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RESEARCH PAPER

Estimation of technical and allocative efficiency of cauliflower farm of Bilaspur district of Chhattisgarh state

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Abstract : The study analysed the technical and allocative efficiency of cauliflower farm in Bilaspur district of Chhattisgarh, using a stochastic frontier production function. Primary data were collected from 154 farmers from 04 blocks of the district. The study revealed return to scale on cauliflower farm is positive and greater than one as 2.50 which floored the farm in stage one production surface. The study also finds that variation in output of cauliflower was due to random factor. The mean technical efficiency of the pooled sample accounted to be 96.4 per cent. The two inputs land size and seed were over utilised as locative efficiency valued less than unity while other factors fertilizer, labour and irrigation were under utilised as valued greater than unity. The study recommends adoption of new method and technology in cauliflower production. The existence of under and over utilisation of resource should be addressed effectively and efficiently by extension personnel with continuous efforts making on precision farming.

Key Words : Technical, Allocative efficiency, Cauliflower farm

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INTRODUCTION

Vegetable has great importance for rural as well as urban community because of its wide range of utility. They constitute the major part of the diet of the Indians who are primarily vegetarians in food habits and are in great demand in the market. It has been observed that economic returns to vegetables are better than other several crops. The yield per unit area is high and suitable for intensive farming lead generation of supplement incomes and expands employment through it. Vegetables support export and international trade. Vegetables are always been a better choice of crop diversification because of good productivity and much higher returns from a unit area. The diversification in favour of these crops improves exports, reduce trade deficit, besides creating more direct and indirect employment. Therefore, assurance of efficient productive system is necessary for proper utilization of resources. Creation of efficient productive system requires awareness of farmers, policy makers and all other stakeholders concerned with the production and actual marketing of vegetables.

Chhattisgarh State has to go long way in vegetable production. In the State there is remarkable gap between actual harvested yield and potential yield of vegetable crops. Hence, scope for harnessing/exploiting potential fully still exists. In the State, during 2010-11 vegetables occupied an area of 0.346 million hectares with the production 4.25 million metric tonnes which accounted 4.1 and 2.9 per cent over the national figures, respectively. The productivity of State 12.3 metric tonnes is quite less than the national average *i.e.* 17.3 metric tonnes. According to the data from Directorate Horticulture, Chhattisgarh the coverage of vegetables in the year 2010-11 was maximum in Bilaspur as 68348.76 hectares which was 20.41 percent of total area in the State followed by Durg, Surguja and Raipur with 14.82, 14.21 and 11.09 per cent, respectively. Whereas, Durg ranked first in production by 88930 metric tonnes which was 21.42 per cent of total production in the State followed by Bilaspur, Sarguja and Raipur with 16.32, 14.53 and 10.10 per cent, respectively. Cauliflower occupies an area of 21624 ha that is 5.21 per cent to total vegetable in the state and 1.69 per cent area of total vegetable in Bilaspur in the year 2014-15.

The yield gap arises mainly due to suboptimal use of resources. The technical efficiency analysis provides better understanding of the productivity gap. The allocative efficiency helps farm to determine the extent to which they can appropriately adjust productive resources in order to achieve optimum productivity. Therefore, this study has been under taken in Bilaspur to analyse the situation of cauliflower production with the following objectives.

Objectives:

– To estimate the technical efficiency of cauliflower of the selected households.

– To estimate the allocative efficiency of each factors of cauliflower production in the study area.

Material and Methods

Sampling and data collection :

The study was conducted in Bilaspur District of Chhattisgarh State. Out of 7 blocks 04 blocks namely Bilha, Masturi, Kota and Takhatpur were selected purposively for the study and from each block, fifteen per cent villages to total number of vegetable growing villages were selected keeping the criterion of highest area under vegetables. A 10 per cent respondent was selected at random with the sample size of 154 farmers. The enquiry was done for the agricultural year 2014-15.

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Analytical procedure :

Estimation of technical efficiency:

Descriptive statistics and Cobb-Douglas stochastic production frontier approach were used to estimate the production function and the determinants of technical, allocative efficiencies among vegetable farmers.

The general form of function is defined by;

$$Y_i = X_i \beta + (V_i - U_i), \quad i = 1,..., N$$

where

Y_i is the production (or the logarithm of the production) of the i[th] firm.

X_i is a $k \times 1$ vector of (transformations of the) input quantities of the i[th] firm.

β is a vector of unknown parameters to be estimated.

V_i is random variable, tow-sided $(-\infty < V_i < \infty)$ normally distributed random error $N \sim (0, \sigma_V^2)$, which are assumed to be independent of the U_i that captures the stochastic effects outside the farmer's control.

U_i is technical inefficiency effects independent of V_i and having half normal distribution with mean zero and constant variance *i.e.* with the production of firm i and $N \sim (0, \sigma_U^2)$.

The estimating equation for the stochastic function is:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_0 6 \ln X_6 + V_1 - U_1$$

where,

Y_i = Out put of the i[th] farmer (q)

X_1 = Farm size (ha)

X_2 = Seed (kg)

X_3 = Fertilizer (kg)

X_4 = Agrochemical (lt)

X_5 = Labour (man-days)

X_6 = Irrigation (ha-cm).

Technical efficiency of an individual firm is defined as:

TE = Y_i / Y_i^* [is obtainable by the use of Frontier 4.1 (Coelli, 1996)]

where,

TE = Technical efficiency

Y_i = Observed output

Y_i^* = Frontier output.

Technical inefficiencies are explained as:

$U_i = \delta_0+\delta_1Z_1+\delta_2Z_2+\delta_3Z_3+\delta_4Z_4+\delta_5Z_5+\delta_6Z_6+\delta_7Z_7+\delta_8Z_8+\delta_9Z_9+\delta_{10}Z_{10}+\delta_{11}Z_{11}$

δ_0 = the intercept

Z_1 = Farm size (ha)

Z_2 = Farming experience (yr.)

Z_3 = Educational level (d)

Z_4 = Household size (number equivalent to adult)

Z_5 = Extension contact (number of visit)

Z_6 = Land ownership (d)

Z_7 = Source of irrigation (d)

Z_8 = Crop diversification (d)

Z_9 = location of farmer (d)

Z_{10} = Age of farmers (yr.)

Z_{11} = Sex (d)

* d= dummy variable

Estimation of allocative efficiency:

Allocative efficiency was estimated from a Cobb-Douglas function using OLS. Using the co-efficient, the marginal product of the i^{th} factor was calculated as:

$$MP_i = \frac{\partial Y}{\partial X_i} = \beta_i \frac{Y}{X_i}$$

But $AP = \frac{Y}{X_i}$

Where,

Y = is the geometrical mean of output.

X_i = is the geometrical mean of input i.

β_i = is the OLS estimated co-efficient of input i.

Value to marginal product of input i (VMP_i) ;

$$VMP_i = MP_i * P_y$$

where,

VMP_i = Value of marginal product of input i.

MP_i = Marginal physical product

P_y = Price of output.

Allocative efficiency (A.E.) = $\frac{VMP_i}{P_i}$

P_i = Marginal cost of the i^{th} input.

Software used for the study:

Estimation of the technical and allocative efficiency were done by using analytical software Frontier 4.1 (Coelli 1996)

Technical efficiency of cauliflower farm :

Table 1 reveals that maximum likelihood estimates for parameters of the stochastic frontier production of cauliflower. The study found that all the estimated variables on small and medium farms were significant at 1 per cent level except irrigation which was significant at 5 per cent level. On marginal farm the variables farm size, fertilizer and labour were significant at 1 per cent level while farm size and fertiliser estimates were significant at 5 per cent and 1 per cent level on large farm, respectively. The elasticity of output with respect to farm size was negative on all size groups of farms except medium farm as it positively elastic to output. The increase in farm size by 1 per cent decreases the output by 1.420, 0.944, 0.928 per cent to total output on marginal, small, large farms while increases the output by 2.179 per cent on medium farms.

The elasticity of output with respect to seed found negative as 1 per cent increase in it decreases the output by 0.117 and 1.214 per cent to total output on small and medium farms, respectively. Additional fertlizer application by 1 per cent to the production of cauliflower increases the output by 0.498, 1.280, 0.286 and 1.519 per cent to total output on marginal to large farms, respectively. The elasticity of output with respect to plant protection was found positive as increase in 1 per cent in it increases the output by 0.934 and 3.257 per cent to toal output on small and medium farms. The elasticity of output with respect to labour was found positive as well as negative with the value 2.741, 1.172 and -3.203 which means that 1 per cent increase in input the output increases by 2.741, 1.172 per cent and decreases output by 3.203 on marginal, small and medium farms, respectively. The elasticity of output with respect to irrigation was found negative on small farm as study result showed 1 per cent increase in irrigation decreases the output by 0.056 per cent and positive on medium farm as 1 per cent increase in it increases the output by 0.205 per cent to total output. The study also revealed that the variables of inefficiency model on marginal and large farms were non-significant. The estimated variables of farm size, farming experience, source of irrigation, location of farm were significant for small farm while only one variable location of farm of large farm was found significant. The return to scale estimated as 3.033, 2.269, 1.51 and 2.34 on marginal to large farms which indicated that all farms were in stage I of production surface showing an increasing return to scale.

The estimated variance parameters of the model gamma (γ) were significant at 1 per cent level as valued 0.984, 1.00 and 1.00 on small to large farms, respectively, which implies that about 98.4, 100 and 100 per cent of the variation in output was attributed to technical efficiency differences among the respective production units. By implication about 1.6 per cent of the variation in output on small farm was due to random factors.

Table 2 shows maximum likelihood estimates for parameters of the stochastic frontier production for cauliflower farm. The study revealed that the co-efficient of farm size, fertiliser and labour estimated as -1.861, 0.262 and 3.361, respectively. This mean elasticity of mean output with respect to fertiliser and labour were positive, 1 per cent increase in fertiliser and labour increases the output 0.262 per cent and 3.361 per cent

Table 1: Maximum likelihood estimates for parameters of the stochastic frontier production model for cauliflower farm

Variables parameter		Farm size											
		Marginal			Small			Medium			Large		
		Estimate	SE	t-ratio	Estimate	SE	t-ratio	Estimate	SE	t-ratio	Estimate	SE	t-ratio
Stochastic frontier													
Constant	β_0	-8.173	0.961	-8.502**	-6.037	0.772	-7.816**	17.507	0.957	18.291**	-5.787	0.969	-5.971**
Ln (farm size)	β_1	-1.420	0.456	-3.113**	-0.944	0.113	-8.341**	2.179	0.147	14.869**	-0.928	0.356	-2.605*
Ln (seed)	β_2	-0.108	0.193	-0.562	-0.117	0.034	-3.444**	-1.214	0.066	-18.429**	-0.033	0.186	-0.179
Ln(fertiliser)	β_3	0.498	0.059	8.420**	1.280	0.041	31.247**	0.286	0.017	16.899**	1.519	0.400	3.799**
Ln (Agrochemical)	β_4	1.407	0.853	1.649	0.934	0.096	9.686**	3.257	0.222	14.679**	0.932	0.654	1.426
Ln (labour)	β_5	2.741	0.274	9.985**	1.172	0.171	6.839**	-3.203	0.181	-17.665**	0.838	0.461	1.819
Ln (irrigation)	β_6	-0.085	0.212	-0.400	-0.056	0.023	-2.462*	0.205	0.045	4.616**	0.012	0.145	0.083
Inefficiency model													
Constant	δ_0	0.033	0.819	0.040	-0.118	0.927	-0.127	0.059	0.935	0.064	0.055	0.937	0.059
Farm size	δ_1	-0.080	0.988	-0.081	3.502	0.788	4.445**	-0.511	0.270	-1.892	0.016	0.979	0.016
Farming experience	δ_2	0.001	0.001	0.352	-0.003	0.001	-2.257*	-0.003	0.003	-1.140	-0.003	0.005	-0.649
Education	δ_3	0.003	0.008	0.342	-0.020	0.015	-1.279	-0.011	0.016	-0.705	-0.055	0.035	-1.562
Family size	δ_4	-0.001	0.006	-0.243	0.036	0.019	1.851	-0.005	0.019	-0.265	-0.002	0.015	-0.140
Extension visit	δ_5	-0.005	0.010	-0.460	-0.029	0.034	-0.863	-0.020	0.021	-0.955	-0.053	0.042	-1.260
Land ownership	δ_6	0.033	0.819	0.040	-0.118	0.927	-0.127	0.059	0.935	0.064	0.055	0.937	0.059
Source of irrigation	δ_7	-0.029	0.035	-0.833	-0.236	0.660	-0.358	0.119	0.704	0.169	0.110	0.716	0.154
Crop diversification	δ_8	0.033	0.819	0.040	-0.242	0.052	-4.685**	0.059	0.935	0.064	0.055	0.937	0.059
Location of farm	δ_9	-0.004	0.016	-0.274	-0.006	0.068	-0.082	-0.085	0.013	-6.368**	-0.003	0.047	-0.054
Age	δ_{10}	0.0003	0.001	0.223	0.014	0.002	6.496**	0.001	0.002	0.431	-0.002	0.008	-0.234
Sex	δ_{11}	-0.027	0.084	-0.327	-0.118	0.927	-0.127	0.059	0.935	0.064	0.055	0.937	0.059
Variance parameters													
Sigma square	σ^2	0.002	0.0003	6.248**	0.002	0.001	4.042**	0.001	0.0003	3.413**	0.001	0.0005	1.863
Gamma	γ	0.00000001	0.001	0.00001	0.984	0.006	159.381**	1.000	0.017	58.666**	1.000	0.021	47.266**
Ln Likelihood FCN	-	166.919			87.935			43.356			27.198		

**t-ratio is significant at 1 % level of significance. *t-ratio is significant at 5% level of significance to total output. While, 1 per cent increase in farm size decreases the output by 1.86 per cent to total output. The study revealed that the labour was the most important factor for cauliflower production. The study also showed inefficiency co-efficient farming experience and family size negative and significant at 1 per cent level of significance. Whereas, co-efficient age found positive and significant at 1 per cent level of significance. The return to scale valued 2.502 meaning that the cauliflower farm floored in stage one of production surface showing increasing return to scale. The estimate of the variance ratio gamma (γ) found positive but non significant which indicated the variation in output was due to random factor.

Table 3 represents the distribution of respondents by technical efficiency estimates of cauliflower farm. The study computed an overall distribution of technical efficiency estimates of cauliflower farm as narrow skewed from 84.7 to 100 per cent with mean 96.4 per cent. This showed a 3.6 per cent shortfall in output to maximum possible output level. The majority of respondents as 95.45 per cent belonged to high efficiency category 90 to 100 per cent while minimum respondents as 1.95 per cent belonged to efficiency category 70 to 90 per cent.

The mean technical efficiency estimates of different size groups of farm were observed as 98.8, 94.4, 96.3 and 96.1 per cent on marginal to large farms, respectively. The shortfalls of output to maximum possible level were observed as 1.2, 5.6, 3.7 and 3.9 per cent on marginal to large farms, respectively. Among all size groups of farms small farm was found as high skewed ranged from 66.4 per cent to 99.8 per cent.

Allocative efficiency of cauliflower farm :

Table 4 presents the allocative efficiency on different size groups of farms of cauliflower cultivation.

Table 2: Maximum likelihood estimates for parameters of the stochastic frontier production model for cauliflower farm

Variables	Parameter	Estimate	SE	t-ratio
Stochastic frontier				
Constant	β_0	-11.606	2.503	-4.637**
Ln (farm size)	β_1	-1.861	0.635	-2.933**
Ln (seed)	β_2	-0.105	0.151	-0.692
Ln (fertiliser)	β_3	0.262	0.027	9.827**
Ln (Agrochemical)	β_4	0.810	0.212	3.815**
Ln (labour)	β_5	3.361	0.685	4.908**
Ln (irrigation)	β_6	0.035	0.029	1.223
Inefficiency model				
Constant	δ_0	0.111	0.705	0.158
Farm size	δ_1	-0.719	1.567	-0.459
Farming experience	δ_2	-0.002	0.000	-5.813**
Education	δ_3	0.004	0.006	0.696
Family size	δ_4	-0.015	0.006	-2.737**
Extension visit	δ_5	-0.0001	0.013	-0.006
Land ownership	δ_6	0.111	0.705	0.158
Source of irrigation	δ_7	-0.060	0.044	-1.367
Crop diversification	δ_8	0.010	0.080	0.128
Location of farm	δ_9	-0.013	0.012	-1.098
Age	δ_{10}	0.003	0.001	2.915**
Sex	δ_{11}	-0.017	0.078	-0.219
Variance parameters				
Sigma square	σ^2	0.004	0.002	2.695**
Gamma	γ	0.021	0.697	0.030
Ln likelihood function	-	198.638		

**t-ratio is significant at 1 % level of significance

The study computed allocative efficiency values for land size as -30.45, -30.03, 72.89 and -22.07 on marginal to large farms, respectively. The values showed an indication of over utilisation of input as having the values less than unity on marginal, small and large farms. While the value greater than unity showed an under utilisation of the input on medium farm.

The computations of values of allocative efficiency for seed were -5.39, -11.18, -70.94 and -4.92 on marginal to large farms, respectively. All the values found less than unity indicated over utilisation of the input by all the size groups of farms. Allocative efficiency values for fertiliser obtained greater than unity for all the size groups of farms as 19.86, 17.59, 8.47 and 53.08 on marginal to large farms, respectively showing under utilisation of this input. Same way agrochemicals found under utilised for all the farms as having allocative efficiency values greater than unity as 147.26, 119.66, 429.74 and 114.09 on marginal to large farms, respectively. Labour was under utilised on marginal, small and large farms as the efficiency values found greater than unity for these farms as 23.47, 17.64 and 7.97, respectively. While medium farm utilised the labour excessively as figure -28.04 witnessed as less than the unity. Allocative efficiency values less than unity indicated irrigation was over utilised on marginal and small farms as valued -18.63 and -34.20, respectively. While allocative efficiency values 24.92 and 14.99 greater than unity observed on medium and large

Table 3: Distribution of respondents by technical efficiency estimates of cauliflower farm

Technical efficiency	Farm size				Overall
	Marginal	Small	Medium	Large	
0.50 < 0.70	0 (0.00)	4 (13.33)	0 (0.00)	0 (0.00)	4 (2.60)
0.70 < 0.90	0 (0.00)	1 (3.33)	2 (11.11)	0 (0.00)	3 (1.95)
0.90 < 1.00	95 (100.00)	25 (83.33)	16 (88.89)	11 (100.00)	147 (95.45)
Total	95 (100.00)	30 (100.00)	18 (100.00)	11 (100.00)	154 (100.00)
Minimum efficiency	0.933	0.664	0.896	0.894	0.847
Maximum efficiency	1.000	0.998	1.000	1.000	1.000
Mean efficiency	0.988	0.944	0.963	0.961	0.964

Note: Figures in parentheses show per cent to total

Table 4: Allocative efficiency on different size group of farms of cauliflower cultivation

Variables	Farm size											
	Marginal			Small			Medium			Large		
	VMP_i	P_i	A.E.	VMP_i	P_i	A.E.	VMP_i	P_i	A.E.	VMP_i	P_i	A.E.
Land size	-224850.72	7384.53	-30.45	-186170.44	6199.01	-30.03	405590.46	5564.19	72.89	-144292.02	6538.49	-22.07
Seed	-48752.77	9047.39	-5.39	-135320.52	12100.25	-11.18	-830425.97	11706.32	-70.94	-54428.85	11059.93	-4.92
Fertilizser	209.40	10.54	19.86	217.31	12.35	17.59	127.15	15.02	8.47	753.97	14.20	53.08
Grochemical	145941.55	991.04	147.26	110067.19	919.83	119.66	437311.71	1017.62	429.74	107167.85	939.29	114.09
Labour	2369.90	100.99	23.47	1741.53	98.71	17.64	-3054.19	108.93	-28.04	868.72	109.06	7.97
Irrigation	-165.07	8.86	-18.63	-273.37	7.99	-34.20	209.00	8.39	24.92	96.13	6.41	14.99

If A.E. =1 then the input is optimally / efficiently used and if A.E. < or > then input is inefficiently used

Table 5: Allocative efficiency in production of cauliflower on selected households

Variables	Co-efficient (β_i)	APP	MPP	Output unit prices (Py)	VMP_i	P_i	Allocative efficiency (VMP_i/ P_i)
Land size	-1.79	124.38	-222.02	1333.33	-296024.83	6421.56	-46.10
Seed	-0.05	387.23	-18.97	1333.33	-25299.00	10008.71	-2.53
Fertiliser	0.25	0.35	0.09	1333.33	115.64	13.03	8.87
Agrochemical	0.63	81.27	51.36	1333.33	68482.58	919.53	74.48
Labour	3.44	0.63	2.18	1333.33	2903.02	99.74	29.11
Irrigation	0.05	1.08	0.05	1333.33	64.71	8.08	8.00

If A.E. =1 then the input is optimally / efficiently used farms as indication of under utilisation of the input irrigation on these farms.

The study found that on marginal and small farms the inputs land size, seed and irrigation were over utilised while fertilizer, agrochemicals and labour were under utilised. On medium farm land size, fertilizer, agrochemicals and irrigation were under utilised while seed and labour were over utlilised. On large farms fertiliser, agrochemicals, labour and irrigation were under utilised whereas inputs land size and seed were over utilised. The study suggested that to increase the production of cauliflower different size groups of farms needed to maximize the under utilised inputs and minimize the over utilised inputs.

Table 5 shows allocative efficiency in production of cauliflower. The study computed the allocative efficiency values for cauliflower production as -46.10, -2.53, 8.87, 74.48, 29.11 and 8.00 for land size, seed, fertiliser, agrochemicals, labour and irrigation inputs, respectively.

The study found two inputs land size and seed were over utlised as allocative efficiency valued less than unity while other four input variables fertiliser, agrochemicals, labour and irrigation were valued greater than unity which indicated a sign of under utilisation of these resources. The study suggested that to maximize the production of cauliflower, the use of inputs land size and seed must be reduced while use of other four inputs like fertilizer, agrochemicals, labour and irrigation must be increased.

Conclusion:

The return to scale estimated as 3.033, 2.269,1.51 and 2.34 on marginal to large farms which indicates that all farms were in state 1 of production surface showing an increasing return to scale. The study reveals that labour was the most important factor in cauliflower production as increase in 1 per cent labour increases the output 3.36 per cent. It is also revealsed that 3.6 per cent short fall in output to maximum possible output level. The study values less than unity on marginal, small and large cauliflower farms, only medium farm shows under utilisation of input as value observed greater than unity.

The existence of variation in current level of production efficiency is a sign of need in improvement in method and technology adoption by farmers to perform agricultural operation in cauliflower production. Therefore, government policy should be aimed at attracting and adopting new method and technology in vegetable production.

The existence of under and over utilization of resource needed to be addressed effectively and efficiently by extension personnel with continuous efforts making on precision farming. This will be vital in achieving increased efficiency and productivity of farms.

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