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State-wise Efficiency of Agricultural Production in India: Data Envelopment Efficiency Approach

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Abstract **Original Research Article**

Agricultural sector in India remains of vital importance to the Indian economy contributing to the overall economic growth through supplies of food and raw materials and providing livelihood support to a substantial share of the population of the country. Indian agriculture is currently facing numerous issues like low productivity, ensuring food security and farmer's income. Efficiency of agriculture in India is very much connected with these issues and has been a topic of extensive research and analysis. The present study attempts to measure the efficiency of agricultural production of the selected twenty major states of India. The efficiency in agricultural production of the states have been evaluated using the non-parametric technique of data envelopment analysis (DEA). The study reveals that there is a wide variation in efficiency scores of agricultural production across the states with an average efficiency score being 0.6. The Tobit regression analysis reveals that the states with higher literacy, higher cropping intensity have higher efficiency levels. The study outcomes from this research will be useful for policymakers to adopt right policy in the direction of sustainable agricultural development.

Keywords: Efficiency, DEA, agricultural productivity, Tobit regression, India.

INTRODUCTION

Agriculture sector in India remains of vital importance to the Indian economy engaging a major share of the total work force. The important roles of the agricultural sector in India include supplying food to growing population, alleviating poverty and malnutrition, supplying agricultural inputs to the industrial sector and promoting income generation of the farmers (Gulati and Bathala 2018, Gaurav and Pandey 2019, Gulati and Sini 2017, Kumar and Staal 2011, Lanjouw & Murgai 2010). Measurement of efficiency of agricultural production is important in the developing country like India for various reasons. First, agriculture being resource-intensive activity uses inputs like land, labor, capital, and others. Efficiency measurement helps us to assess how effectively these resources are being utilized. Second, efficiency measurement help farmers to reduce costs. By understanding where resources are being wasted or underutilized, farmers can make informed decisions to improve efficiency and remain competitive in the market. Third, assessing efficiency helps identify areas where productivity can be improved. This could involve improving production techniques, adopting new technologies, or enhancing management practices. Fourth, efficiency measurement helps comparing between different agricultural systems, regions, or farms. By benchmarking against more efficient operations, farmers can identify areas for improvement and learn from best practices. It also helps policymakers assess the effectiveness of agricultural policies and programs across different regions or countries. Fifth, improving efficiency contributes to sustainable agricultural practices by reducing waste, conserving natural resources, and minimizing environmental footprints. Sixth, efficiency measurement provides valuable information for decision-making in agricultural economics. Farmers, policymakers, and other stakeholders can use efficiency metrics to evaluate the impacts of alternative production methods, technologies, or policy interventions

LITERATURE REVIEW

Efficiency of agriculture in India has been a topic of extensive research and analysis. Various studies have focused on different aspects of agricultural efficiency, including productivity, resource utilization, technology adoption, and policy interventions. We mention here some of the studies related to efficiency. Efficiency analysis covers a range of publications that investigate the technical efficiency, allocative efficiency, and total factor productivity (TFP) of the agricultural sector in India. The review highlights key findings, research methods, data sources, and policy implications from the selected studies.

Technical Efficiency

Many studies (Aggarwal & Klasing, 2020; Joshi & Gulati, 2019; Kumar & Pradhan, 2018; Prasad & Ram, 2017; Singh & Mehta, 2021, Birthal *et al.*, 2007; Charyulu and Biswas 2010; Mathur, 2018, Mishra, 2016; Murthy *et al.*, 2009; Ray and Ghose, 2014) found that Indian agriculture exhibits low technical efficiency, primarily due to outdated farming practices, limited access to modern technology and inadequate infrastructure. Factors that have found affecting technical efficiency include education levels of farmers, farm size, irrigation facilities, access to credit, extension services etc. Policy interventions focusing on improving these have been suggested to enhance technical efficiency.

Allocative Efficiency

Several studies (Kumar & Kumar, 2018; Tiwari & Choudhary 2019; Sarkar & Patil, 2020; Prasad & Jaiswal 2021; Rajkumar, 2022) highlighted issues related to allocative efficiency in Indian agriculture, primarily concerning the suboptimal allocation of inputs. Inefficient input use, particularly excessive use of inputs like chemical fertilizers, pesticide and water has been identified as a major concern. Policy measures such as implementing land reforms, improving market access, and promoting precision agriculture were suggested to enhance allocative efficiency.

Total Factor Productivity (TFP)

TFP measures the overall efficiency of resource utilization in agricultural production. A number of studies (Singh & Sharma, 2022) focused on analyzing TFP growth of agriculture and its determinants in India. Findings suggest that TFP growth has been slow in Indian agriculture, mainly due to low technological progress, the persistence of traditional farming practices and limited research and development. Enhancing TFP requires investments in research and development, institutional support and technology transfer.

The literature on DEA efficiency studies in Indian agriculture demonstrates the importance of addressing technical efficiency, allocative efficiency, and TFP growth to improve agricultural productivity and sustainability. The findings suggest that policy interventions targeting infrastructure development, modernization, resource allocation and extension services can enhance efficiency and promote agricultural growth in India. Further research is needed to explore the effectiveness of specific policy measures and their impact on agricultural efficiency. We have made an attempt to assess technical efficiency of Indian agriculture.

MATERIALS AND METHODS

Agriculture plays a vital role in India's economy, contributing significantly to employment, food security, and rural development. Assessing the efficiency of agricultural production is crucial for sustainable growth, resource allocation, and policy formulation. Data Envelopment Analysis (DEA) is a widely used non-parametric approach to measure and benchmark efficiency.

Data Envelopment Analysis (DEA) is a non-parametric mathematical optimization technique used to evaluate the relative efficiency of multiple decision-making units (DMUs) within a given set. It is generally used to assess the performance and productivity of organizations or entities that generate multiple outputs using multiple inputs. As the techniques DEA does not require any assumptions regarding the functional form of the production or cost functions, it a flexible and robust method for efficiency analysis. The underlying concept of DEA is to compare the efficiencies of DMUs by constructing a production frontier or efficiency frontier, which represents the best achievable performance level. In DEA, each DMU is represented as a vector of input and output variables. Inputs refer to the resources or factors utilized by the DMU to produce outputs, which represent the desired outcomes or products of the DMU's activities. Inputs and outputs can be quantitative or qualitative measures, such as inputs like labor, capital and outputs like revenue, or customer satisfaction.

DEA techniques has various applications in different industries, including agriculture (Sarker and De, 2004). Here are some potential applications of DEA in agricultural production: farm efficiency analysis, resource allocation, technology assessment, benchmarking and best practice identification, policy evaluation, sustainability analysis. The steps followed in DEA are as follows: (i) Defining the DMUs, (ii) identifying inputs and outputs, (iii) Data collection on the chosen inputs and outputs for each DMU, (iv) Selecting DEA model and solving the model Solve the DEA model to calculate the efficiency scores for each DMU. Commonly used models include the CCR (Charnes, Cooper, and Rhodes) and BCC (Banker, Charnes, and Cooper) models, (v) Interpreting the efficiency scores obtained from the DEA analysis. Efficient DMUs will have a score of 1, indicating that they are operating at the production frontier. Inefficient DMUs will have scores less than 1, representing their relative inefficiency. (vi) Identifying the efficient DMUs and examining their practices and strategies to determine best practices that can be adopted by inefficient units for improving their efficiency level.

The objective of this paper is to assess the efficiency of agricultural production for the states in India. We have used Data Envelopment Analysis (DEA) for judging the efficiency of the states in agricultural production. The methodology was developed by Charnes, Cooper and Rhodes based on M.J. Farrel's contribution to productive efficiency. It is linear programming based technique for measuring the performance efficiency of a decision-making unit (DMU) (Jana & Palanisami 2020). DEA models vary in the following ways: (i) according to scale conditions the model cane constant returns to scale (CRS) or variable returns to scale (VRS); (ii) according to the models of orientation these models may be input-oriented model or output oriented model and (iii) the mathematical form of the objective function may differ like piecewise linear, log-linear or Cobb-Douglas forms.

Input-oriented DEA models tries to maximize the proportional decrease in input variables while remaining within the envelopment space (production possibility set), but output-oriented DEA models maximize the proportional increase in the output variables while remaining within the envelopment space. In other words input oriented technical efficiency is based on the question that how much output quantities be proportionally reduced without changing the output quantities produced. On the other hand, output oriented DEA is based on the question that how much output quantity be expanded without altering the input quantities used. Thus the possible improvement of an inefficient DMU could be achieved by either focusing on a proportional input reduction or proportional output augmentation or both simultaneously. We have used input oriented CRS model for the efficiency analysis of efficiency of agricultural production of the states under study.

To give an outline of the technique let us consider that there are 'N' firms producing 'M' different outputs using 'K' different inputs. Thus, Y is an M×N matrix of outputs and X is a K×N matrix of inputs. Both matrices contain data for all 'N' firms. The technical efficiency (TE) measure under the assumption of constant returns to scale (CRS) can be formulated as follows given in equation system (1):

Min θ_i (1)
Subject to
$-Y_i + Y\lambda \geq 0$,
$\theta_i X_i - X\lambda \geq 0$,
$\lambda \geq 0$
θ_i free

Here θi represents firm i's index of technical efficiency relative to the other firms in the sample. Y_i and X_i represents the output and input of firm 'i' respectively. Yλ and Xλ are the efficient projections on the frontier. A measure of θi =1 indicates that the firm is completely technically efficient. Thus, 1- θi measures how much firm i's inputs can be proportionally reduced without any loss in output. The above programme is solved for each firm in the sample and we get TE for each firm.

Here we have the following two inputs:
1. Cost of production of Paddy measured in the unit Rs. /quintal
2. Fertiliser use measured in the unit Kgs/ha

The output of the present analysis is
1. Yield of agricultural production measured in the unit Kgs./ha

The performance of a second-stage analysis of DEA efficiencies using a Tobit regression model is a standard practice among others. The study used Tobit model (Hill *et al.*, 2018; Gujarati, 2009, Spaho, 2015) to find the factors of efficiencies of states. Since the dependent variable (technical efficiency) is a censored variable with the lower limit 0 and upper limits 1 (Bhatt and Bhat 2014), Ordinary Least Square (OLS) estimation gives inconsistent, inefficient and biased estimates because it underestimates the true effect of the parameters by reducing the slope (Gujarati, 2009). Here, the Maximum Likelihood method yields consistent estimates for unknown parameters. The structural equation of the Tobit model is given in equation system (2). Thus, at the second stage, the efficiency scores are regressed on explanatory variables using Tobit regression. The Tobit model can thus be defined for state i:

$$\theta_i^* = \beta_1 + \beta_2 literacy + \beta_3 croppinginten + \beta_4 unemployment + u_i$$
$$\theta_i = \begin{cases} 0, & if\ \theta_i^* \leq 0 \\ \theta_i^*, & if\ \theta_i^* \geq 0 \end{cases} \quad (2)$$

Where, $u_i \sim N(0, \sigma^2)$ denoting error term is normally distributed.

Here, θ_i^* is an unobserved latent variable, θ_i is the actual DEA score. The explanatory variables or regressors are literacy of the state ($literacy$), cropping intensity denoting the ratio of gross cropped area and net cropped area of the state ($oppinginten$) and average rate of unemployment ($unemployment$) and β is the vector of parameters to be estimated. The Tobit model uses the method of maximum likelihood for estimation. The data for the present analysis have been collected from RBI Handbook of Statistics on Indian States. STATA software is used to derive results for the two stage analysis.

RESULTS AND DISCUSSION

Following the DEA methodology for input oriented CRS model we have derived the efficiency score of each state (Coelli, 1996). Summary statistics of the variables considered for the analysis i.e. average of cost of production, fertiliser used and yield for the states is presented in Table 1.

Table 1: Summary Statistics of the Variables under Consideration for Efficiency Analysis

	Cost (Rs./quintal)	Fert (Kgs/ha)	Yield (Kgs/ha)
Max	2925	243.17	4527
Min	717	34.63	1163
Average	1343.2	128.689	2478.95
SD	460.749	60.0749	833.706

Source: Authors' calculation

The correlations of inputs (cost and FERT) output (Yield) are shows in Table 2. This shows that there is low correlation between the inputs considered for analysis.

Table 2: Correlation of Input Output Data

	Cost	Fert	Yield
Cost	1	-0.1655	-0.1202
FERT	-0.1655	1	0.65218
Yield	-0.1202	0.65218	1

Source: Authors' calculation

We have evaluated the efficiencies of 20 major states of India using DEA model. The efficiency scores of the individual states have presented in Figure 1. The average of input-oriented efficiency score of all the states equals 0.6 which indicates that with the same level of agricultural production, the average DMU (state) seems obtaining a performance about 40% less than it should if it was on the efficiency frontier. On average, Indian state could have decreased their input-use by 40 % for producing the same level of output. The standard deviations of the efficiency scores is 0.189 with minimum of 0.207 and maximum of 1. The first stage analysis reveals that the highest efficiency (i.e. value 1) has been attained by two states namely Kerala and Punjab. The states of Maharashtra, Rajastan and Telengana have performed badly in terms of efficiency.

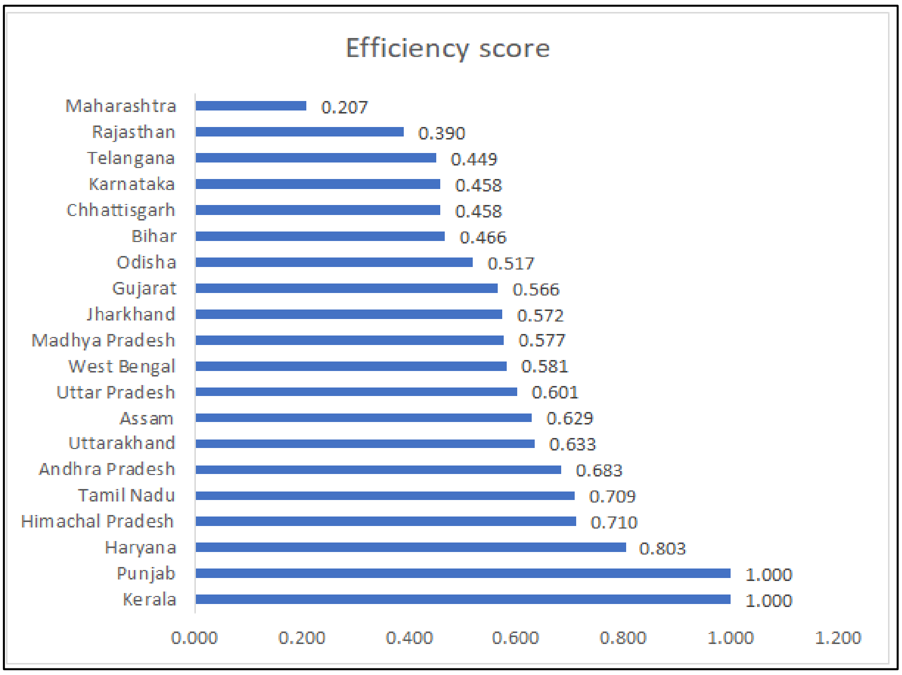

Figure 1: Efficiency Scores of States in agricultural productivity
Source: Authors' estimation

As has already been pointed out, the Tobit model, also called a censored regression model, is designed to estimate linear relationships between variables when there is either left or/and right-censoring in the dependent variable (also known as censoring from below and above). Summary statistics of the variables for second stage regression is reported in Table 3. The Tobit regression results reported in Table 4 reveal that literacy rate, cropping intensity and unemployment rates of the states have significant impact on efficiency levels of the agricultural production of the states. The literacy rate has significant and positive effect on efficiency scores, suggesting that with higher levels of education, agricultural production is better managed. The cropping intensity has significant positive effect on efficiency measures, suggesting that if the agricultural land is more used for agricultural production in a year, the efficiency level also increase because of higher production. It is also observed that unemployment rate has significant positive impact on efficiency of agricultural production. The possible reason may be that with higher unemployment rate, the wage cost of agricultural production may decrease which may lead to higher efficiency.

Table 3: Summary statistics of the variables for second stage regression (Summary statistics)

	Mean	max	min	Std. Dev.	cv
efficiency	.6	1	.207	.19	.316
literacy	73.991	94	61.8	7.549	.102
unemprate	54.6	102	18	23.408	.429
poverty	24.185	47.2	6.2	12.468	.516
croppinginten	144.975	190.6	113	25.498	.176

Source: Authors' estimation

Table 4: Tobit regression result

Tobit regression	Number of obs	=	20
	Uncensored	=	18
Limits: lower = 0	Left-censored	=	0
upper = 1	Right-censored	=	2
	LR chi2 (3)	=	15.23
	Prob > chi2	=	0.0016
Log likelihood = 7.9549663	Pseudo R2	=	-22.4042

Efficiency	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
literacy	.0125805	.0044314	2.84	0.011	.003231	.0219299
croppinginten	.0030135	.0012898	2.34	0.032	.0002922	.0057349
unemprate	.0033449	.0014023	2.39	0.029	.0003864	.0063035
_cons	-.9424174	.3798976	-2.48	0.024	-1.743931	-.1409034
Var (e.efficiency)	.0191674	.0065654			.0093049	.0394836

Source: Authors' estimation

CONCLUSION

This present study investigates the efficiency of major of agricultural production in the major states of India. The efficiency measures of the states have been evaluated using the non-parametric technique of Data Envelopment Analysis (DEA). The study shows that there is substantial variation in efficiency scores across the different states of India with average efficiency score being 0.60. Out of selected twenty states, two states are found to be efficient with scores 1, and the rest are inefficient. The best and the least efficient states individually are identified. The efficiency and performance of states in agricultural production can be increased through various measures. The efficiency study suggests that there is enough scope of reducing the use of inputs like fertiliser use. The second stage regression suggests that efficiency increases with literacy level and cropping intensity. So, to increase the efficiency, government should take steps to improve the education level and skill formation. The other factor to increase efficiency is to increase the cropping intensity which is possible through provision of irrigation facilities (Jana, & Tamang, 2023; Jana et al 2018; Jana, 2009).

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