An Econometric Modeling of Development Process using Artificial Neural Network: A case study of India

Ashok K Sinha

Director, UST Software India Pvt. Ltd.,New Delhi, India
Email id: ak_sinha@ust.net

Abstract: In developing nations GDP is not considered an adequate proxy of development. The per capita income, the quality of life , level of education are considered more relevant parameters of overall development. Economists, planners and researchers have been deliberating on this issue until in 1990 UNDP published Human Development Index [HDI] for all nations in its HDR report [6]. Although there have been several studies in this regard, however a machine learning based econometric model is not yet available which can establish the inter-relationship amongst these two variables in a quantified manner. This paper is an attempt in this direction to develop a model using machine learning approach .The model is implemented using Neural Network toolbox on MATLAB platform[10] with statistical data available from Planning Commission ,India and HDR report of UNDP. The model implementation result is found to be satisfactory. The methodology shown in this paper will be useful in preparing economic planning of India and other developing countries.

Keyword: GDP ,EI, HI,HDI,HDR, ANN

I.   INTRODUCTION

In recent years there has been a growing concern amongst economists, planners and researchers for modeling the development process of a nation. The scene is different for developing nations as compared to that of the developed nation. The problem of developing nation is that they resort to developmental planning as a means to eliminate poverty and thereby raise their standard of living .For them the economic growth expressed in GDP is not a sufficient parameter for development planning; instead they target to develop human capabilities, opportunities and make them knowledgeable as well .In respect of developed nations the human factors have reached to a level which is less sensitive to economic growth .In Indian context this issue can be better explained by splitting the total development into the economic development and the human development. In an attempt to develop computational models for economic development, first classify Indian economic sectors into three sub-sectors :

(a) Agriculture Sector : This includes the Agriculture core sector ,Livestock ,Forestry , Fisheries and related.
(b) Industry Sector : This includes Manufacturing , Energy ,Water Supply and Construction .
(c) Service Sector : This comprises of services in Trade, Hotels, Transport ,Communication ,Real Estate and Financial.

The economic development in India is measured in terms of GDP which include the total value of finished goods and services at market prices produced for final use in the country .Planning Commission India compiles data on sector-wise GDP growth as shown in Figure 1. Several researchers have attempted to model the
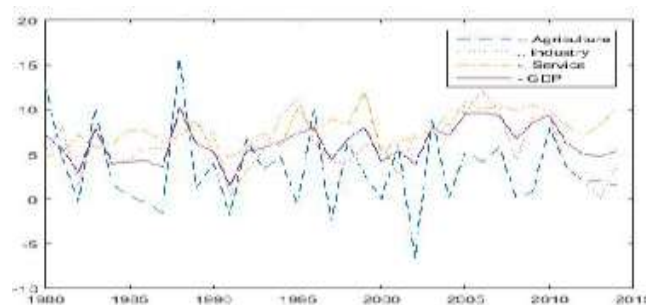

Figure 1 .[% Growth in GDP and share of other sectors at factors cost]
Figure 1[Data From Planning Commission of India]

Economists and researchers have attempted to model the trend of GDP growth over time. Virmani [1] in his paper has presented the trend of GDP growth in India in different phases over the years from 1952 to 2003 and shown that a strong correlation exists between the GDP growth and the rainfall. It says that about 45% of GDP variation is explained by the fluctuation in rainfall .In this study different breakpoints have been identified .However this study does not include the influence of economic sectors on GDP growth. Gordon [2] has

developed a model of GDP growth in USA and established that the GDP is dependent heavily on unemployment rate in the labor market. This model may not be applicable in Indian context .Basu and Annmie [3] in their study have made attempt to analyze and understand the group of forces that have influenced the growth of Indian economy .This study too does not present any econometric analysis of national economy for estimating GDP growth . In the background of these studies the proposed work is an attempt to develop an input-output model of economic development process in India.

The essential purpose of economic activity is the promotion of human development .well-being in a sustainable manner .The decision- making on developmental planning based on GDP were in practice in India and other countries till 1980 .By this time economists and planners realized the need for defining a new index called human development index(HDI) which could very well explain the quality of human lives in general. Sen[4] and Haq [5] developed the concept of human development index to include the quality of life as an important parameter in the planning process for developing countries .Human development is about improving the standard of human lives by not only enhancing income but also providing opportunities and capabilities for leading a descent , longer and healthier life while being knowledgeable as well. Realizing the deficiencies of GDP in explaining the overall development UNDP launched Human Development Report (HDR) for all nations in 1990 [6] .The HDI is computed on the basis of per capita income, educational index(EI) , and health index (HI) .The normalized composite index is called Human Development Index .In India HDI is of vital importance in developmental planning process since a large portion of the population is living below the poverty line and income inequalities are rising by the day. The data on HDI collected from HDR report of UNDP are plotted from 1980 to 2015 as shown in Figure 2.
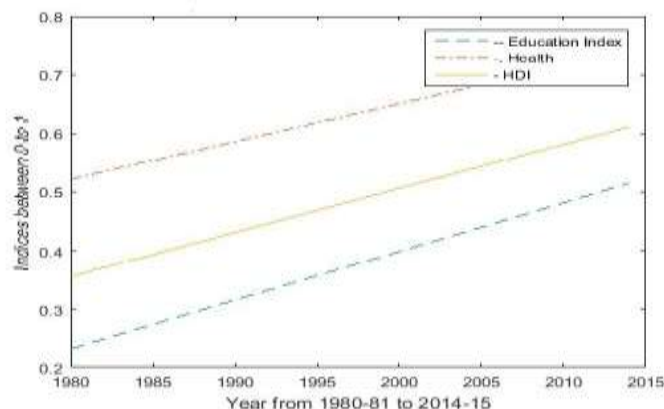

Figure 2 [EI,HI and HDI from HDR report of UNDP]

Several researchers have attempted to establish the relationship between GDP and HDI and resolve the dichotomy of using either of the index as proxy for national development. Khodarbakshi [7] in his paper has described the importance of a more comprehensive indicator of human development in India. The author has evaluated relationship and mutual effects of each of the constituents of HDI and concluded that per capita gross domestic product in Indian economy has little effect on other indicators of HDI. The research, however ,has not presented any quantitative analysis to support the result. Deb [8] in his paper has highlighted the limitations of GDP in reflecting the quality of life and human progress. The research suggest similarity between the ranking of HDI and per capita GDP which is found valid when compared with aggregate data of all countries, but it varies with different countries of different income groups. The research has not explored to develop any quantitative model with comprehensive range of input parameters to study their effects on HDI and GDP and find the correlation between the two. On the one hand, the economic development measured in GDP influences the human development index, on the other hand improvement in the quality of human life contribute to growth of GDP. For developing nation both economic development and human development are important.

II.   PROPOSED MODEL

In the background of these studies and research , the objective of this paper is to develop an artificial neural network [9] based econometric model of national development in India. The model comprises of two sub-models :

(a) Economic Model : This relates the model output GDP with input vector comprising of agriculture ,industry ,service and HDI

(b) Human Development Model : This relates the output HDI with input vector comprising of education index, health index and GDP .The model architecture is shown in Figure 3. This model concept is new as no such attempt has been made by researchers to develop an econometric model of developing nation like

India, using machine learning approach based on Artificial Neural Network [9] architecture The feature is that the inter-relationship between GDP and HDI as
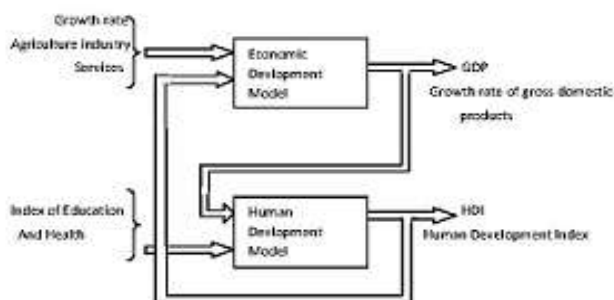

Figure 3. [Model of development process]

shown in Figure 3 and validated using time series data available from Planning Commission and HDR report of UNDP .The model implementation is done using ANN software tools on MATLAB platform[10].

III. MODEL ARCHITECTURE.

Artificial Neural Network (ANN) is derived from biological network of neurons in human body[9]. ANN comprises of three layers as shown in Figure 4.The neural network model used in the study is the multilayer perceptron (MLP) known as a supervised network. This network requires a desired output for machine learning, achieved by creating a model that correctly relates the input to the output using past data so that the model can then be used to produce the output when the desired output is unknown. This uses three-layer architecture: input layer, hidden layer, and output layer.

X_i's are the outputs of input layer neurons and b is the bias
W_{ij}'s are the weights between input layer i and hidden layer j.
V_k's are the weights between hidden layers k and the output layers.
At each of the hidden layer neurons the

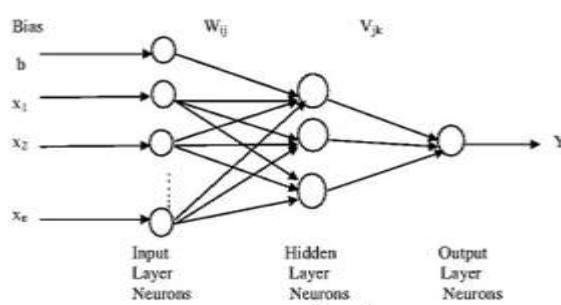net input is $Z_j = \sum_{i=1}^{n} W_{ij} X_{i} + b_j$ [1]

Figure 4.
(Back propagation artificial neural network)

The activation function is chosen to be sigmoid function as given below. The output of hidden layer

$H_{o} = 1/(1+ e^{\sum -kZ_j})$, k is a constant   [2]

IV. MODEL FORMULATION

(a) Economic Development Model:
Hypothesis of this model is that the GDP output in year is a non linear function of input vector of economic sectors and HDI .

GDP=f [AG ,ID, SV, HDI]   [3]

Where GDP is the value of Gross Domestic Product at current prices
AG is the value of agriculture at current prices
ID is the value of Industries at current prices
SV is the value of services at current prices

HDI is the Human Development Index .

The model architecture is represented by Artificial Neural Network (figure 4.) where

Input X = [AG ID SV HDI] ^{T} [4]

Output Y =   GDP   [5]

(b) Human Development Model:

Hypothesis of this model is that the HDI   is a non-linear function of input vector comprising of educational index   EI, the health index HI and the GDP .

HDI = f [EI , HI, GDP]   [6]

 HDI is the human development index .

EI is the educational index as defined by UNDO in its HDR report

HI   is the health index defined by UNDP

GDP   is the Gross Domestic Product .

The model architecture is represented by ANN in Figure 4. Where

Input   X = [EI HI GDP]^T [7]

Output Y = HDI   [8]

(c) Model Implementation Scheme : Artificial Neural Network based machine learning algorithm [11] is used for calibrating the model in this paper. The ANN algorithm is executed with time-series data set on input and output variables by using NN toolbox on MATLAB platform [10].Whole data set for each model is divided into three parts viz., 70% for training ,15% for validation and 15% for testing .

The model computes the weighting coefficients which establishes relationship with input and output variables in the model. The result expressed in the R coefficient is the degree of correlation between the inputs and output. '1' is the best correlation and '0' means random correlation.

V.   Data

Data on different variables and HDR report published annually by UNDP. Statistical data on percent growth in Agriculture ,industry ,Service sector and GDP in India have been   collected from   Planning Commission of India[12] .Time-series data from 1980 to 2014-15 are shown in Figure1.These data are used for development of Economic Model . For another model on Human Development data on educational index ,Health index and Human Development index are collected from HDR report compiled annually by UNDP. Data are plotted over the years from 1980 to 2015 as shown in Figure 2.

VI.   Result

Both economic model and human development model   are based on Artificial Neural Network architecture .The machine learning approach is used for training ,validating and testing the model with the input-output data set on MATLAB platform ,a software package suitable for computational applications[11] .The result of the economic model is shown in Figure 5.The coefficient of model fitting is 0.99634 which is quite satisfactory in such real life applications of statistical data. The result validates the model hypothesis in this work.

As regards the other model on human development similar approach has been used to train, validate and test the model with the input-output data set taken from Figure 2.The coefficient of model fitting in this case is 1, which indicates a perfect fit of the model [Figure. 6]. Assuming that in the next year some variation in the agriculture sector, industry or services take place the paper examines the effect on GDP growth as well as on HDI .The following cases have been examined by using the model.
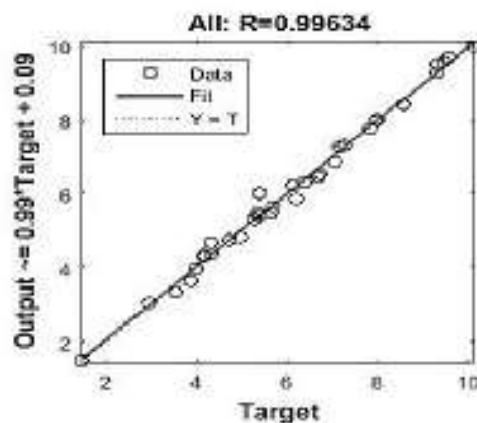

Figure 5 [Validation Result of Economic Model]

Case 1: With 10% increase in growth rate in agriculture ,industry and service sectors with no change in HDI ,there would be 4% increase in growth rate of GDP

Case 2: With 5% fall in growth of all sectors in case 1 , 2% fall is expected in growth rate of GDP .HDI level being same

Case 3: With 20% fall in Agriculture growth rate , and no change in growth rate of other sectors ,GDP growth rate will fall by 5 percent.
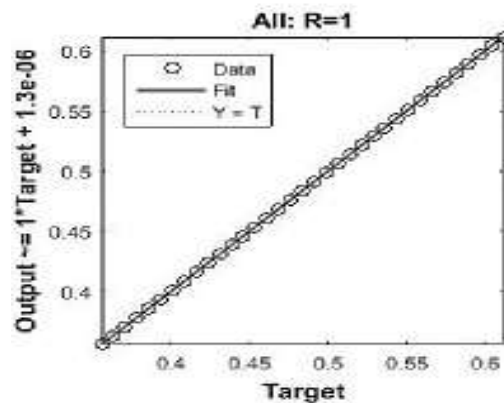
Figure 6 [Validation Result of Human Development Model]

VII.   CONCLUSION

The model development in this paper establishes the inter-relationship between GDP growth and HDI of India . The validation results of both the models are very satisfactory the coefficient of model fitting is more than 0.99 The implementation of the model validates the hypothesis that the quality of life indicated by educational index(EI) and the state of health by health index(HI) influence the GDP growth in India .Similarly the GDP ,EI and HI influence the overall human development index(HDI) in India .The model can be used for estimating the sensitivity of growth of economic sectors on GDP and HDI .The result will help the economists and planners for policy planning and decision making in India and in other developing nations as well.

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