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Economic Efficiency of Farmers Adopting E-Commerce for Production and Marketing of Chilli in Guntur District of Andhra Pradesh

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ABSTRACT: In this study, technical, allocative and economic efficiencies and determinants of technical and economic efficiency of farmers adopting e-commerce for chilli production and marketing in Guntur district of Andhra Pradesh was estimated. The platform selected for the study was Kalgudi Digital platform. The farmers purchase inputs such as tarpaulins, silpaulins, seed, plant-protection chemicals etc., from Kalgudi. Proportionate sampling was used to select respondents from six FPOs for the study. Data envelopment analysis was used to determine the efficiencies of the farmers. Multiple-input and single output variable returns to scale (VRS) DEA was used to measure the efficiencies of farmers. Tobit regression model was used to analyse the determinants of technical and economic efficiencies. The results of the study revealed that, the average technical, allocative and economic efficiency of adopters were, 0.953, 0.653 and 0.626 and that of non-adopters were 0.874, 0.664 and 0.582. The entire adopter and non-adopter sample was pooled, and efficiency was calculated to determine the determinants of technical and economic efficiencies using Tobit model. But the results cannot be implied to the entire state as the study has been conducted in one district of Andhra Pradesh with selected sample of farmers. This is the major drawback of the study. The study had contributed to determine the excess inputs that are used by the farmers, so that they can reduce their usage during the cultivation process.

Keywords: e-commerce, Kalgudi, DEA, Tobit, FPO, chilli, Guntur.

INTRODUCTION

Introduction of new technologies to agriculture is necessary to increase the yield or reduce the cost of cultivation to the farmers. How-ever modern technology like e-commerce trading has low connectivity with improvement of yield but influences the costs and returns of the farmers. Kalgudi is e-commerce platform currently operating in Andhra Pradesh dealing with inputs and outputs of farmers. It not only plays the role of linking farmers with input-dealers, but also facilitates the farmers in selling their chilli produce by linking the farmers with traders therefore eliminating most of the marketing intermediaries. It also provided extension services to the farmers through their official website of Kalgudi on the information of improved technologies and providing those technologies to farmers by linking the stakeholders of those technologies with farmers. Thus, by doing so, our so-called e-commerce platform also influences the production of the farmers. The farmers who are registered in the FPOs will be linked to the platform with the help of FPOs and their input needs will be considered by the e-commerce platform. The unregistered farmers can also access the platform through the Kalgudi official website. In Andhra Pradesh Kalgudi mostly deals with commercial crops like chilli, mango, turmeric and other major horticultural crops.

Chilli is one of the most important commercial crops of India, which is used for vegetables, spice, condiments, sauce, pickles etc. (Geetha and Selvarani 2017). India has immense potential to grow and export different types of chillies required to various markets around the world (Jagtap *et al.*, 2012). In India, Andhra Pradesh is the largest producer of chilli with an area of 1.7 lakh hectares and production of 7.9 lakh tonnes (Directorate of Economics and Statistics, 2021) and it will be produced year-round in Andhra Pradesh. Around 15-20% chilli produced in Andhra Pradesh is exported to other countries (ANGRAU, 2021). Hence it is an important crop for trade to the e-commerce platform. Efficiency analysis of chilli production in Andhra Pradesh will enable the farmers to understand the inputs they were excessively utilising.

Ali *et al.* (2018) analysed the efficiency of offseason capsicum production in Punjab. Kumar *et al.* (2019) also conducted efficiency analysis of organic chilli production in Telangana. Usman and Kasimin (2021) studied the efficiency analysis of red chilli farmers in Pidie Jaya, Indonesia.

In Andhra Pradesh Kalgudi engages 22,023 active chilli farmers from 3 districts namely Guntur, Krishna and Prakasham and uses local language for communication. From Guntur district it almost engages 13489 active chilli farmers from 6 FPOs. Out of them 1387 (10.28%) farmers had adopted e-commerce platform for buying their inputs and selling their output. Comparison of the efficiencies of adopters and non-adopters will facilitate to understand the scope of Kalgudi in marketing chilli.This study is concerned to analyse the technical, allocative and economic efficiencies and the determinants of technical and economic efficiency of adopters and non-adopters of Kalgudi in Guntur district of Andhra Pradesh.

MATERIALS AND METHODS

Data and study area. Andhra Pradesh was purposively selected for the present study as it is the highest chilli producer with 7.01 lakh tonnes (TE 2020-21) in India. In Andhra Pradesh, Guntur district was selected for the study, as it is having the highest area of 0.78 lakh ha with production of 4.1 lakh tonnes (Directorate of Economics and Statistics, 2021) and 1387 farmers were selling their produce through selected e-commerce. In Guntur district, Kalgudi is dealing with 6 FPOs which are linking farmers of six mandals with Kalgudi. The six FPOs were: Amaravathi, Bollapalli, Durgi, Macherla, Peddanandipadu, Veldurthy. Respondents were selected from these six FPOs. Proportionate random sampling method was employed for the selection of respondents from the FPOs. A total of 70 adopters and 140 non-adopters were selected from the 6 FPOs. Farmers who purchase inputs from the e-commerce and sell their output through e-commerce were considered as adopters. The rest were non-adopters. Both adopters and non-adopters were selected from FPOs only. The number of farmers selected from each FPO were presented in Table 1.

Table 1: List of farmers, adopters and non-adopters in each FPO.

FPO	Total Farmers	No. of Adopters	No. of Adopters selected for sample	No. of Non-Adopters	No. of Non-adopters selected for sample
Amaravathi	1885	256	13	1629	19
Bollapalli	1975	149	8	1826	21
Durgi	2453	238	12	2215	26
Macharla	3143	306	15	2837	33
Peddanandipadu	2031	223	11	1808	21
Veldurthy	2002	215	11	1787	20
Total	**13489**	**1387**	**70**	**12102**	**140**

Primary data was collected from chilli farmers by using a comprehensive questionnaire form from the above mentioned six FPOs of Guntur district. Chilli farmers were interviewed about socio-economic variables, prices, quantity of inputs as well as output.

Efficiency Background. Efficiency is a comparison between maximum and existing productivity of a firm (Farrell, 1957). Production frontier was used for the determination of maximum productivity of a firm. Two techniques were used for the estimation of production efficiency named stochastic frontier analysis (SFA) and data envelopment analysis (DEA). DEA method was based on linear programming. Inefficiency exists when there was a gap between actual data and frontier of a firm (Javed *et al.*, 2009). According to Coelli *et al.* (1998), the DEA model can be output or input oriented. Input oriented DEA model was used in this study as chilli farmer has more control over inputs.

Javed *et al.* (2009) explained the technical efficiency as attaining of the maximum product using given inputs with the help of production function. It is calculated with the help of DEA model based on variable or constant returns to scale. Coelli *et al.* (1998) suggested the use of DEA model based on constant returns to scale if all firms were working at optimal scale otherwise the value of technical efficiency was confounded by scale efficiency. Banker et al. (1984) gave the concept of DEA model based on variable returns to scale by using convexity constraints. In the present study variable return to scale DEA model was used.

Analytical Framework and Empirical Models. The current study used the input-oriented DEA model based on variable return to scale for the calculation of technical efficiency respectively. Total farm income (Y) was considered as a dependent variable in efficiency score calculation. Land (X1) in hectares; seed use (X2) in kgs; fertiliser use (X3) in Kgs; plant protection chemical use (X4) in litres; FYM use (X5) in tonnes; irrigation (X6) in numbers; labour use (X7) in mandays; animal power use (X8) in animal days, machine power use (X9) in hours and other inputs used (X10) in number were input variables used in DEA.

(a) DEA Model for technical efficiency estimation: Input oriented DEA model with variable return to scale was used for the estimation of technical efficiency (Banker *et al.*, 1984) and expressed as:

$$\text{Min}_{\theta,\lambda,\phi}$$

Subjected to $-y_i + Y\lambda \geq 0$,

$\phi x_i - X\lambda \geq 0$,

$N_1' \lambda = 1$

$$\lambda \geq 0 \qquad (1)$$

where,

Y - output matrix for n farms.

θ - the total technical efficiency of i^{th} farm.

λ represents N*1 vector of weights (constants)

X - input matrix for n farms.
y_i - the total farm income of the i^{th} farm in rupees.
x_i - the input vector of $x_{1i}, x_{2i} \ldots x_{10i}$ inputs of i^{th} farm.
x_{1i} – Total land used by i^{th} farm (in hectars)
x_{2i} – Seed (kg) used on the i^{th} farm
x_{3i} – Total Fertilizer used (kg)
x_{4i} – Total Plant protection chemicals used (in litres)
x_{5i} – Total FYM used (in tonnes)
x_{6i} - Irrigation given (number) to i^{th} farm
x_{7i} – Total man power used (man-days) on the i^{th} farm
x_{8i} – Total animal power (animal-days) used on the i^{th} farm
x_{9i} – Total machine power (hours) used on the i^{th} farm
x_{10i} – Total other inputs purchased for i^{th} farm
where, in the restriction $N_1' \lambda = 1$, N_1' is convexity constraint which is a N*1 vector of ones and λ is a N*1 vector of weights (constants) which defines the linear combination of peers of the i^{th} DMU. $1 \leq \phi \leq \infty$ and $\phi - 1$ is the proportional increase in output that could be achieved by the i^{th} DMU with the input quantities held constant and $1/\phi$ defines a technical efficiency score which varies between zero and one. If $\phi = 1$ then the farm is said to be technically efficient and if $\phi \leq 1$ the farm lies below the frontier and is technically inefficient.

(b) DEA Model for economic efficiency estimation: The standard procedure for the estimation of economic efficiency is first solving the cost minimization problem by DEA and then defining the economic efficiency as the ratio of minimum cost to the observed cost. The same procedure was adopted in the present study. Economic efficiency is the ratio between minimum cost and observed cost.

Economic Efficiency = minimum cost/observed cost
EE = wi /xi

Following Coelli *et al*. (1998), to estimate economic efficiency (EE), a cost minimization DEA model is specified as Eqn. (2):

$\min \lambda, X_i^E$
$w_i X_i^E$
Subject to- $y_i + Y\lambda \geq 0$
$X_i^E - X\lambda \geq 0$
$N_1' \lambda = 1$
$\lambda \geq 0$ (2)

where,
w_i is vector of input price $w_{1i}, w_{2i}, \ldots\ldots, w_{9i}$ of the i^{th} farm.
X_i^E is the cost minimizing vector of input quantities for the i^{th} firm.
N refers to total number of farms in the sample.
w_{1i} – Rental value of land (Rs/ha)
w_{2i} – Total cost of seed (Rs/ha)
w_{3i} – Total cost of fertilizer (Rs/ha)
w_{4i} – Total cost of Plant protection chemicals (Rs/ha)
w_{5i} – Total cost of FYM (Rs/ha)
w_{6i} – Total cost of Irrigation (Rs/ha)
w_{7i} – Total cost of male labour (Rs/ha)
w_{8i} - Total cost of animal labour (Rs/ha)
w_{9i}– Total cost of machine labour (Rs/ha)
w_{10i} – Total cost Inputs purchased (Rs/ha)

(c) DEA model for allocative efficiency estimation. Allocative Efficiency was obtained by dividing economic efficiency with technical efficiency.

Allocative Efficiency = Economic Efficiency/ Technical Efficiency
AE = EE/TE (3)

(d) Tobit Regression Analysis. In order to identify key determinants of resource use efficiency, technical and economic efficiency scores were separately regressed on selected demographic, socio economic and institutional variables. A censored regression analysis was used to study the role of socio-economic, demography and institutional attributes in explaining technical and economic efficiency in chilli production. Tobit regression was introduced by Tobin (1958) who developed a framework for estimating models of censored dependent variables. As the efficiency index derived from data envelopment analysis is bound between 0 and 1 value, thus it is suitable for use as a simulation analysis to identify the determinant of technical and economic efficiencies among farmers. Efficiency index derived from the Eqn. 1 and 2 can be used as a measure of the performance of farmers. Briefly, Tobit's regression empirical model can be written as follows:

$y^*_t = x_t \beta_0 + \epsilon_t, t = 1, 2, 3, \ldots, n$ (4)
$y_t = y^*_t$ if $y^*_t > c$; and $y_t = c$, otherwise (5)

Where,
y_t= DEA efficiency index used as the observed dependent variable
y^*_t= latent variable (which is not observable)
x_t= vector of explanatory variable
β_0 = is an unknown parameter vector associated with the farm-specific attributes and
ϵ_t = an independent normally distributed error term with zero mean and constant variance

The Equation 5 refers to the efficiency score of farmers 100% (y = c) and the second term represents inefficient farmers (y > c).

The model parameters are estimated by maximizing the Tobit likelihood function of the following form

$L = \Pi Y_t^* > 0 \frac{1}{\delta} f\left(\frac{Y_i - X_i}{\delta}\right) \Pi\ Y_t^* \leq 0\ F\left(-\frac{\beta_{i\,x}}{\delta}\right)$ (6)

Where f and F are the density function and the cumulative function of Y*, respectively. $\Pi Y^* \leq 0$ means the product over those of i for which $Y^* \leq 0$ and $\Pi Y^* > 0$ means the product over those of i for which $y^* > 0$.

The marginal effect of explanatory variables was estimated as follows.

The change in the efficiency scores with respect to a change in an explanatory variable among adopters is:

$(\partial E\ (y_t/y_t^* > 0)/\partial xi = \beta_i \left[1 - \frac{zf(z)}{F(Z)} - \left[\frac{f(z)}{F(Z)}\right] 2\right]$

Where,
F (z) is the cumulative normal distribution of Z,
f (z) is the value of the derivative of the normal curve at a given point (i.e., unit normal density),
Z is the z-score for the area under normal curve and
β_i is a vector of Tobit maximum likelihood estimates and σ is the standard error of the error term

The empirical model of the effects of a set of explanatory variables on the efficiency scores applying the maximum likelihood estimation technique is specified using the following linear relationship:

$y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + ui$

y_i = Efficiency score obtained from DEA

X_1 = Age (in years)

X_2 = Years of Education (in years)

X_3 = Experience (in years)

X_4 =Number of trainings received from Kalgudi

X_5 = FPO Participation (Highly active, mediumly active, not active)

X_6 = off-farm income (1=yes, 0=no)

X_7= Land productivity (tonnes/ha)

X_8= Labour productivity (total revenue/ total labour cost)

X_9= Access to credit

The descriptive statistics of the variables used in the analysis of resource use efficiency were presented in Table 2. FPO participation is dummy variable. Those who actively participated in FPO activities were considered 1 and no much active participation were considered 0.

RESULTS AND DISCUSSION

Summary statistics: Table 2 reveals the summary statistics of socio-economic variables of chilli farmers. The average age of the entire sample was 43.8 years while that of adopters and non-adopters was 43.5 and 44.5 years respectively. The number of years of education received by the farmer was considered for our study. The average years of education for the farmers in our study was 7.4. On average they are having high-school level of education. The average experience of the farmer was 17.6 years, while that of adopters was 17.2 years and non-adopters was 18.4 years. Kalgudi conducted training programs on awareness of the website and how to operate it. Adopters on an average attended 1.5 training programs while non-adopters on an average attended 1.1 training programs from Kalgudi, overall, the farmers had attended 1.2 training programs from Kalgudi. The sample farmers on an average had 0.7 contacts with extension agents and had an average off-farm income of Rs. 112456.6. Land productivity is calculated by total yield of chilli divided by acreage under chilli. Labour productivity measured in terms of gross revenue from the chilli divided by the total labour cost. Productivity of operational cost is estimated by dividing gross revenue with operating expenses. The average land productivity of adopters was 46.5 q/ha, non-adopters was 41.1 q/ha and of total sample was 44.5 q/ha. The average labour productivity of adopters was 4.4 % and that of non-adopters and total sample 3.7% and 3.9%. The average productivity of operational cost was 1.9% for adopters, 1.7% for non-adopters and 1.8% for total sample.

Table 2: Summary statistics of socio-economic variables.

Variable	Units	Adopters	Standard Deviation	Non-adopters	Standard Deviation	Full sample	Standard Deviation
Age	Years	43.5	6.01	44.5	7.15	43.8	5.6
Education	Years	8.1	4.6	7.2	4.1	7.4	4.5
Experience	Years	17.2	7.3	18.4	5.8	17.6	6.3
Training programs received	No.	1.5	0.8	1.1	1.0	1.2	0.9
Contact with Extension Agent	No.	0.9	0.4	0.5	0.4	0.7	0.4
Land Productivity	q/ha	46.5	8.1	41.1	7.1	44.5	7.6
Labour productivity	Per cent	4.4	1.8	3.7	2.1	3.9	2.0
Productivity of operational cost	Per cent	1.9	0.6	1.7	0.9	1.8	0.8
Off-farm income	Rupees	115678.2	12344.5	107883.6	7899.8	112456.6	9877.5

From the Table 2 it was clear that there was not much socio-economic difference between adopters and non-adopters. Similar results were expressed by Lubis *et al.* (2014) in the research on technical, allocative and economic efficiency of pineapple production in West Java, Indonesia. The descriptive statistics of inputs, outputs and cost of the inputs used for the input-oriented DEA model were presented in Table 3.

As discussed above the major inputs used by farmers were land, seed, fertilizer, plant protection chemicals, FYM, irrigation, human labour, animal labour, machine labour and other inputs used (viz., yellow sticky traps, blue sticky traps, tarpaulin sheets, silpaulin sheets, pheromone traps, chilli kits) and the corresponding costs associated with them. The rental value of land also included the land revenue paid by the farmer per hectare yearly. The output was farm income which is equal to gross returns obtained by the farmer through chilli. It did not include the off-farm income obtained by farmer. The average farm income obtained by the adopter was Rs. 6,95,677.67, while that of non-adopters was Rs. 6,60,958.16. The average farm income of the entire sample was Rs. 6,70,972.9. The major difference between adopters and non-adopters was the adopters sell their output through Kalgudi e-commerce platform and hence there will be difference in the price per output and gross returns obtained. Also,the adopters purchased most of their other inputs (*viz.*, yellow sticky traps, blue sticky traps, tarpaulin sheets, silpaulin sheets, pheromone traps, chilli kits) from the Kalgudi while non-adopters do not. Hence there will be difference in the cost of the other inputs. Murthy *et al.* (2009) also used the same inputs and output as yield of tomato to study the efficiency of tomato in Karnataka using DEA.

Table 3: Descriptive Statistics of inputs, output and cost of variable inputs of adopters, non-adopters and sample farmers.

	Variables	Mean			
		Units	Adopters	Non-Adopters	Full sample
Output variable	Farm income	(Rs. /ha)	695677.67	660958.16	670972.9
Input variables	Land	(hectares)	2.19	1.36	1.9
	Seed rate	(kg/ha)	0.275	0.295	0.289
	Fertilizer	(kg/ha)	910.5	811.6	895.1
	Plant protection chemical used	(litres/ha)	31.30	44.95	41.06
	FYM used	(tonnes/ha)	43.77	33.66	37.03
	No. of Irrigation given	Number	10	13	12
	Human labour	(man-days/ha)	293.6	323.8	309.8
	Animal power	(Animal-days/ha)	60.05	75.87	70.6
	Machine power	(hrs/ha)	30.82	40.72	37.4
	Other inputs used	Number	288.41	336.15	225.6
Cost associated with the inputs	Rental value of land	Rs/ha	136875.05	86107.14	122797.6
	Cost of seed	Rs/ha	20011.91	25963.8	23979.84
	Cost of Fertilizer	Rs/ha	16029.78	9887.9	12863.84
	Cost of Plant protection chemical	Rs/ha	107362.2	112173.2	109887.7
	Cost of FYM	Rs/ha	4484.26	3958.22	4236.7
	Cost associated with irrigation	Rs/ha	3680.61	7658.395	6332.47
	Cost of human labour	Rs/ha	158037.1	176889.3	168458.2
	Cost of animal power	Rs/ha	10345.41	15793.8	13977.67
	Cost of machine power	Rs/ha	8379.5	12016.07	10803.91
	Cost of other inputs	Rs/ha	27667.39	28609.286	28138.33

Efficiency score estimation. The average value of technical, allocative and economic efficiencies of adopters, non-adopters and overall sample farmers and the frequency of farmers distributed in the efficiency score range was presented in Table 4-6 respectively. The mean technical efficiency of adopters was 0.953. This indicated that the farmers can still reduce their inputs by 4.7% to produce same amount of output (as the model is input-oriented). Among the 70 adopter farmers, 47 farmers were operating at an efficient level one. This means 67.14% farmers were fully efficient. 7 farmers were operating between efficient level 0.9 to 0.99. They contribute 10% of the adopters. This implies that almost 77.14% of the farmers were operating at efficient level (Linn and Maenhout 2019). 13 farmers (18.57%) were operating at 0.80-0.89 level efficiency, 2 farmers (2.85%) were operating at 0.7-0.79 level efficiency, one farmer (1.42%) is operating at 0.5 to 0.59 level efficiency. This indicated that 22.86% farmers were not operating at optimum efficient level. This implied that there were more technically efficient farmers than non-efficient farmers.

The mean allocative efficiency of the adopters was 0.653. The analysis of allocative efficiency revealed that the farmers' costs on an average 34.7 per cent higher compared to the most efficient farmers. 14 farmers (20%) out of 70 farmers were operating at full efficiency and 18 farmers (25.71%) were operating at efficiency level of 0.9-0.99. This implied that only 45.71 per cent farmers were efficient.

The mean economic efficiency of the adopters was found to be 0.626. These results indicated that the adopters were economically in-efficient and the farmers on an average can reduce the cost by 37.4% to produce same amount of output. 14 farmers (20%) out of 70 farmers were operating at full efficiency and 12 farmers (17.14%) were operating at efficiency level of 0.9-0.99. This implied that 37.14% farmers were efficient.

Table 4: Frequency distribution of Kalgudi adopters on Technical, Allocative and Economic efficiency indexes (N=70).

DEA Score	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
1	47	67.14	14	20	14	20
0.90-0.99	7	10	18	25.71	12	17.14
0.80-0.89	13	18.57	0	0	6	8.57
0.70-0.79	2	2.85	0	0	0	0
0.60-0.69	0	0	1	1.42	1	1.42
0.50-0.59	1	1.42	2	2.85	1	1.42
0.40-0.49	0	0	14	20	7	10
0.30-0.39	0	0	16	22.85	20	28.57
0.20-0.29	0	0	5	7.14	9	12.85
0.10-0.19	0	0	0	0	0	0
<0.10	0	0	0	0	0	0
Sum	70	100	70	100	70	100
Maximum	1.00		1.00		1.00	
Minimum	0.5		0.223		0.222	
Mean	0.953		0.653		0.626	

The mean technical (0.874), allocative (0.664) and economic (0.582) efficiencies of non-adopters were estimated and the results were presented in the Table 5. The mean technical efficiency was 0.874. This indicate that the farmers can still reduce their inputs by 12.6 per cent to produce same quantity of output (as the model is input-oriented). Among the 140 non-adopter farmers, 47 farmers were operating at an efficient level 1. This means 33.57 per cent farmers are fully efficient. 18 farmers were operating between efficient level 0.9 to 0.99.

The mean allocative efficiency of the non-adopters is 0.664. The analysis of allocative efficiency revealed that the farmers' costs on an average 33.6 per cent higher than compared to the most efficient farmers. One farmer (0.71 per cent) out of 140 farmers were operating at full efficiency and 4 farmers (2.85 per cent) were operating at efficiency level of 0.9-0.99. Only 3.56 per cent farmers were allocatively efficient.

Table 5: Frequency distribution of chilli non-adopters on Technical, Allocative and Economic efficiency indexes (N=140).

DEA Score	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
1	47	33.57	1	0.71	1	0.71
0.90-0.99	18	12.85	4	2.85	3	2.14
0.80-0.89	36	25.71	26	18.57	7	5
0.70-0.79	24	17.14	43	30.71	20	14.28
0.60-0.69	10	7.14	24	17.14	50	35.71
0.50-0.59	5	3.57	5	3.57	13	9.28
0.40-0.49	0	0	29	20.71	20	14.28
0.30-0.39	0	0	8	5.71	18	12.85
0.20-0.29	0	0	0	0	8	5.71
0.10-0.19	0	0	0	0	0	0
<0.10	0	0	0	0	0	0
Sum	140	100	140	100	140	100
Maximum	1.00		1.00		1.00	
Minimum	0.554		0.367		0.226	
Mean	0.874		0.664		0.582	

The mean economic efficiency of the non-adopters was 0.582. Even though mean allocative efficiency was higher in non-adopters than adopters, due to low technical efficiency, the economic efficiency was also low for non-adopters. These results indicated that the non-adopters were economically in-efficient and the farmers on an average can reduce the cost by 41.8 per cent to produce same amount of output. Only 1 farmer (0.71 per cent) out of 140 farmers were operating at full efficiency and 3 farmers (2.14 per cent) were operating at efficiency level of 0.9-0.99. This implies that only 2.85 per cent farmers were economically efficient.

The mean technical, allocative and economic efficiencies of pooled farmers were estimated and the results were presented in Table 6.

Table 6: Frequency distribution of overall sample chilli farmers on Technical, Allocative and Economic efficiency indexes.

DEA Score	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
1	89	42.3	1	0.47	1	0.47
0.90-0.99	28	13.33	0	0	0	0
0.80-0.89	37	17.61	52	24.71	46	21.9
0.70-0.79	32	15.23	1	0.47	7	3.33
0.60-0.69	15	7.25	1	0.47	1	0.47
0.50-0.59	4	1.9	15	7.14	2	0.95
0.40-0.49	5	2.38	61	29.04	21	10
0.30-0.39	0	0	45	21.42	84	40
0.20-0.29	0	0	34	16.28	33	15.74
0.10-0.19	0	0	0	0	15	7.14
<0.10	0	0	0	0	0	0
Sum	210	100	210	100	210	100
Maximum	1.00		1.00		1.00	
Minimum	0.47		0.24		0.119	
Mean	0.875		0.503		0.453	

The results showed that the mean technical efficiency of the farmer was 0.875. This indicated that the farmers can reduce their inputs by 12.5 per cent to produce same amount of output. It was observed that only about 42.3 per cent of farms under assumption of variable returns to scale performed with technical efficiency level equal to one and 13.3 per cent farmers were operating at TE in range of 0.9-0.99. Out of 210 farmers 117 farmers were operating at efficient zone. The mean efficiency score was 0.875. Based on this, it could be inferred that remaining 93 farmers, which did not operate at the maximum efficiency level, could reduce the input level by 12.5 per cent and maintain the same level of chilli production as achieved by 55.63 per cent of the farmers.

The mean score of AE was 0.503. The results indicated that on an average pooled sample farmers in the study area could increase chilli output by 49.7 per cent, on other hand, cost of production could be reduced by 49.7 per cent by using right inputs and low input costs. Only one farm was operating at maximum efficient AE.

It was observed that only one farm out of 210 farms, under variable returns to scale performed with economic efficiency level equal to 0.90 or greater. The mean efficiency score was 0.453. This means the farmers on an average were not operating at optimum economic efficiency. Based on this, it could be inferred that remaining farmers, which did not operate at the maximum efficiency level, could reduce the input level by 54.7 per cent and maintain maximum efficiency.

Excess Inputs used and Economic Efficiency: The inputs which the farmers were using in excess amounts at given economic efficiencies and the optimum combination of inputs to be used to attain the economic efficiency at given price (price of inputs were taken into consideration for cost minimisation) were presented in Table 7.

Table 7: Distribution of excess input used for achieving minimum (economically efficient) costs of chilli production for adopters, non-adopters and total sample farmers.

Inputs	Mean cost minimizing inputs used			Mean Inputs used			Excess Inputs used			Excess Input Used out of Mean Input Used (%)		
	A	NA	TF	A	NA	TF	A	NA	TF	A	NA	TF
Land	2.15	0.49	0.49	2.19	1.36	1.9	0.04	0.87	1.41	1.82	63.97	74.21
Seed	0.245	0.238	0.247	0.275	0.295	0.289	0.03	0.057	0.042	10.90	19.32	14.53
Fertiliser	628	741	605	910.5	811.6	895	282.5	70.6	290	31.02	8.6	32.4
PPC	15.4	40.03	14.02	31.3	44.94	41.06	15.9	4.91	27.04	50.73	10.92	65.8
FYM	50.2	30.79	48.4	43.7	33.66	37.03	-6.5	2.87	-11.37	-14.87	8.52	-30.7
Irrigation	7	9	10	10	13	12	3	4	2	0.3	30.76	16.6
Human Labour	135.1	305.2	137.8	293.6	323.8	309.8	158.5	18.56	172	53.98	5.7	55.5
Animal	44.56	80.84	43.8	60.05	75.87	70.6	15.49	-4.97	26.8	25.51	-6.55	37.9
Machine	20.58	38.49	20.5	30.82	40.72	37.4	10.24	2.23	16.9	33.22	5.47	45.18
Other inputs	211.8	212.9	225.6	288.4	336.1	314.1	76.6	123.1	88.5	26.5	36.6	28.1

Note: A = Adopters, NA = Non-adopters and TF = Total sample farmers

Adopters were excessively using human labour (53.98%) and plant protection chemicals (50.73%) followed by machine power (33.22%) and fertilizer (31.02%) at their given cost. The FYM usage was negative (-14.87%) which implied that the farmers should increase the usage of FYM at the given cost. the non-adopters were excessively using land (63.97%), other inputs (36.64%) and irrigation (30.7%). The animal power usage was negative (-6.55%) which implies that farmers should increase the usage of animal labour at their given cost. The pooled farmers were excessively using land at its given rental value (74.21%). There is a need to go for intensive cultivation as the rental value of land was high. The farmers were also excessively using plant protection chemical (65.8%) and human labour (55.5%), machine power (45.18%), animal power (37.9) and fertilizers (32.4) at their given cost. At given cost, usage of FYM was negative, which means the farmers can increase the usage of FYM to improve their efficiency. The irrigation given and usage of seed was also excessive by 16.6% and 14.53%.

The Tobit Results. The determinants of technical and economic efficiency in the production of chilli were estimated and results were presented in Table 8. Number of trainings received, labour productivity and access to credit positively and significantly influencing the technical efficiency of the sample farmers. But land productivity has no significant influence on technical efficiency of the farmer as the yield of the farmer was not taken into consideration in determining the TE of farmer. So, it was estimated that Land productivity has no significant influence. Number of training programmes will improve the adoption of e-commerce platform which will improve the technical efficiency. As number of training programmes increased the farmers get more awareness and will get more technical knowledge on usage of inputs. Hence will have chance for improvement of technical efficiency. Less will be the labour cost, more will be the labour productivity and hence the farmer employs more labour and the technical efficiency also will increase. When farmer get proper credit at right time with reasonable interest rate will enable him to purchase inputs and make farm operations at right time and will increases the yield and consequently gross revenue. This result was in consistent with Lubis *et al.* (2014) where the labour and capital productivity increase the technical efficiency of pineapple farms in west Java province.

Table 8: Results of Tobit Regression Analysis.

Determinants	Technical Efficiency		Economic Efficiency	
	Marginal effect	Std. Error	Marginal effect	Std. Error
Age	-0.00013	0.003	-0.000278	0.0009
Education	0.0017	0.003	0.000565	.00097
Experience	-0.0021	0.0029	-0.0002392	0.00085
Training	0.04***	0.012	0.0035336	0.0039
FPO Participation	-0.0014	0.017	-0.0035518	0.00559
Off-farm income	0.02	0.03	0.04211***	0.01028
Land productivity	0.0012	0.0018	0.001003	0.00054
Labour productivity	0.04***	0.0074	0.070004***	0.0017
Access to credit	0.03**	0.01	0.015703***	0.00508

Note: * = significance at 10%; ** = significance at 5%; *** = significance at 1%

Presence of off-farm income, labour productivity and access to credit positively and significantly influencing the economic efficiency. Presence of off-farm income will improve the total revenue of the farmer, thus improving the economic efficiency. When the labour cost become lower than the labour productivity become higher and will increase the economic efficiency. Land productivity also positively influencing the economic efficiency but not in much significant level. Similar results were obtained by Lubis *et al.* (2014) where the land, labour and capital productivity significantly and positively influence the EE.

Comparison of mean technical, allocative and economic Efficiencies of Adopters and Non-adopters: The average technical, allocative and economic efficiencies of adopters and non-adopters of Kalgudi and of total sample farmers were presented in Table 9. Adopters have more technical and economic efficiencies than the non-adopters. How-ever the allocative efficiencies of non-adopters were higher than the adopters. The mean technical efficiency of total farmers was greater than non-adopters but less than adopters. The mean allocative and economic efficiencies of total farmers were less than both adopters and non-adopters. High cost of inputs reduced the economic efficiencies of both adopters and non-adopters. The overall economic efficiency of total farmers was below optimum level indicating that the farmers were economically non-efficient.

Table 9: Technical, allocative and economic efficiencies of adopters and non-adopters.

Category	Sample size	Technical Efficiency	Allocative Efficiency	Economic Efficiency
Adopters	70	0.953	0.653	0.626
Non-adopters	140	0.874	0.664	0.582
Total Farmers	210	0.875	0.503	0.453

The results were similar to Kumar *et al.* (2020) in their research on FPOs impact on organic chilli production in Telangana, where the TE, AE and EE of members and non-members of FPOs were compared. The study also proved that the members of FPO have greater TE, AE and EE than non-adopters. The current study results there is a contrary that AE of adopters is less than non-adopters. Also, there is a large gap between TE and AE, EEs of the farmers, indicating that there is a large scope for reducing the cost of cultivation of the farmers.

CONCLUSIONS

The study established that chilli farmers are inefficient in the production with mean technical, allocative and economic efficiency levels of 0.875, 0.503 and 0.453, respectively. However, adopters are more efficient than non-adopters both technically and economically but allocatively less efficient. This may be due to using high quantities of inputs by adopters. The adopters were using the inputs in higher excessive quantities (land 1.82%, fertilizer 31.02%, PPC- 50.73%, Human labour- 53.98%, Machine 33.22% and animal 25.51%) than non-adopters (land- 63.97%, fertilizer 8.6%, PPC- 10.92 %, Human labour- 5.7%, Machine 5.47% and animal -6.55%). Only excessive usage of land, seed and FYM and other inputs were higher in non-adopters. This indicate that the non-adopters should reduce the usage of inputs and choose much cost-efficient inputs and adopters should properly allocate their inputs in a cost-efficient manner. Another reason for lower AE of adopters is due to high TE of adopters (as AE = EE/TE). A Tobit regression analysis results reveal that the farmer should attend more training programmes and should reduce the cost associated with labour. He should attain credit from authenticated sources like banks with reasonable interest rates rather than unauthorised sources like middleman.

Finding of the study implies that there should be strategies to improve the farmer technique and fulfil the standard requirement so as to further improve the chilli production efficiency in Guntur District of Andhra Pradesh. Moreover, policies and strategies should also support the adoption of new technologies by the farmer. Furthermore, farmers' associations should also be re-structured in personnel and technology in order to ensure member are benefited from their adoption and improve their resource use efficiency.

FUTURE SCOPE

The current study was conducted only in Guntur district of Andhra Pradesh for chilli crop. With increase in internet usage, e-commerce adoption also increased among the consumers (Balakrishnan *et al.,* 2018). The current e-commerce platform (Kalgudi) also deals with other crops like turmeric, mango and handicrafts made from rural artisians. So, there is a lot of scope to study on other commodities along with chilli. The study can also be extended to other regions of the state. Studies on the condition of e-commerce platforms in various states in the country can also be carried on.

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