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Predictive analysis of FDI inflow in India: A neural network approach

K Y Ingale[1], S V Bharati[2], P V Karale[3]
[1] Assistant Professor, Department of Statistics, Netaji Subhashchandra Bose College, Nanded, Maharashtra, India
[2] Research Scholar, Department of Statistics, SRTMUN, Nanded, Maharashtra, India
[3] Assistant Professor, College of Community Science, VNMKV, Parbhani, Maharashtra, India

Abstract
India is a promptly developing country which is often seen as an investment basement by the industry giants of foreign countries. The recent trends show an exponential increase in the net foreign direct investment in India from the year 2010-2023. Thus, prediction of the future inflows of Foreign Direct Investment (FDI) for the policy makers and the economist to design effective policies and take better decisions. The result of the better policies would help to deal the unbalanced market viability. NNAR modelling is a technique used in statistics and machine learning which harness the advantages of both Auto Regression (AR) and Neural Network (NN) models by integrating them together to form Neural Network Autoregressive model. The present study based on data regarding FDI inflow from 2001-2023 which aims to generate a customised said model for forecasting and analysing the trend of FDI in India. It proposes NNAR (2,2) model for optimal forecasting of net FDI inflow in India.

Keywords: Neural network, auto regression, machine learning, foreign direct investment

Introduction

One of the most striking developments during the last two decades is in the spectacular growth of FDI (Foreign Direct Investment) in the global economic landscape. Foreign direct investment (FDI) is an integral part of an open and effective international economic system and a major catalyst to development. Yet, the benefits of FDI do not accrue automatically and evenly across countries, sectors and local communities. National policies and the international investment architecture matter for attracting FDI to a larger number of developing countries and for reaping the full benefits of FDI for development.

In India role of FDI was first introduced by then finance minister Dr. Manmohan Singh in 1991 in the form of Foreign Exchange Management Act which lead to increase in the domestic capital cash inflows in the country and this will help in economic growth of the country. The importance of FDI has grown considerably in Indian economy day by day. After liberalization its role has changed significantly. Earlier the amount of FDI was low conforming to some selected sectors but now the inflow of FDI has grown tremendously and almost in all the sectors of the economy. The result of the better policies would help in overcoming the unbalanced market viability. NNAR modelling is a technique used in statistics and machine learning (ML) which harness the advantages of both Auto Regression (AR) and Neural Network (NN) models by integrating them together to form auto regression integrated moving average model. Researchers like Mohamad A. *et al* (2020) [8] utilized this model and customized it to forecast daily gold prices. The purpose of this paper is to use the NNAR method to predict the net FDI inflow in India. This research is expected to contribute to the development of the NN method combined with the statistical method because, in the process of identifying this method, there are also statistical methods such as the Partial Autocorrelation Function (PACF) calculation. This NNAR model was developed by R.J. Hyndman, and G. Athanasopoulos, (2019) [7]. The results of this study are expected to be able to predict accurate yearly FDI inflow using a large dataset.

Research Methodology

The forecasting method is a method that is designed based on the analysis of the relationship pattern between variables to be estimated with time variables, which are periodic series. Based on the nature of the data forecasting methods, there are two, namely qualitative and quantitative. There are two types of quantitative methods, namely time series models and causal models [7]. The time series method has experienced rapid development, not only probabilistic (statistical) models, but also non-probabilistic models such as Neural Networks (NN). NN models for forecasting include ELM, Multilayer Perceptron's (MLP), NNAR, and others. Similar methodology was adopted by D. Sena, & N.K. Nagwani (2016) [9] and L. Safitri, *et al.* (2018) [10] to forecast per capita disposable income and mortatlity rates of Indonesian population in their study.

A. Artificial Neural Network

Artificial Neural Network (ANN) is a method that was created to resemble neural networks in humans. This model is used to help human work in many fields, including image processing, some sensor tools in households, offices, hospitals, quantitative forecasting methods, and others. Broadly speaking, ANN consists of inputs, processes, and outputs. The multi hidden layer ANN model, between the input layer and output layer, is hidden by more than one hidden layer, so it is said to be a multi hidden layer ANN. In this study, we will use a hidden layer model, one hidden layer with three neurons and one output, as shown in Figure 1.

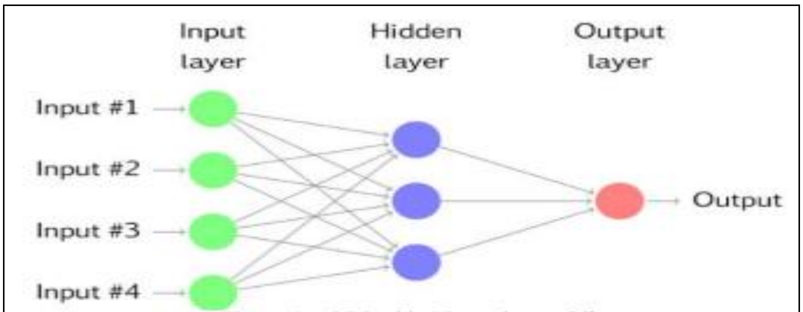

Figure 1. ANN with 4 input layers [6].

Fig 1

B. Model Back propagation

The back propagation model is an algorithmic model in artificial neural networks with supervised learning. This method is often used in the ANN algorithm for forecasting models. Training or learning using back propagation consists of three stages, namely feed forward (forward feed) from the input pattern, counting errors from the learning process, and adjusting the weights. This back propagation model, the input of each note is a weighted linear combination. The weighted linear combination results are modified with nonlinear function to be the output of this ANN. This linear combination function can be written as per R.J. Hyndman, and G. Athanasopoulos, (2019) [7]:

$$z_j = b_j + \sum_{i=1}^{4} w_{ij}\, x_i \qquad (1)$$

Where:
z_j a variable is the sum function of the unit bias to j on the hidden layer,
b_j a variable is a weight in the bias unit to j,
$x_{i,j}$ a variable is the weight of the layer i bias to j,
x_j a variable is the network input to i.
Its activation function is binary sigmoid, which is a nonlinear function as in Equation (2) [6]

$$S(Z) = \frac{1}{1+e^{-z}} \qquad (2)$$

The nonlinear binary sigmoid function is part of the linear combination function in Equation (1). This binary sigmoid function is one of the functions for the backpropagation algorithm in a single layer network model.

C. Neural Network Autoregression (NNAR)

The NNAR model is an ANN, where the input layer is just one variable input with the lag 1, lag 2, and so on models until lag to p, so it is called ANN Autoregressive (NNAR). NNAR was introduced by Hyndman and Athanasopoulos in 2018 with the application program R package program statistics in the "forecast" package with the net function. This model is only for feed forward networks in a single hidden-layer and is denoted by NNAR (p, k), where p denotes lag-p as input and k as notes in hidden layer. This the NNAR method uses a single hidden layer like in Figure 1 above and uses a nonlinear function as in Equation (1) to give weight and produce output from ANN. The activation function uses the binary sigmoid activation function as in Equation (2). This study uses the NNAR model (p, k) with the NNETAR function in R package statistics.

D. Partial Autocorrelation Function (PACF)

PACF or the so-called partial autocorrelation function is a function used to identify the order of autocorrelation on the laq to p. This PACF is written with Equation (3) [8]:

$$\hat{\emptyset}_{k+1,k+1} = \frac{\hat{p}_{k+1} - \sum_{j=1}^{k} \hat{\emptyset}_{kj}\, \hat{p}_{k+1-j}}{1 - \sum_{j=1}^{k} \hat{\emptyset}_{kj}\, \hat{p}_{k+1-j}} \qquad (3)$$

E. Performance Evaluation

To find out how accurate the forecasting is done, it can be evaluated by calculating the value of forecasting accuracy. Forecasting accuracy used in this study is the mean absolute square error (MASE), mean absolute percentage error (MAPE), and root mean square error (RMSE). The calculation of the three accuracy uses Equation (4-6).

$$MASE = \frac{\sum_{i=1}^{n} |e_i|^2}{n} \qquad (4)$$

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left|\frac{e_i}{y_i}\right| \qquad (5)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} e_i^2}{n}} \qquad (6)$$

Results and Discussion

This section summarizes the findings of the research. The first and foremost outcomes depicts the trend of the time series data. The data was observed as time series so it was fitted for autoregressive neural network modeling which resulted that the NNAR (2, 2) was found most suitable and best fitted among several NNAR models. Fig. 1. illustrates forecasted trend of FDI inflow in India by said candidate model. The partial autocorrlation function (PACF) graph depicted in the fig. 3 which shows the pattern the partial autocorrelation of residuals for said fitted model. The dataset was then used for training and testing purposes, divided into the ratio of 7:3 for generated the NNAR model. A range of p and q values were used for modeling to achieve the stability of the generated model. For the range of p and q values, a respective RMSE and MAPE score is computed. The minimum RMSE and MAPE scores was considered to select the optimal p and q values for further evaluations. Parameters obtained for optimal modelling of the time series data using NNAR method are as follows: p: 2; q: 2; The RMSE value is minimum among the others. Fig.2 shows the projected trend of FDI inflow in India for future period. After the model generation for NNAR (2,2), the forecasted values for the forthcoming years (2024-2030) are illustrated in the Table 1.

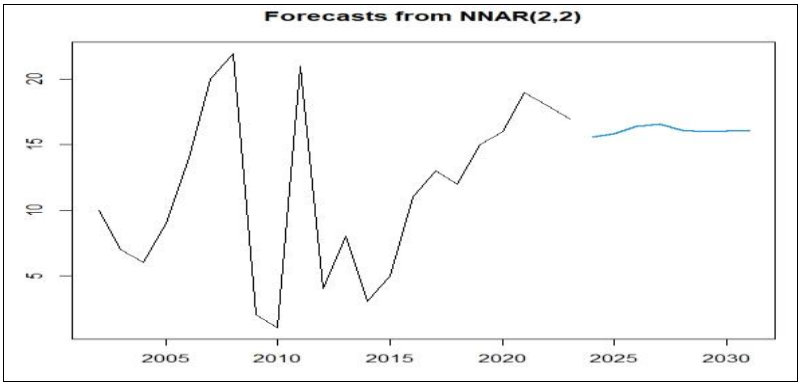

Fig 2: Forecasts of FDI.

Table 1: Projected FDI inflow in India for period 2021-2030 (₹ in crores)

Year	point Forecast
2024	560328
2025	586381
2026	163899
2027	658087
2028	611401
2029	599595
2030	605498

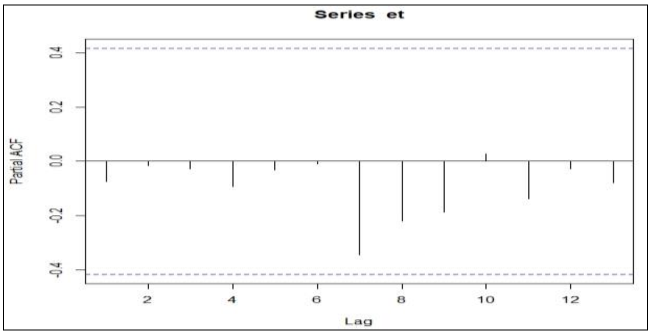

Fig 3: Partial autocorrelation function (PACF) of residuals of fitted NNAR

Conclusion

The rapid development of India is often observed as an investment opportunity by the huge industries of foreign countries. It has become necessary for the statistician, economist and policy makers of India to forecast the future inflows of investments to structure the policies for boosting the economy of country. The candidate NNAR model shows an increasing trend for investments in India through FDI. This proposed model not only helps to forecast the Foreign Direct Investment for the forthcoming years but would also help in allocation of the designing the policies which in turn helps in overcoming the unbalanced market viability

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