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Neural network applications in the forecasting of GDP of Nigeria as a function of key stock market indicators

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ABSTRACT

Stock market provides the bridge through which the savings of surplus units may be transformed into medium and long-term investments in the deficits units. It is reputed to perform critical functions, which promote economic growth and prospects of the economy. Empirical evidence linking stock market development to economic growth has been inconclusive even though the balance of evidence is in favour of a positive relationship between stock market development and economic growth. This paper explores the relationship between stock market and economic growth in Nigeria and attempts to construct its validity or otherwise, using quarterly data from 1990:Q1 to 2009:Q4 for Nigeria by employing artificial neural network as a predictive tool and comparing with the statistical method of multiple regression analysis. Here we take the GDP representing economic growth for this period, as a function of key stock market indicators including Market Capitalization (MC), Number of Deals (ND), All-Share Value Index (ASVI), Total Value of Shares Traded (TVST), and Inflation Rate (IR). From the multivariate statistical analysis, it becomes evident that the independent variables of our model are all highly correlated with the dependent variable of GDP, excepting the inflation rate having a negative correlation value of approximately 0.30. However, the value of the goodness of fit (R^2) is given as 0.85. For comparison of efficiency between ANN and regression analysis we computed five performance measures and it was discovered that ANN outperforms regression analysis significantly, and is thus better suited to stock market prediction.

Key words: Stock market, GDP, Market Capitalization (MC), All-Share Value Index (ASVI), Total Value of Shares Traded (TVST), Inflation Rate (IR), Regression, ANN.

INTRODUCTION

The rapid economic development of any economy depends among other things on ready access of adequate financial resources [1]. The desire to develop financial market in an economy is intimately connected with the objective of accelerating industrial and agricultural development. Among this financial market is the stock exchange which deals with the mobilization of both medium and long-term capital funds. The mechanism of stock exchange came into existence to enable investment, which were inherently illiquid to become liquid through reconversion into cash at the decision of the investor without inconveniencing the company [4,5].

However, in spite of the wider implication the activities and performances of the stock exchange have today in many countries, Nigeria inclusive, prediction of the stock market is still not a simple task. This is mainly as a result of the close to random walk behaviour of a stock time series. The stock market prediction task has divided researchers and academics into two groups, those who believe that mechanism can be devised to predict the market and those who believe that the market is efficient and whenever new information comes up the market absorbs it by correcting itself, thus there is no space for prediction.

A number of different techniques have been applied in predicting stock market returns, these techniques include technical analysis techniques, fundamental analysis and traditional time series forecasting techniques. Technical analyst attempt to predict the market by tracing patterns that come from the study of charts which describe historic data of the market, fundamental analyst study the intrinsic value of a stock and they invest on it if they estimate that its current value is lower than its intrinsic value. In traditional time series, prediction is made by an attempt to create linear prediction models to trace patterns in historical data. These techniques have been unsuccessful in the prediction task due to the complex dynamics of stock market. In recent years techniques based on artificial intelligence approach emerged. One of such techniques uses artificial neutral network for prediction. The aim of this paper is to examine and analyze the use of artificial neural network as a predicting tool.

Researches on neural networks show that Neural Networks have great capability in pattern recognition and machine learning problems such as classification and regression. These days Neural Networks are considered as a common Data Mining method in different fields like economics, business, industry, and science[6,7].

1.1 Objectives

The objectives of this research are to examine and analyze the use of artificial neural network as a predicting tool. We examine the ability of artificial neural network in the prediction of GDP representing Nigeria's economic growth for this period, as a function of key stock market indicators including Market Capitalization (MC), Number of Deals (ND), All-Share Value Index (ASVI), Total Value of Shares Traded (TVST), and Inflation Rate (IR). Accuracy of the artificial neural network will be compared against the traditional prediction technique of multiple linear regression analysis.

1.2 Scopes, Limitations and Assumptions

The potential combination of stock market indices and neural network types are virtually limitless. For this reason, the research was limited to only five key independent stock market variables as a function of GDP, one neural network type and one statistical prediction tool. This allowed the research to build upon and validate previous researches and place boundaries around the vast topics of time series prediction. The single limitation in this research was the scarce availability of large volumes of data which our neural network can easily accommodate, and also the high cost of accessing them limited the training and testing of the networks to twenty nine years data set, 1981-2009. However, this does not reduce the effectiveness of the network.

1.3 Motivation and benefits of neural network in stock prediction

Artificial neural network approach is suitable for the prediction of stock for the following reasons:

- Stock data are highly complex and difficult to model, therefore a non-linear model, such as artificial neural network is beneficial.
- Artificial neural network can interact with noisy data such as stock data and has fault tolerance.

We have the following important definitions.

1.4 Definition (Security)

A *security* is a document that confers upon its owner a financial claim.

1.5 Definition (Stock)

A *stock* is a security that gives its owner the right to a proportion of any profits that might be distributed (rather than reinvested) by the firm that issues the stock and to the corresponding part of the firm in case it decides to close down and liquidate.

1.6 Remark

The owner of the stock is called the *stockholder***.** The profits that the company distributes to the stockholders are called *dividends***.** Dividends are in general random, not known in advance. They will depend on the firm's profits, as well as on the firm's policy.

1.7 Definition (Stock Market)

A *stock market* is a public entity (a loose network of economic transactions, not physical facility or discrete entity) for the trading of company stocks and derivatives at an agreed price. It is also used to describe the totality of all stocks, especially within a country. It is different from a stock exchange which is an entity, in the business of bringing buyers and sellers of stock together. For example, the stock market in Africa includes the trading of stocks listed on the Nigerian stock exchange.

2. The behaviour of the stock market

Economists have continued to argue whether financial markets are generally efficient, the argument stemmed from the fact that investors can temporarily move financial prices away from their long term aggregate price trends. It could be positive or up trends usually referred as a bull market or negative or down trends referred as bear market. Most times, the market seems to react irrationally to economic or financial news, even if the news is likely to have no real effect on the fundamental value of securities itself. Therefore, the stock market may be swayed in either direction by rumours, euphoria, mass panic and press releases, though generally only briefly, as more experienced investors especially the hedge funds quickly rally to take advantage of even the slightest momentary hysteria. The difficulty in the prediction of stock market arises partly from a number of fast market changing events, however the whole idea of efficient market hypothesis (EMH) is that these non-rational reactions to information cancel out, leaving the prices of stock rationally determined.

2.1 The Nigerian Capital Market Development

2.2 Historical Background

The Nigerian Capital Market was established in 1961 to provide and sustain the capital requirements of the Nigerian economy. The mechanism for mobilizing long term funds for investment purposes is the Nigerian Stock Exchange. Between 1961 and 1997, the stock exchange operated a manual call over system with its inherent problems, which could be summarized as undue delays, high risks and manipulations due to long transaction cycles, minimal transparency and therefore a general lack of confidence in the system [2]. Information and communication technology (ICT) transformation in the Nigerian Capital Market began in 1997 with the establishment of the Automated Trading System (ATS). This is a system that enables dealers trade through a network of computers connected to a server using the queuing system. Thus stockbrokers, investors and dealers have equal access to information for purchase and sale of securities and can execute transactions through a network of computer seven from remote locations during the Exchange's trading hours. This has enabled more participants to trade daily boosting liquidity and creating opportunities for price discovery. The ATS eliminated price manipulation, which was prevalent during the call over system and also reduced transaction cycles. In 1999, the Nigerian Stock Exchange introduced a computerized clearing, settlement and delivery system for transactions in listed shares known as the Central Securities Clearing System (CSCS). The CSCS is interfaced with the ATS thereby facilitating a T+3 transaction settlement cycle. In addition, the CSCS is responsible for dematerializing share certificates of quoted companies and storing them in electronic form in a central depository. Other ICT adoptions include the CSCS trade alert, phone-in-service, e-bonus and e-dividend payments.

2.3 Measures of Stock Market Development and Economic Growth

One commonly used measure is the total value of shares traded on a country's stock exchange as a share of GDP[3,4,5]. This indicator complements the market capitalization ratio and signals whether market size is matched by trading activity. In other words, if it is very costly or risky to trade, there will not be much trading. Secondly, an alternative measure is the value of traded shares as a percentage of total market capitalization (the value of stocks listed on the exchange). This turnover ratio measures trading relative to the size of the stock market (market capitalization). The third measure is the value-traded-ratio divided by stock price volatility. Markets that are liquid should be able to handle heavy trading without large price swings. Empirically, it is not the size or volatility of the stock market that matters for growth but the ease with which shares can be traded.

MATERIALS AND METHODS

There is a large amount of interest for the use of neural networks in the domain of stock exchange [6,7]. The neural networks can be retrained from time to time with the latest data, for example including GDP results and interest rates.

2.4.1 The Neural Network model

The true power and advantage of neural networks lies in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modeled. Traditional linear models are simply inadequate when it comes to modeling data that contains non-linear characteristics. In this paper, one model of neural network is selected among the main network architectures used in engineering. The basis of the model is neuron structure [8] as shown in Fig. 3.1. These neurons act like parallel processing units. An artificial neuron is a unit that performs a simple mathematical operation on its inputs and imitates the functions of biological neurons and their unique process of learning. From Fig. 3.1 we have,

$$v_k = \sum_{j=1}^{m} x_j w_{kj} + b_k$$

The neuron output will be
$y_k = f(v_k)$

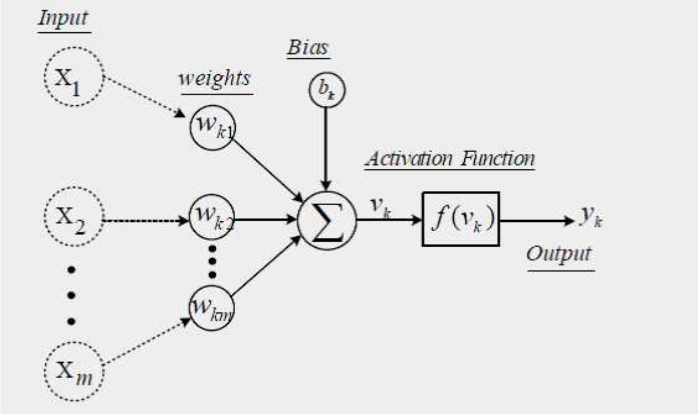


Fig. 3.1 Mathematical structure of ANN

2.4.2 Remark
For our analysis we used the ANN algorithm built into SPSS17 software [9]. The algorithm implements automatically the Multi Layer Perceptron neural network with gradient descent learning.

2.4.3 Learning by Gradient Descent Error Minimization
The Perceptron learning rule is an algorithm that adjusts the network weights w_{mn} to minimize the difference between the actual outputs y_{ki} and the target outputs t_{ki}. We can quantify this difference by defining the *sum squared error* function, summed overall output units *i* and all training patterns *m*:

$$E(w_{mn}) = \frac{1}{2}\sum_{k=1}^{m}\sum_{i=1}^{n}(t_{ki} - y_{ki})^2$$

It is the general aim of network ***learning*** to minimize this error by adjusting the weights w_{mn}.

Consider the gradient of *E*;

$$\nabla E(\boldsymbol{w}) = \nabla E(w_1, \ldots, w_n) = \left[\frac{\partial E}{\partial w_0}, \frac{\partial E}{\partial w_1}, \ldots, \frac{\partial E}{\partial w_n}\right]$$

And the training rule becomes;

$$\Delta \boldsymbol{w} = -\eta \nabla E(\boldsymbol{w})$$

Component wise this implies;

$$\Delta w_i = -\eta \frac{\partial E}{\partial w_i}$$

And the weight update is given as before;

$$w_i \leftarrow w_i + \Delta w_i$$

2.4.4 Remark: The Perceptron training rule can be proved to converge
1. If training data is linearly separable
2. and η sufficiently small

To understand the gradient descent, consider the simple linear unit;

$$o = w_0 + w_1 x_1 + \cdots + w_n x_n$$

We are basically interested in *learning* the w_i 's that minimize the squared error

$$E(w_1,\ldots,w_n) \equiv \frac{1}{2}\sum_{j\in D}(t_j - o_j)^2$$

Where D is the set of training examples. E defines the loss function we wish to minimize.

We now proceed to derive the gradient descent minimization as follows;

$$\begin{aligned}
\frac{\partial E}{\partial w_i} &= \frac{\partial}{\partial w_i}\frac{1}{2}\sum_j (t_j - o_j)^2 \\
&= \frac{1}{2}\sum_j \frac{\partial}{\partial w_i}(t_j - o_j)^2 \\
&= \frac{1}{2}\sum_j 2(t_j - o_j)\frac{\partial}{\partial w_i}(t_j - o_j) \\
&= \sum_j (t_j - o_j)\frac{\partial}{\partial w_i}(t_j - \mathbf{w}\cdot\mathbf{x}_j) \\
\Rightarrow \quad \frac{\partial E}{\partial w_i} &= \sum_j (t_j - o_j)(-x_{i,j})
\end{aligned}$$

2.4.5 Statistical Technique

Regression method is one of the most widely used statistical techniques [10]. Multiple regression analysis is a multivariate statistical technique used to examine the relationship between a single dependent variable and a set of independent variables. The objective of the multiple regression analysis is to use independent variables whose values are known to predict the single dependent variable. The effect of *independent variables* on the *response* is expressed mathematically be the regression or response function *f*:

$$y = f(x_1, x_2, \ldots, x_n; \beta_1, \beta_1, \ldots, \beta_n)$$

y - dependent variable. $\beta_1, \beta_1, \ldots, \beta_n$- *regression parameters* (unknown!)
f - the form is usually assumed to be known. The regression model for the observed response variable is written

$$z = y + \varepsilon = f(x_1, x_2, \ldots, x_n; \beta_1, \beta_2, \ldots, \beta_m) + \varepsilon$$

ε- error in observed value z.

To find *unknown regression parameters* $\{\beta_1, \beta_2, \ldots, \beta_m\}$, the *method of least squares* **[**10**]** can be applied:

$$E(\beta_1, \beta_2, \ldots, \beta_m) = \sum_{j=1}^{n}(z_j - y_j)^2 = \sum_{j=1}^{n}\left(z_j - f(x_1, x_2, \ldots, x_n; \beta_1, \beta_2, \ldots, \beta_m)\right)^2$$

where $E(\beta_1, \beta_2, \ldots, \beta_m)$ is the error function or sum of squares of the deviations.

To estimate $\beta_1, \beta_1, \ldots \beta_m$ we minimize E by solving the system of equations:

$$\frac{\partial E}{\partial \beta_i} = 0, \quad i = 1, 2, \ldots, m$$

2.5 Model Specification and Analysis and Results

Here we take the GDP representing economic growth for this period, as a function of key stock market indicators including Market Capitalization (MC), Number of Deals (ND), All-Share Value Index (ASVI), Total Value of Shares Traded (TVST), and Inflation Rate (IR).

The regression model to consider in this study takes the All-Share Value Index (*ASVI*), Number of Deals (*ND*), Market Capitalization (*MC*), Total Value of Shares Traded (*TVST*) and Inflation Rate (*IR*) as the explanatory variables and Gross Domestic Product(*GDP*) as dependent variable. This is used to obtain reliable parameter estimates in the regression. The model to be used can be specified as

$$GDP = f(ASVI, ND, MC, TVST, IR)$$

More precisely;

$$GDP = \beta_0 + \beta_1 ASVI + \beta_2 ND + \beta_3 MC + \beta_4 TVST + \beta_5 IR$$

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5 > 0.$

2.5.1 Performance measures

Since we are considering two prediction models, namely, neural network and regression, we compare the results obtained for their individual predictions and find out which model is more efficient. This is done using the following five statistical performance measures.

i) Mean Absolute Error (MAE) = $\frac{1}{n}\sum_{t=1}^{n}\left|y_t - \hat{y}_t\right|$

ii)Mean Absolute Percentage Error (MAPE) = $\frac{1}{n}\sum_{t=1}^{n}\frac{\left|y_t - \hat{y}_t\right|}{y_t}$

iii) Mean Square Error (MSE) = $\frac{1}{n}\sum_{t=1}^{n}\left(y_t - \hat{y}_t\right)^2$

iv) Root Mean Square Error (RMSE) = $\sqrt{\sum_{t=1}^{n}\frac{\left(y_t - \hat{y}_t\right)^2}{n}}$

v)Normalized Mean Square Error (NMSE) = $\frac{\sum_{t=1}^{n}\left(y_t - \hat{y}_t\right)^2}{\sum_{t=1}^{n}\left(y_t - \bar{y}_t\right)^2}$

Where y_t and $\hat{y}_t$ are the actual and predicted values $\bar{y}_t$ is the mean value of y_t. The smaller the values of error the closer are the predicted values to the actual values.

2.5.2 Data Sources, Definitions and Measurement of Variables

Quarterly data with a sample period from 1990:Q1 to 2009:Q4 is adopted. This is to ensure enough data points for the analysis in order to cater for the loss of degree of freedom. The data are obtained from the Central Bank of Nigeria and Nigeria Stock Exchange (NSE) official reports and publications.

2.5.3 Investment Ratio (IR)

This is calculated as gross fixed capital formation divided by nominal GDP. According to the endogenous economic theory, investment provides a positive link to economic growth.

2.5.4 Market Capitalization Ratio (MCR)

This the aggregate valuation of the company based on its current share price and the total number of outstanding stocks. It is calculated by multiplying the current market price of the company's share with the total outstanding shares of the company.

2.5.5 Turnover Ratio (TR)

Liquidity is the ease and speed with which economic agents can buy and sell securities. With a liquid market, the initial investors do not lose access to their savings for the duration of the investment project because they can easily, quickly, and cheaply, sell their stake in the company. Thus, more liquid markets could ease investment in long term, potentially more profitable projects, thereby improving the allocation of capital and enhancing prospects for long term growth. The ratio measures the market liquidity which is usually given as total value of shares traded divided by total value of listed shares or market capitalization.

2.5.6 Total Value of Shares Traded Ratio (TVSTR)

This measurement is given as the ratio of total value of shares traded to GDP. It measures the degree of trading relative to the size of the economy. Therefore, it reflects stock market liquidity on an economy-wide basis.

2.5.7 All Share Value Index (ASVI)

This is a series of numbers which shows the changing average value of the share prices of all companies on a stock exchange, and which is used as a measure of how well a market is performing.

2.5.8 Gross Domestic Product(GDP)

This is the market value of a all officially recognized final goods and services produced within a country in a given period of time. GDP per capita is often considered an indicator of a country's standard of living.

2.6 Computer Output for Regression Analysis

Descriptive Statistics			
	Mean	Std. Deviation	N
GDP	339.8124	157.82794	29
ASVI	9640.18	13727.197	29
ND	551993.2759	1.07531E6	29
MC	1539.8276	3221.95674	29
TVST	142.1703	408.02499	29
IR	21.2000	18.38652	29

Correlations							
		GDP	ASVI	ND	MC	TVST	IR
Pearson Correlation	GDP	1.000	.889	.853	.851	.687	-.298
	ASVI	.889	1.000	.848	.913	.561	-.324
	ND	.853	.848	1.000	.856	.738	-.278
	MC	.851	.913	.856	1.000	.740	-.271
	TVST	.687	.561	.738	.740	1.000	-.164
	IR	-.298	-.324	-.278	-.271	-.164	1.000

a. Predictors: (Constant), IR, TVST, ASVI, ND, MC

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.923[a]	.851	.819	67.17741	.851	26.311	5	23	.000

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	241.571	25.239		9.571	.000	189.361	293.782
	ASVI	.009	.003	.809	3.199	.004	.003	.015
	ND	2.183E-5	.000	.149	.787	.439	.000	.000
	MC	-.012	.013	-.237	-.889	.383	-.039	.015
	TVST	.115	.059	.297	1.962	.062	-.006	.236
	IR	-.091	.732	-.011	-.124	.903	-1.604	1.423

a. Dependent Variable: GDP

2.6.1 Regression equation

From the above table the regression table is given by;

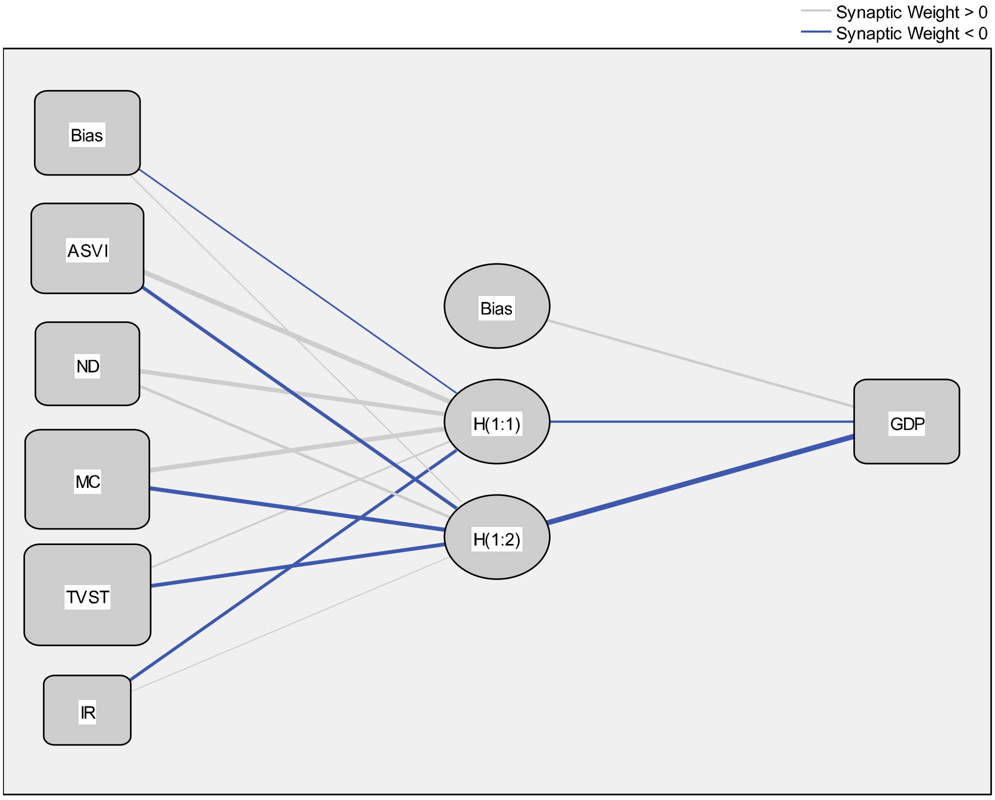
$$GDP = 241.571 + 0.009ASVI + 2.183\times10^{-5}ND - 0.012MC + 0.115TVST - 0.091IR$$

2.6.2 Computer Output for Artificial Neural Network Analysis

Multilayer Perceptron

Case Processing Summary			
		N	Percent
Sample	Training	23	79.3%
	Testing	6	20.7%
Valid		29	100.0%
Excluded		0	
Total		29	

Parameter Estimates				
Predictor		Predicted		
		Hidden Layer 1		Output Layer
		H(1:1)	H(1:2)	GDP
Input Layer	(Bias)	-.192	.071	
	ASVI	1.497	-.405	
	ND	.701	.363	
	MC	1.101	-.670	
	TVST	.234	-.642	
	IR	-.397	.047	
Hidden Layer 1	(Bias)			.343
	H(1:1)			-.244
	H(1:2)			-1.980



Hidden layer activation function: Hyperbolic tangent

Output layer activation function: Identity

Model Summary		
Training	Sum of Squares Error	.483
	Relative Error	.044
	Stopping Rule Used	1 consecutive step(s) with no decrease in error[a]
	Training Time	0:00:00.003
Testing	Sum of Squares Error	.095
	Relative Error	.021

Dependent Variable: GDP
a. Error computations are based on the testing sample.

Independent Variable Importance		
	Importance	Normalized Importance
ASVI	.212	66.7%
ND	.148	46.5%
MC	.302	94.9%
TVST	.318	100.0%
IR	.021	6.5%

2.6.3 Performance Evaluation of ANN and Regression Analysis

The table below shows summary of the results obtained for the statistical and neural network for the prediction of GDP as a function of some key variables in the Nigeria stock market. The predicting abilities of the two models are accessed using Mean Absolute Error (MAE), Mean Square Error (MSE), Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE) and Normalized Mean Square Error.

	MAE	MAPE	MSE	RMSE	NMSE
Regression	36.94	0.11	3618.01	60.15	0.15
ANN	25.26	0.093	896.894	29.95	0.037

The results clearly show that neural network, when trained with sufficient data and proper inputs, can better predict the volume of stock market. Statistical technique is well established, however the forecasting ability is reduced as the data becomes more complex.

CONCLUSION

The main objective of this project has been to examine and analyze the use of artificial neural network as a predictive tool and to compare it with the traditional prediction technique of multiple linear regression analysis. Comparison of the outcomes of the ANN model with the multiple regression model shows that the ANN model outperforms multiple regression significantly. The results clearly establish that the ANN model performs better than multiple regression model in capturing the underlying structure of the non-linear process of the stock and accurately predict the GDP as a function of key stock exchange variables. The implication of this study is that the decision making process in directional stock volume behaviour is more accurately modeled through a neural network approach, than multiple regression models.

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