International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2019): 7.583

Prediction of the Repo Rate of India Using Artificial Neural Network

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Abstract: ***REPO signifies "Re-Purchase Option", a variable benchmark through which the Reserve Bank of India lends money to other financial institutions – majorly banks. Financial institutions, in the time of liquidity crunch, can borrow from RBI against their pledged securities to overcome such crises. Banks further use repo rate as a measure to decide their lending rate (Rate of Interest on loans). Repo rate is used by monetary authorities to control inflation. It is very important to estimate the repo rate as it is a very important tool for the Reserve Bank of India (RBI) to control inflation trends. Raising or cutting the rates by the RBI will make borrowing more expensive or cheaper for commercial banks. This paper aims to predict the Repo Rate (Interest Rate) of India, where the input data set (predictors) consists of the Crude oil pricein Indian Rupee (INR), Dollar price in INR, Gold price in INR and Bank rate of RBI India. As a data set, daily price and index values were used between January, 2015 to September, 2020 period. An Artificial Neural Network (ANN) with Regression to Multilayer Perceptron (MLP) in Keras is used to predict the repo rate.***

Keywords: Artificial Neural Network (ANN), Keras, Multilayer Perceptron (MLP), Repo Rate

1. Introduction

In the dynamic global economy, the accuracy in forecasting the Repo Rate is of crucial importance for any future investment. The use of computational intelligence-based techniques for forecasting Bank Interest rates has been proved extremely successful in recent times. The aim of this study is to design a neural network-based model using Keras which has ability to predict the Repo Rate with higher accuracy level.

Price stability is a prerequisite in providing momentum for sustainable economic growth. Price control becomes very important in the economy because it determines the welfare of the society not only from the economic aspect but also political and social aspect. Real income of the society continuously declines due to high inflation. Thus, resulting in low standard of living and poverty. Unstable inflation also creates uncertainty for economic agents in making decisions. Therefore, Predicting Repo Rate becomes important because price stability is one of the main prerequisites for maintaining overall economic stability.

The purpose of this paper is to predict the Repo Rate (Interest Rate) of India, where the input data set (predictors) consists of Crude Oil Price, Dollar Price, Gold Price and the Bank rate of Reserve Bank of India (RBI). There is a dynamic relationship between gold price, US Dollar Price, Crude Oil price and Bank Rates. All these variables have witnessed significant changes over time and hence, it is absolutely necessary to validate the relationship periodically.

An Artificial Neural Network (ANN) with Keras is built in this research study with 10 layered perceptron. Keras is a compact and easy to learn high level python library that runs on the top of TensorFlow. It allows developers to focus on the main concepts of deep learning, such as creating layers for neural networks, while taking care of the nitty-gritty details of tensors, their shapes, and their mathematical details [1]. The Logistic Regression Model is used in order to tune the weight and bias in each iteration keeping an aim of minimization of the loss functions.

2. Literature Review

This paper is basically focused on the factors like exchange rate of US dollar with INR, Crude oil price, gold price and bank interest rates in India. Each of the factors is studied with the repo rate of India. The relationship between the factors and the repo rate is emphasized in this paper. According to Sindhu, there exists an inverse relation between the US Dollar and gold prices. The crude oil prices have an impact on the gold prices. Gold prices and repo rates are interdependent. Gold prices and inflation rates are also dependent and positively correlated [2].

It can be derived that as the repo rate increases the gold prices decreases. Because increase in repo rate reduces money in the economy which decreases the purchasing power of an individual. The inflation and gold rate are positively correlated with each other.

Crude oil prices and levels of inflation are often seen as being connected in a cause-and-effect relationship. As oil

prices move up, inflation which is the measure of general price trends throughout the economy, follows the same direction, higher. On the other hand, as the prices falls, inflationary pressure starts to ease. History shows that the two are indeed correlated, but the relationship has deteriorated since the oil spike of the 1970s [3].

Iftikhar ul Sami and Khurum Nazir Junejo predicted the price of gold using approximately 42 variables such as Oil Spot Price, Oil Future Price, Gold Spot Price, Gold Future Price, also economic factors (inflation, interest rate, etc.) are used and many other predictors. They used two ML models, namely neural networks, and linear regression. Neural networks also known as artificial neural networks (ANN) [4]. But as the authors are only predicting the gold price, they have considered the data from various countries and not only limited to just one.

Navin and Dr. G. Vadivu derived the gold rates with the attributes of gold itself. And study includes decision trees and support vector regression algorithms for predicting gold rates, but do not report any results [5].

Abd Wahab Nursu'aidah predicted monthly price of gold. The monthly sample data of gold price (in RM per ounce) were taken from January 2004 to November 2015. The model performance was evaluated in term of error magnitude (EM) and directional change error (DCE). The result of the study had suggested that the ANN model with LMBP algorithm had perform the best model compared to ARIMA model and another ANN model using RBP and SCGBP algorithm (Wahab,2016) [6].

Preeti Garg shows comparison of repo rate with other factors such as inflation, bank rate, CRR, etc. in an elaborated manner and her study shows a direct relation between the repo rate and bank rate. It's mostly from the perspective of economy of India, technical analysis for prediction of repo rate is not seen [7].

Anil Kumar and Prof. N.S Malik have researched the impact of 2 major economic factors i.e., repo rate and inflation on a commodity (gold). For this study, data from April 2009 to December 2014 is considered. During which daily prices of gold and other selected factors were considered and then converted into average monthly prices. The conclusion drawn is that both, inflation and repo rate do not affect the gold prices [8].

Liquid funds or cash funds, where investors flock for capital preservation and easy redemption, invest in short maturity instruments like commercial papers or bonds issued by companies. The market value of these instruments is affected by changes in yields on short tenure government securities or a change in the repo rate. Subsequently, the value of cash funds' portfolios, which invest in these instruments, is also affected. A rise in interest rate (or repo rate) results in a fall in prices of existing bonds and a fall in interest rates (or repo rate) leads to a rise in prices of existing bonds. Therefore, any reduction in the repo rate is likely to have a positive impact on cash funds also[9].

3. Proposed Methodology

In order to establish the quantitative relationship between Repo rate and price of crude oil, price of gold, US Dollar and bank rate, data was collected from various secondary sources for example, the official site of Government of India for Bank rates and repo rates. The prices of the corresponding dates were collected from the official site of 'The economic Times' Newspaper. The journals were referred to understand the relationship between price movements of Repo Rate and other predictors. In addition to usage of statistical packages the quantitative data was analysed through logistic regression analysis and trend analysis technique. The Artificial Neural Network (ANN) is then applied to predict the Repo rate. The research methodology used in this research is the secondary research or desk research that involves using already existing data. The existing data is summarized and collated to predict the repo rate of India. The data is collected from the official sites of government of India as well the information regarding the financial agencies from the internet. Section 4 explains the details of the Dataset, the relationship between the data values as well as the machine learning concepts used in this research paper.

4. Dataset

The gold prices, crude oil prices and the US dollar changes on daily basis. The repo rate is affected by world's major events. In this study, the dataset consists of the exchange rate of US Dollar in Indian rupees, the daily closing prices of Gold and Crude Oil, Bank Rate and Repo Rate released by the Reserve Bank of India spanning across the period of January 1, 2015 to September 4, 2020. The exchange rates of US Dollar in INR were obtained from investing.com [10]. Daily closing prices of gold and crude oil were obtained from www.mcxindia.comfrom the Commodity Wise Section. [11].

The data collected was verified and validated by checking the government-initiated websites. The data related to repo rates was collected from www.bankbazaar.com [12], but there were discrepancies in the historical data of repo rate. According to them the repo rate released on 7th August 2019 was 4.4, which was changed on 6th February 2020 to 5.15. But according to the official RBI press release, the repo rate was not changed on 6th February 2020 but on 4th October 2019 to 5.15 and then was changed next on 22nd May 2020.The final and correct repo rate data, later was obtained from the Monetary Policy Statements released at least 4 times in a year by the Reserve Bank of India[13].The source for the Bank Rate is same as the Repo Rate.The descriptive statistics of the data collected is summarized in Table 1.

Table 1: Descriptive statistics of Crude Oil, Dollar, Gold, Bank Rate and Repo Rate

	Crude Oil	Dollar	Gold	Bank Rate	Repo Rate
Count	1454	1454	1454	1454	1454
Mean	3489.8	67.91	31945.4	6.618	6.16
std	741.36	3.617	6125.82	1.077	0.845
min	937	61.36	24675	4.25	4
25%	3033	64.88	28458	6.25	6
50%	3399.5	67.14	30081	6.5	6.25

75%	3981.5	70.81	32140	7	6.5
max	5646	76.98	55845	9	8

The Timeseries graphs of prices of US Dollar, Gold Prices, Bank Rate of India, Crude Oil Prices and Repo Rate of India over a span of 5 years are depicted in the Figure 1 (a), 1(b), 1(c), 1(d) and 1(e) respectively. The graphs show the diverse nature of Data and their behaviour.

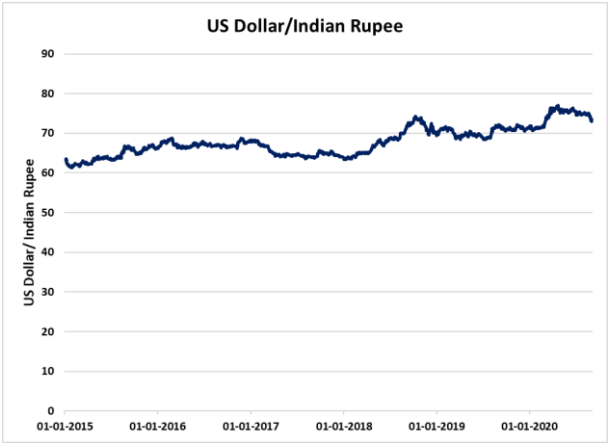


Figure 1(a): Time Series graph of USD

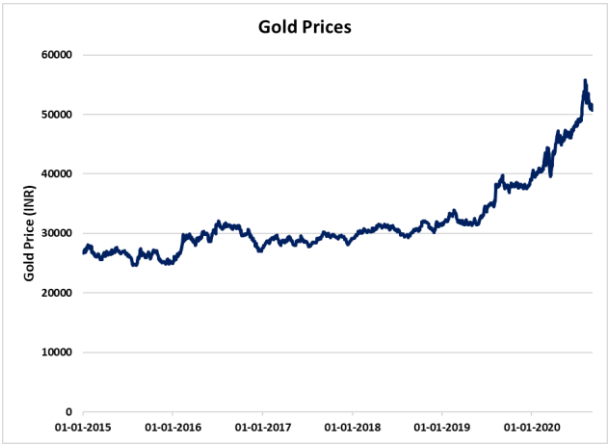


Figure 1(b): Time Series graph Gold Prices

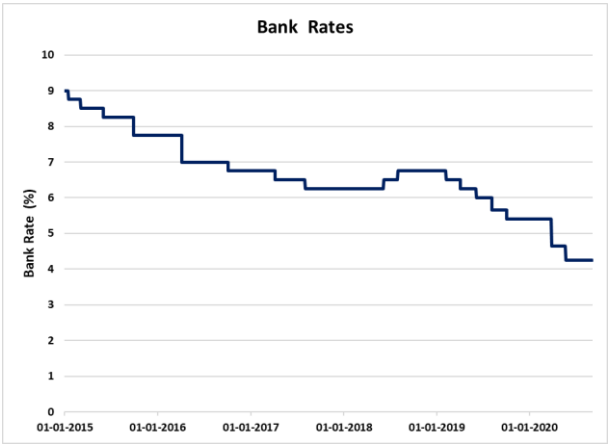


Figure 1(c): Time Series graph of Bank Rates

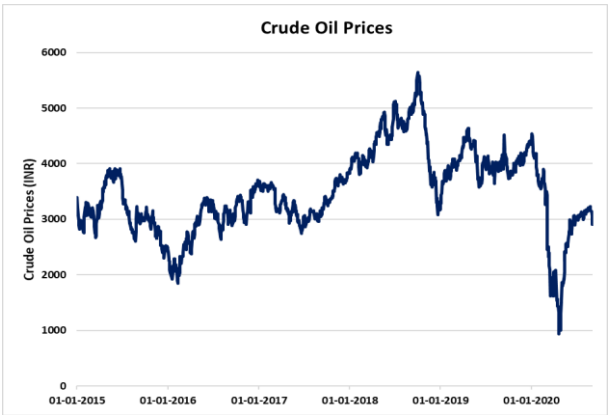


Figure 1(d): Time Series graph of Crude Oil Prices

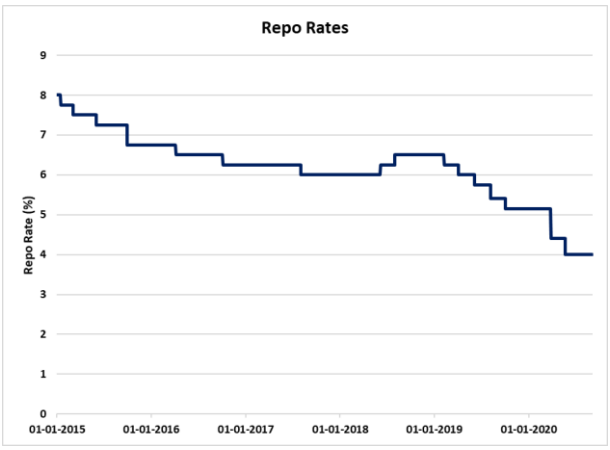


Figure 1(e): Time Series graph of Repo Rates

The correlation between the collected data is studied and the correlation among the predictors and the predicted variable are listed in Table 2.

Table 2: Correlation analysis of USD, Gold Rate, Repo Rate, Bank Rate and Crude Oil

	USD/INR	*Gold*	*Repo Rate*	*Bank Rate*	*Crude Oil*
USD/INR	1				
Gold	0.818	1			
Repo Rate	-0.748	-0.90	1		
Bank Rate	-0.729	-0.858	0.979	1	
Crude Oil	0.081	-0.054	0.0099	-0.115	1

The graphical presentation of the correlation relationship between the different predictors and repo rate is shown in Figure 2.

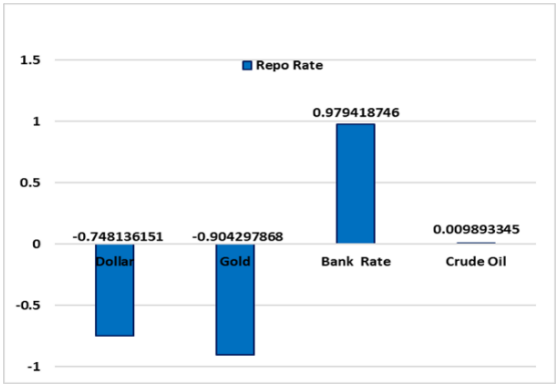


Figure 2: Correlation Graph for Repo Rate vs USD, Gold Rate, Bank Rate and Crude Oil

The trend analysis shown in Figure 3 is studied with the data collected and it is found that the crude oil price and inflation have important role in the gold market. There is a positive correlation between gold prices and crude oil prices. A negative and significant relationship is found between the returns of gold and US Dollar. There is inverse relationship between Gold price and Dollar value, positive correlation between Gold price and Crude oil price, Gold prices and repo rates are negatively correlated. The graphs in Figure 3(a), 3(b),3(c) and 3(d) clearly shows that the gold prices and repo rate are negatively correlated, similarly Crude oil and US dollar have a significant inverse relationship with the repo rate whereas bank rate and repo rate and positively correlated with each other. The data collected shows interesting characteristics as the predictors are also directly or inversely corelated related to other predictors.

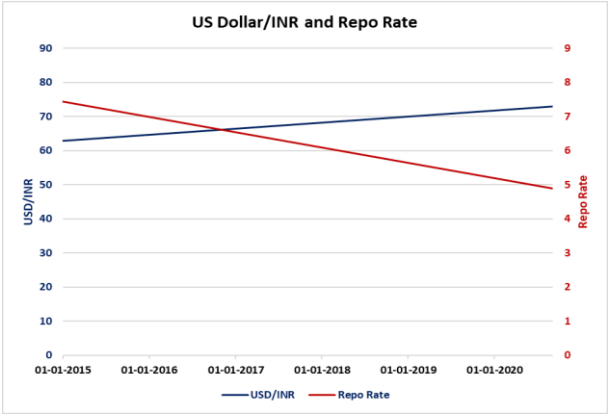


Figure 3 (a): Trend Analysis of USD/INR and Repo Rate

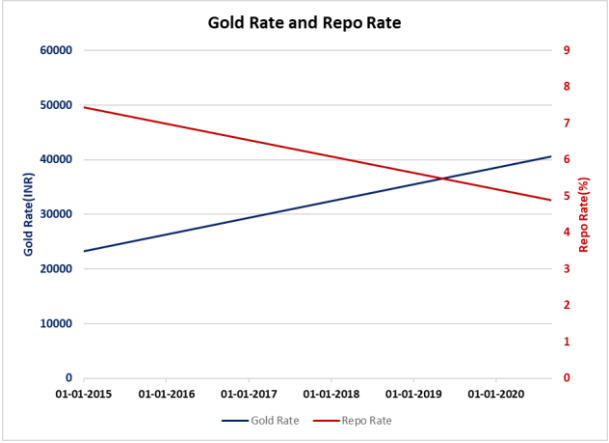


Figure 3 (b): Trend Analysis of Gold Rate and Repo Rate

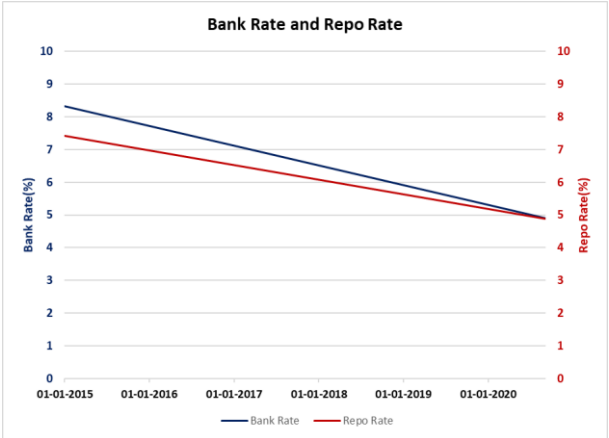


Figure 3 (c): Trend Analysis of Bank Rate and Repo Rate

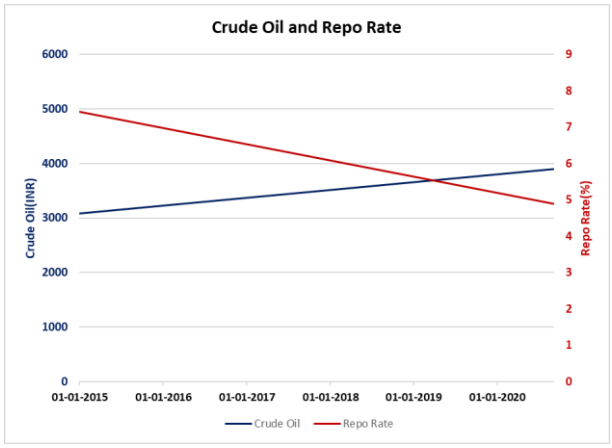


Figure 3 (d): Trend Analysis of Crude oil and Repo Rate

5. Machine learning Model

Artificial Neural Network: This paper used Multi-layer Neural Network (MLNN), which is an Artificial Neural Network (ANN) model as a prediction model. An ANN is a computational network (a system of nodes and the interconnection between nodes) inspired by biological networks, which are the complex networks of neurons in human brains. The nodes created in the ANN are supposedly programmed to behave like actual neurons, and hence they are artificial neurons [14]. Fig 4 below depicts the layers of ANN.

A multilayer perceptron model with 8 hidden layers is explained below:

a) **Input Layer:** The input layer consists four neurons representing financial factors responsible for predicting repo rate (dollar prices in INR, gold price in INR, bank rates and crude oil prices).
b) **Hidden Layer:** The 8 hidden layers contains 128, 1024, 2048, 1024, 512, 256, 128 and 16 neurons respectively. Batch Normalization is applied to each layer and the activation function used is 'ReLU', a non -linear activation function at each layer.
c) **Output Layer:** The output layer contains one neuron, representing the predicted value of the repo rate.

The difference between the predicted value and the true value of a machine learning model for a single sample is called loss. The smaller the loss, the better the model. If the predicted value is equal to the true value, there is no loss. Mean square error (MSE) is used in this paper to compute the regression loss function [15]. The MSE function as given in equation 1 calculated the sum of the squares of the distance between the predicted value and the true value.

$$MSE = \sum_{i=1}^{n} (y_i - y^p{}_i)^2$$

Equation 1: Mean square error (MSE)

To optimize the loss, the AdamOptimizer is used is this ANN, which is a popular optimizer along with others like Stochastic Gradient Descent and AdaGrad. Within AdamOptimizer(), one can optionally specify

the learning rate as a parameter.The value used in this ANN is 0.02. to get 95.732% result accuracy.

Keeping in view of the characteristic of the dataset, random sampling is considered for the training data set and test dataset. The trials were carried out with 10%, 20% and 25% test data. The complete dataset comprises of 1454 rows is taken. For 10% Test data randomly 1308 rows were considered for training data and 146 rows were considered for the test data. In 20% test data 1163 rows were considered for training data and 291 rows for test data and in 25 % test data 1090 rows were randomly selected as training data and 364 rows for test data. 95.732% accuracy is obtained by training 90% of the data as training set.

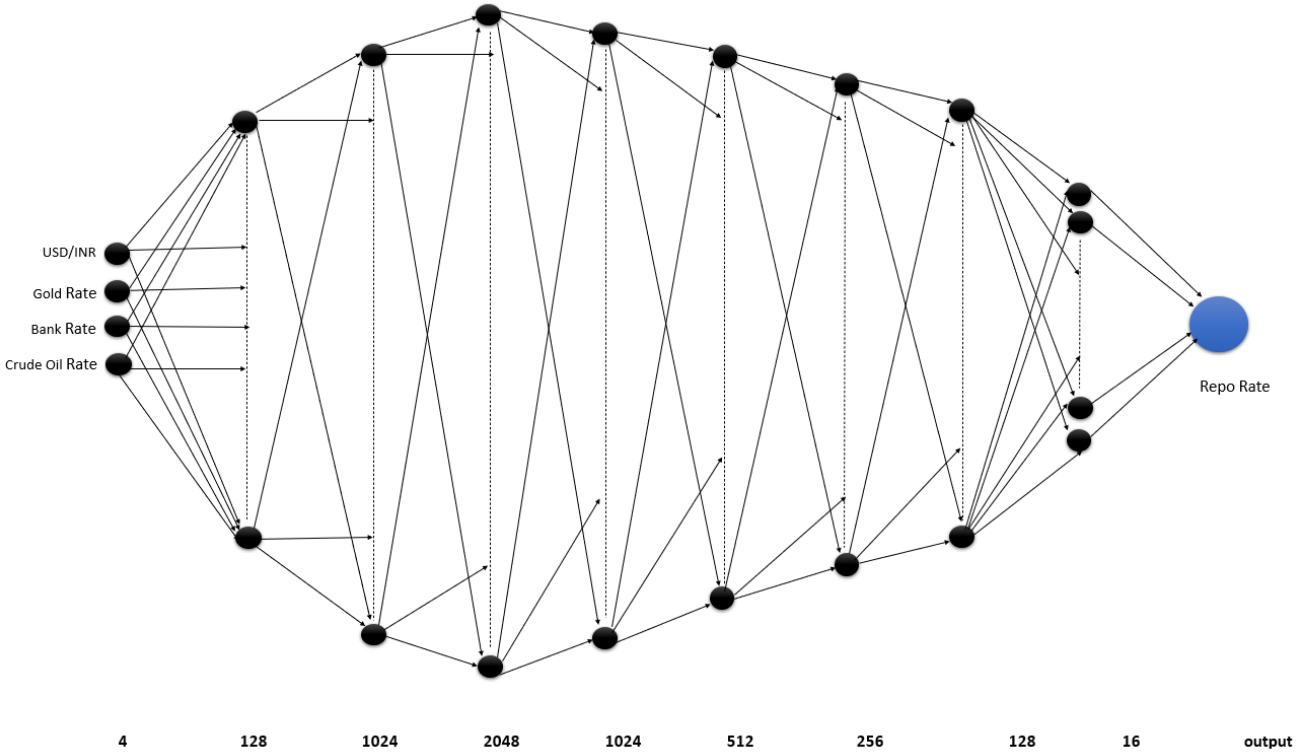
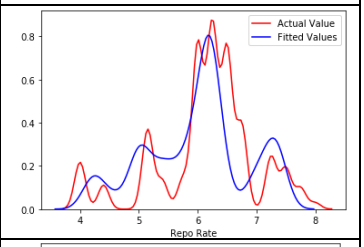
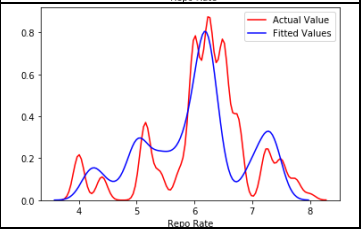


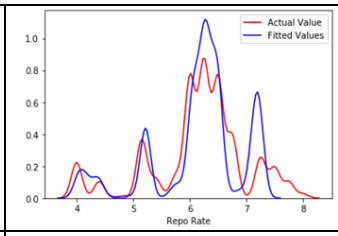
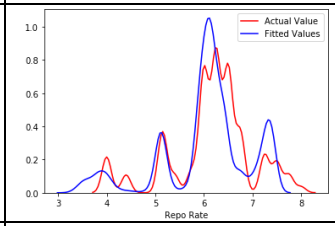
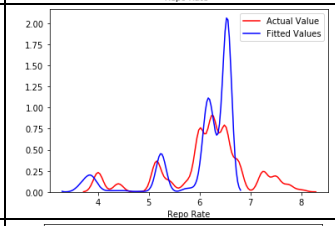
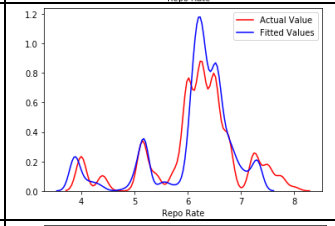
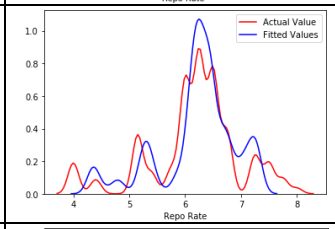
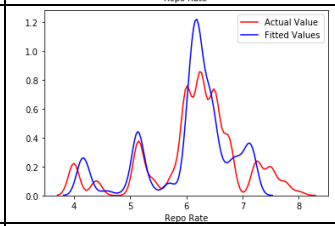
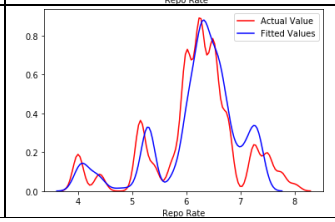
Figure 4: layers of ANN

6. Result and Findings

The results are shown in Table 3. Loss function used is the Mean Square Error (MSE) and to optimize the lossAdamOptimizer is used. The data set comprised of 1454 rows is tested with 10 %, 20% and 25% test data. On each dataset the test accuracy is calculated with 50, 70 and 100 epochs. The minimum loss value is .065043922 with maximum test accuracy of 95.732% with 10% test data and 100 epochs.

Table 3: Prediction Results

Sr. No.	Train Data	Test Data	Epochs	Loss	Actual Value	Predicted Value	Test Accuracy	
1.	1090	364(25%)	50	0.19759652	4.4	4.2837944	87.519%	
2.	1090	364(25%)	70	0.20001562	4.4	4.2040577	87.002%	

3.	1090	364(25%)	100	0.20573631	4.4	4.1955285	89.543%	
4.	1163	291	50	0.19759652	4.4	4.2837944	88.1132%	
5.	1163	291	70	0.1887234	4.4	3.891094	84.981%	
6.	1163	291	100	0.21533304	4.4	3.9651113	91.6178%	
7.	1308 (90%)	146 (10%)	50	0.20745462	4.4	4.537	93.651%	
8.	1308 (90%)	146 (10%)	70	0.1887432	4.4	4.3107047	94.231%	
9.	1308 (90%)	146 (10%)	100	.065043922	4.4	4.3863747	95.732%	

7. Conclusion

In the study, repo rate which are primarily used to control and regulate the available liquidity in India's economic system, was estimated using Artificial Neural Networks (ANN). ANN is used in the financial sector as well as in many areas because of their ease of design, rapid adaptation to probing and successful results in spite of a small number of donations. For estimating the future value of the dependent variable, the weekly values of the independent variables between 2015 and 2020 were used. As a result of the study, it is seen that there is a strong correlation between the repo rate and the input variables used in the study. Using the artificial neural network model, repo rate was estimated with a high success rate of 95.732%. In addition to the ANN model, other data mining methods can also be applied to get higher rate of precision.

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