Gold Price Forecasting Using Machine Learning Techniques: Review of a Decade

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Gold Price Forecasting Using Machine Learning Techniques: Review of a Decade

Saumendra Das, Janmenjoy Nayak, B. Kamesh Rao, Kanithi Vakula, and Ashanta Ranjan Routray

Abstract Price of the gold plays a major role in monetary as well as financial systems. Prediction and forecasting the upcoming tendency of gold prices and other valuable metals will be helpful for investors and money managers to evade choosing when to supply this commodity. Central banks throughout the globe uphold gold reserves to assure the currency holders, the money of their shareholders, and foreign-debt creditors. They also utilize the gold treasury as a means to manage inflation and toughen their country's economic standing. During this procedure, the prediction of the gold rate has become the biggest issue now a days. So, various methods, especially intelligent techniques, have played a vital role in predicting gold prices. Moreover, a comparative investigation on the impact of machine learning (ML) algorithms such as support vector machine (SVM), random forest (RF), linear regression (LR), decision tree (DT), and other hybrid methods for gold price forecasting has been made. Some significant research directions for additional research on gold price prediction are highlighted which may assist the researchers to widen proficient intelligent techniques for the prediction of gold rate.

Keywords Forecasting · Gold price · Machine learning

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1 Introduction

All over history, nearly all recognized culture has utilized gold to represent beauty, purity, power, and achievement. Today we persist to utilize gold for our most important objects such as money, awards, wedding rings, Olympic medals, and crucifixes. No further substance of the equal rarity seizes a more perceptible and major role in our society. It has been exploited as a means of money or exchange due to its extremely limited supply as well as high value. Previous transactions were made with pieces of silver or gold. The infrequency, desirability, and value of gold make it a matter of lasting value. For a modern year, there is an outstanding raise in investor concern in gold. This is because of the insecurity of flat money worth and the augmented tendency of a gold rate. Due to the exclusive dealing and hedging functions of the earlier metal market, particularly from the economical crisis of 2008, the global interest in precious metals has augmented to a new height. Gold is a type of valuable metal enhanced by mankind. It became an international currency for the outstanding position of domestic prevalence when global financial activities have become more extensive. Gold plays a vital role in the financial enhancement and social constancy of individual society by its well-known characteristics. As a tough currency as well as valuable metal, gold has been attracted a lot of awareness for its function as assessed value, means of storage, circulation, payment and many more. Most of the owners of gold store it in a variety of bars or bullion coins as a hedge against a rise or additional financial disturbances. So, the prediction of the gold rate becomes a significant tool to assist the investor in choosing the correct time to sell or buy the gold transactions. Forecasting of the gold price is a broadly discovered area, motivating small and large-scale investors as well as numerous global organizations. During the year 2008 economical crisis, various equities fall by more than 40% and also several key mineral product rates fell while the price of gold increased by 6%. Early investigations have stated that the production of gold is strongly influenced by alterations in its cost and all these cases like the value of gold and the result of gold rate on other financial activities [1] remind the significance of rate forecasting. Price forecasting is an essential part of financial decision-making. Forecasting gold is becoming ever more vital in the twentieth century. Gold has been operated vigorously on international markets. Various gold trading derivatives in worldwide gold markets are also operated, such as gold options, gold futures, forward contracts, and many more. Surprisingly, since the cost of gold differs in an inadequate range, gold is capable of decreasing the result of inflation, managing the increase of cost, and aid carrying out constructive monetary policy. So, gold becomes an imperative device for risk equivocation and a savings avenue. As a result, forecasting the gold price turned out to be very important for investors. However, factors that result in the cost of gold are various and difficult. It is not simple to forecast the price of gold precisely. Scholars have made many investigations on the forecasting of gold prices and also have produced many outstanding research outcomes.

Forecasts can be utilized in many ways; particularly, persons may exploit forecasts to aim to make profits from tentative activities, verify optimal administration strategies, or create business decisions. Similar to any additional goods, the price of gold rely on supply as well as demand. Gold is storable and the supply is collected over centuries. The spot rate is the present market cost at which a product is acquired or traded for instant payment and delivery. It is distinguished from the upcoming prices, which is the value at which both the parties have the same opinion to carry out on a future date. Gold spot prices are determined twofold a day by supply and demand in the gold market. Fractional alteration in the gold rate can result in vast profits or losses for these government banks and investors. Prediction increment and decrement in the daily gold prices may assist investors to make a decision when to get the product. Many investigations have been made by researchers to predict gold prices. For the last 10 years, the gold price is determined by features like the British pound, the frequently weakening US dollar, the worldwide credit crunch, soaring demand from institutional investors and Central Banks, political unrest, terror attacks, and many more. Similarly, there are other intelligent methods such as machine learning (ML) [2], deep learning (DL) [3], and ensemble learning (EL) [4] that can also use for forecasting gold prices to provide exact and statistically important forecasts for the gold price respectively. ML is a kind of artificial intelligence (AI) that permits applications of software to become more precise at predicting results. Algorithms of ML utilize historical information as input to forecast the latest output rates. For the qualitative prediction of gold rate, many forecasting techniques have been urbanized such as the gray model, time series analysis, and regression model [5]. ML techniques play a vital role in predicting the price of gold. Various techniques such as support vector machine (SVM), random forest (RF), decision tree (DT), logistic regression (LR), and many more were used in previous studies to predict the gold rate and found accurate results. Wen et al. [6] have introduced a method of multi-scale instability study by using SVM techniques and outperformed better results in predicting gold price. Navin and Vadivu [7] have developed a model for forecasting gold rates based on support vector regression (SVR) and decision tree (DT) and found that SVR is the best method for the huge quantity of the dataset and DT for the attribute selection, respectively. Weng et al. [8] have proposed a new extreme learning machine algorithm (GA-ROSELM) to forecast the gold price that is gathered from various public websites.

In this paper, a deep analysis of various ML methods used for gold price prediction has been explored clearly. The main focus relied on support vector machines, linear regression, random forest, KNN, etc. for intelligent forecasting of gold prices. The rest of the sections of this paper is divided into the following sections: Section 2 describes the various methods of ML techniques that are used for gold price forecasting. Critical analysis has been clarified in brief (Sect. 3) along with detailed discussions in Sect. 4. Finally, Sect. 5 concludes by providing significant future directions.

2 Literature Survey

Gold has always taken the main place in the country's financial systems, and amid populations. Owing to its uniqueness, it is used as a prevarication tool or acts as a secure haven in chaotic circumstances. The literature has been highly focused due to the high attention of not only academicians or scientists but also governments as well as investors toward the expensive metal. Many ML techniques have been used for predicting gold prices accurately. A few of them are mentioned below.

2.1 Support Vector Machine (SVM)

SVM is a classification technique. In this, the data item can be plotted as a point in n-dimensional space with the value of every attribute being the value of an exacting coordinate. SVM has played a major role in predicting gold prices. Raghuram [2] has introduced a method to predict prices of gold with stock market files by combining ML as well as statistical forecasting techniques. The authors have tried to contrast two prediction techniques to forecast the price of gold with SVM as well as regression. The required information has been collected from stock and international market indicators. It was found that the stock market indicator can be utilized as a better predictor for the gold rate. The proposed model attained a better accuracy rate by using different performance metrics. Onsumran et al. [9] have focused on the text mining advance of gold costs volatility technique. The technique was enhanced to assess how the articles have manipulated gold price instability. The chosen news article resources have provided various financial indicators like Bill Auction, Redbook index, Retail Sales, market manufacturing PMI, financial activity, and many more. The authors have used SVM as well as chi-squared statistic methods and other two classification techniques like K-nearest neighbor (KNN) and naïve Bayes (NB) to predict the accuracy of weighting approaches. SVM was found to be a better method out of all compared methods with an accuracy rate of 87.52% and stood as a superior technique in the view of both the classifier and attributes weighting advance. Some other important applications are mentioned in Table 1.

2.2 Linear Regression (LR)

LR is utilized to assess real values that rely on continuous variables. LR is used to establish a relationship among dependent as well as independent variables by fitting an appropriate solution. LR remained a favorite choice for gold price prediction. Bingol et al. [10] have introduced an approach to surveying the relationship of the gold rate with several descriptive variables that tend to be measured as signs of geopolitical and economical disasters. The study has surveyed the probability of

Table 1 Results of other SVM methods for gold price prediction

S no.	Application area	Method	Year	Results	References
1	Prediction	SVM, ARIMA	2020	SVM model outperformed better compared to other regression models	Makala and Li [10]
2	Prediction	SVM, KNN, DT, LR	2018	SVM and KNN algorithms have given an acceptable performances	Al-Dhuraibi and Ali [11]
3	Prediction	SVM	2018	SVMs perform better than ANNs in predicting the gold price	Wen et al. [6]
4	Prediction	SVM and LR	2013	SVM and LR have gained significant profitability	Potoski [12]
5	Forecasting	SVM, ARMA, ANFIS	2009	The projected methods were found to be the powerful tools to model the discharge time series	Wang et al. [13]

forecasting gold rates. The authors have used four various ML algorithms, such as LR, SVM, vector autoregression model (VAR), and autoregression integrated moving average (ARIMA), and found that LR has the highest scoring algorithm and ARIMA as the lowest scoring algorithm. Sekar et al. [14] have proposed a multi-variable linear regression model for the prediction of gold commodity with the removal of uncertainty. It is majorly helpful toward the importance of understanding the investments in gold (especially during fluctuation time). By the consideration of five years of data, they simulated the developed model and proved it as an efficient predictor of gold price. Some other major applications are mentioned in Table 2.

2.3 Support Vector Regression (SVR)

SVR uses a similar principle as SVM for the problems of regression. SVR, which is a part of SVM, can be applied to resolve the problems of regression as well as other related prediction problems. Suranart et al. [18] have made a study to analyze the evaluation of gold price prediction with SVR, neural network (NN), and radial basis function network (RNFN). All these three methods were learning techniques

Table 2 Results of other LR models for gold price prediction

S no.	Application area	Method	Year	Results	References
1	Prediction	LR, RFR, GBR	2020	Random forest regression (RFR) was found to have better prediction accuracy followed by GBR	Manjula and Karthikeyan [4]
2	Prediction	LR, ANN	2017	LR was found to have a faster training time compared to ANN	Sami and Junejo [15]
3	Prediction	LR	2017	The experimental results gave the predicted future values of the commodities	Sekar et al. [16]
4	Forecasting	MLR	2009	Achieved a high level of predictive accuracy	Ismail et al. [17]

by using the factors of short-term prices of gold. This study has made to analyze the tendency of the gold rate and also helped to choose to acquire gold and map the saving plan that the gold will make. This is made for entrepreneurs, financiers, and speculators who do dealings about gold. The details of gold rate analysis will be intended for accuracy by the divergence, the whole average value, average error (AE), average squared error (ASE), and the absolute average error value (AAEV). Dubey [19] has proposed a method for gold price prediction with SVR as well as adaptive neural fuzzy inference systems (ANFIS) techniques. SVM was developed with the epsilon SVR technique and ANFIS was enhanced with clustering and grid partition techniques. The authors have used various performance metrics such as mean absolute percentage error (MAPE), mean absolute error (MAE), root mean square error (RMSE), and Nash–Sutcliffe model efficiency coefficient (E). It was found that the methods acquired with SVR have outperformed the ANFIS models. Some more applications along with results were mentioned in Table 3.

2.4 Random Forest (RF)

RF is an ensemble method for a group of DTs. It consists of a collection of DTs, where the average prediction of each tree is used to predict the output. Many researchers have used RF for the prediction of the gold rate, which also played a significant role. Liu and Li [24] have used the RF method to predict the tendency of fluctuations of the gold rate. Based on real-world information, the authors have made extensive

Table 3 Results of other SVR models for gold price prediction

S no.	Application area	Method	Year	Results	References
1	Forecasting	SVR	2020	The proposed model adheres closer to gold price evolution than ordinary least square regression	Plakandaras et al. [20]
2	Prediction	SVR, linear regression (LR), RF	2020	LR method was found as a suitable method to predict the future gold price	Sekar et al. [14]
3	Forecasting	SVR	2019	DWT-SVR has obtained the best economic outcome and highest statistical accuracy of all alternative forecasting models	Risse [21]
4	Prediction	SVR, ANFIS	2016	SVR method had better prediction ability	Dubey [19]
5	Forecasting	DT and SVR	2015	DT found to have less mean square error than the SVM	Navin [7]
6	Forecasting	NN, SVR, RBFN	2014	SVR was found to have highest prediction rate	Suranart et al. [18]
7	Prediction	Wavelet transform (WT) and empirical mode decomposition (EMD) using SVR	2012	EMD has more accurate prediction than WT	Jian-Hui and Wei [22]
8	Prediction	SVR, DT	2003	Combination of the decision tree and SVR got better performance	Ongsritrakul and Nuanwan [23]

experiments. The proposed experiment has attained a high forecast rate that signified data mining as a dominant technique to forecast the trends of rising or fall of the gold price. RF has strong compliance with difficult data and has high accuracy. The outperformed results proved that the grouping of Standard & Poor's 500 Index (S&P500) and Dow Jones Industrial Average (DJIA) exposed a positive capacity in forecasting the tendency of gold price. Pierdzioch and Risse [25] have proposed a multivariate random forest-based prediction model to predict the rates of gold, silver along with other two precious metals. With the comparison of single and multivariate

random forest techniques, the proposed model can predict the accurate price of these metals with a greater prediction rate.

2.5 K-Nearest Neighbor

KNN is a simple algorithm and can be applied for both regressions as well as classification problems. The simpler algorithmic steps of K-means allow for greater use in solving all kinds of real-life problems. Al-Dhuraibi and Ali [11] have used classification methods to forecast the gold price. Prediction of gold rate is important in major fields such as political, economical, trading, and investment surroundings. Better investment assessment could be completed when the value of gold rates is exactly forecasted. The major aim of the author's proposed method is to predict if the gold will increase or decrease in the upcoming future. Various classification algorithms such as DT, SVM, KNN, as well as LR have been used to forecast gold price prediction. The authors have used the Rapid miner software to evaluate the performance of chosen algorithms. KNN among all algorithms found better performance.

2.6 Others

Apart from general ML techniques such as SVM, DT, RF, etc., there are some other methods such as hybrid techniques, advanced ML models, and many more that showcased their efficiency during the prediction of gold price and are mentioned in Table 4.

3 Critical Analysis

In this paper, thorough investigations are being made on the use and applications of ML algorithms for predicting gold prices. Various ML algorithms such as SVM, RF, LR, SVR, DT, and many more have been considered for the gold price prediction. It is quite clear to note that many ML algorithms have shown their efficiency for predicting gold prices accurately. In this current study, several ML algorithms single-handedly as well as with the combination of other methods have been used to predict the present as well as future gold rate. Literature indicated that most of the methods are being enhanced by SVM, LR, SVR, DT, and RF. Apart from these, many other methods are being enlarged in the combination of more than one ML technique. The papers are considered from different popular databases such as Springer, IEEE Explore, Science Direct, Google Scholar, etc. based on keyword search, and approximately most of the applications in ML techniques are covered.

Table 4 Results of other ML models for gold price prediction

S no.	Application area	Method	Year	Results	References
1	Forecasting	Genetic algorithm regularization online extreme learning machine (GA-ROSELM)	2020	GA-ROSELM performed better than ARIMA, SVM, BP, ELM	Weng et al. [8]
2	Prediction	Independent component analysis (ICA) and gate recurrent unit neural network (GRUNN)	2019	ICA-GRUNN provides prediction with high accuracy, and outperformed ARIMA, RBFNN, LSTM, ICA-LSTM and GRUNN	Jianwei et al. [26]
3	Prediction	Gradient boosting machine (GBM) and XGBoost	2018	XGBoost attained high accuracy compared to GBM	Røine and Holter [27]
4	Forecasting	Least squares support vector machine	2018	It was found to have higher accuracy and is more efficient method for predicting price of gold price	Yang [28]
5	Forecasting	Multilayer perceptron (MLP)	2019	The results specified the predictor variables' high capacity to estimate future gold price instability	Alameer et al. [29]
6	Prediction	MLP and learning financial agent-based simulation (L-FABS)	2020	Found better accuracy	Neri [30]
7	Prediction	ANFIS, ANN	2013	The ANFIS and ANN methods are both powerful tools for modeling the gold price and ANFIS is a little better and robust than ANN	KangaraniFarahani and Mehralian [31]

(continued)

Table 4 (continued)

S no.	Application area	Method	Year	Results	References
8	Forecasting	MLP, ANFIS	2018	The proposed method outperformed both traditional as well as modern forecasting techniques	Hafezi and Amir [32]
9	Forecasting	ANFIS	2012	ANFIS model outperforms better than other models	Yazdani-Chamzini et al. [33]
10	Prediction	MLP	2002	MLP neural networks improve the forecasting ability of the models	Fathian and Kia [34]
11	Forecasting	Autoregressive integrated moving average (ARIMA) and generalized autoregressive conditional heteroskedatic (GARCH)	2016	ARIMA-GARCH has improved the estimating and forecasting accuracy	Yaziz et al. [5]
12	Prediction	Gray prediction model	2017	The projected model has achieved better precision rate	Zhu and Dong [35]

3.1 Performance Analysis of Different Machine Learning Techniques

From the systematic review, it has been cleared that various researchers have used several ML approaches in the prediction of gold prices. Mostly, SVM, LR, and SVR amid the obtainable ML approaches have been utilized more in the prediction of gold price. As SVM is the finest classifier algorithm with a better accuracy rate, it provides the best prediction outcomes. The performance analysis of various ML techniques for predicting gold price has been mentioned in Table 5.

3.2 Popular ML Methods

As our major aim of research work was on developments and usage levels of the ML approach for predicting gold price, in our survey, we analyzed the overall usage levels of ML for predicting the price of gold, and the obtained outcomes have been depicted in Fig. 1.

Table 5 Performance analysis of several ML techniques in gold price prediction

Month and year	Method	Evolution criteria	Accuracy	References
June, 2019	Decomposing wavelet-support vector regression (DWT-SVR)	Accuracy	93%	Risse [21]
January, 2019	MLP, whale optimization algorithm-NN (WOA-NN)	Root mean square error (RMSE), MSE	99%	Alameer et al. [29]
August, 2019	Independent component analysis (ICA) and gate recurrent unit neural network (GRUNN)	Mean absolute deviation (MAD), RMSE, and the mean absolute percentage error (MAPE)	NA	Jianwei et al. [26]
January, 2020	Genetic algorithm regularization online extreme learning machine (GA-ROSELM)	RMSE, MAPE, MAE, MSE, MAD, MDE	NA	Weng et al. [8]
May, 2019	MLP, L-FABS	MAPE	NA	Neri [30]
August, 2013	ANFIS	RMSE, percentage error, mean tendency error (MTE)	NA	KangaraniFarahani and Mehralian [31]
December, 2018	MLP, ANFIS	RMSE	NA	Hafezi and Akhavan [32]
April, 2020	SVM	Accuracy, recall, and precision	60%	Raghuram [2]
March, 2012	ANFIS and ARIMA	RMSE, MAE	NA	Yazdani-Chamzini et al. [33]
April, 2020	Gray prediction model	MAPE	NA	Zhu and Dong [35]
October, 2020	LR, RFR, GBR	MSE, RMSE, MAE, accuracy	95%	Manjula and Karthikeyan [4]
November, 2015	SVM, KNN, and naïve Bayes	Accuracy	SVM—87.52% KNN—85.57% NB—76.60%	Onsumran et al. [9]
June, 2018	SVM, KNN, DT, LR	Precision, recall	Precision—100% Recall—73.49%	Al-Dhuraibi and Ali [11]

(continued)

Table 5 (continued)

Month and year	Method	Evolution criteria	Accuracy	References
August, 2003	SVR, LR, NN	MSE, MAD, MAPE	NA	Ongsritrakul and Soonthornphisaj [23]
January, 2016	SVR, ANFIS	RMSE, MAE, MAPE	99%	Dubey [19]
September, 2020	LR, SVM, VAR, ARIMA	R-squared, MAE, RMSE	73%	Makala and Li [10]
December, 2018	XGBoost, GBM	MAE, RMSE	NA	Røine and Holter [27]

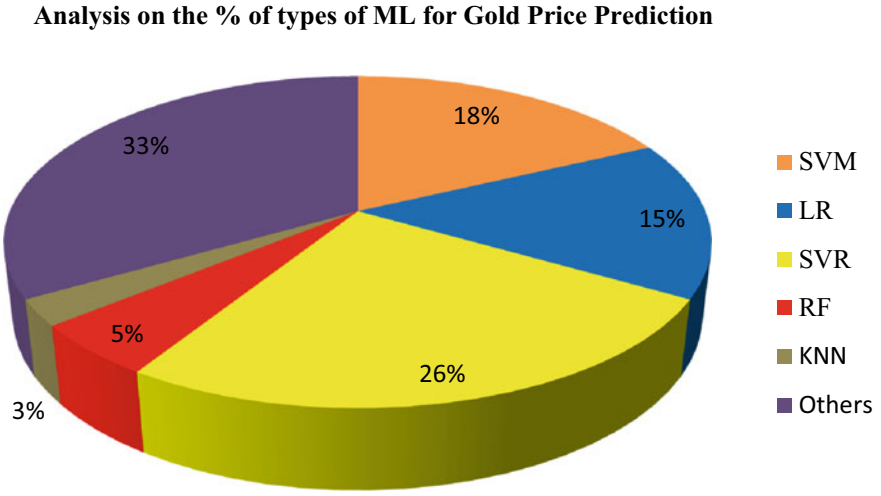

Fig. 1 Analysis of types of ML methods for gold price forecasting

Here, SVR among SVM, RF, KNN, SVR, and LR got the majority of the accuracy rate and is placed the highest ML technique in predicting gold price, followed by SVM. On the other hand, KNN is the lowest ML technique in forecasting gold prices.

3.2.1 Other ML Methods

Apart from SVM, LR, RF, KNN, SVR, and DT methods, some other machine learning techniques such as genetic algorithm regularization online extreme learning machine, ICA-GRUNN, least squares support vector machine, MLP, L-FABS, ANFIS, ARIMA, GARCH, gray prediction model, and many more have been showing their efficacy in predicting the gold price, and their analysis has been depicted clearly in Fig. 2.

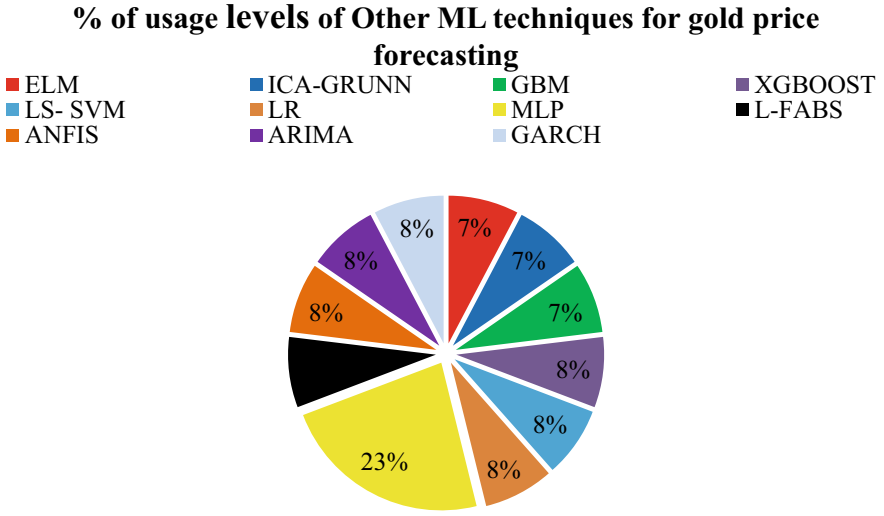

Fig. 2 Usage levels of ML methods for gold price forecasting

3.3 Analysis on Publications of Articles Related to Gold Price Prediction and Forecasting

The majority of the researchers have made their research on the prediction and forecasting of the gold price using various ML as well as DL techniques. Out of all our articles, we found most researchers have published a prediction of gold price followed by gold price forecasting. In this section, we divided prediction as well as forecasting-based articles and calculated the frequency of their publications accordingly. From our deep analysis, we got 57% of the articles to belong to the prediction of gold rates and 43% of articles to belong to the forecasting of gold rate. That means, most of the researchers have focused on predicting the price than forecasting it. This study has been depicted in Fig. 3.

4 Discussion

In this study, we made a deep analysis using various ML techniques for predicting the price of gold. As the prediction of gold has become a major issue nowadays, the improvement of proper prediction models for gold is playing a vital role these days. This current study concentrated on an analysis of ML methods for gold price forecasting. Till now, ML has showcased its efficacy for better understanding as well as forecasting of the gold price. There have been several types of research completed in the past to learn about the dealings of the results of the cost of the gold, which consist of the open interest, index rate of the customers of the USA and EU (US CPI

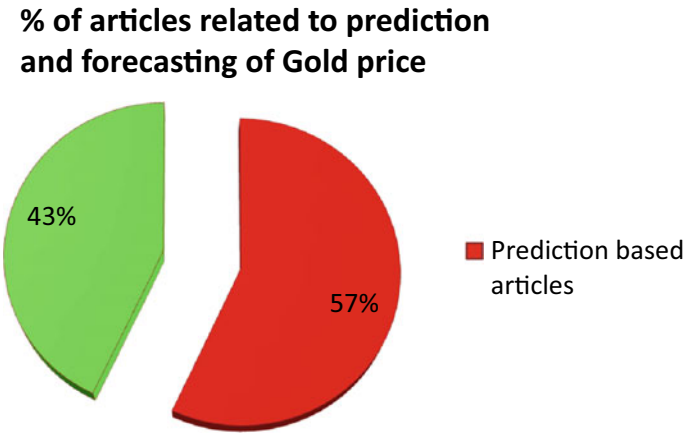

Fig. 3 Articles related to the gold price for prediction and forecasting

and EURO CPI), and the trade rate of Euros or dollars [1]. There are many examples of research made for forecasting the price of gold, such as examining the trend of the gold rate [36], resembling the tendency of the gold price in the upcoming by utilizing the difficult regression techniques [37], and forecasting the gold rate with SVM [38]. New techniques for exactly predicting the long-term gold rate fluctuations were projected in [29] by using a modern meta-heuristic technique known as whale optimization algorithm (WOA) to train the MLP. Some hybrid techniques on the forecasting of time series along with their applications for the gold rate prediction and estimation were proposed in [26] by combining ICA as well as GRUNN, respectively. Similarly, the majority of the researchers have made their investigation in gold price forecasting by using advanced ML techniques such as ensemble-based ML methods for gold price prediction [4], multiple linear regression models for predicting gold rate [17], ESMD multi-frequency grouping method for predicting gold price [28], and some other hybrid ARIMA-GARCH techniques in gold price forecasting [35], etc. Till now research is only limited to forecasting as well as prediction, but many other fields are there to perceive and make an advanced study.

5 Conclusion

The researchers are always energetic in mentioning the rising confronts that happen in various application fields. In this current study, a complete summary of current work in the gold price forecast by using various ML techniques has been presented. Initially, the significance of gold and the impact of ML methods in predicting gold prices have been detailed. As ML techniques are effective approaches to predict results in an enhanced manner, the majority of the researchers have shown their interest in choosing ML. Following this, the study is widened by making a critical survey on

the development of studies carried on gold price prediction and the performance of various ML approaches. Finally, at the end of the article, a few key points observed in various other research works have been detailed in the discussion and a division of systematic review is highlighted that may help the researchers and to expand more exact prediction models in the prediction of gold rate. This study is apparent that the ML methods have always been a prominent choice to predict or forecast the gold price. This paper mainly focuses on various kinds of ML techniques that use for forecasting gold rates along with their performance analysis. The major aim of this current research has concentrated on the various ML techniques utilized for gold price prediction. Section 2 is the evidence that ML has enormous popularity and it has received attention from various researchers.

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