

Forecasting Method for Indian Food grains

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ABSTRACT

In this study an attempt is made to propose a method of forecasting technique for production of total food grains. In fact as a first step specify the linear and multiplicative regression models with available independent variables with and without one time period lag dependent variable as one of the independent variables and select one of the above four specifications having maximum adjusted R^2 for forecasting purpose. In the second step assume that each of the independent variable $[X_i (i= 1,2...k) \text{ and } Y_{t-1}]$ in the model is related to time variable as linear, exponential and power functions. Estimate these relations for each of the independent variables and select the best one based on adjusted R^2 and predict the future values for all independent variables. As a third step substitute the future values of the independent variables obtained from step 2 in the selected model obtained from step 1. The obtained values are called forecasted values through proposed method. As a fourth step we assume that the dependent variable Y is related to time as linear, exponential and power functions, select one of these estimated relations with maximum adjusted R^2 for forecasting. Compare the forecasted values through proposed method and that of time series method using adjusted R^2 or MSE criteria. This methodology is applied to India as a whole as well as six regions of India for forecasting total production of food grains assuming total production of food grains (rice, wheat, cereals and pulses) is a function of their corresponding irrigated area with and without one time period lag dependent variable as one of the independent variables.

Key words: Food grains, Total production, Forecast, Regression models, Time series models, Adjusted R^2 .

Mathematics Subject Classification: 62JXX

1. INTRODUCTION

Indian economy depends on agriculture. The agricultural sector has a major share in India's economic development. The aim of the present study is to propose a method of forecasting technique for the total production of various food grains in India such as rice, wheat, cereals and pulses. As part of forecasting method, we fit linear and multiplicative models (with and without one time period lag dependent variable as one of the independent variables) to various regions such as India as well as various zones namely north, east, central, west, south and northeast of India. Of all the four proposed models one is selected based on maximum value of $\bar{R}^2$ (adjusted R^2). Using the selected model, we forecast the future production for each zone as well as India. Similarly, for each of the six zones and

India, we fit different time series models by taking total production as dependent variable and time period as independent variable and select a model with maximum value of $\bar{R}^2$ and forecast the future production. At the end we compare the forecasted values obtained with respect to proposed models and time series models. This study reveals that the value of $\bar{R}^2$ for proposed models is better than that of time series models. Here the variables under study are total production of food grains (i.e., rice, wheat, cereals, and pulses) denoted by Y_t (in thousand tonnes) and Irrigated areas of rice, wheat, cereals and pulses denoted by X_1 , X_2 , X_3 and X_4 respectively (in thousand hectares). Since the data on wheat is not available in few states of the zones namely west, south and north east of India, we consider three independent variables X_1 , X_2 , and X_3 under study as irrigated areas of rice, cereals and pulses respectively for the three zones and India as a whole. This study is conducted for a time series data of 16 years from 2000-01 to 2015-16 taken from the “**Hand Book of Statistics on Indian States**” published by Reserve Bank of India.

2. Review of literature

I Sekhar and Suresh Pal (2012): studied the changing pattern of growth in the productivity of crops rice and wheat in the Indo-gangetic plains. To study the growth stability of the two crops in the plain, an instability index was constructed. The instability analysis was considered for a time series data ranging from 1961 to 2008. This study makes an attempt to assess the trend pattern in the growth and estimate of growth of output and inputs of rice and wheat crops. Also suggests strategies to enhance the rate of growth in the production of the two crops. Sanjay Kumar and Deepak Prashar (2012) analyzed the changing trends in the area, production and productivity of food grains in Himachal Pradesh. To study the pattern of trends in area, production and productivity of food grains simple percentage method was adopted.

A Sharma (2013), studied trend pattern in the irrigated area, production and productivity of food grains in the North eastern states of India. This study was based on the time series data from the 1980-81 to 2011-12. In this study, to analyze the trend pattern linear, quadratic, exponential functional forms were used. Also Compound growth rate, coefficient of variation, instability indices were estimated to analyze the growth pattern in the region. This study reveals that the increase in the production is due to increase in area and as well the combined effect of area and productivity of food grain crops in the north eastern states. Kumar Sanjay, Barik Kaustav, Prashar Deepak (2013): studied “Cropping and Land Use pattern in Himachal Pradesh: Case of District Solan”. This study mainly concentrates on pattern of cropping and land use as a part of agriculture diversification in Himachal Pradesh with reference to a case of Solan district. To realize about the changes in area under various crops percentage method was used as a statistical tool.

M.K. Debnath, Kartic Bera, P. Mishra (2013): Analyzed the forecasting of area, production and yield of cotton in India. This study purely concentrates on forecasting area of cultivation and production of cotton in India using Auto regressive Integrated Moving Averages model. This analysis is carried out for a time series dated of 60 years from 1950-2010. The study reveals that ARIMA (0,1,0), ARIMA(1,1,4) and ARIMA(0,1,1) are the best fitted model for forecasting cultivated area, production and yield of cotton respectively in India. Sheeren .Z and Banu .S (2016): studied

“Agriculture diversification and food security concerns in India”. This paper emphasizes the diversification of agriculture towards high value commodities such as fruits, vegetables, milk, meat, eggs, livestock, fish etc are emerging sources of income and employment generations. This paper analyses the trend and agriculture diversification patterns and the impact on food security in India.

Ruchi .M (2017): studied “Food grains in India: Growth, instability and decomposition analysis”. In this study area, production and yield of food grains in India were considered and analyzed their trend pattern 2001-02 to 2015-16. To study the trend simple statistical tools were used and the relative share of area and productivity in the growth of production of food grains is estimated. This study concludes that the growth in the production is due to the growth in area or yield or the interaction of both area and yield of food grains. Ankur Jain (2018): studied “Analysis of Growth and instability in Area, Production, Yield and Price of Rice in India”. In this study an attempt was made to know the instability in the production of rice in India. This paper emphasizes the study of growth rates in the area, production and yield of rice and instability in the same three factors across the states of India. In this study, farm harvest prices and wholesale prices of rice are also taken into consideration for the instability analysis. For this study the time series data was considered for a period of 41 years from 1970-71 to 2011-12.

S.V. Halawar (2019): studied the trend analysis of major food grains such as rice, wheat, coarse cereals, pulses and sugarcane in India. This study provides future estimates for the production of various food grains as well as sugarcane in India. For this purpose, various statistical techniques such as Analysis of variance, Line charts are employed and also analyzed the trend pattern in the production of food grains in India. Lokesh (2019): Analyzed the trends and decomposition of agricultural growth in Himachal Pradesh. This paper tries to estimate the growth in the output of food grains with reference to growth of area and growth of yield. For this purpose decomposition analysis was employed. This analysis reveals that the increase in the output is majorly due to the effect of yield of food grains in the state. To analyze the trends in the area, production and yield of food grains compound growth rates are used. This study was conducted for the period of 36 years from 1980-81 to 2015-16.

3. Methodology

In this chapter an attempt is made to propose a method of forecasting technique with reference to linear and multiplicative regression models with and without one time log production dependent variable as one of the independent variables. The procedure is given below. As a first step we consider the following specifications.

$$Y_t = \alpha_0 + \sum_{i=1}^k \alpha_i X_{it} + \epsilon_{1t} \quad (1)$$

$$Y_t = \beta_0 + \sum_{i=1}^k \beta_i X_{it} + \beta_{k+1} Y_{t-1} + \epsilon_{2t} \quad (2)$$

$$Y_t = \gamma_0 \prod_{i=1}^k (X_i^{Y_{it}}) e^{\epsilon_{3t}} \quad (3)$$

$$Y_t = \delta_0 \prod_{i=1}^k (X_i^{\delta_{it}}) Y_{t-1}^{\delta_{(k+1)t}} e^{\epsilon_{4t}} \quad (4)$$

One of the above four specifications (1)-(4) with maximum $\bar{R}^2$ may be selected for forecasting purpose.

In the second step assume that the dependent variable Y_t and each of the independent variables $[X_{it} (i= 1, 2 \dots k), Y_{t-1}]$ involved in the model is a function of time and specified as

$$Y_t, X_{it} \text{ \& } Y_{t-1} = a + b t \quad (5)$$

$$= a e^{bt} \quad (6)$$

$$= a t^b \quad (7)$$

$$= a b^t \quad (8)$$

Select the linear specification (5) and one of the three non-linear specifications (6)-(8) with maximum $\bar{R}^2$ for each of $X_{it} (i= 1, 2 \dots k)$ and Y_{t-1} ; and for Y_t , select one specification from (5) – (8) with maximum $\bar{R}^2$.

Compute the forecasted values of dependent variable Y_t , independent variables $X_{it} (i=1, 2, \dots, k)$ and Y_{t-1} from the above selected models.

As a third step substitute the forecasted values of all independent variables in the selected model from step one. The obtained values of dependent variable are called forecasted values through proposed method.

Compare the forecasted values of dependent variable Y_t obtained through proposed method from step three with that of obtained from step two using $\bar{R}^2$ or MSE criteria.

Estimation:

In particular let us consider the following linear and multiplicative regression models with dependent variable Y_t and four independent variables X_1, X_2, X_3, X_4 as

$$Y_t = \alpha_0 + \alpha_1 X_{1t} + \alpha_2 X_{2t} + \alpha_3 X_{3t} + \alpha_4 X_{4t} + \epsilon_{1t} \quad (9)$$

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \beta_5 Y_{t-1} + \epsilon_{2t} \quad (10)$$

$$Y_t = \gamma_0 X_{1t}^{\gamma_1} X_{2t}^{\gamma_2} X_{3t}^{\gamma_3} X_{4t}^{\gamma_4} e^{\epsilon_{3t}} \quad (11)$$

$$Y_t = \delta_0 X_{1t}^{\delta_1} X_{2t}^{\delta_2} X_{3t}^{\delta_3} X_{4t}^{\delta_4} Y_{t-1}^{\delta_5} e^{\epsilon_{4t}} \quad (12)$$

Y_t = dependent variable

Y_{t-1} = Independent variable

X_{it} = Independent variables ($i=1, 2, 3, 4$)

$\alpha_i (i = 0, 1, 2, 3, 4), \beta_j (j = 0, 1, 2, 3, 4, 5)$

$\gamma_k (k = 0, 1, 2, 3, 4), \delta_l (l = 0, 1, 2, 3, 4, 5)$ are parameters

ϵ_{it} : error variables ($i = 1, 2, 3, 4$).

After converting the non-linear models (11) to (12) into linear using natural logarithms, we may apply OLS method to estimate parameter.

Hence OLS estimate of parametric vector β in general linear model $Y = X\beta + \epsilon$ is $(X'X)^{-1} X'Y$.

Time series models

(i) Linear trend: $Y = a + bt$

$$\hat{b} = \frac{\sum Yt - \frac{\sum Y \sum t}{n}}{\sum t^2 - \frac{(\sum t)^2}{n}}, \quad \hat{a} = \bar{Y} - \hat{b}t$$

Exponential curve trend:

(i) $Y = a e^{bt}$

$$\ln Y = \ln a + bt$$

$$y = A + bt$$

$$\hat{b} = \frac{\sum yt - \frac{\sum y \sum t}{n}}{\sum t^2 - \frac{(\sum t)^2}{n}}, \quad \hat{A} = \bar{y} - \hat{b}t$$

$$\hat{a} = \text{Antilog}(\hat{A})$$

(ii) $Y = a b^t$

$$\ln Y = \ln a + t \ln b$$

$$y = A + Bt$$

$$\hat{B} = \frac{\sum yt - \frac{\sum y \sum t}{n}}{\sum t^2 - \frac{(\sum t)^2}{n}}, \quad \hat{A} = \bar{y} - \hat{B}t$$

$$\hat{a} = \text{Antilog}(\hat{A}), \quad \hat{b} = \text{Antilog}(\hat{B})$$

Power curve trend: $Y = a t^b$

$$\log Y = \log a + b \log t$$

$$y = A + bT, \text{ where } \log Y = y, T = \log t, \log a = A$$

$$\hat{b} = \frac{\sum yT - \frac{\sum y \sum T}{n}}{\sum T^2 - \frac{(\sum T)^2}{n}}, \quad \hat{A} = \bar{y} - \hat{b}\bar{T} \rightarrow \hat{a} = \text{Antilog}(\hat{A}). \text{ Here } R^2 = \frac{\hat{\beta}'X'Y}{Y'Y}, \quad \bar{R}^2 = 1 - (1 - R^2) \left(\frac{n-1}{n-k} \right)$$

4. Results

In this section, we presented

- (i) the estimated specifications of proposed linear and multiplicative regression models with and without one time period log dependent variable which were intended initially to forecast the total production of food grains.
- (ii) the estimated specifications of different independent variables in terms of linear, exponential and power curve trends.
- (iii) the estimated specifications of selected time series models for forecasting of total production of food grains.
- (iv) the production forecasts obtained through (i) and (iii) and the relevant interpretations with respect to India and various zones.

4.1 Estimation of Total production of food grains

In this section, we estimate the total production of food grains to India as a unit, as well as North zone, East zone, Central zone, West zone, South zone, North East zone and presented the results with the data available on the study variables using the methodology given.

The variables under study are

Y_t : Total production of food grains

X_{1t} , X_{2t} , X_{3t} , X_{4t} : Irrigated area of rice, wheat, cereals and pulses respectively

Y_{t-1} : Total production of food grains with one period time lag.

(1) For India:

Specification (i):

$$Y_t^{\wedge} = -149697 + 6.0856801X_{1t} - 3.4502328X_{2t} + 5.5656148X_{3t} \\ (1.3259306) \quad (0.7425853) \quad (1.0526999)$$

$$R^2 = 0.8663332 \quad \bar{R}^2 = 0.8329165$$

Specification (ii):

$$Y_t^{\wedge} = -108027.42 + 6.3519908X_{1t} - 4.5536452X_{2t} + 5.6822691X_{3t} - 0.1795277Y_{t-1} \\ (1.4878653) \quad (1.646745) \quad (1.2447411) \quad (0.2420502)$$

$$R^2 = 0.8591205 \quad \bar{R}^2 = 0.8027687$$

Specification (iii): (Selected for Production forecasts)

$$\ln Y_t^{\wedge} = -12.22506 + 1.9779357 \ln X_{1t} - 0.6426865 \ln X_{2t} + 0.9532376 \ln X_{3t} \\ (0.4120396) \quad (0.144971) \quad (0.1757188)$$

$$R^2 = 0.8705759 \quad \bar{R}^2 = 0.8382199$$

Specification (iv):

$$\ln Y_t^{\wedge} = -9.2099382 + 2.0483809 \ln X_{1t} - 0.8412298 \ln X_{2t} + 0.9797722 \ln X_{3t} - 0.1690648 \ln Y_{t-1} \\ (0.4571857) \quad (0.2851389) \quad (0.2100012) \quad (0.2117254)$$

$$R^2 = 0.866498 \quad \bar{R}^2 = 0.8130972$$

(2) For North zone:

Specification (i):

$$Y_t^{\wedge} = -192448.84 + 4.8845973X_{1t} + 12.658957X_{2t} + 7.296983X_{3t} - 1.0881629X_{4t} \\ (4.3394357) \quad (6.3281674) \quad (8.0850459) \quad (7.3790271)$$

$$R^2 = 0.6964248 \quad \bar{R}^2 = 0.5860338$$

Specification (ii):

$$Y_t^{\wedge} = -182973.04 + 6.0822534X_{1t} + 8.1450294X_{2t} + 15.588304X_{3t} - 6.2347794X_{4t} + 0.384622Y_{t-1} \\ (4.8497798) \quad (9.2086498) \quad (10.707963) \quad (8.582107) \quad (0.3794159)$$

$$R^2 = 0.7341112 \quad \bar{R}^2 = 0.5863952$$

Specification (iii):

$$\ln Y_t^{\wedge} = -19.291247 + 0.5482025 \ln X_{1t} + 2.3725196 \ln X_{2t} + 0.3643899 \ln X_{3t} - 0.0499217 \ln X_{4t} \\ (0.4546542) \quad (1.1007912) \quad (0.34276) \quad (0.2062798)$$

$$R^2 = 0.7214878 \quad \bar{R}^2 = 0.6202106$$

Specification (iv): (Selected for Production forecasts)

$$\ln Y_t^{\wedge} = -18.730116 + 0.696572 \ln X_1 + 1.5462177 \ln X_2 + 0.7173466 \ln X_3 - 0.2034502 \ln X_4 + 0.3850412 \ln Y_{t-1}$$

(0.5105608) (1.5937133) (0.4434975) (0.2407724) (0.3697645)

$$R^2 = 0.7592887 \quad \bar{R}^2 = 0.6255603$$

(3) For East zone:

Specification (i):

$$Y_t^{\wedge} = -105249.86 + 1.8715588 X_1 + 24.758147 X_2 + 49.780988 X_3 - 4.2562964 X_4$$

(0.6142995) (5.6878916) (12.637738) (6.6622801)

$$R^2 = 0.9101473 \quad \bar{R}^2 = 0.8774736$$

Specification (ii):

$$Y_t^{\wedge} = -105057.36 + 1.7795254 X_1 + 25.981591 X_2 + 53.991523 X_3 - 6.3896876 X_4 - 0.0750546 Y_{t-1}$$

(0.643184) (6.1835683) (13.97335) (7.1996112) (0.1331591)

$$R^2 = 0.911837 \quad \bar{R}^2 = 0.8628576$$

Specification (iii): (Selected for Production forecasts)

$$\ln Y_t^{\wedge} = -19.501535 + 0.769973 \ln X_1 + 1.6426875 \ln X_2 + 1.5672718 \ln X_3 - 0.1808446 \ln X_4$$

(0.2265643) (0.3775272) (0.3984724) (0.3334503)

$$R^2 = 0.9127889 \quad \bar{R}^2 = 0.8810758$$

Specification (iv):

$$\ln Y_t^{\wedge} = -19.126262 + 0.7311691 \ln X_1 + 1.7419425 \ln X_2 + 1.7179747 \ln X_3 - 0.3000274 \ln X_4 - 0.0898966 \ln Y_{t-1}$$

(0.2328009) S(0.4040845) (0.4282746) (0.3544373) (0.1247151)

$$R^2 = 0.9170938 \quad \bar{R}^2 = 0.8710348$$

(4) For Central zone:

Specification (i): (Selected for Production forecasts)

$$Y_t^{\wedge} = -42841.403 + 5.1536498 X_1 + 5.8379511 X_2 - 0.0987964 X_3 + 2.0987144 X_4$$

(2.5460431) (1.3818729) (1.8044479) (1.3207926)

$$R^2 = 0.9828563 \quad \bar{R}^2 = 0.9766222$$

Specification (ii):

$$Y_t^{\wedge} = -40928.027 + 5.842538 X_1 + 6.9756954 X_2 - 1.0234443 X_3 + 1.0735932 X_4 - 0.1329338 Y_{t-1}$$

(2.5321875) (1.5269209) (1.8631803) (1.6181736) (0.1009821)

$$R^2 = 0.9846045 \quad \bar{R}^2 = 0.9760514$$

Specification (iii):

$$\ln Y_t^{\wedge} = -12.044416 + 0.7718117 \ln X_1 + 1.099983 \ln X_2 + 0.0374443 \ln X_3 + 0.6826597 \ln X_4$$

(0.712582899) (0.34392163) (0.23546471) (0.39952718)

$$R^2 = 0.967456 \quad \bar{R}^2 = 0.9556218$$

Specification (iv):

$$\ln Y_t^{\wedge} = -8.9552898 + 1.0804248 \ln X_1 + 1.5064903 \ln X_2 - 0.2160393 \ln X_3 + 0.1214215 \ln X_4 - 0.2366298 \ln Y_{t-1}$$

(0.55980096) (0.29916119) (0.20081737) (0.41142443) (0.09295446)

$$R^2 = 0.9799536 \quad \bar{R}^2 = 0.9688167$$

(5) For West zone:

Specification (i):

$$Y_t^{\wedge} = -7306.7575 + 2.0861435X_1 - 0.0524043X_2 + 3.264592X_3$$

(3.1082517) (0.5025241) (1.0203438)

$$R^2 = 0.7501487 \quad \bar{R}^2 = 0.6876859$$

Specification (ii):

$$Y_t^{\wedge} = -3142.8501 + 2.449952X_1 - 0.1077194X_2 + 3.0047815X_3 - 0.092647Y_{t-1}$$

(3.9992934) (0.6125297) (1.1888799) (0.2411521)

$$R^2 = 0.7035909 \quad \bar{R}^2 = 0.5850272$$

Specification (iii): (Selected for Production forecasts)

$$\ln Y_t^{\wedge} = -1.4581501 + 0.2094017 \ln X_1 - 0.0711497 \ln X_2 + 1.1738014 \ln X_3$$

(0.3034133) (0.3180137) (0.376423)

$$R^2 = 0.753545 \quad \bar{R}^2 = 0.69193136218$$

Specification (iv):

$$\ln Y_t^{\wedge} = 1.5091028 + 0.2952732 \ln X_1 - 0.1416613 \ln X_2 + 1.015968 \ln X_3 - 0.1537023 \ln Y_{t-1}$$

(0.3827978) (0.3796956) (0.4310268) (0.2340211)

$$R^2 = 0.7092875 \quad \bar{R}^2 = 0.5930025$$

(6) For South zone:

Specification (i): (Selected for Production forecasts)

$$Y_t^{\wedge} = 23006.554 + 4.761956X_1 - 4.7587169X_2 + 0.8168936X_3$$

(0.8002864) (1.4465317) (1.9050464)

$$R^2 = 0.7859922 \quad \bar{R}^2 = 0.7324902$$

Specification (ii):

$$Y_t^{\wedge} = 33629.903 + 5.4793666X_1 - 6.2042092X_2 + 0.5970289X_3 - 0.1986391Y_{t-1}$$

(1.1438363) (2.1469248) (2.0285857) (0.2065476)

$$R^2 = 0.7988643 \quad \bar{R}^2 = 0.71841$$

Specification (iii):

$$\ln Y_t^{\wedge} = 8.6710167 + 1.0651314 \ln X_1 - 0.9320004 \ln X_2 + 0.0423012 \ln X_3$$

(0.1815916) (0.2631634) (0.2998384)

$$R^2 = 0.7712988 \quad \bar{R}^2 = 0.7141234$$

Specification (iv):

$$\ln Y_t^{\wedge} = 13.340189 + 1.3075555 \ln X_1 - 1.3355699 \ln X_2 + 0.0097527 \ln X_3 - 0.2944098 \ln Y_{t-1}$$

(0.2619597) (0.395648) (0.3049698) (0.217244)

$$R^2 = 0.7092875 \quad \bar{R}^2 = 0.5930025$$

(7) For North-East zone:

Specification (i):

$$Y_t^{\wedge} = -8799.7175 + 2.8975319X_1 + 1.9240773X_2 + 24.650405X_3$$

(0.5733973) (5.324321) (4.7509578)

$$R^2 = 0.9653419 \quad \bar{R}^2 = 0.9566774$$

Specification (ii): (Selected for Production forecasts)

$$Y_t^{\wedge} = -7685.7929 + 2.5253651X_1 + 0.8110752X_2 + 20.060718X_3 + 0.2148679Y_{t-1}$$

(0.6368224) (5.228504) (5.3512659) (0.1288245)

$$R^2 = 0.9722832 \quad \bar{R}^2 = 0.9611965$$

Specification (iii):

$$\ln Y_t^{\wedge} = -8.6685429 + 1.6051763\ln X_1 + 0.0428552\ln X_2 + 0.783775\ln X_3$$

(0.3071076) (0.2168085) (0.1614096)

$$R^2 = 0.9626125 \quad \bar{R}^2 = 0.9532657$$

Specification (iv):

$$\ln Y_t^{\wedge} = -7.8184647 + 1.3814181\ln X_1 + 0.0107843\ln X_2 + 0.6314826\ln X_3 + 0.2233506\ln Y_{t-1}$$

(0.3306319) (0.2065069) (0.1734436) (0.1199333)

$$R^2 = 0.9716467 \quad \bar{R}^2 = 0.9603054$$

(8) For (North + East + Central):

Specification (i):

$$Y_t^{\wedge} = -168438.6 + 5.1404348X_1 + 7.9666316X_2 - 7.0575606X_3 + 2.8305371X_4$$

(2.4974108) (4.0604322) (7.2525601) (5.4202056)

$$R^2 = 0.8807063 \quad \bar{R}^2 = 0.8373267$$

Specification (ii):

$$Y_t^{\wedge} = -109868.67 + 5.2891377X_1 + 9.3990729X_2 - 13.703834X_3 + 2.6606047X_4 - 0.3084021Y_{t-1}$$

(3.0436394) (6.2295265) (11.129897) (8.6712705) (0.3126292)

$$R^2 = 0.8802455 \quad \bar{R}^2 = 0.8137153$$

Specification (iii): (Selected for Production forecasts)

$$\ln Y_t^{\wedge} = -10.8310263 + 1.023024505\ln X_1 + 1.306246354\ln X_2 - 0.29629623\ln X_3 + 0.183113336\ln X_4$$

(0.487673) (0.632873) (0.367186) (0.3501289)

$$R^2 = 0.8815405 \quad \bar{R}^2 = 0.8384643$$

Specification (iv):

$$\ln Y_t^{\wedge} = -4.3404649 + 0.967467\ln X_1 + 1.7129058\ln X_2 - 0.720323\ln X_3 + 0.03855466\ln X_4 - 0.4112349\ln Y_{t-1}$$

(0.5654299) (0.9179809) (0.5520724) (0.5506056) (0.3043818)

$$R^2 = 0.8895253 \quad \bar{R}^2 = 0.8281504$$

(9) For (West + South + North-East):

Specification (i): (Selected for Production forecasts)

$$Y_t^{\wedge} = -16592.12336 + 6.200155807X_1 - 1.782942956X_2 + 2.86588248X_3$$

(1.0993006) (0.4564415) (0.8777018)

$$R^2 = 0.8899089 \quad \bar{R}^2 = 0.8623861$$

Specification (ii):

$$Y_t^{\wedge} = -10519.08 + 6.957791X_1 - 1.9567014X_2 + 2.3328053X_3 - 0.0846808Y_{t-1}$$

(1.6605574) (0.9518221) (1.1636888) (0.2189313)

$$R^2 = 0.8922209 \quad \bar{R}^2 = 0.8491093$$

Specification (iii):

$$\ln Y_t^{\wedge} = -1.750542 + 1.3241339 \ln X_1 - 0.5299476 \ln X_2 + 0.584991 \ln X_3$$

$$(0.233815) \quad (0.1507258) \quad (0.1926939)$$

$$R^2 = 0.8822709 \quad \bar{R}^2 = 0.8528386$$

Specification (iv):

$$\ln Y_t^{\wedge} = 1.0376597 + 1.6079373 \ln X_1 - 0.7046995 \ln X_2 + 0.4167193 \ln X_3 - 0.1945718 \ln Y_{t-1}$$

$$(0.3526637) \quad (0.2894873) \quad (0.2512295) \quad (0.2136396)$$

$$R^2 = 0.8921994 \quad \bar{R}^2 = 0.8490791$$

The figures in the parentheses of the above equations indicate the standard errors of their respective estimates of the parameters.

From the above estimated equations, based on the selected specifications of linear or multiplicative models with respect to various zones (or regions), the corresponding values of coefficient of multiple determination (R^2) and adjusted coefficient of multiple determination ($\bar{R}^2$) are observed in the table (1).

Table (1): R^2 And $\bar{R}^2$ On The Basis of Selected Specifications of India & Zones

S No	Region	R^2	$\bar{R}^2$
1	INDIA	0.8705759	0.8382199
2	NORTH ZONE	0.7592887	0.6255603
3	EAST ZONE	0.9127889	0.8810758
4	CENTRAL ZONE	0.9828563	0.9766222
5	WEST ZONE	0.753545	0.6919314
6	SOUTH ZONE	0.7859922	0.7324902
7	NORTH EAST ZONE	0.9722832	0.9611965
8	(NORTH+EAST+CENTRAL)	0.8815405	0.8384643
9	(WEST+SOUTH+NORHT EAST)	0.8899089	0.8623861

INDIA:

For India, the value of R^2 is 0.87 and it is highly significant. This indicates that 87% of the total variation in the dependent variable (i.e., total production) is explained by the three independent variables X_1 , X_2 , and X_3 (i.e., irrigated areas of rice, cereals, pulses) respectively. Similarly, we may write the interpretation for the zones (or regions) which contain three independent variables namely west, south, north east and the region which is the combination of west, south and north east zones.

NORTH ZONE:

For North zone, the value of R^2 is 0.76 which is highly significant. It indicates that 76% of the total variation in the dependent variable is explained by all the four independent variables X_1 , X_2 , X_3 and X_4 (i.e., irrigated areas of rice, wheat, cereals and pulses) respectively.

Similarly, we may write the interpretation for the zones (or regions) which contain four independent variables namely east, central and the region which is the combination of north, east and central zones.

4.2 Estimation of Independent Variables

As part of second step, the estimated equations for the prediction of each of the different independent variables X_{it} ($i = 1, 2, 3, 4$) and Y_{t-1} (i.e., the dependent variable with one time lag period) using linear, exponential and power curve trends for India and various zones of India are given by

(A) India:

(i) Irrigated area of rice (X_1):

Specification (i):

$$\ln X_1^{\wedge} = 2.3679779 - 0.0005712 \ln t$$

(0.0009036) $R^2 = 0.0277481$ $\bar{R}^2 = -0.0416984$

Specification (ii): (Selected for forecasts)

$$\ln X_1^{\wedge} = 2.3677755 - 0.000105t$$

(0.0001493) $R^2 = 0.0341292$ $\bar{R}^2 = -0.0348616$

Specification (iii):

$$\ln X_1^{\wedge} = 2.3677755 - 0.000105t$$

(0.0001493) $R^2 = 0.0341292$ $\bar{R}^2 = -0.0348616$

(ii) Irrigated area of cereals (X_2):

Specification (i):

$$\ln X_2^{\wedge} = 2.338929 - 0.0078822 \ln t$$

(0.0019299) $R^2 = 0.5436916$ $\bar{R}^2 = 0.5110982$

Specification (ii):

$$\ln X_2^{\wedge} = 2.3368668 - 0.001535t$$

(0.0002365) $R^2 = 0.7505061$ $\bar{R}^2 = 0.7326851$

Specification (iii): (Selected for forecasts)

$$\ln X_2^{\wedge} = 2.3368668 - 0.001535t$$

(0.0002365) $R^2 = 0.7505061$ $\bar{R}^2 = 0.7326851$

(iii) Irrigated area of pulses (X_3):

Specification (i): (Selected for forecasts)

$$\ln X_3^{\wedge} = 2.2953641 + 0.0059993 \ln t$$

(0.0014911) $R^2 = 0.5362435$ $\bar{R}^2 = 0.5031181$

Specification (ii):

$$\ln X_3^{\wedge} = 2.2991134 + 0.0009119t$$

(0.0002689) $R^2 = 0.4509447$ $\bar{R}^2 = 0.4117265$

Specification (iii):

$$\ln X_3^{\wedge} = 2.2991134 + 0.0009119t$$

(0.0002689) $R^2 = 0.4509447$ $\bar{R}^2 = 0.4117265$

(B) North zone:

(i)Irrigated area of rice (X_1):

Specification (i):

$$\text{Ln } X_1^{\wedge} = 2.2131015 + 0.0049953 \text{Ln } t$$

(0.0013313)

$$R^2 = 0.5199387$$

$$\bar{R}^2 = 0.483011$$

Specification (ii):

$$\text{Ln } X_1^{\wedge} = 2.214851504 + 0.0009426t$$

(0.000211)

$$R^2 = 0.6055572$$

$$\bar{R}^2 = 0.5752155$$

Specification (iii): (Selected for forecasts)

$$\text{Ln } X_1^{\wedge} = 2.214851504 + 0.0009426t$$

(0.000211)

$$R^2 = 0.6055572$$

$$\bar{R}^2 = 0.5752155$$

(ii)Irrigated area of wheat (X_2):

Specification (i):

$$\text{Ln } X_2^{\wedge} = 2.2671094 + 0.0029236 \text{Ln } t$$

(0.0005378)

$$R^2 = 0.694536$$

$$\bar{R}^2 = 0.6710388$$

Specification (ii):

$$\text{Ln } X_2^{\wedge} = 2.268053673 + 0.000561691t$$

(0.000068376)

$$R^2 = 0.838469803$$

$$\bar{R}^2 = 0.826044403$$

Specification (iii): (Selected for forecasts)

$$\text{Ln } X_2^{\wedge} = 2.268053673 + 0.000561691t$$

(0.000068376)

$$R^2 = 0.838469803$$

$$\bar{R}^2 = 0.826044403$$

(iii) Irrigated area of cereals (X_3):

Specification (i):

$$\text{Ln } X_3^{\wedge} = 2.1289455 - 0.0093015 \text{Ln } t$$

(0.0017673)

$$R^2 = 0.6805925$$

$$\bar{R}^2 = 0.6560227$$

Specification (ii): (Selected for forecasts)

$$\text{Ln } X_3^{\wedge} = 2.126281737 - 0.0018296t$$

(0.00020367)

$$R^2 = 0.861243648$$

$$\bar{R}^2 = 0.850570083$$

Specification (iii):

$$\text{Ln } X_3^{\wedge} = 2.126281737 - 0.0018296t$$

(0.00020367)

$$R^2 = 0.861243648$$

$$\bar{R}^2 = 0.850570083$$

(iv)Irrigated area of pulses (X_4):

Specification (i):

$$\text{Ln } X_4^{\wedge} = 2.0905111 - 0.0110285 \text{Ln } t$$

(0.0035484)

$$R^2 = 0.4263029$$

$$\bar{R}^2 = 0.3821723$$

Specification (ii):

$$\text{Ln } X_4^{\wedge} = 2.087851439 - 0.0022316t$$

(0.00053658) $R^2 = 0.57090605$ $\bar{R}^2 = 0.537898823$
 Specification (iii): (Selected for forecasts)

$$\ln X_4^{\wedge} = 2.087851439 - 0.0022316t$$

(0.00053658) $R^2 = 0.57090605$ $\bar{R}^2 = 0.537898823$

(v) Dependent variable with one time period log ($Y_{t-1}^{\wedge}$):

Specification (i):

$$\ln Y_{t-1}^{\wedge} = 2.4233915 + 0.0056429 \ln t$$

(0.0020326) $R^2 = 0.3722013$ $\bar{R}^2 = 0.3239091$

Specification (ii):

$$\ln Y_{t-1}^{\wedge} = 2.424792753 + 0.001136777t$$

(0.00031906) $R^2 = 0.494049788$ $\bar{R}^2 = 0.455130541$

Specification (iii): (Selected for forecasts)

$$\ln Y_{t-1}^{\wedge} = 2.424792753 + 0.001136777t$$

(0.00031906) $R^2 = 0.494049788$ $\bar{R}^2 = 0.455130541$

(C) East zone:

(i) Irrigated area of rice (X_1):

Specification (i):

$$\ln X_1^{\wedge} = 2.2681033 - 0.000105 \ln t$$

(0.0015439) $R^2 = 0.57090605$ $\bar{R}^2 = 0.537898823$

Specification (ii): (Selected for forecasts)

$$\ln X_1^{\wedge} = 2.2667913 - 0.0006904t$$

(0.0002428) $R^2 = 0.3660308$ $\bar{R}^2 = 0.3207472$

Specification (iii):

$$\ln X_1^{\wedge} = 2.2667913 - 0.0006904t$$

(0.0002428) $R^2 = 0.3660308$ $\bar{R}^2 = 0.3207472$

(ii) Irrigated area of wheat (X_2):

Specification (i):

$$\ln X_2^{\wedge} = 2.0599121 + 0.0005414 \ln t$$

(0.0011606) $R^2 = 0.0153033$ $\bar{R}^2 = -0.0550321$

Specification (ii):

$$\ln X_2^{\wedge} = 2.0593172 + 0.0001921t$$

(0.00018695) $R^2 = 0.0701179$ $\bar{R}^2 = 0.0036977$

Specification (iii): (Selected for forecasts)

$$\ln X_2^{\wedge} = 2.0593172 + 0.0001921t$$

(0.00018695) $R^2 = 0.0701179$ $\bar{R}^2 = 0.0036977$

(iii) Irrigated area of cereals (X_3):

Specification (i):

$$\ln X_3^{\wedge} = 1.938373 + 0.0111584 \ln t$$

(0.0019795) $R^2 = 0.6941538$ $\bar{R}^2 = 0.6723076$

Specification (ii): (Selected for forecasts)

$$\text{Ln } X_3^{\wedge} = 1.9426815 + 0.0020096t$$

$$(0.0002521)$$

$$R^2 = 0.8195062$$

$$\bar{R}^2 = 0.8066138$$

Specification (iii):

$$\text{Ln } X_3^{\wedge} = 1.9426815 + 0.0020096t$$

$$(0.0002521)$$

$$R^2 = 0.8195062$$

$$\bar{R}^2 = 0.8066138$$

(iv) Irrigated area of pulses (X_4):

Specification (i):

$$\text{Ln } X_4^{\wedge} = 2.0907596 - 0.0104968 \text{Ln } t$$

$$(0.0033991)$$

$$R^2 = 0.4051812$$

$$\bar{R}^2 = 0.3626941$$

Specification (ii):

$$\text{Ln } X_4^{\wedge} = 2.0881743 - 0.0020632t$$

$$(0.0004792)$$

$$R^2 = 0.5697217$$

$$\bar{R}^2 = 0.5389875$$

Specification (iii): (Selected for forecasts)

$$\text{Ln } X_4^{\wedge} = 2.0881743 - 0.0020632t$$

$$(0.0004792)$$

$$R^2 = 0.5697217$$

$$\bar{R}^2 = 0.5389875$$

(D) Central zone:

(i) Irrigated area of rice (X_1):

$$X_1^{\wedge} = 5330.185 + 20.094412t$$

$$(10.8105338)$$

(ii) Irrigated area of wheat (X_2):

$$X_2^{\wedge} = 3072.2875 + 164.4705882t$$

$$(21.1798339)$$

(iii) Irrigated area of cereals (X_3):

$$X_3^{\wedge} = 2730.82 - 54.338382t$$

$$(6.351328)$$

(iv) Irrigated area of pulses (X_4):

$$X_4^{\wedge} = 4490.57 + 127.34324t$$

$$(15.9275)$$

(E) West zone:

(i) Irrigated area of rice (X_1):

Specification (i): (Selected for forecasts)

$$\text{Ln } X_1^{\wedge} = 2.0037181 + 0.0219437 \text{Ln } t$$

$$(0.0033066)$$

$$R^2 = 0.7587881$$

$$\bar{R}^2 = 0.7415586$$

Specification (ii):

$$\text{Ln } X_1^{\wedge} = 2.018589 + 0.0031994t$$

$$(0.0007171)$$

$$R^2 = 0.5870837$$

$$\bar{R}^2 = 0.5575897$$

Specification (iii):

$$\text{Ln } X_1^{\wedge} = 2.018589 + 0.0031994t$$

$$(0.0007171)$$

$$R^2 = 0.5870837$$

$$\bar{R}^2 = 0.5575897$$

(ii) Irrigated area of cereals (X_2):

Specification (i):

$$\ln X_2^{\wedge} = 2.2739754 - 0.0084552 \ln t$$

$$(0.0027543)$$

$$R^2 = 0.4023219$$

$$\bar{R}^2 = 0.3596306$$

Specification (ii): (Selected for forecasts)

$$\ln X_2^{\wedge} = 2.2723215 - 0.0017123t$$

$$(0.0003732)$$

$$R^2 = 0.6005556$$

$$\bar{R}^2 = 0.5720239$$

Specification (iii):

$$\ln X_2^{\wedge} = 2.2723215 - 0.0017123t$$

$$(0.0003732)$$

$$R^2 = 0.6005556$$

$$\bar{R}^2 = 0.5720239$$

(iii) Irrigated area of pulses (X_3):

Specification (i): (Selected for forecasts)

$$\ln X_3^{\wedge} = 2.1754611 + 0.009096 \ln t$$

$$(0.0036578)$$

$$R^2 = 0.3063799$$

$$\bar{R}^2 = 0.2568356$$

Specification (ii):

$$\ln X_3^{\wedge} = 2.1822452 + 0.0012533t$$

$$(0.0006464)$$

$$R^2 = 0.211694$$

$$\bar{R}^2 = 0.1553864$$

Specification (iii):

$$\ln X_3^{\wedge} = 2.1822452 + 0.0012533t$$

$$(0.0006464)$$

$$R^2 = 0.211694$$

$$\bar{R}^2 = 0.1553864$$

(F) South zone:

(i) Irrigated area of rice (X_1):

$$X_1^{\wedge} = 7706.6515 - 109.47617t$$

$$(55.191885)$$

(ii) Irrigated area of cereals (X_2):

$$X_2^{\wedge} = 6338.8366 - 103.13406t$$

$$(16.510962)$$

(iii) Irrigated area of pulses (X_3):

$$X_3^{\wedge} = 4655.2639 + 0.3303941t$$

$$(22.067673)$$

(G) For North east zone:

(i) Irrigated area of rice (X_1):

$$X_1^{\wedge} = 3273.3771 + 10.622857t$$

$$(6.86613424)$$

(ii) Irrigated area of cereals (X_2):

$$X_2^{\wedge} = 218.86857 + 5.0864286t$$

$$(0.50147158)$$

(iii) Irrigated area of pulses (X_3):

$$X_3^{\wedge} = 158.68 + 6.2375t$$

$$(0.77443178)$$

(H) (North + East + Central):

(i)Irrigated area of rice (X_1):

Specification (i): (Selected for forecasts)

$$\text{Ln } X_1^{\wedge} = 2.3344177 - 0.0001596 \text{Ln } t$$

$$(0.0009007)$$

$$R^2 = 0.0022379$$

$$\bar{R}^2 = -0.0690308$$

Specification (ii):

$$\text{Ln } X_1^{\wedge} = 2.334052 + 0.000007013t$$

$$(0.0001494)$$

$$R^2 = 0.0001581$$

$$\bar{R}^2 = -0.0712592$$

Specification (iii):

$$\text{Ln } X_1^{\wedge} = 2.334052 + 0.000007013t$$

$$(0.0001494)$$

$$R^2 = 0.0001581$$

$$\bar{R}^2 = -0.0712592$$

(ii)Irrigated area of wheat (X_2):

Specification (i):

$$\text{Ln } X_2^{\wedge} = 2.2981547 + 0.0054137 \text{Ln } t$$

$$(0.0010679)$$

$$R^2 = 0.6473222$$

$$\bar{R}^2 = 0.6221309$$

Specification (ii):

$$\text{Ln } X_2^{\wedge} = 2.2996308 + 0.0010473t$$

$$(0.0001025)$$

$$R^2 = 0.8817018$$

$$\bar{R}^2 = 0.8732519$$

Specification (iii): (Selected for forecasts)

$$\text{Ln } X_2^{\wedge} = 2.2996308 + 0.0010473t$$

$$(0.0001025)$$

$$R^2 = 0.8817018$$

$$\bar{R}^2 = 0.8732519$$

(iii)Irrigated area of cereals (X_3):

Specification (i):

$$\text{Ln } X_3^{\wedge} = 2.2026704 - 0.0082656 \text{Ln } t$$

$$(0.0012317)$$

$$R^2 = 0.7628585$$

$$\bar{R}^2 = 0.7459198$$

Specification (ii): (Selected for forecasts)

$$\text{Ln } X_3^{\wedge} = 2.1992998 - 0.0014676t$$

$$(0.000148)$$

$$R^2 = 0.8752984$$

$$\bar{R}^2 = 0.8663912$$

Specification (iii):

$$\text{Ln } X_3^{\wedge} = 2.1992998 - 0.0014676t$$

$$(0.000148)$$

$$R^2 = 0.8752984$$

$$\bar{R}^2 = 0.8663912$$

(iv)Irrigated area of pulses (X_4):

Specification (i): (Selected for forecasts)

$$\text{Ln } X_4^{\wedge} = 2.2092847 + 0.0074607 \text{Ln } t$$

$$(0.0013796)$$

$$R^2 = 0.676248$$

$$\bar{R}^2 = 0.6531229$$

Specification (ii):

$$\text{Ln } X_4^{\wedge} = 2.2131166 + 0.0012318t$$

$$(0.0002306)$$

$$R^2 = 0.6709344$$

$$\bar{R}^2 = 0.6474297$$

Specification (iii):

$$\text{Ln } X_4^{\wedge} = 2.2131166 + 0.0012318t$$

(0.0002306)

$R^2 = 0.6709344$

$\bar{R}^2 = 0.6474297$

(I) (West + South + North East):

(i) Irrigated area of rice (X_1):

$$X_1^{\wedge} = 12366.1225 + 66.06867647t$$

(47.67057)

(ii) Irrigated area of cereals (X_2):

$$X_2^{\wedge} = 22755.667 - 323.93699t$$

(59.888364)

(iii) Irrigated area of pulses (X_3):

$$X_3^{\wedge} = 11939.04 + 91.073971t$$

(58.983273)

The figures in the parentheses of the above equations indicate the standard errors of their respective estimates of the parameters.

From the above estimated equations of different independent variables, the selected specifications of linear, exponential and power curve trends with respect to various zones (or regions), are observed below.

INDIA:

For India, the selected specifications of estimated equations for the three independent variables and the corresponding values of R^2 and $\bar{R}^2$ are specified below. In the case of the independent variable X_2 either of the specifications (ii) & (iii) may be selected. Here specification (ii) is selected arbitrarily for the prediction. The value of R^2 with reference to each independent variable is significant at 5% level of significance.

$$\text{Ln } X_1^{\wedge} = 2.3677755 - 0.000105t,$$

$$R^2 = 0.0341292$$

$$\bar{R}^2 = -0.0348616$$

$$\text{Ln } X_2^{\wedge} = 2.3368668 - 0.001535t,$$

$$R^2 = 0.7505061$$

$$\bar{R}^2 = 0.7326851$$

$$\text{Ln } X_3^{\wedge} = 2.2953641 + 0.0059993 \text{Ln } t,$$

$$R^2 = 0.5362435$$

$$\bar{R}^2 = 0.5031181$$

Similarly, we may write the interpretation for the zones (or regions) from (B)-(I) with respect to the selected specifications of X_{it} ($i = 1, 2, 3, 4$) and Y_{t-1} .

4.3 Estimation of Time series Models

As part of forecasting total production (Y_t) using time series models, the estimated specifications of linear, exponential and power curve trends, the corresponding values of R^2 and $\bar{R}^2$ with respect to India and various zones (or regions) are observed below.

A) India:

$$Y_t^{\wedge} = 124468.13 + 2360.0321t$$

(486.03069)

B) North zone:

Specification (i):

$$\text{Ln } Y_t^{\wedge} = 11.286636 + 0.0619437 \text{Ln } t$$

(0.0215093)

$R^2 = 0.3720159$

$\bar{R}^2 = 0.3271599$

Specification (ii): (Selected for forecasts)

$$\text{Ln } Y_t^{\wedge} = 11.308583 + 0.0113881t$$

(0.0033133)

$R^2 = 0.4576446$

$\bar{R}^2 = 0.4189049$

Specification (iii):

$$\text{Ln } Y_t^{\wedge} = 11.308583 + 0.0113881t$$

(0.0033133)

$R^2 = 0.4576446$

$\bar{R}^2 = 0.4189049$

(C) East zone:

$$Y_t^{\wedge} = 32306.135 + 668.5752941t$$

(160.65504)

(D) Central zone:

Specification (i):

$$\text{Ln } Y_t^{\wedge} = 9.4058812 + 0.3111096 \text{Ln } t$$

(0.0215093)

$R^2 = 0.6466927$

$\bar{R}^2 = 0.6214564$

Specification (ii):

$$\text{Ln } Y_t^{\wedge} = 9.5176271 + 13597.308t$$

(0.007843)

$R^2 = 0.7905787$

$\bar{R}^2 = 0.77562$

Specification (iii): (Selected for forecasts)

$$\text{Ln } Y_t^{\wedge} = 9.5176271 + 13597.308t$$

(0.007843)

$R^2 = 0.7905787$

$\bar{R}^2 = 0.77562$

(E) West zone:

Specification (i): (Selected for forecasts)

$$\text{Ln } Y_t^{\wedge} = 9.7389973 + 0.1366743 \text{Ln } t$$

(0.0510079)

$R^2 = 0.3389855$

$\bar{R}^2 = 0.2917701$

Specification (ii):

$$\text{Ln } Y_t^{\wedge} = 9.8400371 + 0.0189369t$$

(0.007843)

$R^2 = 0.2368554$

$\bar{R}^2 = 0.1823451$

Specification (iii):

$$\text{Ln } Y_t^{\wedge} = 9.8400371 + 0.0189369t$$

(0.007843)

$R^2 = 0.2368554$

$\bar{R}^2 = 0.1823451$

(F) South zone:

Specification (i): (Selected for forecasts)

$$\text{Ln } Y_t^{\wedge} = 10.317688 + 0.0401867 \text{Ln } t$$

	(0.0545849)	$R^2 = 0.037273$	$\bar{R}^2 = -0.0314933$
Specification (ii):			
$\text{Ln } Y_t^{\wedge} = 10.338375 + 0.0066295t$			
	(0.0090495)	$R^2 = 0.0369194$	$\bar{R}^2 = -0.0318721$
Specification (iii):			
$\text{Ln } Y_t^{\wedge} = 10.338375 + 0.0066295t$			
	(0.0090495)	$R^2 = 0.0369194$	$\bar{R}^2 = -0.0318721$

(G) North East zone:

$$Y_t^{\wedge} = 5011.7775 + 179.1967647t$$

(30.448271)

(H) (North + East + Central):

$$Y_t^{\wedge} = 125240.46 + 3047.3366t$$

(440.72762)

(I) (West + South + North East):

$$Y_t^{\wedge} = 53064.8 + 1325.7096t$$

(353.07941)

The figures in the parentheses of the above equations indicate the standard errors of their respective estimates of the parameters.

The selected specifications of time series models with respect to various zones (or regions), are observed below.

INDIA:

In the case of India, the estimated specification of the time series model is

$$Y_t^{\wedge} = 124468.13 + 2360.0321t.$$

This indicates that, the dependent variable (Y_t) is linearly associated with the time independent variable. i.e., the growth that occurring yearly in the total production is in the linear trend.

NORTH ZONE:

In the case of north zone, the selected time series model is either of the specifications (ii) and (iii) and is $\text{Ln } Y_t^{\wedge} = 11.308583 + 0.0113881t$.

Since the above specification is in a log-linear (exponential) form, it indicates that, the rate of change in the total production (Y_t) is in the exponential trend. Here R^2 is 0.46 which is a significant value and indicates that 46% of the change in Y_t is due to the time variable t . Similarly, we may write the interpretation for the zones (or regions) from (C)-(I).

4.4 Comparison

In this section, in order to come to a conclusion that which estimation (i.e. Proposed or Time series) gives a best estimation, a comparison is being made in terms of the corresponding $\bar{R}^2$ (i.e. adjusted coefficient of determination) values as observed in the table below.

Table (2): $\bar{R}^2$ Values Obtained for India as well as Zones With respect to Selected Specifications of Proposed and Time series Models

S No	Regions/Zones	$\bar{R}^2$ based on selected specification of	
		Proposed models*	Time series models**
1	NORTH	0.6255603	0.4189049
2	EAST	0.8810758	0.5210509
3	CENTRAL	0.9766222	0.77562
4	WEST	0.6919314	0.2917701
5	SOUTH	0.7324902	-0.0314933
6	NORTH EAST	0.9611965	0.6915902
7	INDIA	0.8382199	0.6008311
8	N+E+C	0.8384643	0.7573129
9	W+S+NE	0.8623861	0.4661508

Note: *: $\bar{R}^2$ obtained with reference to Proposed models can be observed under section 4.1.

**: $\bar{R}^2$ obtained with reference to Time series models can be observed under section 4.2.

From the above table, since the values of $\bar{R}^2$ for the proposed models are better than that of time series models, it can be understood that the proposed models will give good estimation.

The predicted values of the different independent variables are substituted in the selected specifications of linear or multiplicative models thereby we obtained the forecasted values of the total production of food grains with respect to India and various zones for the period 2016-2050.

These production forecasts are to be compared with the production forecasts obtained, from selected time series models. The production forecasts which are obtained based on the selected specifications of proposed models and time series models are observed in the tables (2) and (3) respectively.

Table (3): PRODUCTION FORECASTS (In '000 Tonnes) FOR INDIA AS WELL AS ZONES ON THE BASIS OF SELECTED SPECIFICATION OF PROPOSED MODEL

S NO	YEARS	Forecasted Total Production (Y _t) of Food grains from the Model selected for Forecasting ('000 tonnes)								
		NORTH ZONE	EAST ZONE	CENTRAL ZONE	WEST ZONE	SOUTH ZONE	NORTH EAST ZONE	INDIA	N+E+C	W+S+NE
1	2016	100645.81	43003.28	34437.05	25101.00	32828.91	8322.68	165559.53	176398.67	74943.07
2	2017	101911.55	44007.42	35773.41	25321.28	32798.65	8516.96	168318.66	179664.43	76191.27
3	2018	103196.09	45036.98	37109.77	25533.08	32768.38	8711.23	171122.58	182986.11	77439.48
4	2019	104499.74	46092.65	38446.12	25737.23	32738.12	8905.50	173972.01	186365.21	78687.68
5	2020	105822.81	47175.14	39782.48	25934.44	32707.85	9099.77	176867.65	189803.23	79935.89
6	2021	107165.62	48285.19	41118.84	26125.31	32677.59	9294.04	179810.25	193301.60	81184.09
7	2022	108528.49	49423.53	42455.19	26310.38	32647.32	9488.31	182800.55	196861.78	82432.30
8	2023	109911.76	50590.96	43791.55	26490.11	32617.06	9682.58	185839.32	200485.18	83680.50
9	2024	111315.76	51788.25	45127.91	26664.91	32586.79	9876.85	188927.31	204173.25	84928.71
10	2025	112740.83	53016.25	46464.26	26835.16	32556.53	10071.12	192065.31	207927.40	86176.91
11	2026	114187.34	54275.78	47800.62	27001.18	32526.26	10265.39	195254.12	211749.08	87425.12
12	2027	115655.62	55667.71	49136.97	27163.25	32496.00	10459.66	198494.54	215639.72	88673.32
13	2028	117146.05	56892.95	50473.33	27321.65	32465.73	10653.94	201787.40	219600.80	89921.52
14	2029	118658.99	58252.42	51809.69	27476.60	32435.47	10848.21	205133.51	223633.77	91169.73
15	2030	120194.81	59647.05	53146.04	27628.32	32405.20	11042.48	208533.73	227740.12	92417.93
16	2031	121753.91	61077.82	54482.40	27772.84	32374.94	11236.75	211988.91	231921.38	93666.14
17	2032	123336.66	62545.75	55818.76	27922.84	32344.67	11431.02	215499.93	236179.05	94914.34
18	2033	124943.47	64051.85	57155.11	28065.97	32314.41	11625.29	219067.67	240514.70	96162.55
19	2034	126574.73	65597.21	58491.47	28206.56	32284.14	11819.56	222693.03	244929.89	97410.75
20	2035	128230.87	67182.90	59827.83	28344.73	32253.88	12013.83	226376.93	249426.22	98658.96
21	2036	129912.28	68810.07	61164.18	28480.62	32223.61	12208.10	230120.28	254005.32	99907.16
22	2037	131619.41	70479.88	62500.54	28614.33	32193.35	12402.37	233924.03	258668.84	101155.37
23	2038	133352.68	72193.51	63836.89	28745.99	32163.08	12596.64	237789.14	263418.45	102403.57
24	2039	135112.54	73952.21	65173.25	28875.68	32132.82	12790.92	241716.58	268255.86	103651.77
25	2040	136899.43	75757.24	66509.61	29003.49	32102.55	12985.19	245707.34	273182.81	104899.98
26	2041	138713.81	77609.91	67845.96	29129.52	32072.29	13179.46	249762.42	278201.07	106148.18
27	2042	140556.15	79511.57	69182.32	29253.85	32042.02	13373.73	253882.83	283312.44	107396.39
28	2043	142426.92	81463.61	70518.68	29376.54	32011.76	13568.00	258069.60	288518.76	108644.59
29	2044	144326.61	83467.44	71855.03	29497.67	31981.49	13762.27	262323.80	293821.88	109892.80
30	2045	146255.70	85524.55	73191.39	29617.30	31951.23	13956.54	266646.49	299223.72	111141.00
31	2046	148214.69	87636.46	74527.75	29735.49	31920.96	14150.81	271038.74	304726.21	112389.21
32	2047	150204.10	89804.71	75864.10	29852.31	31890.70	14345.08	275501.66	310331.32	113637.41
33	2048	152224.45	92030.93	77200.46	29967.80	31860.43	14539.35	280036.36	316041.07	114885.62
34	2049	154276.26	94316.77	78536.81	30082.02	31830.17	14733.62	284643.99	321857.52	116133.82
35	2050	156360.07	96663.94	79873.17	30195.01	31799.90	14927.89	289325.68	327782.74	117382.02

Table (4): PRODUCTION FORECASTS (In '000 Tonnes) FOR INDIA AS WELL AS ZONES ON THE BASIS OF SELECTED TIME SERIES MODEL

S NO	YEARS	Forecasted Total Production (Y _t) of Food grains from the selected Time series model ('000 tonnes)									
		NORTH ZONE	EAST ZONE	CENTRAL ZONE	WEST ZONE	SOUTH ZONE	NORTH EAST ZONE	INDIA	N+E+C	W+S+NE	
1	2016	98931.25	43671.91	35843.73	24989.84	33912.72	8058.12	164588.68	177045.18	75601.86	
2	2017	100064.33	44340.49	37946.84	25185.83	33990.71	8237.32	166948.71	180092.52	76927.57	
3	2018	101210.39	45009.07	40173.34	25372.63	34064.65	8416.52	169308.74	183139.86	78253.28	
4	2019	102369.57	45677.64	42530.49	25551.13	34134.94	8595.71	171668.77	186187.19	79578.99	
5	2020	103542.03	46346.22	45025.93	25722.09	34201.93	8774.91	174028.80	189234.53	80904.70	
6	2021	104727.91	47014.79	47667.80	25886.15	34265.93	8954.11	176388.84	192281.87	82230.41	
7	2022	105927.38	47683.37	50464.67	26043.90	34327.20	9133.30	178748.87	195329.20	83556.12	
8	2023	107140.59	48351.94	53425.65	26195.83	34385.96	9312.50	181108.90	198376.54	84881.83	
9	2024	108367.69	49020.52	56560.36	26342.40	34442.41	9491.70	183468.93	201423.88	86207.54	
10	2025	109608.84	49689.09	59879.00	26483.98	34496.74	9670.89	185828.96	204471.21	87533.25	
11	2026	110864.22	50357.67	63392.36	26620.94	34549.10	9850.09	188189.00	207518.55	88858.96	
12	2027	112133.97	51026.24	67111.86	26753.59	34599.63	10029.29	190549.03	210565.88	90184.67	
13	2028	113418.26	51694.82	71049.61	26882.21	34648.46	10208.48	192909.06	213613.22	91510.38	
14	2029	114717.26	52363.39	75218.39	27007.06	34695.70	10387.68	195269.09	216660.56	92836.09	
15	2030	116031.14	53031.97	79631.78	27128.36	34741.45	10566.88	197629.13	219707.89	94161.80	
16	2031	117360.06	53700.54	84304.12	27246.34	34785.80	10746.07	199989.16	222755.23	95487.51	
17	2032	118704.21	54369.12	89250.60	27361.17	34828.84	10925.27	202349.19	225802.57	96813.22	
18	2033	120063.75	55037.69	94487.32	27473.03	34870.65	11104.47	204709.22	228849.90	98138.93	
19	2034	121438.87	55706.27	100031.30	27582.09	34911.30	11283.66	207069.25	231897.24	99464.64	
20	2035	122829.73	56374.85	105900.56	27688.50	34950.84	11462.86	209429.29	234944.58	100790.35	
21	2036	124236.52	57043.42	112114.20	27792.38	34989.35	11642.06	211789.32	237991.91	102116.06	
22	2037	125659.43	57712.00	118692.43	27893.86	35026.87	11821.25	214149.35	241039.25	103441.76	
23	2038	127098.63	58380.57	125656.62	27993.06	35063.45	12000.45	216509.38	244086.59	104767.47	
24	2039	128554.31	59049.15	133029.44	28090.10	35099.14	12179.65	218869.41	247133.92	106093.18	
25	2040	130026.67	59717.72	140834.85	28185.06	35133.99	12358.84	221229.45	250181.26	107418.89	
26	2041	131515.89	60386.30	149098.23	28278.04	35168.03	12538.04	223589.48	253228.60	108744.60	
27	2042	133022.17	61054.87	157846.47	28369.13	35201.30	12717.24	225949.51	256275.93	110070.31	
28	2043	134545.69	61723.45	167108.00	28458.40	35233.84	12896.44	228309.54	259323.27	111396.02	
29	2044	136086.67	62392.02	176912.94	28545.95	35265.67	13075.63	230669.57	262370.61	112721.73	
30	2045	137645.30	63060.60	187293.18	28631.83	35296.83	13254.83	233029.61	265417.94	114047.44	
31	2046	139221.78	63729.17	198282.48	28716.11	35327.35	13434.03	235389.64	268465.28	115373.15	
32	2047	140816.31	64397.75	209916.57	28798.86	35357.25	13613.22	237749.67	271512.62	116698.86	
33	2048	142429.11	65066.32	222233.27	28880.13	35386.56	13792.42	240109.70	274559.95	118024.57	
34	2049	144060.37	65734.90	235272.66	28959.99	35415.31	13971.62	242469.74	277607.29	119350.28	
35	2050	145710.32	66403.47	249077.12	29038.47	35443.50	14150.81	244829.77	280654.63	120675.99	

5. Conclusion

It is observed that the values of $\bar{R}^2$ for the selected specifications of linear and multiplicative models are larger than that of selected specifications of time series models. This indicates that the proposed forecasting model is a better model than a time series forecasting model. Since the proposed models are observed to be the best models, with reference to them the following points are observed.

1. For India (when considered as a whole unit), the multiplicative model without one time period log dependent variable, best fits the data. The forecasts of total production of food grains in thousand tonnes for the next 35 years i.e. from 2016 to 2050 with reference to the above selected model are observed to be 164588.68, 166948.71, 169308.74,..... and 280654.63.
2. For the North zone, the multiplicative model with one time period log dependent variable, best fits the data. And the production forecasts obtained (in '000 tonnes) for the future years with reference to the selected model are observed to be 98931.25, 100064.33, 101210.39,..... and 145710.32.
3. As in the case of India, similarly for East zone, West zone and as well as for the combination of North & East & Central zones the multiplicative model without one time period log dependent variable, best fits the data. The production forecasts (in '000 tonnes) for
 - (i) East zone are observed to be 43671.91, 44340.49, 45009.07,..... and 66403.47.
 - (ii) West zone are observed to be 24989.84, 25185.83, 25372.63,..... and 29038.47.
 - (iii) The region which is a combination of North & East & Central zones, the production forecasts are observed to be 177045.18, 180092.52, 183139.86,..... and 280654.63.
4. For Central zone, South zone and as well as for the combination of West, South and North east zones, the linear model without one time period log dependent variable, gives a best fit for the data. And the production forecasts (in '000 tonnes) for
 - (i) Central zone are observed to be 35843.73, 37946.84, 40173.34,..... and 249077.12.
 - (ii) South zone are observed to be 33912.72, 33990.71, 34064.65,..... and 35443.50.
 - (iii) The region which is a combination of West, South and North east zones are observed to be 75601.86, 76927.57, 78253.28,..... and 120675.99.
5. For North east zone, the linear model with one time period log dependent variable gives a best fit for the data. The production forecasts for the future years are observed to be 8058.12, 8237.32, 8416.52,..... and 14150.81.

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