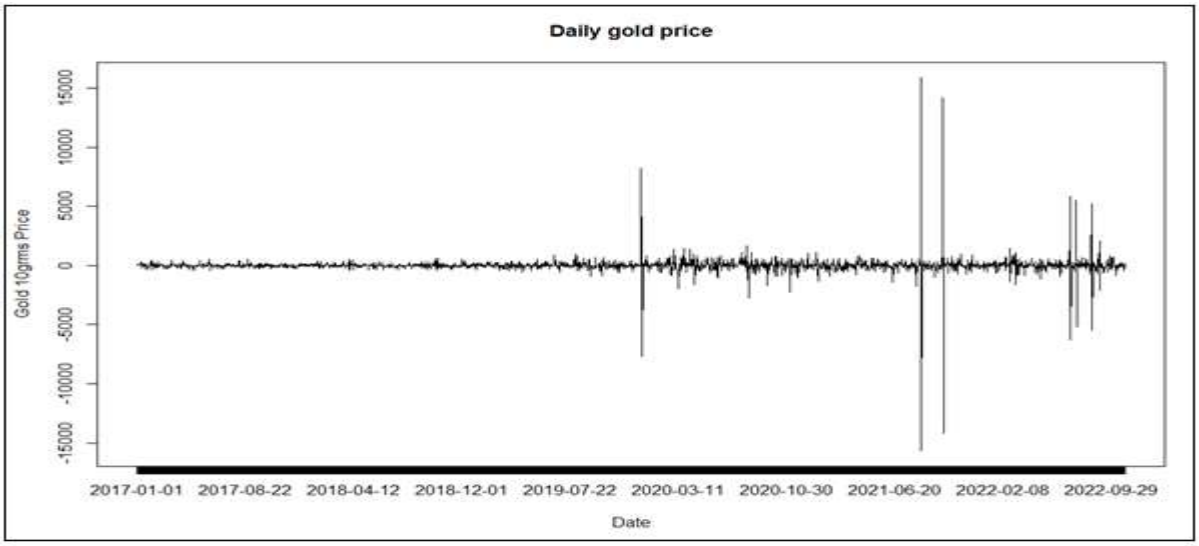

Figure 3.1.3: Transformed (d=1) series plot for gold prices in India(Rs/10 gm)

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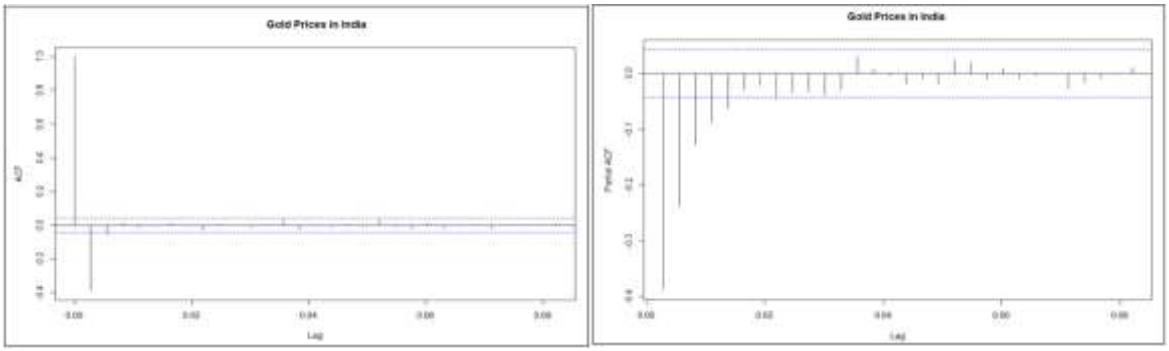

Figure 3.1.4: ACF and PACF plots for transformed series of gold prices in India

As seen in figure 3.1.4 above, the autocorrelation disappears with the onset of the first seasonal difference. The data is stationary right now. The ACF and PACF charts are used to identify the ARIMA model and choose its parameters. Using Ljung-Box Q statistics, the model's suitability is examined, and the parameter's importance is confirmed. The following table 3.1.1 provides a tentative model.

Table 3.1.1: Tentative models of ARIMA

ARIMA Models	AIC	BIC	Significance of the parameter	Lj Box Q Statistics	Significance	Adequacy
ARIMA(2,1,2)(1,0,1)	33593.57	33633.11	Insignificant	5.610	0.220	adequacy
ARIMA(0,1,0)	34111.5	34117.15	Insignificant	324.580	0.000	Inadequate
ARIMA(1,1,0)(1,0,0)	33773.54	33790.49	Insignificant	143.580	0.000	Inadequate
ARIMA(0,1,1)(0,0,1)	33595.42	33612.36	Insignificant	14.488	0.070	adequacy
ARIMA(0,1,0)(1,0,0)	34113.43	34124.73	Insignificant	324.780	0.000	Inadequate
ARIMA(0,1,0)(1,0,1)	34115.43	34132.38	Insignificant	324.780	0.000	Inadequate
ARIMA(1,1,0)(0,0,1)	33773.53	33790.48	Insignificant	143.600	0.000	Inadequate
ARIMA(1,1,0)(1,0,1)	33775.54	33798.13	Insignificant	143.590	0.000	Inadequate
ARIMA(2,1,0)	33651.44	33668.39	Significant	57.131	0.000	Inadequate
ARIMA(2,1,0)(1,0,0)	33652.83	33675.43	Insignificant	57.808	0.000	Inadequate
ARIMA(2,1,0)(0,0,1)	33652.82	33675.41	Insignificant	57.849	0.000	Inadequate
ARIMA(2,1,0)(1,0,1)	33654.81	33683.05	Insignificant	57.858	0.000	Inadequate
ARIMA(3,1,0)	33619.56	33642.15	Significant	30.892	0.000	Inadequate
ARIMA(3,1,0)(1,0,0)	33620.58	33648.82	Insignificant	31.272	0.000	Inadequate
ARIMA(3,1,0)(0,0,1)	33620.55	33648.8	Insignificant	31.318	0.000	Inadequate
ARIMA(3,1,0)(1,0,1)	33621.78	33655.67	Insignificant	31.653	0.000	Inadequate
ARIMA(1,1,2)(0,1,1)	33518.92	33547.15	Significant	4.975	0.547	adequacy
ARIMA(4,1,0)	33606.11	33634.36	Significant	19.355	0.004	Inadequate

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ARIMA(5,1,0)	33600	33633.89	Significant	12.837	0.025	Inadequate
ARIMA(6,1,0)	33600.44	33639.98	Insignificant	11.522	0.021	Inadequate
ARIMA(1,1,2)	33588.87	33611.48	Significant	5.14	0.64	adequacy

The above table 3.1.1 shows that the model ARIMA (1, 1, 2) is chosen above alternative models for forecasting future daily gold prices based on low AIC and BIC values with Q statistics of 5.14. The ARIMA (1, 1, 2) model, which is anticipated with future daily gold prices in India, is the most appropriate one. The following table 3.1.2 contains the estimated parameters.

Table 3.1.2 Model Parameters

Parameters	Estimates	Std.Error	z value	Pr(>|z|)
ar1	0.61	0.244	2.51	<0.001
ma1	-1.15	0.25	-4.54	<0.001
ma2	0.29	0.15	1.88	<0.001

The parameters are substituted in the ARIMA (1, 1, 2) in Table 3.2.2 above, and the best model is

$$(1 - \varnothing_1 B)(1 - B)z_t = (1 - \theta_1 B - \theta_2 B^2)\epsilon_t$$

$$(1 - 0.61B)(1 - B)z_t = (1 + 1.15B - 0.29B^2)\epsilon_t$$

The autocorrelation and partial autocorrelation functions of various appearances are used to test the residuals plots.

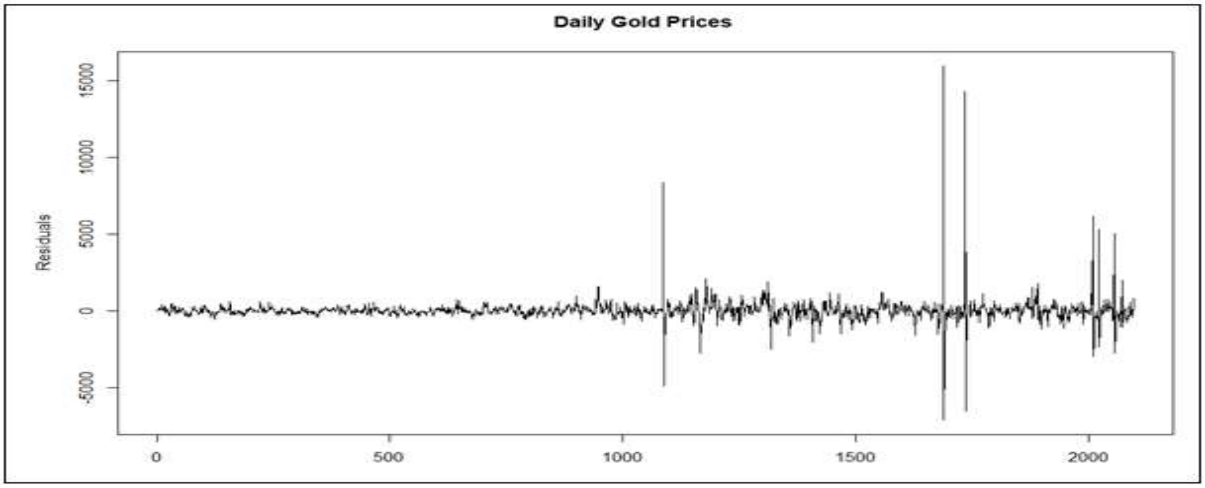

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Figure 3.1.5: Residulas series for gold prices.

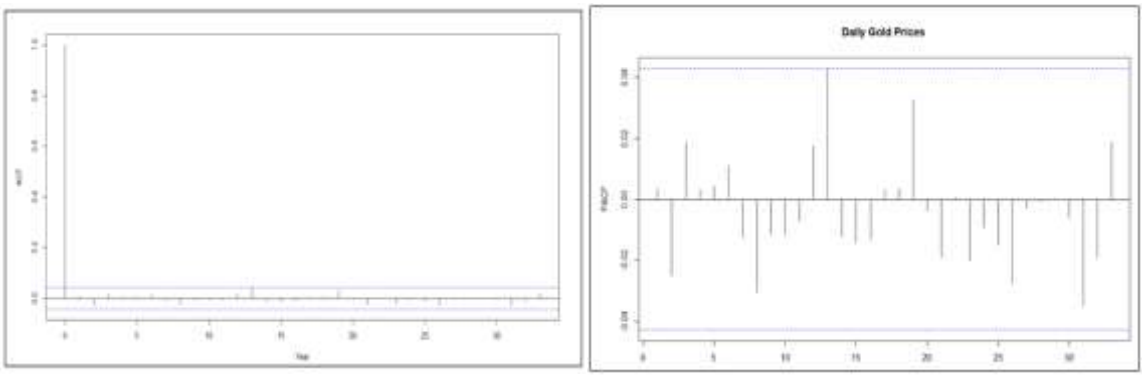

Figure 3.1.6: ACF and PACF residulas plot for gold prices

The residuals plot for PACF can be seen in the above figures to be significantly different from the range of 0 to 0.04. The Ljung-Box test is used to validate the model's suitability. After creating the model, this test is used to examine the series' residuals. So, Ho: the model is adequate, and H1: the model is insufficient, are the respective hypotheses for the model.

Table 3.1.3: LJung Box_ Q test Statistics

Model	ARIMA(1,1,2)
Statistics	5.14
Degrees of freedom	7
Significance	0.64

In table 3.1.3, the hypothesis value is greater than the probability value of 0.05, resulting in the acceptance of the null hypothesis and the conclusion that the model is adequate. As a result, the ARIMA (1, 1, 2) model works better for predicting gold prices on a daily basis in India. Table 3.1.4 below lists predicted daily gold prices (10 grms) in India from October 1st, 2022, to October 30th, 2022.

Table 3.1.4 Forecasts of daily prices of gold in India using ARIMA (1,1,2)

Date	Actual gold prices	Forecasted gold prices		Date	Actual gold prices	Forecasted gold prices
01-10-2022	50027	49940.57		16-10-2022	50492	49871.00

02-10-2022	50132	49913.67		17-10-2022	50493	49870.98
03-10-2022	50801	49897.17		18-10-2022	50363	49870.97
04-10-2022	51481	49887.04		19-10-2022	50293	49870.96
05-10-2022	51997	49880.82		20-10-2022	50313	49870.96
06-10-2022	51838	49877.01		21-10-2022	50625	49870.95
07-10-2022	51968	49874.67		22-10-2022	50625	49870.95
08-10-2022	51968	49873.23		23-10-2022	50528	49870.95
09-10-2022	51155	49872.35		24-10-2022	50642	49870.95
10-10-2022	50919	49871.81		25-10-2022	50713	49870.95
11-10-2022	50946	49871.48		26-10-2022	50723	49870.95
12-10-2022	50549	49871.27		27-10-2022	50292	49870.95
13-10-2022	50518	49871.15		28-10-2022	50235	49870.95
14-10-2022	50290	49871.07		29-10-2022	50235	49870.95
15-10-2022	50290	49871.03		30-10-2022	50449	49870.95

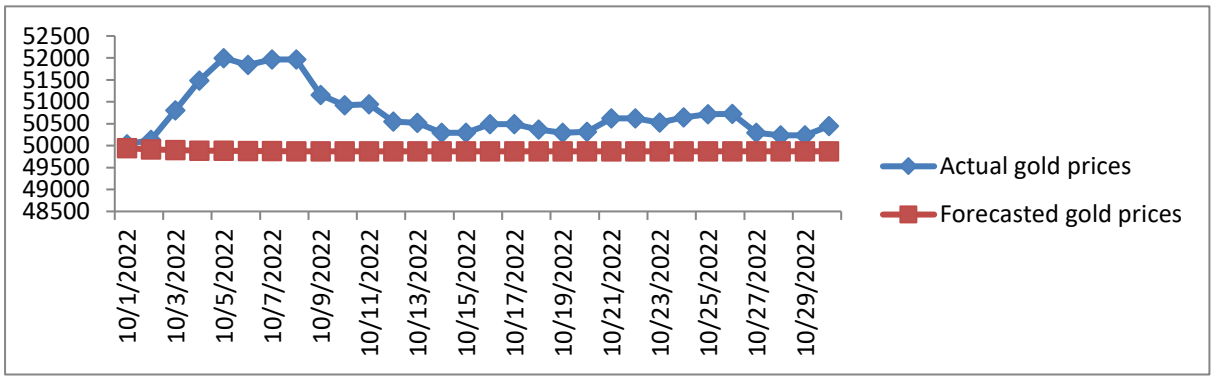

Figure 3.1.7: Forecasts of daily prices of gold in India using ARIMA (1,1,2)

The test data set is used to validate the model's performance once it has been developed using the training data set. The following table 3.5.5 displays the model's performance in the test sample.

Table 3.5.5: Performance of the ARIMA (1,1,2) Model

Data Set	RMSE	MAE	MAPE
Training Set	723.28	292.89	0.69
Test Set	1022.98	853.04	1.67

The mean absolute error for the training and test sets, as shown in table 3.5.5 above, was Rs 292.89 and Rs 853.04, respectively. In the training and test sets, the root mean square error was RS 723.28 and RS 1022.98 rupees, respectively. The

mean absolute percentage error was 0.69 percent and 1.67 percent in the training and test sets, respectively, slightly higher than the amount that was advised.

3.2 Feed Forward Neural Network Model

The total number of neurons in the FFNN model is two, and it displays lag1 values. One output layer is needed in this model, and it displays the forecast for gold prices in India. Without performing a forward or backward selection process to acquire the hidden layers, there is no straightforward method to determine the quantity of hidden neurons. Under the back propagation methodology, the hyperbolic tangent function is used as the activation function. In order to compute some iterative models utilising random hidden neurons and arrive at the best model, the forward selection procedure is used. The best model is determined using the minimum error measures. The following table 3.2.1 lists the preliminary model.

Table 3.2.1: Tentative models in FFNN Model

Number of Layer			Train			Test		
Input	**hidden**	**Ouput**	**RMSE**	**MAE**	**MAPE**	**RMSE**	**MAE**	**MAPE**
1	2	1	632.27	222.00	0.54	1144.46	439.28	0.85
1	3	1	636.25	241.24	0.60	1137.72	454.32	0.88
1	4	1	552.77	194.95	0.48	1060.14	368.64	0.70
1	5	1	634.29	227.96	0.56	1145.35	445.33	0.86

According to the above table, the 1-4-1 network has lower error measurements than other networks. The FFNN 1-4-1 network used for the data is shown in the following diagram.

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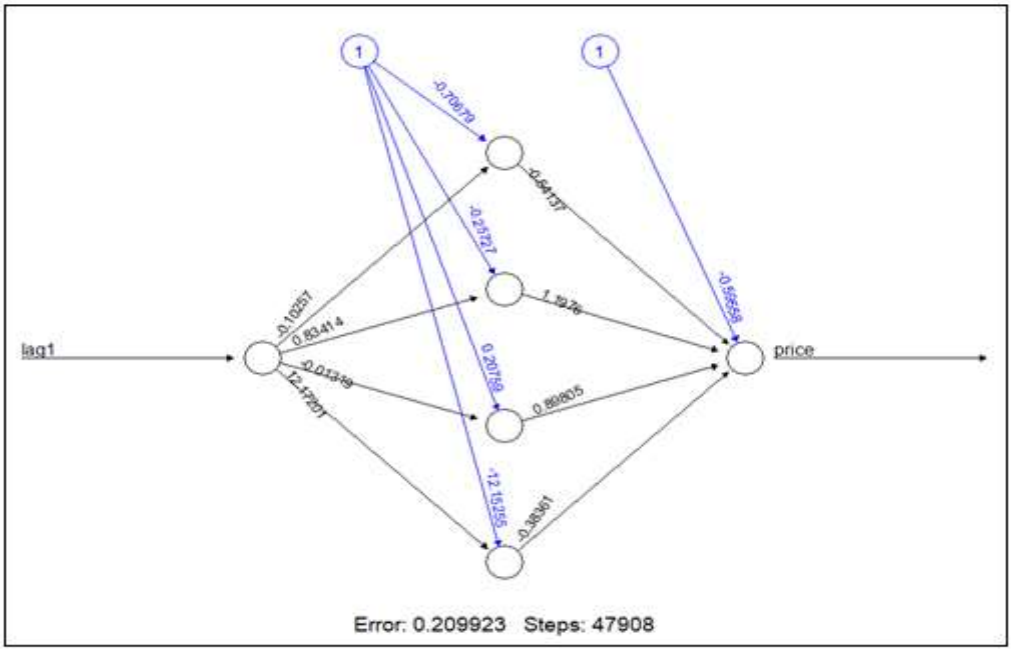

Figure 3.3.1: FFNN model diagram

The 1-4-1 model was chosen based on model performance after building the network model and testing multiple models. The higher hidden layers were constructed in the R programming language. The following table 3.2.2 displays the parameters and the best model, which is 1-4-1.

Table 3.2.2 Parameters of the FFNN Model

Parameter Estimates	
error	0.2099
reached.threshold	0.0097
steps	47,908
Intercept.to.1layhid1	-0.7068
lag1.to.1layhid1	-0.1026
Intercept.to.1layhid2	-0.2573
lag1.to.1layhid2	0.8341
Intercept.to.1layhid3	0.2076
lag1.to.1layhid3	-0.0132
Intercept.to.1layhid4	-12.1526
lag1.to.1layhid4	12.1720
Intercept.to.price	-0.5956
1layhid1.to.price	-0.5414
1layhid2.to.price	1.1976
1layhid3.to.price	0.8981

1layhid4.to.price	-0.3836

Now, the activation functions are

H_1 = Tanh[-0.706-0.102 $\bar{Z}_{t-1}$]

H_2 = Tanh[-0.257+0.834 $\bar{Z}_{t-1}$]

H_3 = Tanh[0.207-0.013 $\bar{Z}_{t-1}$]

H_4 = Tanh[-12.152-12.17$\bar{Z}_{t-1}$]

Where $\bar{Z}_{t-1} = \frac{lag1-\min(lag1)}{\max(lag1)-\min(lag1)}$

$\bar{Z}_{t-1}$ is rescaled input variable.

Now, the feed-forward neural network model equation is

O_t = -0.54137 H_1 + 1.1976 H_2 +0.89805 H_3 -0.38361 H_4 – 0.5958

The following table 3.2.3 provides the fitted forecasting model and test sample used to evaluate the model's performance.

Table 3.2.3: Performance of the FFNN 1-4-1 model

Data Set	RMSE	MAE	MAPE
Training Set	552.77	194.95	0.48
Test Set	1060.14	368.64	0.70

According to the above findings, the mean absolute error for the training and test sets was Rs 196.52 and Rs 367.23, respectively. In the training and test sets, the root mean square error was Rs 553.41 and Rs 1049.09, respectively. The mean absolute percentage error was 0.49 percentages in the training set and 0.70 percentages in the test set, respectively, somewhat over the level that is advised. The following table 3.4.5 lists the daily gold prices as determined by the forecasting model.

Table 3.2.4: Forecasts of daily prices of gold in India using FFNN 1-4-1 Model.

Date	Actual gold prices	Forecasted gold prices		Date	Actual gold prices	Forecasted gold prices
01-10-2022	50027	50361		16-10-2022	50290	50258
02-10-2022	50027	50013		17-10-2022	50492	50258
03-10-2022	50132	50013		18-10-2022	50493	50446

04-10-2022	50801	50111		19-10-2022	50363	50447
05-10-2022	51481	50731		20-10-2022	50293	50326
06-10-2022	51997	51352		21-10-2022	50313	50261
07-10-2022	51838	51816		22-10-2022	50625	50279
08-10-2022	51968	51674		23-10-2022	50625	50569
09-10-2022	51968	51790		24-10-2022	50528	50569
10-10-2022	51155	51790		25-10-2022	50642	50479
11-10-2022	50919	51055		26-10-2022	50713	50584
12-10-2022	50946	50839		27-10-2022	50723	50650
13-10-2022	50549	50864		28-10-2022	50292	50659
14-10-2022	50518	50498		29-10-2022	50235	50260
15-10-2022	50290	50470		30-10-2022	50235	50207

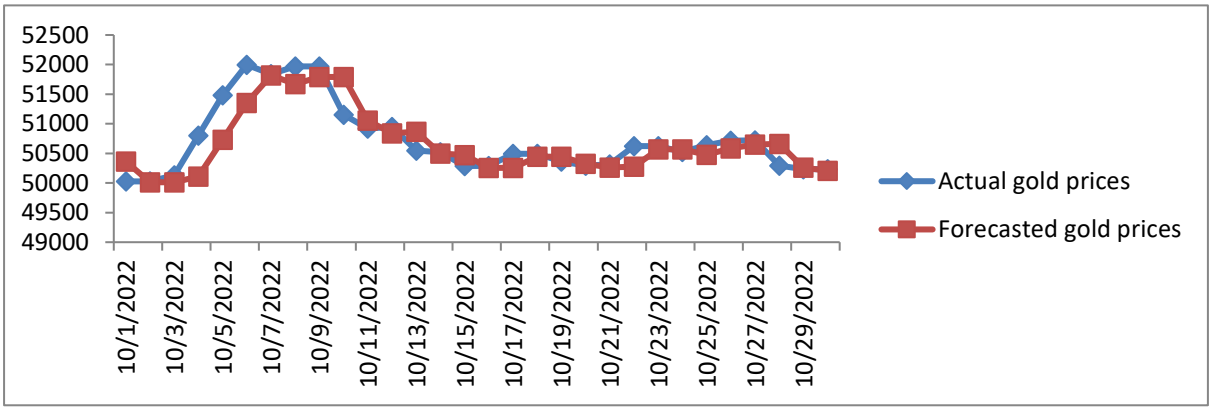

Figure 3.3.2: Testing sample forecasting using FFNN

In the above figure 3.3.2, it was noted that the FFNN models produce better results, and the graph also performs better.

4 Comparison of Forecasts models for daily prices of gold in India.

In both cases, the accuracy measures of the models' performances on training samples and test sample results differ significantly. When compared to the ARIMA, the FFNN model error measures are more effective and adaptable for training and testing samples. Consequently, the FFNN model forecast outperforms the ARIMA. The two models are compared in the table below.

Table 4.1: Comparison of Forecasts models for daily prices of gold in India

	ARIMA			FFNN		
	RMSE	MAE	MAPE	RMSE	MAE	MAPE
Training Set	723.28	292.89	0.69	552.77	194.95	0.48
Test Set	1022.98	853.04	1.67	1060.14	368.64	0.70

5 Conclusion

From the above analysis, it can be seen that the FFNN models outperform the ARIMA model when it comes to forecasting gold prices. As a result, the FFNN model has been used to project future daily gold prices in India. The ARIMA and FFNN models' predictions are shown in Tables 5.1 and Figures 5.1.

Table 5.1: Forecasted values of ARIMA and FFNN models

Date	Actual gold prices	ARIMA Forecasted gold prices	FFNN Forecasted gold prices
01-10-2022	50027	49940.57	50361.17
02-10-2022	50027	49913.67	50012.67
03-10-2022	50132	49897.17	50012.67
04-10-2022	50801	49887.04	50110.77
05-10-2022	51481	49880.82	50730.94
06-10-2022	51997	49877.01	51351.87
07-10-2022	51838	49874.67	51815.8
08-10-2022	51968	49873.23	51673.57
09-10-2022	51968	49872.35	51789.91
10-10-2022	51155	49871.81	51789.91
11-10-2022	50919	49871.48	51055.46
12-10-2022	50946	49871.27	50839.41
13-10-2022	50549	49871.15	50864.19
14-10-2022	50518	49871.07	50498.35
15-10-2022	50290	49871.03	50469.65
16-10-2022	50290	49871.00	50258.01
17-10-2022	50492	49870.98	50258.01
18-10-2022	50493	49870.97	50445.57
19-10-2022	50363	49870.96	50446.5
20-10-2022	50293	49870.96	50325.88

21-10-2022	50313	49870.95	50260.8
22-10-2022	50625	49870.95	50279.4
23-10-2022	50625	49870.95	50568.63
24-10-2022	50528	49870.95	50568.63
25-10-2022	50642	49870.95	50478.91
26-10-2022	50713	49870.95	50584.34
27-10-2022	50723	49870.95	50649.87
28-10-2022	50292	49870.95	50659.09
29-10-2022	50235	49870.95	50259.87
30-10-2022	50235	49870.95	50206.81

Figure 5.1, which shows a forecast comparison using ARIMA and FFNN models, shows that the performance of the latter model is higher than that of the closer.

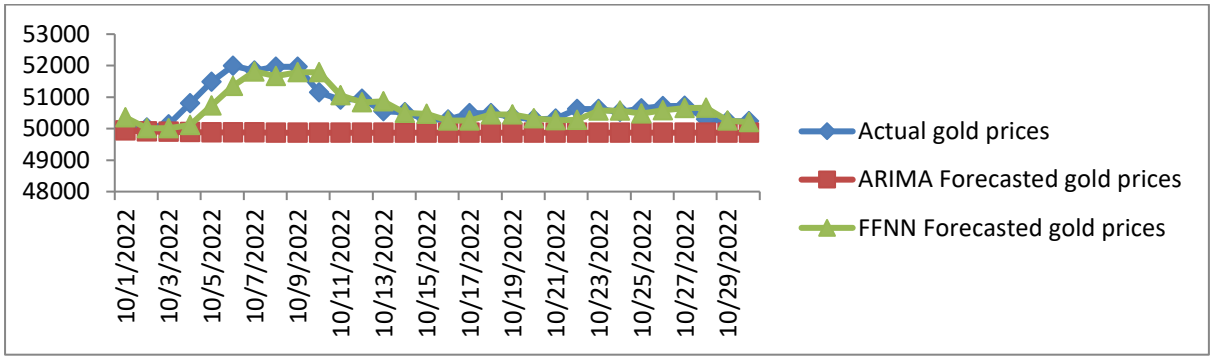

Figure 5.1: Forecasted values of ARIMA and FFNN models.

6. References:

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