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Cobb-Douglas Production Function For Measuring Efficiency in Indian Agriculture: A Region-wise Analysis

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ABSTRACT

The paper examines the production efficiency of agricultural system in four regions of India categorized as eastern, western, northern and southern regions using state level data for the period 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 of regions ranges from 0.8824 to 0.3759 for 2005-06 to 2013-14. The statistically significant variables explaining inefficiencies in the agricultural production are total state road length per unit of area and share of agricultural NSDP to state NSDP. The major inputs were institutional credit, net irrigated area and consumption of both fertilizers and pesticides.

Keywords: Stochastic Frontier Analysis (SFA), technical efficiency; Cobb-Douglas production function, agricultural production

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 with the country facing massive challenges of high incidence of rural poverty and malnourishment in large numbers of children. Majority of the rural workforce still depends on agriculture for employment and thus, the pressure on agriculture to increase production remains extremely high. Agriculture makes significant contributions to development as an economic activity, as a means of livelihood and as a provider of environmental services. 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). Additionally, agriculture, in tandem with other sectors, e.g. the industrial sector, can increase growth, production and lead to the reduction of poverty. Around 15.2% of the total population is undernourished in India and so the loss of food production due to inefficiency is a major concern (FAO). So the analysis of inefficiency of agricultural production units in India is a pertinent issue for any policy prescription relating to poverty and hunger. Inefficiency has a number of major effects, for example, low level of production with a given level of input, under-utilization of resources and increase in cost of production.

Both demand and supply side factors are vital in agricultural market. In the present paper, we have tried to study some issues of the latter, that is, whether the Indian states are efficiently utilizing their factors of production. Msuya (2008) shows that, low productivity is one of the primary causes of low and unstable value added output, leading to a stagnant rural economy with persistence of poverty. According to the assumption of mainstream neoclassical paradigm, producers in an economy always operate efficiently. However, the producers do not always operate efficiently. In fact, the output level, costs and profits would be different for two firms which appear otherwise identical in terms of their technological status and these differences can be explained in terms of efficiency and some unforeseen exogenous shocks. Given the resources (inputs), a producer is said to be technically inefficient if it fails to produce the maximum possible output (Desli *et al.* 2002). Low levels of production despite a certain level of input, under-utilization of resources and increase in cost of production are among the major effects of inefficiency. This paper studies state level data from the agriculture sector in India using a Cobb-Douglas production function for the period 2005-06 to 2013-14 to analyze the efficiency dynamics of a "typical" firm in different regions of India during the post reform period and understand and investigate the factors responsible for agricultural production at the national level. Inefficiency can be measured by several methods but our focus in this paper is on the stochastic frontier (SF) methodology developed by Battese and Coelli (1995).

Traditionally, stochastic frontier models have been used to estimate technical efficiency in micro units, e.g., firms, agricultural farms, etc. But recently this methodology has also been extended for use in the estimation of regional efficiencies (Margono & Sharma, 2004).

Carter & Zhang (1994) estimated the growth of agricultural production efficiency in nine centrally planned economies, namely, Bulgaria, the former Czechoslovakia, the former East Germany, Hungary, Poland, Romania, the former Yugoslavia, the former Soviet Union (FSU), and the Peoples' Republic of China (PRC) over two time periods, 1965-1977 and 1978-1989. The second time period was marked by agricultural policy reform for most of the nine countries. Their major finding was that production efficiency improved during 1978-89, resisting a fall in the growth of agricultural output. On a comparative basis, gains in production efficiency were large in Central and Eastern Europe and in China, even though economic reforms were deeper in China (which was characterized by private production). The slowing down of growth in agricultural production in the 1980's was due to slower growth of inputs, particularly fertilizer and not due to production inefficiencies. They concluded that privatization of farming may not be essential for achieving high production efficiency gains.

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

A study by Kea *et al.* (2016) attempted to measure technical efficiency and determine the core factors affecting rice production in Cambodia. The SFA model was applied to a dataset generated from the government document "Profile on Economics and Social" of 25 provinces between the years 2012 and 2015. The results showed that capital investment in agricultural machineries, actual harvested area, and technical fertilizer application within provinces determined the level of output of rice production in Cambodia. The overall mean efficiency of rice production was estimated to be 78.4%, implying that, given the same level of inputs and technology, technical efficiency can be further improved. The findings also revealed that the most important factors influencing technical efficiency of rice production in Cambodia include irrigation, production techniques and number of agricultural supporting staff. The study strongly recommended capital investment, improvement in the technical skills of rural farmers and their supporting staff and the development of irrigation systems and good water management practices as effective measures which can be implemented by the central government and related agencies for improving Cambodian rice production.

We hypothesize that Indian states are different in their technical efficiency with respect to the agricultural production because of factors that are state specific.

Methodology

Productivity varies due to differences in technology, differences in the efficiency in the production process and the difference in the environment in which the production units operate. The efficiency/inefficiency of a production unit means the comparison between the observed and potential/optimal output or input. Efficiency of production units can be technical, allocative, scale or economic. Technical efficiency is defined as the effectiveness with which a given set of inputs is used to produce an output level. A firm is said to be technically efficient if a firm is producing the maximum output from the minimum quantity of factors of production such as labour, capital and technology.

Koopmans 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) 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) 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'.[1]

Battese and Coelli (1995) 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) inefficiency frontier model for panel data is as follows:

$$Y_{it} = \exp(x_{it}\beta + V_{it} - U_{it}) \qquad \ldots(1)$$

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 $(0,\sigma_V^2)$ 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),

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

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. $W_{it} > -z_{it}\delta$. These assumptions are consistent with U_{it} being a non-negative truncation of the $N(z_{it}\delta, \sigma^2)$-distribution. The inefficiency frontier production function (l)-(2) differs from that of Reifschneider and Stevenson (1991) in that the W-random variables are not identically distributed nor are they required to be non-negative, as in the latter paper. Further, the mean, $z_{it}\delta$, of the normal distribution, which is truncated at zero to obtain the distribution of U_{it} is not required to be positive for each observation, as in Reifschneider and Stevenson (1991). 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.

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 2005-06 to 2013-14. The states taken into consideration are the following: Orissa and Bihar representing the eastern zone of India; Gujarat and Maharashtra representing the western zone; Punjab and Uttar Pradesh representing the northern zone; Tamil Nadu and Karnataka representing the southern zone[2] for the period 2005-06 to 2013-14. Regions are represented by a set of states which constitute identical production frontier.

Data on variables such as total agricultural production, institutional credit, net irrigated area, consumption of fertilizers, and consumption of pesticides[3] were collected for the specified states of India. Information on the rural literacy rate, level of technical education in rural areas, 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. As discussed in the section on methodology, the technical efficiency is studied for the specified regions of India with respect to the agricultural sector using Stochastic Frontier Analysis (SFA) with the help of Cobb-Douglas production function which is one of the most commonly used production functions. In the present study we follow Battese and Coelli (1995) model. This enables us to simultaneously measure state level technical efficiency and to test the impact of a few (selected) state specific characters and exogenous factors on the level of technical inefficiency. The stochastic frontier production functions to be estimated are:

Cobb-Douglas

$$\ln(Y_{it}) = \beta_0+\beta_1\ln(INSCRE_{it})+\beta_2\ln(NIA_{it})+\beta_3\ln(CONFER_{it})+\beta_4\ln(CONPES_{it})+V_{it}-U_{it} \quad \ldots(3)$$

where the technical inefficiency effects are assumed to be defined by,

$$U_{it} = \delta_0 + \delta_1\ln(RATELIT_{it}) + \delta_2\ln(RATETECHEDU_{it}) + \delta_3\ln(LENROAD_{it}) + \delta_4\ln(SHARENSDP_{it}) \quad \ldots(4)$$

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

Y is the total agricultural production of the individual states considered[4].

$INSCRE_{it}$ 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[5].

NIA_{it} is the Net Irrigated Area of each state. It is measured in terms of '000 hectares[6].

$CONFER_{it}$ 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[7].

$CONPES_{it}$ represents consumption of pesticides. It is measured in terms of metric tonnes[8].

$RATELIT_{it}$ 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[9].

$RATETECHEDU_{it}$ 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[10].

$LENROAD_{it}$ 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[11].

$SHARENSDP_{it}$ 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[12].

V_{it} and U_{it} are as defined in the previous section. The V_{it} s are assumed to be iid $N(0,\sigma_V^2)$ 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.

Levene's Test is performed to identify the homogeneous set of states. 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. 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 for the concerned period and for the specified set of states, 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. The following table shows the summary statistic for variables in the stochastic frontier production function for the concerned regions in India. The figures are computed across eight states during 2005-06 to 2013-14. From the standard deviation figures we find considerable inter-state variations in institutional credit, net irrigated area, consumption of fertilizers and consumption of pesticides.

Table 1: Descriptive Statistics of Variables in the Stochastic Frontier Production Function for the Regions of India

	Minimum	Maximum	Mean	Std. Deviation
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 are obtained using the computer program, FRONTIER 4.1 for the Cobb-Douglas model. These estimates, together with the estimated standard errors of the maximum-likelihood estimators, are as follows.

Table 2: Estimates of the Parameters of the Stochastic Frontier Production Function (Cobb-Douglas Model) and Determinants of Technical Inefficiency in Agricultural Production for the Period 2005-06 to 2013-14

Variables	Co-efficient	Variables	Co-efficient
Constant	-0.322	Constant	-0.949**
	(0.400)		(0.283)
1n ($INSCRE_{it}$)	0.197**	1n ($RATELIT_{it}$)	0.047
	(0.056)		(0.202)
1n (NIA_{it})	0.384**	1n ($RATETECHEDu_{it}$)	0.075
	(0.109)		(0.415)
1n ($CONFER_{it}$)	0.763**	1n ($SHARENSDP_{it}$)	-0.273**
	(0.084)		(0.108)
1n ($CONPES_{it}$)	0.105**	1n ($SHARENSDP_{it}$)	-0.743**
	(0.058)		(0.093)

*Figures in parenthesis represent standard errors. ** indicates significant at 5% level.*

As shown in Table 2, for the sub-period 2005-06 to 2013-14, the coefficients of institutional credit, net irrigated area, consumption of fertilizers and consumption of pesticides are positive and significant at 5% level of significance indicating that the level of production is responsive highly to any given change in the concerned factors of production. 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. The mean efficiency estimates of the states over the specified time period have been calculated as follows.

Table 3: Mean Efficiency Estimates of the Eight States for the Period 2005-06 to 2013-14 (Cobb-Douglas Model)

State	Mean Efficiency Estimate	Standard Deviation
Orissa	0.5782	0.0796
Bihar	0.5499	0.0690
Gujarat	0.5212	0.0467
Maharashtra	0.8824	0.0630
Punjab	0.3759	0.0409
Uttar Pradesh	0.5233	0.0351
Karnataka	0.5908	0.0538
Tamil Nadu	0.8529	0.0554

For the sub-period 2005-06 to 2013-14, it was observed that southern region was the most efficient, followed by western region, eastern region and lastly northern region. As represented in the table Maharashtra 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 Orissa and lowest in Uttar Pradesh.

The efficiency estimates obtained from the total effect model is represented in the Table 4.

CONCLUSION

The principal objective of this paper is to analyze production efficiency in the regions of India. The paper used a stochastic frontier model, employing time series data ranging from 2005-06 to 2013-14. The basic findings can be summarized as follows:

For 2005-06 to 2013-14,

(a) The results obtained from the stochastic frontier estimation show that inefficiency

Table 4: Efficiency Estimates of Eight States obtained from the Total Effect Model for the Period 2005-06 to 2013-14 (Cobb-Douglas Model)

	Orissa	Bihar	Gujarat	Maharashtra	Punjab	Uttar Pradesh	Karnataka	Tamil Nadu
2005-06	0.522256	0.500159	0.511704	0.73522701	0.32253	0.47737801	0.539028	0.80519109
2006-07	0.525229	0.478764	0.469047	0.89421555	0.332247	0.5036519	0.586866	0.84876351
2007-08	0.536014	0.463922	0.506246	0.91181994	0.351652	0.50578971	0.590862	0.8468225
2008-09	0.487619	0.492436	0.501912	0.83717555	0.342799	0.49129762	0.520122	0.79476712
2009-10	0.523549	0.571384	0.479457	0.90117009	0.381862	0.51246957	0.557739	0.79225979
2010-11	0.577558	0.565138	0.488464	0.88393981	0.381823	0.5307478	0.583747	0.82895969
2011-12	0.659582	0.602208	0.546629	0.90883197	0.421851	0.58556373	0.590338	0.89222152
2012-13	0.655249	0.614976	0.587931	0.91941795	0.417016	0.53848311	0.661727	0.93104231
2013-14	0.716946	0.660377	0.599807	0.95067164	0.43139	0.56518572	0.68758	0.93622112

is present in agricultural production of the states where mean efficiency estimates ranges from 0.8824 to 0.3759 during the years of our study for the regions.

(b) Sufficient evidence of positive relationship between agricultural productivity and higher use of fertilizers, and pesticides is seen along with the significance of net irrigated area and institutional credit for these states.

(c) The variables found to be statistically significant for the variations in technical efficiency among rice farmers are total state road length per unit of area and share of agricultural NSDP to state NSDP.

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END NOTES

1. Neogi C (2005)
2. The set of states of analysis are identified which passes the homogeneity test of error variance.
3. As discussed in the section of Introduction.
4. Data obtained from http.// www.rbi.org.in/ accessed in December 2015 and July 2016
5. Data obtained from http.//www.nabard.org/.in accessed in December 2015
6. Data obtained from http./www. indiastat.com accessed in December 2015 and July 2016
7. Data obtained from Fertilizer Statistics accessed in July 2016
8. Data obtained from http./www. indiastat.com accessed in December 2015 and July 2016
9. Literacy data is obtained from Census 2001and 2011. 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 2001 and 2011, GOI.
10. Rate of technical education is calculated on the basis of the data collected from Census 2001 and 2011. 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 2001and 2011, GOI.
11. 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) and from http://data.gov.in/ accessed in July 2016 and September 2016
12. 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 States 1960-61 to 2006-07. EPW Research Foundation and from http://data.gov.in/ accessed in July 2016 and September 2016

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