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Estimation of technical and allocative efficiency of cabbage farm in Bilaspur District of Chhattisgarh State

Ajay Tegar, KNS Banafar and Anjum Ahmad

Abstract
The study investigated the technical efficiency and allocative efficiency of cabbage farm in Bilaspur District of Chhattisgarh, using a stochastic frontier production function. The primary data were collected from 154 randomly selected respondents. The study revealed return to scale on as 1.998, 2.35, 3.81 and 2.177 on marginal to large farms of cabbage respectively that indicates the production of cabbage falls into stage one of production surface. Overall the sum value of estimate were 2.045 indicates an increasing return to scale falling into first stage of production surface. The coefficient value of gamma (γ) found positive but non-significant which showed that variation in output was due to random factor. The mean technical efficiency of the pooled sample accounted to be 94 per cent that means there is scope to increase technical efficiency by 6 percent. The two inputs land size and seed were over utlised as allocative efficiency valued less than unity while other four inputs *viz* fertiliser, agrochemicals, labour and irrigation were valued greater than unity which indicated under utilisation of these resources. The study suggested that to maximize the production of cabbage inputs land size and seed must be decreased while other inputs like fertiliser, agrochemicals, labour and irrigation must be increased.

Keywords: technical efficiency, allocative efficiency, stochastic frontier production, maximum likelihood estimates, return to scale.

Introduction
The economic returns to vegetables are better than other several crops. The production yield of vegetable in per unit area is high and suitable for intensive farming lead generation of supplement incomes and expands employment through it. Vegetables are always been a better choice of crop diversification. The diversification in favour of these crops improves exports, reduce trade deficit, besides creating more direct and indirect employment. The assurance of efficient productive system is necessary for proper utilization of resources. Creation of efficient productive system requires awareness among 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, during 2010-11 vegetables occupied an area of 0.346 million hectares with the production 4.25 million metric tonnes (Indian Horticulture Database 2011 published by National Horticulture Board) 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 per cent of total area in the State followed by Durg, Surguja and Raipur with 14.82, 14.21 and 11.09 per cent, respectively. In stead of the large area of vegetables in Bilaspur District the productivity i.e. 9.91 metric tonnes per hectare does not coincide with its coverage. The yield gap mainly arises due to suboptimal or inefficiency use of resources (Bhende, 2008) [3]. Hence, measurement of technical and allocative efficiency is needful. The analysis of technical and allocative efficiency give base to determine the extent to which resources can be appropriately adjusted in order to achieve optimum productivity (Ugwumba, 2010, Singh *et al*. 2017a; Singh *et al*. 2017b; Singh *et al*. 2017c; Singh *et al*. 2018; Tiwari *et al*. 2018; Tiwari *et al*. 2019a; Tiwari *et al*. 2019b; Kour *et al*. 2019; Singh *et al*. 2019b) [26, 12, 13, 14, 15, 16, 17, 18, 19, 20].

Therefore, this study has been under taken in Bilaspur with the following objectives:

1. To estimate the technical efficiency of selected cabbage farm.
2. To estimate the allocative efficiency of each factors of cabbage cultivation.

Methodology

Sampling and Data Collection

The study was conducted in Bilaspur District of Chhattisgarh State. A 10 per cent respondent was selected at random with the sample size of 154 farmers from four Blocks namely Bilha, Masturi, Kota and Takhatpur of the District. The study was based on primary data for the agricultural year 2014-15.

Analytical Framework

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 efficiencies among vegetable farmers (Tsoho *et al*., 2012) [25].

The general form of function is defined by Equation (1);

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

Where,

Y_i is the production (or the logarithm of the production) of the ith firm.

X_i is a $k \times 1$ vector of (transformations of the) input quantities of the ith 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 (2) for the stochastic function is;

$$InY_i = \beta_0 + \beta_1 InX_1 + \beta_2 InX_2 + \beta_3 InX_3 + \beta_4 InX_4 + \beta_5 InX_5 + \beta_6 InX_6 + V_i - U_i \quad (2)$$

Where,

Y_i = Out put of the ith farmer (q)

X_1 = Farm size (ha)

X_2 = Seed (kg)

X_3 = Fertilizer (kg)

X_4 = Agrochemical (L)

X_5 = Labour (man-days)

X_6 = Irrigation (ha-cm)

Technical efficiency of an individual firm is defined as Equation (3);

Technical efficiency is obtainable by the use of Frontier 4.1 of Coelli 1996, the same was also used by Karthick *et al*., 2013; Ogundari K., 2007; and Singh *et al*., 2011 [9, 10, 21].

$$TE = Y_i / Y_i^* \quad (3)$$

Where,

TE = Technical efficiency

Y_i = Observed output

Y_i^* = Frontier output

Technical inefficiencies are explained as Equation (4);

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} \quad (4)$$

U_i = Technical inefficiencies

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 ordinary least square (OLS). The same function was used by Abdulai, A. 2006; and Ugwumba *et al*. 2012 [1, 27]. And also Equation numbers (5), (6) and (7) were used by Douglas, K. 2013 [5] in his study to estimate allocative efficiency. Using the coefficient, the marginal product MP_i of the ith factor X was calculated as;

$$MP_i = \frac{\partial Y}{\partial X_i} = \beta_i \frac{Y}{X_i} \quad (5)$$

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

Where,

Y = is the geometrical mean of output.

X_i = is the geometrical mean of input i.

β_i = is the OLS estimated coefficient of input i.

Value to marginal product of input i (VMP_i);

$$\text{VMP}_i = \text{MP}_i * \text{P}_y \quad (6)$$

Where,
VMP_i = Value of marginal product of input i.
MP_i = Marginal Physical product
P_y = Price of output

Allocative efficiency (A.E.) = $\frac{\text{VMP}_i}{\text{P}_i}$ (7)

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

Results and Discussion
The results obtained from the present study as well as discussions have been summarized under the following heads:

Technical efficiency of cabbage farm
Table 1 reveals that maximum likelihood estimates for parameters of the stochastic frontier production for different size group of cabbage farms. As in the table the estimates of farm size, seed were significant at 5 per cent on marginal farm and at 1 per cent level on small to large farms. Fertiliser estimates were found positively significant at 1 per cent on small and large farms. Estimates of agrochemical found positively significant at 1 per cent on medium farm while negative on large farms. Estimates for labour found significant at 1 per cent on marginal, small and large farms. Estimates for irrigation observed non-significant value for all size groups of farms.
The elasticity of output with respect to farm size on all size groups of farm were found negative as -0.501, -0.840, -3.495 and -0.741meaning that 1 per cent increase in farm size decreases the output by 0.501, 0.840, 3.495 and 0.741 per cent to total output. Elasticity of output with respect to seed was found positive on small and large farms while, negative on marginal and medium farms. The estimated value shows that 1 per cent increase in seed increases output by 0.278 and 0.634 per cent to total output on small and large farms while decreases the output by 0.446 and 2.791 per cent on marginal and medium farm. Application of additional fertiliser by 1 per cent to the cabbage production increases the output by 1.768 and 1.962 per cent to total output on small and large farms. Elasticity of output with respect to agrochemical found positive on medium and negative on large farm as valued 9.785 and -0.840 respectively. Increase of labour by 1 per cent increases the output by 1.248, 1.298 and 1.160 on marginal, small and large farms respectively. All inefficiency variables on marginal farms found non-significant whereas farm size of inefficiency model found significant at 5 per cent on small farm while significant at 1 per cent on large farm. Extension visit estimates were significant at 1 per cent level on medium and large farms. An estimate for crop diversification was found significant negatively on small farm.
Estimates of age were found significantly positive at 1 per cent level on small and medium farm. In the study the return to scale observed as 1.998, 2.35, 3.81 and 2.177 on marginal to large farm of cabbage respectively which indicates the production of cabbage falls into stage one of production surface indicating an increasing return to scale.
The estimated variance parameters of the model gamma (γ) was observed significant on small, medium and large farms as valued 0.888, 1.00 and 1.00 respectively, which implies that about 88.8, 100.00 and 100.00 per cent of the variation in cabbage output was due to farmers practices on small, medium and large farms. About 11.2 per cent of variation in output was due to random factors on small farms.
Table 2 shows maximum likelihood estimates for parameters of the stochastic frontier production for cabbage farm. In which, the coefficient of labour valued 1.449 found significant at 5 per cent level of significance. The estimated elasticity of mean output with respect to labour appeared positive meaning that increase in 1 per cent input labour increases output by 1.45 per cent to total output. The study also found that coefficient of all inefficiency variables were non significant. The return to scale was positive and greater than one. This revealed that the cabbage production was on first stage of production surface as the value 2.045 indicated an increasing return to scale.
The coefficient value of gamma (γ) found positive but non significant which showed that variation in output was due to random factor.
As in the Table 3 an overall distribution of technical efficiency estimates of cabbage farm as moderately skewed from 72.3 to 99.8 per cent with mean 94.0 per cent. The study found a shortfall in output by 6 per cent to maximum possible output level. The maximum number of respondents 93.51 per cent belonged to high efficiency category 90 to 100 per cent while minimum respondents 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 97.8, 92.3, 93.1 and 92.9 per cent on marginal to large farms respectively. The shortfalls of output to maximum possible level were 2.2, 7.7, 6.9 and 7.1 per cent on marginal to large farms respectively. Large variation was observed on small farm as efficiency ranged from 53.9 to 99.5 per cent followed by medium farm as efficiency ranged 67.2 to 100 per cent. Least variation was found on marginal farm followed by large farm.

Table 1: Maximum likelihood estimates for parameters of the stochastic frontier production model for cabbage 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
Constant	β_0	-2.477	1.064	-2.328*	-8.533	0.242	-35.295**	2.362	0.677	3.489**	-8.801	1.142	-7.708**
Ln (farm size)	β_1	-0.501	0.246	-2.033*	-0.840	0.139	-6.049**	-3.495	0.045	-78.032**	-0.741	0.054	-13.703**
Ln (seed)	β_2	-0.446	0.214	-2.080*	0.278	0.049	5.731**	-2.791	0.184	-15.171**	0.634	0.108	5.869**
Ln(fertiliser)	β_3	0.320	0.175	1.833	1.768	0.107	16.465**	0.170	0.102	1.657	1.962	0.150	13.042**
Ln (Agrochemical)	β_4	1.337	0.683	1.957	-0.111	0.304	-0.363	9.785	0.594	16.483**	-0.840	0.273	-3.072**
Ln (labour)	β_5	1.248	0.445	2.806**	1.298	0.203	6.381**	0.091	0.169	0.537	1.160	0.172	6.736**
Ln (irrigation)	β_6	0.040	0.273	0.148	-0.043	0.162	-0.264	0.050	0.067	0.739	0.002	0.090	0.022
Inefficiency model													
Constant	δ_0	-0.001	0.851	-0.001	-0.007	0.928	-0.008	-0.098	0.936	-0.105	0.149	0.939	0.159
Farm size	δ_1	-0.161	0.551	-0.292	-1.518	0.705	-2.154*	7.725	0.877	8.810**	-1.701	0.925	-1.838
Farming experience	δ_2	0.004	0.017	0.227	-0.001	0.002	-0.324	-0.011	0.002	-6.389**	-0.001	0.005	-0.184

Education	δ_3	0.015	0.030	0.503	0.012	0.014	0.905	-0.046	0.014	-3.225**	-0.137	0.031	-4.447**
Family size	δ_4	-0.014	0.024	-0.558	0.102	0.030	3.351**	-0.142	0.031	-4.642**	-0.058	0.013	-4.354**
Extension visit	δ_5	-0.016	0.066	-0.237	-0.106	0.053	-2.010	0.244	0.031	7.864**	-0.188	0.073	-2.581*
Land ownership	δ_6	-0.001	0.851	-0.001	-0.007	0.928	-0.008	-0.098	0.936	-0.105	0.149	0.939	0.159
Source of irrigation	δ_7	-0.016	0.457	-0.034	-0.015	0.665	-0.022	-0.196	0.710	-0.276	0.298	0.727	0.410
Crop diversification	δ_8	-0.001	0.851	-0.001	-0.435	0.075	-5.838**	-0.098	0.936	-0.105	0.149	0.939	0.159
Location of farm	δ_9	0.003	0.072	0.048	-0.113	0.097	-1.164	-0.119	0.069	-1.727	0.085	0.053	1.602
Age	δ_{10}	0.0002	0.014	0.013	0.016	0.002	6.448**	0.007	0.002	3.516**	-0.006	0.007	-0.844
Sex	δ_{11}	-0.017	0.272	-0.061	-0.007	0.928	-0.008	-0.098	0.936	-0.105	0.149	0.939	0.159
Variance parameters													
Sigma square	σ^2	0.006	0.004	1.368	0.005	0.001	7.677**	0.003	0.001	4.867**	0.001	0.001	1.030
Gamma	γ	0.042	0.631	0.066	0.888	0.030	29.968**	1.000	0.001	1878.820**	1.000	0.0001	11039.59**
Ln Likelihood FCN	-	109.329			61.347			41.470			27.287		

**t-ratio is significant at 1% level of significance. *t-ratio is significant at 5% level of significance.

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

Variables	Parameter	Estimate	SE	t-ratio
Stochastic frontier				
Constant	β_0	-3.347	0.962	-3.478**
Ln (farm size)	β_1	-0.515	0.355	-1.448
Ln (seed)	β_2	-0.375	0.223	-1.682
Ln(fertiliser)	β_3	0.325	0.464	0.700
Ln (Agrochemical)	β_4	1.125	0.854	1.318
Ln (labour)	β_5	1.449	0.637	2.274*
Ln (irrigation)	β_6	0.036	0.097	0.371
Inefficiency model				
Constant	δ_0	-0.002	0.871	-0.002
Farm size	δ_1	-0.009	0.995	-0.009
Farming experience	δ_2	-0.003	0.006	-0.506
Education	δ_3	0.017	0.027	0.617
Family size	δ_4	-0.012	0.056	-0.214
Extension visit	δ_5	-0.011	0.077	-0.147
Land ownership	δ_6	-0.002	0.871	-0.002
Source of irrigation	δ_7	-0.044	0.268	-0.163
Crop diversification	δ_8	0.006	0.197	0.029
Location of farm	δ_9	-0.002	0.092	-0.026
Age	δ_{10}	0.005	0.003	1.627
Sex	δ_{11}	-0.011	0.774	-0.015
Variance parameters				
Sigma square	σ^2	0.007	0.003	2.216*
Gamma	γ	0.023	0.605	0.038
Ln Likelihood Function	-	170.800		

**t-ratio is significant at 1% level of significance. *t-ratio is significant at 5% level of significance.

Table 3: Distribution of respondents by technical efficiency estimates of cabbage farm.

Technical efficiency	Farm size				Overall
	Marginal	Small	Medium	Large	
0.50 < 0.70	0	4	3	0	7
	(0.00)	(13.33)	(16.67)	(0.00)	(4.55)
0.70 < 0.90	0	0	0	3	3
	(0.00)	(0.00)	(0.00)	(27.27)	(1.95)
0.90 < 1.00	95	26	15	8	144
	(100.00)	(86.67)	(83.33)	(72.73)	(93.51)
Total	95	30	18	11	154
	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)
Minimum efficiency	0.916	0.539	0.672	0.766	0.723
Maximum efficiency	0.998	0.995	1.000	1.000	0.998
Mean efficiency	0.978	0.923	0.931	0.929	0.940

Note- Figures in parenthesis show per cent to total.

Allocative efficiency of cabbage

Table 4 presents the allocative efficiency on different size groups of farms of cabbage cultivation. In which, the allocative efficiency values were found for land size as -11.00, -20.85, -66.22 and -18.59 on marginal to large farms respectively. All the values were less than unity that resulted an over utilisation of this input on all size groups of farms.

Allocative efficiency values for input seed worked out to be -21.98, -20.45, -68.94 and 11.11 on marginal to large farm respectively. As the figures obtained less than unity for marginal to medium farms revealed an over utilisation of input seed and figure greater than unity indicated under utilisation of input seed on large farm. Allocative efficiency values for input fertiliser were obtained as 9.73, 16.05, 10.50 and 55.06 on marginal to large farm explained an under utilisation of fertiliser on these farms as found all the values more than unity. Allocative efficiency values for input agrochemicals were obtained as 156.83, 187.66, 653.81 and -23.98 on marginal to large farms respectively revealed an under utilisation of this input on marginal to medium farms as values found greater than unity and over utilisation on large farm as value found less than unity. Labour was found under utilised on all size groups of farms as valued greater than unity *viz*. 11.56, 13.30, 2.91 and 12.17 on marginal to large farms respectively. Irrigation was under utilised on marginal and large farms as allocative efficiency valued greater than unity with 8.78 and 19.53 respectively. The same input found over utilised on small and medium farms with the figures less than unity as -36.69 and -0.20 respectively.

Table 4: Allocative efficiency on different size group of farms of cabbage 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	-81248.45	7384.53	-11.00	-129237.82	6199.01	-20.85	-368449.81	5564.19	-66.22	-121545.09	6538.49	-18.59
Seed	-237892.90	10822.46	-21.98	-232704.14	11381.18	-20.45	-885299.65	12841.63	-68.94	111392.21	10024.39	11.11
Fertiliser	126.16	12.96	9.73	184.20	11.48	16.05	160.91	15.32	10.50	752.27	13.66	55.06
Agrochemical	146264.43	932.66	156.83	166969.00	889.74	187.66	661815.40	1040.91	635.81	-21569.20	926.39	-23.28
Labour	1081.20	93.52	11.56	1099.55	82.65	13.30	330.91	113.54	2.91	1278.09	105.01	12.17
Irrigation	69.96	7.97	8.78	-244.59	6.67	-36.69	-1.01	4.99	-0.20	120.94	6.19	19.53

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

The study suggests that to increase the production of cabbage on all size groups of farms needed to increase the under utilised resources and reduce the over utilised resources.

Table 5 reveals allocative efficiency in production of cabbage. The allocative efficiency values for cabbage production worked out to be -14.27, -18.61, 10.81, 134.46, 12.81 and 6.91 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 inputs were valued greater than unity which indicated under utilisation of these resources.

Table 5: Allocative efficiency in production of cabbage on selected households.

Variables	Coefficient (β_i)	APP	MPP	Output unit prices (Py)	VMP_i	P_i	Allocative Efficiency (VMP_i / P_i)
Land size	-0.53	137.99	-73.14	1253.33	-91664.11	6421.56	-14.27
Seed	-0.38	416.70	-157.10	1253.33	-196894.59	10581.27	-18.61
Fertiliser	0.30	0.38	0.11	1253.33	143.55	13.28	10.81
Agrochemical	1.12	88.94	99.43	1253.33	124621.74	926.85	134.46
Labour	1.46	0.69	1.01	1253.33	1260.35	98.41	12.81
Irrigation	0.04	1.12	0.04	1253.33	51.77	7.49	6.91

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

The study suggests that to maximize the production of cabbage inputs land size and seed must be decreased while other inputs like fertiliser, agrochemicals, labour and irrigation must be increased.

Conclusions

The study found return to scale on cabbage farm positive and greater than one as 2.045 which indicates an increasing return to scale having cabbage production on first stage of production surface. The analysis shows a non-significant value of variation which means the variation in output was due to random factor. The mean technical efficiency of the pooled sample accounted to be 94 per cent.

The study found two inputs land size and seed were over utlised as allocative efficiency valued less than unity while other four inputs were valued greater than unity which indicated under utilisation of these resources.

The study suggests that to maximize the production of cabbage inputs land size and seed must be decreased while other inputs like fertiliser, agrochemicals, labour and irrigation must be increased.

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