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Research Article

TECHNICAL EFFICIENCY AND FACTORS INFLUENCING TECHNICAL EFFICIENCY OF PRODUCTION OF BT COTTON SEEDS IN NON-CONVENTIONAL AREAS OF KARNATAKA

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Abstract- Understanding efficiency of farmers in mobilizing their resources and factors influencing those efficiencies is important in developing countries as efficiency gain by farmers can contribute in economic gain. The present study has estimated the technical and scale efficiencies of Bt cotton seed-production farms in Karnataka, considering different production levels and has identified the determining factors of their technical efficiency. The study is based on the data collected from the major Bt cotton seed -producing regions of Karnataka, *viz.* Chikkaballapura from Non-conventional area (NCA) and Gadag from Conventional area of Karnataka. Data Envelopment analysis (DEA) and Multiple linear regression models have been used for estimating the technical efficiency and its determinants, respectively. The study has indicated that nearly 69 per cent of Bt cotton seed production farms in Karnataka including in farms at NCA and CA were inefficient as they were operating at level of below 90 per cent. Most of the farms in Karnataka (73.75%) have been have been performing with increasing returns to scale which shows potential to expand production and productivity. Multiple linear production function analysis, used to identify the factors influencing TE indicated that age (0.0144) and capital efficiency (0.5256) in NCA and capital efficiency (0.5704) in CA were found to influence TE significantly and positively.

Keywords- Bt cotton, Technical Efficiency, Seed Production, Non-Conventional area, Conventional area.

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Introduction

Improper utilization of resources by farmers is one of the main reasons of low productivity and high production costs per unit in agriculture in world and India is not different from that, which results in lower efficiencies in the production of crops. Measuring efficiency is the popular approach to understand the performance of farmers in mobilizing their resources in the given technology. Understanding efficiency of farmers in mobilizing their resources and factors influencing those efficiencies is important in developing countries as efficiency gain by farmers can contribute in economic gain (World Bank, 2011). For the estimation of technical efficiency, several methods like ordinary least squares (OLS) regression, stochastic frontier analysis (SFA) and total factor productivity (TFP) indices using price-based index numbers (PIN), are used. The OLS methods are well known and easy to implement, however, it has been documented that it requires the specification of a functional form for the production technology and provides information about the average performance rather than frontier performance. Frontier performance was addressed by SFA with specifying error term capturing data noise and inefficiency. However, SFA methods still require a functional form to be specified, plus distribution forms for its composed error structure (Coelli and Battese 1996). PIN methods, such as the popular Tornqvist TFP index, suffer from the problem that it requires access to the reliable price information (which is often difficult to obtain) and it does not explicitly accommodate scale effects. Of late, the popular method of estimating the maximum possible output has been the "*data envelopment analysis*" (DEA), advocated by Charnes, *et al.,* 1978, which overcomes most of these limitations [1]. Present paper has used this method to estimate the technical efficiency in Bt cotton seed production farms and factors influencing technical efficiency in Non-conventional areas of Karnataka.

Methodology

Study Regions and Data

In Karnataka, Bt cotton seed production is mostly taken up by the private seed companies and there are three major locations as per the seed industry classification *viz*. Gajendragada, Chintamani and Sira regions. The Gajendragada region falls under conventional area of seed production. The districts fall under this region is Gadag, Koppal, Raichur, Baghalkot and Haveri. The Chintamani and Sira regions fall under non-conventional areas of seed production and Chintamani region occupies more area under Bt cotton seed production than Sira region. Therefore, it was proposed to select one district in each of these areas and hence, Gadag from conventional area and Chikkaballapura from non-conventional area are selected for the study. The selection of farmers from the selected districts is done using multi-stage purposive cum random sampling procedure. In the first stage two talukas Chintamani from Chikkaballapura and Rona from Gadag district were purposively selected as these talukas contribute significantly to the Bt cotton seed production. In the next stage, major villages in these talukas involved in the seed production were short listed purposively. In the final stage a total of 40 farmers in each district were selected randomly for the study and thus making up a total sample size of 80 for the study.

Analytical Framework

Estimation of Technical Efficiency

Technical efficiency refers to a firm's ability to produce the maximum possible output from a given combination of inputs and technology. Data Envelopment Analysis (DEA) advocated by Charnes, *et al.,* 1978 [1], which overcome most of these limitations and hence used in the present study to examine the technical efficiency. The details are given below.

Data Envelopment Analysis: DEA approach was first used by Farrell, 1957 [2]. This approach did not receive wide attention till the publication of paper of Charnes, *et al.,* 1978 [1], which coined the term *data envelope analysis.* DEA was applied by using both classic models CRS (constant returns to scale) and VRS (variable returns to scale) with input orientation, in which one seeks input minimization to obtain a particular product level. Under assumption of constant returns to scale, the linear programming models for measuring the efficiency of farms [3],

Min $\theta\ \lambda\ \theta$

Subject to $-y_i + Y\lambda \geq 0$

$\theta X_i - X\lambda \geq 0$

$\lambda \geq 0$ ………………………………………. [a].

Where

y_i is a vector ($m \times 1$) of output of the i*th* Producing Farms (TPF)

x_i is a vector ($k \times 1$) of inputs of the i*th*TPF

Y is an output matrix ($n \times m$) for n TPFs

X is an input matrix ($n \times k$) for n TPFs

θ is the efficiency score, a scalar whose value will be the efficiency measure for the i*th* TPF. If θ=1, TPF (Total productivity factor) will be efficient; otherwise, it will be inefficient.

λ is a vector ($n \times 1$) whose values are calculated to obtain the optimum solution. For an inefficient TPF, the λ values will be the weights used in the linear combination of other, efficient, TPFs, which influence the projection of the inefficient TPF on the calculated frontier. The specification of constant returns is only suitable when the firms are working at optimum scale. Otherwise, measures of technical efficiency can be mistaken for scale efficiency, which considers all types of returns to production, *i.e*., increasing, constant and decreasing. Therefore, the CRS model is reformulated by imposing a convexity constraint. The measure of Technical efficiency obtained in the model with variable returns is also named pure technical efficiency as it is free of scale effects, and the following linear programming model estimates it:

Min $\theta\ \lambda\ \theta$

Subject to $-y_i + Y\lambda \geq 0$

$\theta X_i - X\lambda \geq 0$

$N_1\lambda = 1$

$\lambda \geq 0$ …………………….. [b]

Where $N_1$is a vector ($n \times 1$) of ones.

When there are differences between the values of the efficiency scores in the models CRS and VRS, scale inefficiency is confirmed, indicating that the return to scale is variable, *i.e*., it can be increasing or decreasing [4]. The scale efficiency values for each analyzed unit can be obtained by the ratio between the scores for technical efficiency with constant and variable returns as follows.

$\theta s = \theta CRS\ (XK,YK)/\theta VRS\ (XK,YK)$…………………[c]

Where

$\theta CRS\ (XK,YK)$ is the technical efficiency for the model with constant returns.

$\theta VRS\ (XK,YK)$ is the technical efficiency for the model with variable returns.

θs is scale efficiency.

It was pointed out that VRS model [b] makes no distinction as to whether TPF is operating in the range of increasing or decreasing returns. The only information that one has is that if the value obtained by calculating the scale efficiency in CRS and VRS model [c] is equal to one, the TPF will be operating with constant returns to scale. However, when θ*s* is smaller than one, increasing or decreasing returns can occur. Therefore, to understand the nature of scale inefficiency, it is necessary to consider another problem of linear programming *i.e*., the convexity constraint of VRS model [b], N1λ=1, is replaced by $N1\lambda \leq 1$ for the case of non-increasing returns, or by $N1\lambda \geq 1$, for the model with non-decreasing returns. Therefore, in this work, the following models were also used for measuring the nature of efficiency.

Non-increasing returns

Min $\theta\ \lambda\ \theta$

Subject to $-y_i + Y\lambda \geq 0$

$\theta X_i - X\lambda \geq 0$

$N_1\lambda \leq 1$

$\lambda \geq 0$ ……………………………….[d]

Non-decreasing returns

Min $\theta\ \lambda\ \theta$

Subject to $-y_i + Y\lambda \geq 0$

$\theta X_i - X\lambda \geq 0$

$N_1\lambda \geq 1$

$\lambda \geq 0$ ……………………………….[e]

It is to state here that all the models presented above should be solved *n* times, *i.e*., the model is solved for each TPF in the sample. Gross yield (Q/ha) was used as a output(Y) in the present case and total men labour (man-days), total women labour (woman days), farm yard manure(t), plant nutrients N (Kg), P(kg), K(kg) separately, capital inputs(Rs) on plant protection, other input costs and fixed input costs as inputs(X). The models were solved using the DEAP version 2.1 taking an input orientation to obtain the efficiency levels.

Factors influencing the technical efficiency

To analyse the Factors influencing the technical efficiency the Bt cotton seed production, multiple linear regression analysis was attempted, considering the technical efficiency score as dependent variable and age, family size, farming experience, education period, cropping intensity, human labour productivity, Organic manure productivity, Nitrogen productivity, Phosphorous productivity, Potash productivity and ROR (capital efficiency) of Bt cotton seed production as independent variables.

The empirical model was:

$Y = aX_1 + bX_2 + cX_3 + dX_4 + eX_5 + fX_6 + gX_7 + e$

Where,

Y = Technical efficiency

X_1 = Age (years)

X_2 = Family size (in No.)

X_3 =Farming Experience (years)

X_4 = literacy (years of schooling)

X_5 = Cropping intensity (in Per cent)

X_6 = Human labour productivity (Kg/human day)

X_7 = capital efficiency (returns/rupee of working costs)

In addition to the fitting the above model to production process of two regions, the model was also fitted to pooled data to examine the factors influencing the Bt cotton seed production in Karnataka.

Results and Discussion

Technical efficiency

Technical efficiency under constant returns scale

To obtain the efficiency levels of each of the Bt cotton seed production farms, DEA models, which are input oriented, were used at different production scales under the assumption of constant returns to scale (CRS). Under this assumption, it was expected that all seed production firms are operating at optimum scale due to perfect competition. The range of technical efficiency (TE) estimated is presented in [Table-1]. The highest average TE (0.80) was observed in CA than in NCA (0.74) and for the pooled category it was 0.77.

The criterion used by Ferreira (2005) was used in the present study to decide the cut-off score for efficient farms. Farms that operated at 0.90 or more score were considered as efficient farms. The explanation for this flexibility, according to Ferreira (2005), is to avoid compromising the analysis though a farm that stands out as being an outlier rather than for its true relative efficiency. Data recording errors and external factors were attributed for this flexibility. It could be seen from the table that the highest percentage of farmers (31.25%) in the study region were found have technical efficiency of 90 and above in the pooled category *i.e*., 25 out of 80 farmers in the pooled group of Bt cotton seed growers in Karnataka were efficient in production. Remaining 68.75 per cent of farms can reduce the input level by 23 per cent and still maintain the same level of gross returns as achieved by the 31.25 per cent of the farmers.

Table-1 *Range of technical efficiency (TE) in Bt cotton seed production in Bt Cotton seed production areas of Karnataka*

TE Score	Bt Cotton seed production					
	NCA(Chikkaballapura)		CA (Gadag)		Pooled	
	No	%	No	%	No	%
Upto 0.45	4	10	0	0	4	5
0.45 to 0.60	6	15	6	15	12	15
0.60 to 0.75	10	25	9	22.5	19	23.75
0.75 to 0.90	7	17.5	13	32.5	20	25
>0.90	13	32.5	12	30	25	31.25
Total	40	100	40	100	80	100
Average TE score	0.74		0.8		0.77	

Note: NCA: Non-Conventional Area; CA: Conventional Area

The maximum efficiency figures were similar in both the areas of production *i.e.*, 32.50 per cent in NCA at Chikkaballapura (13 farmers out of 40) and 30 per cent in CA at Gadag (12 farmers out of 40). Farms in NCA can reduce the input level by 26 per cent and farms in CA can reduce by 20 per cent and still maintain the same level of gross returns as achieved by the 32.50 and 30 per cent of the farmers in the respective areas of production. Similar results were also obtained in Sreenivasa Murthy et al. (2009) [6]. On the lower side, nearly four per cent of farmers in NCA and no farmers in CA were having TE score less than 45 per cent

Impact on technical efficiency due to variable returns to scale

When the assumption of constant returns to scale was relaxed and with the calculation of the model with variable returns to scale, the impact of production scale on the technical efficiency level was visible. This relaxation was necessitated, as all the Bt cotton seed producing farms are not operating at optimum scale due to imperfect competition, constraint in input availability, etc. Here the efficiency of 90 per cent and less has considered as the cutoff point for inefficiency. The results of such relaxation are presented in [Table-2]. The details in two production areas are presented below. With the calculation of the model with variable returns to scale, the impact of production scale on the technical efficiency level was visible. In NCA, the number of efficient farms increased more than double to 85 per cent and the average technical efficiency score increased to 0.97. These superior results from model with variable returns are mainly due to the inclusion of scale efficiency which previous model did not take into consideration the existence of scale inefficiency. Further, lower value of standard deviation of mean in model with variable returns suggests concentration of farms in the higher efficiency levels. As regards to scale efficiency, 35 per cent of Bt cotton seed production farms (14 out of 40) under NCA were performing at optimum scale or were close to the optimum scale (farms having scale efficiency values equals or more than 0.9). In case of farms in CA, the average technical efficient score has increased to 0.98 and nearly 90 per cent of farms had the score equal or more than 0.90. These superior results from model with variable returns are mainly due to the inclusion of scale efficiency which previous model did not take into consideration the existence of scale inefficiency. The number of farms which were performing at optimum scale was 32.50 per cent. In case of pooled group of Bt cotton seed growers, in case of variable returns, the average technical efficient score was 0.97 and nearly 87.50 per cent of farms had the score equal or more than 0.90. The number of farms which were performing at optimum scale was marginally higher at 33.75 per cent. For operating optimum scale there is a need to advise the farmers regarding the proper input management, timely cultivation of crops, adoption of new technologies, etc. to overcome the inefficiencies in production.

Table-2 *Efficiency measures and descriptive statistics of Bt cotton seed production according to scale of operations.*

Scale of operations	Efficient farms (≥ 0.90)			Efficiency measures		
	No	%	Mean	Std deviation	Max	Min
Non-Conventional area – Chikkaballapura						
Technical efficiency (Constant returns)	13	32.5	0.74	0.228	1	0.165
Technical efficiency (Variable returns)	34	85	0.97	0.052	1	0.799
Scale efficiency	14	35	0.76	0.226	1	0.165
Conventional Area – Gadag						
Technical efficiency (Constant returns)	12	30	0.8	0.154	1	0.53
Technical efficiency (Variable returns)	36	90	0.98	0.054	1	0.775
Scale efficiency	13	32.5	0.82	0.146	1	0.53
Pooled						
Technical efficiency (Constant returns)	25	31.25	0.77	0.022	1	0.165
Technical efficiency (Variable returns)	70	87.5	0.97	0.006	1	0.775
Scale efficiency	27	33.75	0.79	0.021	1	0.165

Distribution of Bt cotton seed farms according to the types of return among different scale of operations

To know the number of efficient farms, extent of inefficiency and optimum scale of operation, it is also important to understand the distribution of Bt cotton seed production farms in three regions of production frontier *i.e.*, how many farms are under increasing or decreasing or constant returns. The results are presented in [Table-3]. Bt cotton seed production farms operating in the region of increasing returns or the suboptimal region found to be lower (72.50%) in NCA than in CA (75%). The production scale of these farms can be increased while decreasing costs, since they were performing below the optimum production scale. Decreasing returns region was found only in farms operating at CA which was very marginal 2.50 per cent of farms. They could increase their technical efficiency if they reduced the production level. This region is also called as supraoptimal, which means that the farms were performing above the optimum scale of production. In the constant region of frontier *i.e.*, optimum scale of production, nearly 27.50 per cent of farms in NCA and 22.50 per cent farms in conventional area (25% for the pooled group) were operating in this region. Similar results were also obtained in Raghavendra (2013) [5].

Table-3 *Distribution of Bt cotton seed production farms in NCA vis-a-vis CA according to the types of return among different scale of operations*

Types of return	Bt cotton seed production		
	NCA	CA	Pooled
Increasing returns	29 (72.5)	30 (75)	59 (73.75)
Constant returns	11 (27.5)	9 (22.5)	20 (25)
Decreasing returns	0 (0)	1 (2.5)	1 (1.25)
Total	40 (100)	40 (100)	80 (100)

Note :1: NCA: Non-Conventional Area; CA: Conventional Area
2: Figures in the parentheses indicate percentage to total in the respected column

Determinants of Technical Efficiency of Bt cotton seed production in Karnataka

A multiple linear production function was used to determine the factors, which influence technical efficiency. Various socio-economic as well as production factors particularly the productivity factors were included in the model and the results are presented in [Table-4].

Non-conventional area: The co-efficient of multiple determination (R^2) was 0.59 and fitted model was significant. The regression co-efficients of age (0.0144) and capital efficiency (0.5256) were positive and significant while the coefficient of farming experience (-0.0135) was significant, but negative. While all other factors of technical efficiency like cropping intensity (0.0008), family size (-0.0067), literacy (-0.0077) and human labour productivity (-0.3663) were statistically non-significant.

Conventional area: The co-efficient of multiple determination (R^2) was 0.47. The regression co-efficient of capital efficiency (0.5704) was significant and it was the only factor, which influenced the technical efficiency of Bt cotton seed production farms. All other included factors of technical efficiency like age (-0.0041), family size (-0.0030), cropping intensity (-0.0006), human labour productivity (-0.4898), farming experience (0.0048) and literacy (0.0025) were statistically non-significant.

Pooled category: The co-efficient of multiple determination (R^2) for pooled data was 0.40. The regression co-efficient of capital efficiency (-0.3969) was the only significant factor and all other factors of technical efficiency like farming experience (-0.0025), literacy (-0.0039), human labour productivity (-0.2296), age (0.0014), family size (0.0062) and cropping intensity (0.0006) were statistically non-significant [7-9].

Table-4 *Factors which influence technical efficiency of Bt Cotton seed production in Karnataka*

Sl. No.	Parameters	Bt cotton seed production		
		NCA (Chikkaballapura)	CA (Gadag)	Pooled
1	Constant	-0.1094 (0.2681)	0.565 (0.1903)	0.2498 (0.1759)
2	Age (years)	0.0144* (0.007)	-0.0041 (0.0052)	0.0014 (0.0045)
3	Family size (in No.)	-0.0067 (0.0139)	-0.003 (0.0053)	0.0062 (0.0055)
4	Farming experience (years)	-0.0135* (0.0056)	0.0048 (0.0049)	-0.0025 (0.0039)
5	Literacy (years of schooling)	-0.0077 (0.0071)	0.0025 (0.0057)	(0.0039) (0.0048)
6	Cropping intensity (in Per cent)	0.0008 (0.0009)	-0.0006 (0.0007)	0.0006 (0.0006)
7	Human Labour productivity (kg/human day)	-0.3663 (0.1892)	-0.4898 (0.345)	-0.2296 (0.1558)
8	Capital efficiency (returns/rupee of working costs)	0.5256** (0.1497)	0.5704* (0.2514)	0.3969** (0.1174)
9	Coefficient of multiple determination (R^2)	0.59	0.47	0.40

Note 1: NCA: Non-Conventional Area; CA: Conventional Area.
2:* (5% significance) ** (1% significance)

Conclusions

Technical and scale efficiencies have been estimated for Bt cotton seed production in Karnataka using data envelopment analysis (DEA). The factors, which influence the technical efficiency of tomato production, have also determined using multiple linear regression equation. Nearly 69 percent of Bt cotton seed production farms in Karnataka including in farms at NCA and CA were inefficient as they were operating at level of below 90 per cent. So to increase the efficiency level of these farms beyond90percent farmers have to allocate the resources properly. This requires the call for the key role of extension and other line departments in providing technical information to farmers. We observed superior results from the model with variable returns than constant returns are mainly due to the inclusion of scale efficiency further, lower value of standard deviation of mean in model with variable returns suggests concentration of Bt cotton seed production farms in the higher efficiency levels. Capital efficiency factor turned out to be most critical in impacting the technical efficiencies in both the regions, thus increasing capital efficiency would provide the higher production yields. In addition to these two variables, age and the farming experience in NCA have found to have significant impacts on the technical efficiency levels. Thus, these two inputs in sociological factors could potentially increase the productivity of Bt cotton seed production. Whereas in CA none of the mentioned sociological factors found to have significant influence on technical efficiency in Bt cotton seed production.

Application of Research: applicable in the field of production economics to derive efficiency of farms.

Research Category: Applied research

Abbreviations:
NCA (Non-Conventional area),
CA (Conventional area)

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