Measurement of Production Efficiency: A Case of Indian Agricultural Production in Post Reforms Period

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ABSTRACT

The paper examines the production efficiency of agricultural system in regions of India using state level data for the period 1990-91 to 2004-05 and for 2005-06 to 2013-14. Stochastic production frontier model using panel data, as proposed by Battese and Coelli (1995), has been used for estimating the efficiency variations taking an integrated effect model into consideration. State level mean efficiency estimates ranges from 0.9660 to 0.4369 during 1990-91 to 2004-05 and from 0.8648 to 0.4805 for 2005-06 to 2013-14. The statistically significant efficiency variables are rate of rural literacy, rate of rural technical education, total state road length per unit of area and share of agricultural NSDP to state NSDP and the major inputs were net irrigated area and consumption of pesticides for the period 1990-91 to 2004-05. For the period 2005-06 to 2013-14, institutional credit, consumption of fertilizers and consumption of pesticides shares a significant and positive relation with the level of production. The total state road length per unit of area and share of agricultural NSDP to state NSDP are found to reduce inefficiency in agricultural production.

Keywords: *Stochastic Frontier Analysis (SFA); Technical Efficiency; Translog Production Function; Agricultural Production.*

JEL Classification: Q14, Q15, Q16

1. INTRODUCTION

Agriculture is of primary importance in the Indian scenario. Despite India having achieved self-sufficiency in food production at the macro level, there still remains a food deficiency. The country still faces massive challenges of high incidence of rural poverty and malnourishment in large numbers of children. Moreover, the dependence of the rural workforce on agriculture for employment has not declined in proportion to the sectoral contribution to gross domestic product (GDP). Thus, the pressure on agriculture to increase production remains extremely high. In comparison to growth in other sectors, GDP growth in agriculture has been shown to be at least twice as effective in reducing poverty (World Development Report 2008) [1]. In 2015, farmers in low- and middle-income countries invested more than USD 170 billion a year in their farms; an average of about USD 150 per farmer [2]. Agriculture remains of importance in many countries despite their different agendas for pursuing sustainable growth and reducing poverty. In India, the increase in the agricultural production growth rate has been striking in the post-independence era in comparison to the earlier decades. A distinguishing feature, however, of agriculture in post-independence India is the wide regional variation in growth of output both at the macro level and in each crop.

Around 15.2% of the total population is undernourished in India in 2015 [2], and so the loss of food production due to inefficiency is a major concern. So the analysis of inefficiency of agricultural production units in India is a pertinent issue for any policy prescription relating to poverty and hunger. In economics, the mainstream neoclassical paradigm assumes that the producers in an economy always operate efficiently. However, the producers are not always efficient. Traditionally, stochastic frontier models have been used to estimate technical efficiency in micro units, e.g., firms, agricultural farms, etc. This methodology has also been extended for use in the estimation of regional efficiencies by Margono & Sharma, 2004 [3].

Gumbau (1998) [4] analysed the (in)efficiency of the seventeen Spanish regions over the period 1986–91, using a stochastic frontier approach. They used different distributional assumptions to estimate each region's (in)efficiency as well as the influence of the inputs on the productivity gains. The results showed that, the inefficiency varies between the 15% and 19% on an average.

Kaneko *et al.* (2004) [5] applied stochastic frontier analysis (SFA) techniques on a provincial level data set of China from 1999 to 2002 measuring technical and water efficiency in their agricultural production. The study gave three important insights: corn is the most important crop for improving economic and water efficiency, the average annual temperature responded greatly to the change in water efficiency and though utilization of irrigation water was provided by water reservoirs, it led to less efficiency in water use.

Meon and Weill (2005) [6] studied the relationship between governance and macroeconomic technical efficiency on a sample of 62 developed and developing countries. They applied Battese and Coelli (1995)'s method [7] at the aggregate level. They found that better governance, measured by six complementary indices representing different dimensions of governance, marked greater efficiency.

Constantin *et al.* (2009) [8] in their study applied a Cobb-Douglas, Translog Stochastic Production Function and Data Envelopment Analysis to estimate inefficiencies over time. He also calculated respective TFP (Total Factor Productivity) sources for main Brazilian crops i.e. rice, beans, maize, soybeans and wheat for the period 2001-2006. Assuming a Translog technology for stochastic frontier analysis for Brazilian agriculture, no increase in aggregate productivity throughout the analyzed period was observed. Ranking the regions in a descending order, it was found that the Northeast Brazilian region obtained the highest rank for efficiency followed by North, Southeast and Center-west. The most significant inputs contributing to Brazilian agriculture productivity were land and agriculture credit, where the latter was used to represent the contribution of machinery to Brazilian agricultural efficiency. Inputs related to agricultural defensives and limestone were found to be insignificant in explaining Brazilian agricultural productivity for the specified time period.

Djokoto (2012) [9] estimated technical efficiency of Ghana's agricultural sector for the period 1976-2007 and identified the major factors that influence technical efficiencies using the stochastic frontier analysis model. The results showed that land had been overused, implying negative inelasticity. Technology variables, fertilizers and tractors were found to be positively related to output. The level of inefficiency was found to be 21% along with decreasing returns to scale.

Jansouz *et al.* (2013) [10] examined the agriculture sector efficiency in Middle Eastern and North African (MENA) countries by obtaining agriculture sector data from FAO. They used the technique of Stochastic Frontier Analyses (SFA). The results revealed that efficiency ranged between 41 % in Egypt and 87 % in Bahrain. The mean efficiency levels were about 0.70 for agriculture sector over the period 1995-2008 indicating that 30 % of total cost could be saved if agriculture sectors were operating efficiently. The study was performed on 210 panel data from 15 Middle East and North Africa countries from 1995 to 2008.

This paper analyzes state level data from the agricultural sector in India for the period 1990-91 to 2004-05 and from 2005-06 to 2013-14 to study the efficiency dynamics of a "typical" firm in some regions of India during the post reform years. Although several methods are available to measure inefficiency, our focus in this paper is on the stochastic frontier (SF) methodology developed by Battese and Coelli (1995) [7]. We hypothesize that regions of India differ in their technical efficiency pertaining to the agricultural production due to factors that are region specific. In this paper we tried to understand and investigate the factors responsible for improving efficiency in agricultural production at the regional level.

2. METHODOLOGY

This section discusses in brief the methodology used in this paper which is the stochastic frontier analysis to perform an efficiency analysis with respect to Indian agriculture. The efficiency/inefficiency of a production unit means the comparison between the observed and potential/optimal output or input. One of the most important forms of studying efficiency of production units is technical efficiency. Koopmans [11] defined technical efficiency of input on the basis of disposability condition i.e. the vector of inputs is technically efficient if and only if increasing any output and decreasing any input is possible only by decreasing some other output or increasing some other input. Farrell (1957) [12] and others suggest a measure of technical efficiency in terms of deviation of observed points from the points on the frontier constructed from observed points. Debreu (1951) [13] gave a measure of technical efficiency in terms of maximum possible proportionate reduction of all variable inputs or maximum possible proportionate expansion of all output, which is called 'radial measure' [14].

Stochastic Frontier Analysis (SFA) originated with two papers published nearly simultaneously by two teams on two continents. Meeusen and Van den Broeck (MB) (1977) [15] appeared in June and Aigner, Lovell and Schmidt (ALS) (1977) [16] appeared a month later. This was followed by a third paper by Battese and Corra (1977) [17]. These three original SFA models shared a composed error structure and each was developed in a production frontier context. The model can be expressed as:

$$y = f(x;\beta).\exp\{v-u\}$$

where y is scalar output, x is a vector of inputs and β is a vector of technology parameters. The first error component $v \sim N(0,\sigma_v^2)$ is intended to capture the effects of statistical noise and the second error component $u \geq 0$ is intended to capture the effects of technical inefficiency. Thus producers operate on or beneath their stochastic production frontier $\left[f(x;\beta).\exp\{v\} \right]$ according as $u = 0$ or $u \rangle 0$.

To seek determinants of efficiency variation, early studies adopted a two-stage approach, in which efficiencies are estimated in the first stage and estimated efficiencies are regressed against a vector of explanatory variables in a second stage. More recent studies, including those of Kumbhakar, Ghosh and McGuckin (1991) [18], Reifschneider & Stevenson (1991) [19], Huang and Liu (1994) [20] and Battese and Coelli (1995) [7] have adopted a single stage approach in which explanatory variables are incorporated directly into the efficiency error component (Kumbhakar & Lovell, 2000) [21].

Battese and Coelli (1995) [7] proposed a stochastic frontier production function, which has firm effects assumed to be distributed as a truncated normal random variable, in which the inefficiency effects are directly influenced by a number of variables. Battese and Coelli (1995) [7] inefficiency frontier model for panel data is as follows:

$Y_{it} = \exp(x_{it}\beta + V_{it} - U_{it})$ ……………………………………….. (1) where

Y_{it}, denotes the production at the t-th observation (t = 1, 2,….., T) for the i-th firm (i = 1, 2,..., *N)*

x_{it}, is a (1xk) vector of values of known functions of inputs of production and other explanatory variables associated with the i-th firm at the t-th observation;

β is a $(kx1)$ vector of unknown parameters to be estimated;

the V_{it} s are assumed to be iid $N\left(0, \sigma_V^2\right)$ random errors, independently distributed of the U_{it} s.

the U_{it} s are non-negative random variables, associated with technical inefficiency of production, which are assumed to be independently distributed, such that U_{it} is obtained by truncation (at zero) of the normal distribution with mean, $z_{it}\delta$ and variance, σ^2.

z_{it} is a $(1xm)$ vector of explanatory variables associated with technical inefficiency of production of firms over time; and

δ is an $(mx1)$ vector of unknown coefficients.

Equation (1) specifies the stochastic frontier production function in terms of the original production values. The technical inefficiency effect, U_{it}, in the stochastic frontier model (1) could be specified in equation (2),

$$U_{it} = z_{it}\delta + W_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where the random variable, W_{it}, is defined by the truncation of the normal distribution with zero mean and variance, σ^2, such that the point of truncation is $-z_{it}\delta$ i.e. $W_{it}\rangle - z_{it}\delta$. These assumptions are consistent with U_{it} being a non-negative truncation of the $N\left(z_{it}\delta, \sigma^2\right)$-distribution. The method of maximum likelihood is proposed for simultaneous estimation of the parameters of the stochastic frontier and the model for the technical inefficiency effects.

The inefficiency specification used by Battese and Coelli (1995) [7] is the most frequently used in empirical studies among panel data models. In their model, inefficiency depends on some exogenous variables allowing investigation of how exogenous factors influence inefficiency.

We have performed the analyses using a commonly used form of production function: trans-log model. This is a relatively flexible functional form, as it does not impose assumptions about constant elasticities of production nor elasticities of substitution between inputs. It thus allows the data to indicate the actual curvature of the function, rather than imposing *a priori* assumptions. In general terms, this can be expressed as:

$$\ln Q_{j,t} = \beta_0 + \sum_i \beta_i \ln X_{j,i,t} + \frac{1}{2}\sum_i \sum_k \beta_{i,k} \ln X_{j,i,t} \ln X_{j,k,t} - u_{j,t} + v_{j,t}$$

where $Q_{j,t}$ is the output *j* in period *t* and $X_{j,i,t}$ and $X_{j,k,t}$ are the variable and fixed inputs (*i,k*) to the production process. The error term is separated into two components (as discussed earlier), where $v_{j,t}$ the stochastic error is term and $u_{j,t}$ is an estimate of technical inefficiency.

3. RESULTS AND DISCUSSION

3.1 Empirical Model

For performing a study on technical efficiency across regions using stochastic production function technique, data was taken on some of the states of India on a panel data for the time period considered from 1990-91 to 2004-05 and from 2005-06 to 2013-14. The states taken into consideration are the followings: West Bengal and Bihar representing the eastern zone of India; Gujarat and Maharashtra representing the western zone; Punjab and Haryana representing the northern zone while Tamil Nadu and Karnataka representing the southern zone[1] for the period 1990-91 to 2004-05. Orissa and Bihar representing the eastern zone of India; Gujarat and Maharashtra representing the western zone; Punjab and Uttar Pradesh representing the northern zone while Tamil Nadu and Karnataka representing the southern zone[2] for the period 2005-06 to 2013-14. For each time period, regions are represented by a set of states which constitute identical production frontier. It is however, to be noted that the study does not seek to compare the relative increase or decrease in efficiency of individual regions between the two time periods selected. Data on variables such as total agricultural production, institutional credit, net irrigated area, consumption of fertilizers, and consumption of pesticides were collected

[1] The set of states of analysis are identified which passes the homogeneity test of error variance.

[2] The set of states of analysis are identified which passes the homogeneity test of error variance.

for the specified states of India. Information on the rural literacy rate, level of technical education, length of roads, share of agricultural NSDP to total NSDP for states are used to explain the differences in the inefficiency effects among the farmers. The technical efficiency is studied for the specified regions of India with respect to the agricultural sector using Stochastic Frontier Analysis (SFA) Translog production functions, which is one of the most commonly used production functions. The stochastic frontier production function to be estimated is:

Trans-log:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(INSCRE_{it}) + \beta_2 \ln(NIA_{it}) + \beta_3 \ln(CONFERT_{it}) + \beta_4 \ln(CONPES_{it}) +$$
$$\ln(INSCRE_{it})\left[\frac{1}{2}\beta_5 \ln(INSCRE_{it}) + \beta_6 \ln(NIA_{it}) + \beta_7 \ln(CONFERT_{it}) + \beta_8 \ln(CONPES_{it})\right] +$$
$$\ln(NIA_{it})\left[\frac{1}{2}\beta_9 \ln(NIA_{it}) + \beta_{10} \ln(CONFERT_{it}) + \beta_{11} \ln(CONPES_{it})\right] +$$
$$\ln(CONFERT_{it})\left[\frac{1}{2}\beta_{12} \ln(CONFERT_{it}) + \beta_{13} \ln(CONPES_{it})\right] +$$
$$\ln(CONPES_{it})\left[\frac{1}{2}\beta_{14} \ln(CONPES_{it})\right] + V_i - U_i$$

where the technical inefficiency effects are assumed to be defined by

$$U_{it} = \delta_0 + \delta_1 \ln\left(RATELIT_{it}\right) + \delta_2 \ln\left(RATETECHEDU_{it}\right) + \delta_3 \ln\left(LENROAD_{it}\right) + \delta_4 \ln\left(SHARENSDP_{it}\right)$$

Where ln denotes the natural logarithm (i.e. logarithm to the base e);

Y is the total agricultural production of the individual states considered.[3]

$INSCRE_{it}$ represents institutional credit which comprises of purpose wise refinance disbursements by NABARD under investment credit provided to each representative states. It shows refinances given for the purpose of minor irrigation, land development and farm mechanization. It is measured in terms of rupees lakh.[4]

[3] Data obtained from http:// www.rbi.org.in/ accessed in December 2015.

[4]Data obtained from http://www.nabard.org/.in accessed in December 2015.

NIA_{it} is the Net Irrigated Area of each state. It is measured in terms of '000 hectares.[5]

$CONFER_{it}$ represents consumption of fertilizers by each representative state. Its principal components include N (nitrogen), P (Phosphate) and K (potassium). It is measured in terms of '000 tonnes.[6]

$CONPES_{it}$ represents consumption of pesticides .It is measured in terms of metric tonnes.[7]

$RATELIT_{it}$ represents rate of literacy of the rural areas of the representative states and the rate is calculated in terms of total rural population of the state.[8]

$RATETECHEDU_{it}$ represents rate of technical education of the rural areas of the representative states and the rate is calculated in terms of total rural population of the state.[9]

$LENROAD_{it}$ represents length of roads per square kilometer area of the representative state. Importance of infrastructure in explaining inefficiency is brought into the analysis by considering this variable.[10]

$SHARENSDP_{it}$ is share of agricultural Net State Domestic Product to total Net State Domestic Product. We have attempted to consider the significance of agricultural sector in the state's economic scenario by this variable.[11]

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[5] Data obtained from http:/www. indiastat.com

[6] Data obtained from Fertilizer Statistics.

[7] Data obtained from http:/www. indiastat.com

[8] Literacy data is obtained from Census 1991 and 2001.Each year's literacy rate is calculated based on the decennial growth rate of literacy and the total population of the rural areas in the respective states. Data obtained from Census Reports 1991, 2001, GOI.

[9] Rate of technical education is calculated on the basis of the data collected from Census 1991 and 2001. Each year's rate of technical education is calculated based on the decennial growth rate of technical education and the total population of the rural areas in the respective states. Data obtained from Census Reports 1991, 2001,GOI.

[10] Length of roads has been taken for each state and adjusted to take into consideration the area of the respective state. Data obtained from India Infrastructure Database Vol II by Buddhadeb Ghosh & Prabir De. Bookwell, New Delhi(2005)

V_{it} and W_{it} are as defined in the previous section.

3.2 Results

Levene's Test (Levene 1960) is used to test if k samples have equal variances. Equal variances across samples are called homogeneity of variance. Levene's Test of Equality of Error Variances was performed for the regions where value of log(share of agricultural Net State Domestic Product to total Net State Domestic Product) was incorporated as the covariate. As shown in Table 1, Levene's Test is insignificant, indicating that the group variances are equal (hence the assumption of homogeneity of variance is likely to be accepted) for the concerned region.

Table 1: Result of Levene's Test of Equality of Error Variances

F-Value	Significance Level
.615	.742

Levene's Test of Equality of Error Variances was performed with respect to the concerned regions for 2005-06 to 2013-14. It was calculated with a significance value of 0.115. Levene's Test is insignificant, indicating that the group variances are equal (hence the assumption of homogeneity of variance is likely to be accepted) for the chosen set of states representing different regions of India.

Table 2 shows the summary statistic for variables in the stochastic frontier production function for the concerned regions in India.

[11] Net state domestic product data is available for different base periods i.e 1990 -1993 data is given at the base period 1980-81 and 1993-2005 data is given for the base period 1993-94 . The method of splicing has been used to represent the data set with respect to the base period 1993-94.A ratio of current to constant prices NSDP has been considered.Data obtained from Domestic Product of States1960-2005. EPW Research Foundation.

Table 2: Descriptive Statistics of variables in the stochastic frontier production function for the regions of India

	Minimum	Maximum	Mean	Std. Deviation
1990-91 to 2004-05				
Institutional Credit	594	30928	10083.24	6608.596
Net Irrigated Area	1911	4203	2930.87	595.862
Consumption of fertilizers	585	1930	1012.54	296.742
Consumption of pesticides	832	7500	3953.98	1783.542
2005-06 to 2013-14				
Institutional Credit	1187	51919	15664.21	9380.59
Net Irrigated Area	1248	13929	4495.26	3489.89
Consumption of fertilizers	413	4651	1851.29	1080.20
Consumption of pesticides	555	9563	3368.92	2702.51

Maximum-likelihood estimates of the parameters of the model for the subperiod 1990-91 to 2004-05 are obtained using the computer program, FRONTIER 4.1for the Translog model. These estimates, together with the t-values and estimated standard errors of the maximum-likelihood estimators, are as in Table 3.

Table 3: Estimates of the parameters of Stochastic Frontier Production Function and Determinants of Technical Inefficiency in Agricultural Production (1990-91 to 2004-05)

	Coefficient	t-Values	Standard Error
Constant	-170.5148**	-5.8943	28.9289
$\ln(INSCRE_{it})$	-0.8268	-0.6490	1.2740
$\ln(NIA_{it})$	36.2250**	5.1087	7.0909
$\ln(CONFER_{it})$	-2.0413	-0.4042	5.0500
$\ln(CONPES_{it})$	11.9143**	5.6865	2.0952
0.5 $\ln(INSCRE_{it})\ \ln(INSCRE_{it})$	-0.0861	-1.7289	0.0498
0.5 $\ln(NIA_{it})\ \ln(NIA_{it})$	-2.8165**	-2.9332	0.9602
0.5 $\ln(CONFER_{it})\ \ln(CONFER_{it})$	-0.2567	-0.5326	0.4820
0.5 $\ln(CONPES_{it})\ \ln(CONPES_{it})$	-0.4966**	-4.4419	0.1118
$\ln(INSCRE_{it})\ \ln(NIA_{it})$	-0.1672	-1.0239	0.1633
$\ln(INSCRE_{it})\ \ln(CONFER_{it})$	0.4694**	3.9983	0.1174
$\ln(INSCRE_{it})\ \ln(CONPES_{it})$	-0.0402	-0.7585	0.0530
$\ln(NIA_{it})\ \ln(CONFER_{it})$	-0.3506	-0.6476	0.5414
$\ln(NIA_{it})\ \ln(CONPES_{it})$	-1.2880**	-5.9246	0.2174
$\ln(CONFER_{it})\ \ln(CONPES_{it})$	0.3768**	2.2563	0.1670
Constant	-0.9546**	-2.0450	0.4668
$\ln(RATELIT_{it})$	-1.0156**	-3.1297	0.3245
$\ln(RATETECHEDU_{it})$	-0.2103**	-6.7188	0.0313
$\ln(LENROAD_{it})$	-0.4948**	-6.4849	0.0763
$\ln(SHARENSDP_{it})$	-0.6955**	-5.0804	0.1369

Figures in parentheses represent standard error. ** indicates significant at 5% level

Table 4: Estimates of the parameters of Stochastic Frontier Production Function and Determinants of Technical Efficiency (2005-06 to 2013-14)

	Coefficient	t-Values	Standard Error
Constant	4.7936**	4.8124	0.9961
$\ln(INSCRE_{it})$	2.8690**	3.5957	0.7979
$\ln(NIA_{it})$	0.2219	1.8694	0.1187
$\ln(CONFER_{it})$	21.5962**	22.5831	0.9563
$\ln(CONPES_{it})$	5.8544**	8.9285	0.6557
0.5 $\ln(INSCRE_{it})\ln(INSCRE_{it})$	24.2783**	27.3743	0.8869
0.5 $\ln(NIA_{it})\ln(NIA_{it})$	1.5747**	2.9994	0.5250
0.5 $\ln(CONFER_{it})\ln(CONFER_{it})$	-2. 7815**	2.9816	0.9329
0.5 $\ln(CONPES_{it})\ln(CONPES_{it})$	-0.4967**	-2.7472	0.1808
$\ln(INSCRE_{it})\ln(NIA_{it})$	-0.1079	-0.4496	0.2400
$\ln(INSCRE_{it})\ln(CONFER_{it})$	-0.2729	-1.1376	0.2399
$\ln(INSCRE_{it})\ln(CONPES_{it})$	0.2876	1.7232	0.1669
$\ln(NIA_{it})\ln(CONFER_{it})$	-3.9786**	-7.3176	0.5437
$\ln(NIA_{it})\ln(CONPES_{it})$	0.4891	2.2333	0.2190
$\ln(CONFER_{it})\ln(CONPES_{it})$	-0.3147	-1.3750	0.2288
Constant	-0.5769**	-3.0850	0.1870
$\ln(RATELIT_{it})$	0.0052	0.0221	0.2351
$\ln(RATETECHEDU_{it})$	-0.0032	-0.0066	0.4831
$\ln(LENROAD_{it})$	-0.2741**	-2.3508	0.1166
$\ln(SHARENSDP_{it})$	-0.3782**	-5.8436	0.0647

Figures in parentheses represent standard error. ** indicates significant at 5% level

Maximum-likelihood estimates of the parameters of the model for the subperiod 2005-06 to 2013-14 are obtained using the computer program, FRONTIER 4.1for the Translog model. These estimates, together with the t-values and estimated standard errors of the maximum-likelihood estimators, are given in Table 4.

For the sub-period 1990-91 to 2004-05, the mean efficiency estimates of the states over the specified time period have been calculated and shown in Table 5.

Table 5: Mean Efficiency Estimates of the Eight States for the period 1990-91 to 2004-05

State	Mean Efficiency Estimate	Standard Deviation
West Bengal	0.5564	0.0516
Bihar	0.4369	0.0375
Gujarat	0.6133	0.0781
Maharashtra	0.8160	0.0916
Punjab	0.9660	0.0125
Haryana	0.9163	0.0322
Karnataka	0.8377	0.0984
Tamil Nadu	0.9167	0.0525

For the sub-period 2005-06 to 2013-14, the mean efficiency estimates of the states over the specified time period have been calculated and shown in Table 6.

Table 6: Mean Efficiency Estimates of the Eight States for the period 2005-06 to 2013-14

State	Mean Efficiency Estimate	Standard Deviation
Orissa	0.5848	0.1092
Bihar	0.4868	0.0601
Gujarat	0.5222	0.0777
Maharashtra	0.7606	0.2002
Punjab	0.4805	0.0452
Uttar Pradesh	0.4992	0.0946
Karnataka	0.6521	0.1694
Tamil Nadu	0.8648	0.1303

3.3. Discussion

For the sub-period 1990-91 to 2004-05, the input elasticities from the translog production function using data for agricultural production in the panel of the considered regions are shown in Table 3. The coefficients of net irrigated area and consumption of pesticides are positive and significant at 5% level of significance indicating that the level of production is highly responsive to any given change in the concerned factors of production. Net irrigated area has the largest value, indicating that the increase in regional agricultural production depends mainly on this input. Wider irrigated areas affect production favourably, since irrigation is considered as a risk-reducing input that tends to increase average yield when rainfall is inadequate.

There exist diminishing marginal productivities for net irrigated area and consumption of pesticides.Institutional credit and consumption of pesticides shares a statistically significant positive relation to consumption of fertilizers implying they are no-substitutes to each other. Net Irrigated area and consumption of pesticides shares a statistically significant negative relation to each other.

In the inefficiency model, a statistically significant negative coefficient indicates a decrease in inefficiency level with the increase in the level of explanatory variables representing the regional characteristics. In this model, all four variables, that is rate of rural literacy (representing variations in education level of rural population of each region), rate of rural technical education(representing variations in the level of technical education of rural population of each region), length of roads per square kilometer(indicating variations in infrastructural development of the concerned regions) and share of agricultural NSDP to total NSDP(measuring the importance of the agricultural sector in the concerned state) play a significant role in reducing inefficiency in agricultural production.

As shown in Table 4, for the sub-period 2005-06 to 2013-14, the coefficients of institutional credit, consumption of fertilizers and consumption of pesticides are positive and significant at 5% level of significance indicating that the level of production is highly responsive to any given change in the concerned factors of production. Consumption of fertilizer has the largest value, indicating that the increase in regional agricultural production depends mainly on this input. There exist diminishing marginal productivities for consumption of fertilizers and consumption of pesticides and positive marginal productivities for institutional credit and net irrigated area. Net irrigated area and consumption of fertilizer shares a statistically significant negative relation implying they are substituted to each other. In this model, length of roads per square kilometer and share of agricultural NSDP to total NSDP play a significant role in reducing inefficiency in agricultural production.

For the sub-period 1990-91 to 2004-05, the mean efficiency estimates of the states over the specified time period have been calculated as follows: Northern region was the most efficient, followed by southern states, western states and lastly eastern region. As represented in Table 5, Punjab ranked first with respect to efficiency estimates, estimated on the basis of the above specified empirical model, with Bihar attaining the last position. Standard Deviation was found to be the highest in Karnataka and the lowest in Punjab.

For the sub-period 2005-06 to 2013-14, it was observed that southern region was the most efficient, followed by western states, eastern states and lastly northern region. As represented in Table 6, Tamil Nadu ranked first with respect to efficiency estimates, estimated on the basis of the above specified empirical model. Standard Deviation was found to be highest in Maharashtra and lowest in Punjab.

4. CONCLUSION

The production efficiency of agricultural system in regions of India using state level data for the period 1990-91 to 2004-05 and for 2005-06 to 2013-14 has been estimated using stochastic production frontier model as proposed by Battese and Coelli (1995)[7]. A translog production function has been used to perform the analysis. Regions are represented by a homogeneous set of states for each time period. State level mean efficiency estimates range from 0.9660 to 0.4369 during 1990-91 to 2004-05 and from 0.8648 to 0.4805 for 2005-06 to 2013-14. The statistically significant efficiency variables are rate of rural literacy, rate of rural technical education, total state road length per unit of area and share of agricultural NSDP to state NSDP and the major inputs were net irrigated area and consumption of pesticides for the period 1990-91 to 2004-05.For the period 2005-06 to 2013-14, institutional credit, consumption of fertilizers and consumption of pesticides shares a significant and positive relation with the level of production. The total state road length per unit of area and share of agricultural NSDP to state NSDP are found to reduce inefficiency in agricultural production. The study indicates some significant variables which play important roles in increasing agricultural production and improving its efficiency.

Thus among the homogeneous set of states there has been a shift in the importance attached to the different factors of production and the variables explaining efficiency in the agricultural sector in India in the post-reforms period. Government policies aimed at improving the performance of this sector should therefore be formulated keeping in view the change in the important factors of production and efficiency variables.

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COMPETING INTERESTS

The authors declare that no competing interests exist.

AUTHORS CONTRIBUTIONS

All authors have contributed to the final manuscript and have been listed in order of their contribution. All authors have read and approved the final manuscript.

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