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An Adaptive Network Based Fuzzy Inference System for the Prediction of Gold Price Using Generalized Autoregressive Conditional Heteroskedasticity (GARCH) Method

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Abstract: **Developing a precise model for forecasting gold price is critical because of its unique features. Hence, continued research is directed to improve forecasting models employing a variety of techniques. In previous researches, ARIMA (Autoregressive Integrated Moving Average) and MLR (Multiple Linear Regression) model we have incorporated both heteroskedastic concept and learning past prediction errors. In this paper an enhanced ANFIS-GARCH model is proposed to overcome the above issues and compared with the Existing models. ANFIS-GARCH is comparatively good and robust than Existing models. ANFIS-GARCH has the capability to integrate and simulate knowledge from quantitative and qualitative source to model the behavior changes in the prediction. The coefficient of determination (R2), Root Mean Squared Error (RMSE) are utilized to evaluate the performance of developed model.**

Keywords: **Generalized Autoregressive Conditional Heteroskedasticity (GARCH), Gold price, Forecasting, US dollar, Inflation, ARIMA model, MLR Model.**

1. INTRODUCTION

Gold is an irreplaceable commodity due to its venture resource status and worth potential. Gold is a unique product that is holding esteem amid financial emergencies [***Reddy, p, 2016***]. Gold would definitely maintain its charm irrespective of the time duration till the economy of the world remains dubious [***Gold council, 2015***]. People do invest in gold since gold is a hedge against inflation and return on gold investment is high related to inflation rate [***Guha, et. al, 2016***].

Gold is a famous nonmonetary tool in the financial market. Gold is described in terms of high-risk and high-yield. Gold price is considered as an outcome of world's economic trends and the expectation of investors. Hence, forecasting of gold price is a vital issue in economics and therefore, gold price forecasting is a crucial issue in economics **[*Shafiee&Topal, 2010*].**

Forecasting of security price volatility is a major challenge in the present financial and economic conditions. Hence, forecasting of gold price with higher precision is significant for the world economy and commodity markets. Numerous methods and mathematical models are available for forecasting gold price, e.g. Autoregressive Integrated Moving Average model [***A. Parisi, et. al, 2008***], jump and dip diffusion model [***Shafiee&Topal, 2010***], multi-linear regression model [***Z. Ismail, et. al, 2009***], Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model [***Kristjanpoller, et. al, 2015***], artificial intelligence models such as Artificial Neural Networks (ANN) [***M. C. Lineesh, et. al, 2010***] and Generalized Autoregressive Conditional Heteroskedasticity (ANN-GARCH) model [***Kristjanpoller, et. al, 2015***].

In order to forecast the gold price with high precision, we have proposed an enhanced adaptive Network-based Fuzzy Inference System GARCH model. This proposed model eliminates the previous prediction errors and provides accurate value with high precision. The reason behind selecting ANFIS-GARCH is that it is highly robust and good compared to existing models. ANFIS-GARCH has the capability to integrate and simulate knowledge from quantitative and qualitative source to model the behavior changes in prediction [Xuefeng Yan, et. al, 2013].

2. LITERATURE REVIEW

Various models used for forecasting gold prices and its drawbacks are discussed in this section.

Ismail, 2009 forecasted the gold price using multiple linear regression method. Accuracy of gold price highly depends on the factors that influence gold price. Accuracy is also dependent on other major factors that influence the future gold prices. They used stepwise procedures to solve multi co-linearity problem by reducing the number of independent variables. The problem of correlated error terms was solved by Prais-Winsten method.

Jian-hui, Y. and D. Wei, 2012 forecasted the gold price using Empirical Mode Decomposition (EMD). The utilized model is capable of dealing with non-linear and non-stationary data. The model showed that the better performance compared to traditional Wavelet Transform (WT) methods.

Khan, 2013, G, D.M, 2012 & Abdullah, 2012 conducted a study to forecast the gold price using Autoregressive Integrated Moving Average (ARIMA) model. For obtaining accurate forecasting of gold price, it is divided in to shorter period of time and the calculation is made in series for longer period of time. But in previous papers, forecasting of gold price was done for longer period of time which reduced the accuracy in analyzing the gold price.

Li, B, 2014 presented a study on forecasting of gold price using Wavelet Neural Network - Artificial Bee Colony (WNN-ABC). WNN has weakness in generalization ability to forecast price of gold for long period of time as the macroeconomics indexes which can affect gold price showing significant variation from time to time.

Liu, C, 2009 analyzed the forecasting of gold price using Genetic Algorithm-BP neural network (GABP). The connection weight of multilayer feed forward neural network was optimized in order to enhance the precision and learning efficiency, and extend the searching space of neural network.

Mombeini, H. and A. Yazdani-Chamzini, 2015 carried out study to forecast gold price using ANN. The main drawbacks in the research are long training time and involvement of more number of parameters in forecasting process.

Parisi, A, 2008 investigated on gold price forecasting using rolling and recursive neural network and showed that the mentioned method could be utilized as an alternative to technical analysis and conventional time series method like ARIMA for prediction.

Pierdzioch, et. al, 2016 forecasted returns on the gold price and silver price using boosting algorithm. Nature of the revision of data on gold price is less. The revisions and delays in availability affecting forecast accuracy were measured.

3. METHODOLOGY

Since classical models, such as Ordinary Least Squares (OLS) are not suitable for situations in which the variance is heteroskedastic which is the case for financial time-series. Engle (1982) introduced Auto Regressive Conditional Heteroskedasticity (ARCH) models in which the current error variance is a function of the terms of error of previous periods. Subsequently, Bollerslev (1986) generalized these models and proposed the GARCH (generalized autoregressive conditional heteroskedasticity) process that consists of symmetric model in which conditional variance depends on the conditional variances (from previous periods) and square of perturbations. One of the reasons that these models have been widely used in the financial literature is due to the fact that it captures 280 volatility clustering.

3.1 Objectives:

- To find the significance difference between ANFIS-GARCH, GARCH, ARIMA and MLR models.
- Analyzing gold price fluctuation for previous years.
- Developing ANFIS-GARCH model for predicting gold price for further months.

3.2 Hypothesis to Be Used:

The following hypothesis were taken for this study.

H0: There is no significance difference between GARCH, ARIMA and MLR models.

H1: There is a significance difference between GARCH, ARIMA and MLR models.

In equation (1) to illustrate, suppose P_i is an index of prices from a financial series, r_t indicates return or percentage price variation. Where, the index "i" denotes an observation to the daily closing. It is given by the formula.

$$r_t = \log P_i - \log P_{i-1} \qquad (1)$$

For the series of returns, the GARCH model may be expressed as follows:

$$r_t = \rho + \varepsilon_t \sigma_t$$

$$\sigma_t^2 = \eta_0 + \sum_{i=1}^{s} \eta_i \varepsilon_{t-i}^2 + \sum_{i=1}^{r} \lambda_i \sigma_{t-i}^2 \qquad (2)$$

Where,

σ

-residual process

ε

-residual

In above equation (2), r ≥ 0, s > 0, $\eta_0 > 0$, $\eta_i > 0$, I = 1…….r and $\lambda_i \geq 0$, I = 1….r conditions on the parameters are taken to ensure that the conditional variance of the GARCH (r, s) is always positive. In addition, to ensure a finite expected value of the variance it is assumed that:

$$\sum_{i=1}^{s} \eta_i + \sum_{i=1}^{r} \lambda_i < 1 \qquad (3)$$

Realized the forecasted parameter through GARCH model and the ANFIS is a kind of ANN. The technique integrates both neural networks and fuzzy logic principles. It has potential to capture the benefits of both in a single framework. Its inference system corresponds to a set of fuzzy if- then rules that have the learning capability to approximate nonlinear function.

3.3 Existing Method:

In existing papers, gold rate has been predicted and calculated by using many techniques such as MLR (Multiple Linear Regression Model), ARIMA, logistic regression of binary classifications and Back propagation models.

3.3.1 Gold Rate Prediction Using Proposed Model and Multiple Linear Regression Model:

The most appropriate approach to the understanding of gold prices is the multiple Linear Regression Model (MLR). MLR is a study on the relationship between a single dependent variable and one or more independent variables, as this case with gold price as the single dependent variable. The multiple linear regression model were estimated and predicted using Statistical Package of Social Science (SPSS). But in our proposed, the gold rate has been predicted using Fuzzy based Garch Technique. The MSE and error value was stated in below table using SPSS for both models.

Predicted Gold Rate from 2016 to 2020

Table 1: Descriptive calculations using multiple linear Regression Model

Descriptive Statistics			
	Mean	Std. Deviation	N
Gold Rate	22839.55	6430.421	20

3.3.2 Gold Rate Prediction using ARIMA Model:

The future gold rate were predicted and stated in table 2.

Predicted Gold rate from 2016 to 2020:

Table 2: Calculations using ARIMA model

Param	Value
μ	16.89
φ_1	0.00
θ_1	0.00
σ	4821.38
d	1

Table 3: Mean and Standard deviation of ARIMA model

Year	**Mean**	**STD**	**UL**	**LL**
2009	29850.89	4821.376	39300.62	20401.17
2010	29867.79	6818.456	43231.71	16503.86
2011	29884.68	8350.869	46252.08	13517.28
2012	29901.57	9642.752	48801.02	11002.12
2013	29918.46	10780.92	51048.69	8788.24
2014	29935.36	11809.91	53082.36	6788.356
2015	29952.25	12756.16	54953.87	4950.631
2016	29969.14	13636.91	56697	3241.288
2017	29986.04	14464.13	58335.21	1636.865
2018	30002.93	15246.53	59885.58	120.2783
2019	30019.82	15990.7	61361.01	-1321.37
2020	30036.71	16701.74	62771.52	-2698.09
Mean=29943.8 Standard Deviation=3765.048				

3.3.3 Gold Rate Prediction using GARCH Model:

The gold price value for the years 2000 to 2020 is tabulated (table 7). The forecasted RMSE value of gold price using GARCH model is shown in figure 2 and table 4.

Table 4. Gold Rate Prediction from 2001-2020 using GARCH

Year	**Gold Rate**	**RMSE**
2001	12532	25.03198
2002	12788	25.28636
2003	15042	27.42444
2004	16904	29.07232
2005	18523	30.43271
2006	19599	31.30415
2007	27358	36.98513
2008	28689	37.87413
2009	27767	37.26057
2010	25001	35.35605
2011	28479	37.73526
2012	29078	38.13004
2013	22235	33.34292
2014	27245	36.90867
2015	31347	39.58977

2016	23391	34.19868
2017	25963	36.02985
2018	26153	36.16144
2019	29110	38.15102
2020	21267	32.60905

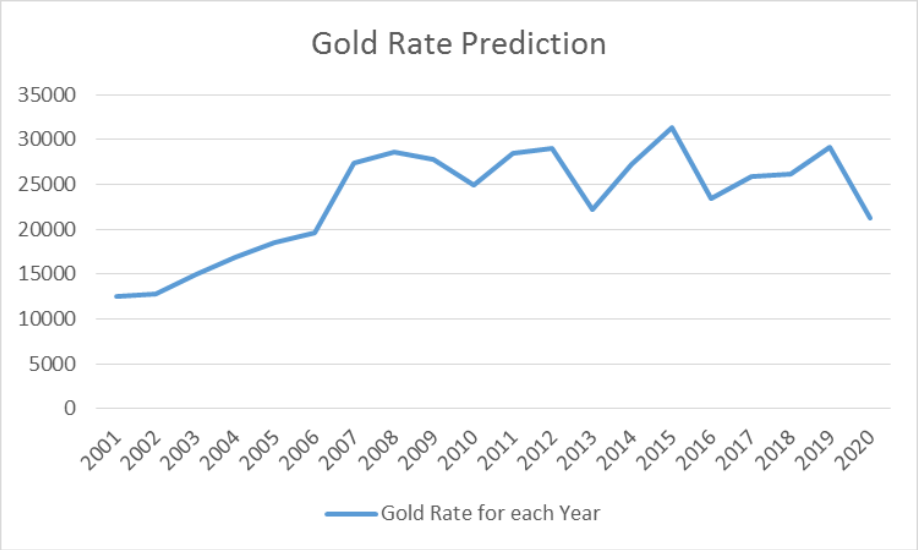

Fig 1. Gold Rate Prediction

Predicted Gold Rate from 2001 to 2016:

Table 5: Calculations using GARCH model

GARCH(1,1)	
Param	Value
α_0	2008.99
α_1	0.50
β_1	0.50

Table 6: Descriptive Calculations using GARCH Model from 2001 to 2016

PARAMETER	**VALUES**
Mean	22873.63
Standard Deviation	6213.893

Predicted for 2017 to 2020

The future gold rate were predicted and stated in table 4.

Table 7: Descriptive Calculations using GARCH Model from 2017 to 2020

Year	**Gold Rate**
2017	25963
2018	26153
2019	29110
2020	21267

S.D and Mean values using GARCH model

Mean	25623.25
Standard Deviation	3241.934

The above table shows that the descriptive calculations of collected data using Garch model. It is achieved the standard deviation value of 3241 and mean value of 25623 respectively. From the analysis GARCH model is more significant than the existing models. It is concluded that there is significance difference between the GARCH, ARIMA and MLR models.

3.4 Gold Rate Prediction Using ANFIS-GARCH Model:

In proposed method, the gold rate were effectively calculated by using ANFIS-GARCH technique. The ANFIS-GARCH model equation is given by,

$$X_{norm} = (X - X_{\min)} / (X_{\max} - X_{\min})$$

Gold rate were predicted and calculated using above equation and which is tabulated in table 6.

Table 8: Gold Rate Prediction using ANFIS-GARCH Model

Year	Observed Gold Rate	Predicted Using ANFIS-GARCH
2001	12532	0
2002	12788	0.013606
2003	15042	0.133404
2004	16904	0.232368
2005	18523	0.318416
2006	19599	0.375605
2007	27358	0.787988
2008	28689	0.85873
2009	27767	0.809726
2010	25001	0.662716
2011	28479	0.847568
2012	29078	0.879405
2013	22235	0.515706
2014	27245	0.781982
2015	31347	1
2016	23391	0.577146
2017	31581.83	0.938269
2018	32207.63	1.622395
2019	32552.04	-1.16408
2020	32835.17	-0.94247
Average Values	24757.73	0.462424

The above calculations are predicted from 2017 to 2020 based on previous gold rates from 2001 to 2015 using trend analysis. After the calculation of trend analysis, the estimated gold rate were predicted by using ANFIS-GARCH model technique and which is graphically represented in below graph.

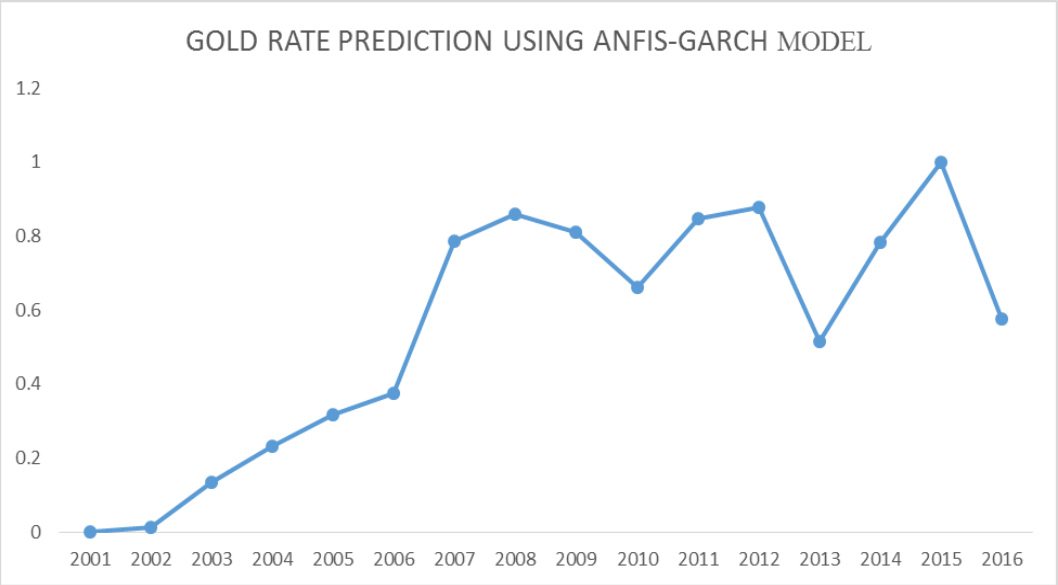

Fig 2: Gold Rate Prediction from 2001-2016

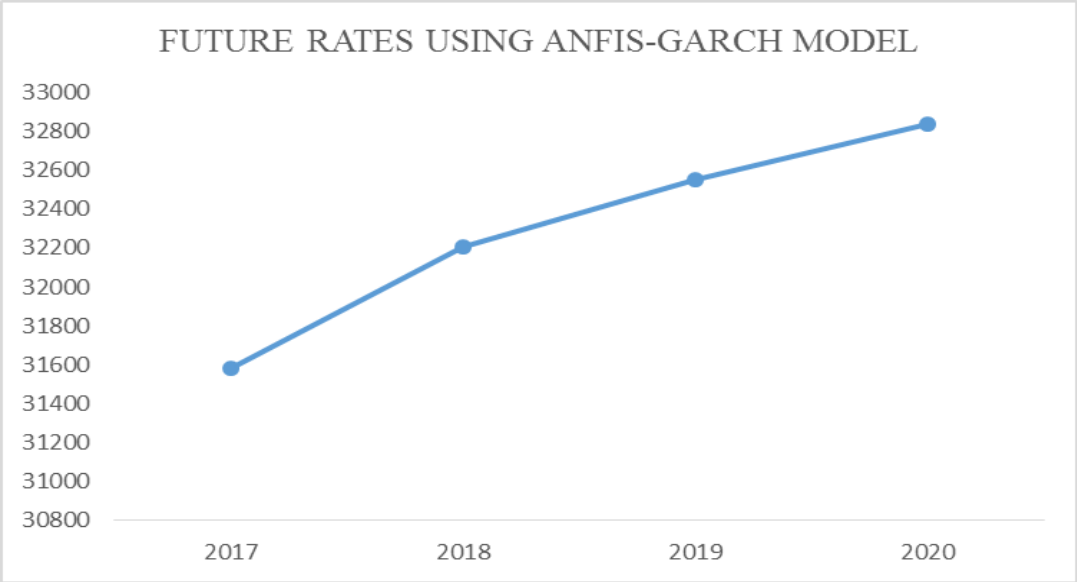

Fig 3: Gold Rate Prediction from 2017-2016

The RMSE, MAE and R^2 value for predicted gold rate were calculated by using following equations.

$$MAE = \frac{\sum_{i=1}^{N} |A_i - P_i|}{N}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (A_i - P_i)^2}{N}}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{N} (A_i - P_i)^2}{\sum_{i=1}^{N} (A_i - \bar{A}_i)^2}$$

The RMSE, MAE and R^2 value for predicted gold rate was calculated using above equations and tabulated in table 7.

Table 9: Calculations of RMSE, MAE and R^2

Year	RMSE	MAE	R^2
2001	2802.24	626.6	1.05073
2002	4043.916	25575.97	1.141393
2003	5825.69	45125.6	2.396913
2004	7559.595	67615.07	4.632492
2005	9261.341	92613.41	8.826163
2006	10734.61	117591.7	14.43328
2007	16184.74	191500.5	11.6899
2008	18143.97	229505.1	121.722
2009	18626.13	249895.7	49.88473
2010	17677.91	250003.4	51.53
2011	21119.96	313259.7	58.56553
2012	22523.04	348925.4	45.29828
2013	17926.01	289048.3	77.68039
2014	22794.15	381419.1	81.4019

2015	27146.43	470190	22.63029
2016	20921.03	374246.8	79.8927
2017	29116.14	536875.1	21.41702
2018	30553.3	579708.2	18.68845
2019	31728.94	618510.9	17.44344
2020	32836.11	656722.2	16.52557
Average Values	18376.26	291947.9	613.1924

Table 7 shows that the Calculation of RMSE, MAE and R^2 value from 2001 to 2020. The predicted gold rate achieves the highest RMSE value in the year of 2020. Similarly, the gold arte achieves the highest MAE value in the year of 2020. In R^2 calculation, the gold rate achieves the highest value in the year of 2014. The average value of RMSE, MAE and R^2 is 18376.26, 291947.9 and 613.1924 respectively. The overall standard deviation calculation of predicted gold rate was tabulated in table 8.

Table 10: S.D Calculations for Predicted Values from ANFIS-GARCH Model

2001-2016	Standard Deviation (Observed Value)	0.330263
2017-2020	Standard Deviation (Predicted Values from ANFIS-GARCH)	1.378922

The above table shows that that standard value calculations of predicted gold rate values from ANFIS-GARCH model technique. The standard deviation value of observed gold rate is 0.330263 and standard deviation value of predicted gold rate is 1.378922. It achieves the lowest standard deviation value when compared to other model such as MLR, GARCH and ARIMA. The comparison between all models were tabulated and graphically represented in below.

Table 11: Comparison between ANFIS-GARCH, MLR, ARIMA and GARCH

MODELS	STANDARD DEVIATION VALUE
MLR	6430.421
ARIMA	3765.048
GARCH	6213.893
ANFIS-GARCH	1.378922

The above table shows that the standard deviation value of all models. ANFIS-GARCH achieves the lowest standard deviation value in the range of 1.378922 when compared to other models and techniques which is graphically represented in below graph.

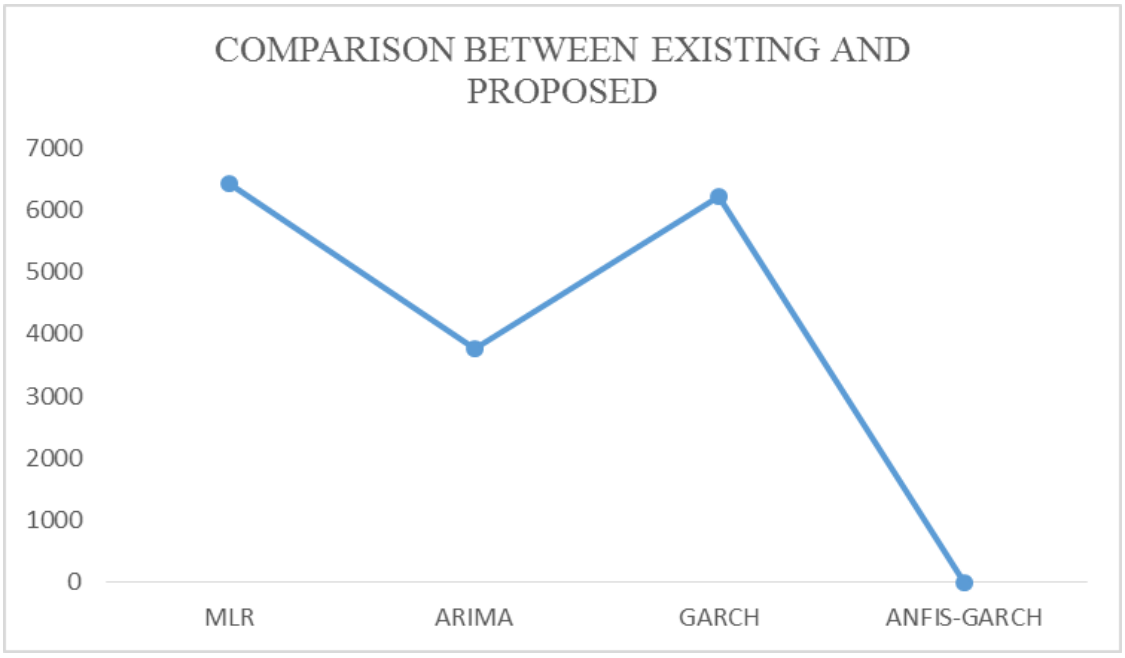

Fig 4: Comparison between ANFIS-GARCH, MLR, ARIMA and GARCH

4. DATA, DISCUSSION & RESULTS

The actual gold price was forecasted using the gold price, silver price, USD index, oil price, inflation rate, interest rate, stock market index and gold world production. The statistical parameters collected for the forecasting process is explained in table 6. The current price of gold is shown in the above mentioneed fig 3.

Table 12: Statistical parameters of each data set

Variable	Type of data	Maximum	Minimum	Unit	Symbol	Resource
Gold price	Monthly	1320.25	400.524	$/ounce	G	www.kitco.com
Silver price	Monthly	17.650	5.26	$/ounce	S	www.kitco.com
USD index	Monthly	1.06976	0.826	-	C	research.stlouisfed.org
Oil price	Monthly	51.23	46.14	$/barrel	O	www.economagic.com
Inflation rate	Monthly	0.41%	0.08%	-	Inf	www.inflationdata.com
Interest rate	Monthly	8.89	2.42	-	Int	www.econstats.com
Stock market index	Monthly	17160	4219.25	$	DJ	finance.yahoo.com
World gold production	Monthly	230.52	186.23	Ton	Pg	Minerals.usgs.gov

The above table shows that the detail calculations regarding minimum and maximum value of gold price, silver price, USD price, Oil price in india.

5. CONCLUSION

The proposed enhanced ANFIS-GARCH model has proven to be a best model for forecasting volatility. There is an improvement shown in predicting gold price with high precision when compared to the conventional forecasting method. The proposed novel method effectively forecasts the current gold price and future price by determining the financial variables. The results clearly explains that enhanced ANFIS-GARCH model improves the forecasting results compared to GARCH, ARIMA and MLR model for current gold price volatility. It shows that ANFIS-GARCH model improves the forecast results as compared with that of ARIMA model. So it is concluded that the enhanced ANFIS-GARCH model is effective for the prediction of gold price. Hence, the alternative hypothesis gets accepted and null hypothesis gets rejected.

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