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RESEARCH ARTICLE :

An analysis of technical and allocative efficiency of brinjal farm in Bilaspur district of Chhattisgarh

AJAY TEGAR, K.N.S. BANAFAR, A.K. GAURAHA AND G. CHANDRAKAR

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SUMMARY : The study investigated the technical efficiency and allocative efficiency of brinjal farm in Bilaspir district of Chhattisgarh, using a stochastic frontier production function. Pre-tested questionnaires were used to collect the primary data from 154 randomly selected respondents. The study revealed return to scale on brinjal farm positive and less than unity as 0.58 which indicated that brinjal production in stage two of the production surface. The stochastic frontier analysis showed that 22.3 per cent of the variation in brinjal output attributed to technical efficiencies differences among the production units. About 77.7 per cent of the variation in output was due to random factors such as unfavourable weather, water scarcity, pest and disease attack and other factors outside the control of producer including errors in data collection and aggregation. The mean technical efficiency of the pooled sample accounted to be 96.1 per cent. Allocative efficiency in production of brinjal was not optimum as input variables were either under utilized or over utilized. Allocative efficiency of labour in brinjal production seed was under utilized. Rests of the input variables were over utilized. No farm from different categories size groups of farms of vegetable growers found using the resources efficiently.

KEY WORDS :
Technical efficiency, Allocative efficiency, Stochastic frontier production, Maximum likelihood estimates, Return to scale

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Author for correspondence :
AJAY TEGAR
Department of Agricultural Economics, T.C.B. College of Agriculture and Research Station, Sarkanda
BILASPUR
(C.G.) INDIA
Email: tegar17575@gmail.com
See end of the article for authors' affiliations

BACKGROUND AND OBJECTIVES

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 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 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. Instead 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. A clear gap is identified between harvested yield and potential yield. The yield gap mainly arises due to suboptimal or efficiency use of resources. Hence, measurement of technical and allocative efficiency is needful as the analysis provides better understanding of the productivity gap and helping farmers 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 with the following objectives.

Objectives :

–To estimate the technical efficiency of selected brinjal farms.

–To estimate the allocative efficiency of each factors of vegetable production.

RESOURCES AND METHODS

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 2013-14.

The following analytical procedure was adopted to analyse the data:

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;

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

where,

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

X_i is a k x 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;

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + V_i - U_i$$

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, 1998).

where,

TE = Technical efficiency

Yi = Observed output

Y_i^* = Frontier output.

Technical inefficiencies are explained as;

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

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 MP_i of the i^{th} factor X was calculated as;

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

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

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) ;

$$VMP_i = MP_i \times P_y$$

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.

OBSERVATIONS AND ANALYSIS

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

Technical efficiency of brinjal farm :

Table 1 revealed that the elasticity of farm output with respect to farm size on medium farm estimated to be an increasing function that means increase in 1 per cent in farm size increases the output by 0.495 per cent. The elasticity of output with respect to seed found to be positive on marginal farm and negative on medium farm which means 1 per cent increase in seed impact increase in output by 0.085 per cent and decrease by 0.210 per cent output to total output on respective farms. The elasticity of output with respect to fertilizer decreases output by 0.208, 0.217 and 0.710 to total output on marginal, small and medium farms, respectively. The elasticity of output with respect to the plant protection found positive on medium farm as 0.259 and negative on small and large farms as -0.232 and -0.480, respectively. The elasticity of output with respect to labour found positive on all farms. The increase in 1 per cent labour input increases the output by 0.807, 1.302, 0.467 and 1.503 per cent on marginal to large farm orderly. The elasticity of output with respect to irrigation was found positive on small farm as 0.116.

All inefficiency variables on marginal and large farm were found non-significant. Variable farm size of inefficiency model were found significant at 5 per cent level on small farm while same found positively significant at 1 per cent level on medium farm. Farming experience was found positively significant at 1 per cent level on both small as well as medium farm. Education was found negatively significant at 5 per cent level on medium farm. Extension visit also negatively significant at 1 per cent level on small farm. Location of farm found negative and significant at 1 per cent level on medium farm. Age was found negative and significant on small farm. The return to scale on marginal, small and medium farms valued positive but less than unity as 0.883, 0.874 and 0.218, respectively, showing decreasing return to scale. This showed that the brinjal production on these three farms fell in stage two of the production surface. While return to scale valued 1.09 on large farm that was greater than unity which having the meaning that brinjal production on the farm fell under stage one of the production surface explaining increasing return to scale.

The estimate of variance ratio gamma (γ) found significant at 1 per cent level on marginal, medium and large farms while same found non-significant on small farm. The value obtained for gamma as 1.00 is high for all farms except small explaining that 100 per cent of the variation in the output attributed to technical efficiency differences among the production units.

Table 2 showed that maximum likelihood estimates for parameters of the stochastic frontier production for brinjal farm. The elasticity of frontier output with respect to farm size, labour and irrigation were estimated as 0.157 and 0.491, respectively. Given the specification of the Cobb-Douglas Frontier Model the result showed that the elasticity farm output estimated to be an increasing function of farm size, seed, plant protection, labour and irrigation. The study found labour to be the most important factor in brinjal production which is significant at 1 per cent level of significance.

The elasticity of farm output was estimated negative as -0.131 with respect to the input ferlitlizer. Since it is significant, it indicates that 1 per cent increase in fertilizer, other things remaining constant bring about decrease of 0.131 per cent to total output. The return to scale was positive and less than unity as valued 0.58. This finding is inline with results obtained from Tsoho *et al.* (2012). This shows that brinjal production was in stage two of the production surface that indicates a decreasing return to scale.

The study found that explanatory variables farm size and location of farm of inefficiency model positive and significant at 1per cent and 5 per cent level of significance, respectively. The estimate of the variance ratio gamma (γ) found significant as the value estimated 0.223. This implies that about 22.3 per cent of the variation in output

Table 1 : Maximum likelihood estimates for parameters of the stochastic frontier production model for brinjal farm in Bilaspur

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	0.494	0.955	0.517	-1.153	1.102	-1.047	5.273	0.799	6.598**	-2.551	1.230	-2.073
Ln (farm size)	β_1	-0.064	0.072	-0.887	-0.124	0.071	-1.736	0.495	0.062	7.922**	-0.221	0.170	-1.300
Ln (seed)	β_2	0.085	0.020	4.181**	0.029	0.045	0.659	-0.210	0.043	-4.900**	0.213	0.238	0.894
Ln(fertilizer)	β_3	-0.208	0.057	-3.616**	-0.217	0.105	-2.065*	-0.710	0.111	-6.398**	0.060	0.743	0.080
Ln (PP)	β_4	-0.075	0.128	-0.586	-0.232	0.107	-2.160*	0.259	0.068	3.796**	-0.480	0.154	-3.114*
Ln (labour)	β_5	0.807	0.485	1.664	1.302	0.282	4.610**	0.467	0.173	2.707*	1.503	0.974	1.543
Ln (irrigation)	β_6	0.338	0.680	0.497	0.116	0.050	2.296*	-0.083	0.063	-1.318	0.015	0.195	0.077
Inefficiency model													
Constant	δ_0	-0.126	0.978	-0.129	0.052	0.936	0.055	-0.010	0.935	-0.011	0.002	0.939	0.003
Farm size	δ_1	-0.016	0.999	-0.016	-2.184	0.877	-2.491*	1.324	0.227	5.841**	0.017	0.755	0.023
Farming experience	δ_2	0.015	0.084	0.181	0.004	0.001	4.381**	0.002	0.001	3.228**	0.0004	0.002	0.190
Education	δ_3	-0.321	0.520	-0.617	-0.003	0.004	-0.777	-0.006	0.002	-2.543*	-0.014	0.048	-0.286
Family size	δ_4	-0.079	0.376	-0.210	-0.005	0.005	-0.903	0.007	0.005	1.418	-0.013	0.011	-1.112
Extension visit	δ_5	-0.266	0.892	-0.298	-0.023	0.008	-2.767**	0.009	0.008	1.211	-0.035	0.105	-0.336
Land ownership	δ_6	-0.126	0.978	-0.129	0.052	0.936	0.055	-0.010	0.935	-0.011	0.002	0.939	0.003
Source of irrigation	δ_7	-0.217	0.931	-0.234	0.103	0.708	0.146	-0.021	0.707	-0.029	0.005	0.725	0.007
Crop diversification	δ_8	-0.126	0.978	-0.129	0.052	0.936	0.055	-0.010	0.935	-0.011	0.002	0.939	0.003
Location of farm	δ_9	-0.267	0.948	-0.281	-0.003	0.014	-0.214	-0.025	0.008	-3.269**	0.031	0.019	1.597
Age	δ_{10}	0.016	0.120	0.130	-0.004	0.001	-4.039**	0.0004	0.0004	-0.848	0.002	0.010	0.148
Sex	δ_{11}	-0.127	0.979	-0.130	0.052	0.936	0.055	-0.010	0.935	-0.011	0.002	0.939	0.003
Variance parameters													
Sigma square	σ^2	0.187	0.063	2.979**	0.0003	0.0001	3.408**	0.0001	0.00002	3.164**	0.001	0.001	1.021
Gamma	γ	1.000	0.0004	2570.31**	0.453	0.229	1.978	1.000	0.014	69.531**	1.000	0.001	1068.855 **
Ln likelihood FCN	-	193.049			84.725			66.107			29.387		

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 2 : Maximum likelihood estimates for parameters of the stochastic frontier production model for brinjal farm in Bilaspur

Variables	Parameter	Estimate	SE	t-ratio
Stochastic frontier				
Constant	β_0	2.506	0.214	11.726**
Ln (farm size)	β_1	0.157	0.017	9.087**
Ln (seed)	β_2	0.018	0.010	1.753
Ln(fertilizer)	β_3	-0.131	0.026	-5.043**
Ln (Plant protection)	β_4	0.040	0.017	2.313
Ln (labour)	β_5	0.491	0.064	7.705**
Ln (irrigation)	β_6	0.005	0.021	0.219
Inefficiency model				
Constant	δ_0	-0.061	0.707	-0.087
Farm size	δ_1	1.305	0.157	8.298**
Farming experience	δ_2	-0.0003	0.0002	-1.373
Education	δ_3	0.002	0.001	1.088
Family size	δ_4	0.0003	0.001	0.204
Extension visit	δ_5	-0.005	0.004	-1.374
Land ownership	δ_6	-0.061	0.707	-0.087
Source of irrigation	δ_7	-0.004	0.006	-0.597
Crop diversification	δ_8	0.001	0.007	0.196
Location of farm	δ_9	0.006	0.003	1.979*
Age	δ_{10}	0.0004	0.0002	1.877
Sex	δ_{11}	-0.008	0.018	-0.413
Variance parameters				
Sigma square	σ^2	0.0002	0.00003	8.304**
Gamma	γ	0.223	0.042	5.246**
Ln likelihood function	-	439.342		

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 3 : Distribution of respondents by technical efficiency estimates of brinjal farm in Bilaspur district

Technical efficiency	Farm size				Overall
	Marginal	Small	Medium	Large	
0.000 < 0.10	0	0	0	0	0
	0	0	0	0	0
0.10 < 0.30	0	0	0	0	0
	0	0	0	0	0
0.30 < 0.50	0	0	0	0	0
	0	0	0	0	0
0.50 < 0.70	0	0	0	0	0
	0	0	0	0	0
0.70 < 0.90	0	0	5	0	5
	(0.00)	(0.00)	(27.78)	(0.00)	(3.25)
0.90 < 1.00	95	30	13	11	149
	(100.00)	(100.00)	(72.22)	(100.00)	(96.75)
Total	95	30	18	11	154
	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)
Minimum efficiency	0.907	0.914	0.858	0.915	0.899
Maximum efficiency	0.994	0.999	1.000	1.000	0.998
Mean efficiency	0.970	0.970	0.933	0.969	0.961

Note- Figures in parenthesis show per cent to total. Field survey (2014) attributed to technical efficiency differences among the production units. By implication about 77.7 per cent of the variation in output was due to random factors.

The result in Table 3 showed the distribution of technical efficiency estimates among respondents of brinjal farm. There was a narrow variation in the level of technical efficiency estimates. The range was 89.9 to 99.8 per cent with a mean of 96.1 per cent. The mean level of technical efficiency indicated that on an average short fall of output by 3.9 per cent to the maximum possible level of output. The large number of respondents as 96.75 per cent belonged to the most efficient category 90 to 100 per cent. The technical efficiency 100 per cent also reported by Hussaini and Abayomi (2010). Whereas, 3.25 per cent respondents belonged to the category 70 to 90 per cent. The study found that marginal and small farms were on same level of efficiency as 97 per cent. Among all size groups of farms large variation in technical efficiency was found on medium farm with a range 85.8 to 100 per cent with mean 93.3 per cent.

Allocative efficiency of brinjal farm :

Table 4 presented allocative efficiency on different size groups of farms of brinjal cultivation. The study computed the allocative efficiency values for the input land size as 0.06, 2.89, 4.85 and -6.96 on marginal to large farms, respectively. The values of allocative efficiency for input land size were less than unity on marginal and large farm showed over utilisation of the input by these farms. Whereas, the values for the same on small and medium farm were obtained greater than unity carrying an indication of under utilisation of the same resource by these farms.

The allocative efficiency values for the input seed were obtained as -0.42, -2.40, -4.32 and 16.60 on marginal to large farms, respectively. The values of allocative efficiency for input seed were less than unity on marginal to medium farms meaning that the input seed was over utilized by these farms, while large farm under utilized of the same as value observed greater than unity. The allocative efficiency values for the input fertlizer were found as -10.41, -13.77, -17.81 and 2.07 on marginal to large farms, respectively. The values of allocative efficiency for input were less than unity on marginal to medium farms showed the over utilisation of fertilizer by these farms, while large farm under utilized of the same input as value observed greater than unity. The allocative efficiency values for the input agrochemicals were found to be -3.51, -15.20, -14.36 and -76.45 on marginal to large farms, respectively. The figures explained an over

Table 4 : Allocative efficiency on different size group of farms of brinjal cultivation in Bilaspur district of Chhattisgarh

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	470.98	7384.53	0.06	17943.72	6199.01	2.89	27009.89	5564.19	4.85	-45485.58	6538.49	-6.96
Seed	-5256.55	12568.49	-0.42	-29963.44	12473.21	-2.40	-64551.13	14936.08	-4.32	239946.23	14451.05	16.60
Fertilizer	-140.75	13.52	-10.41	-174.16	12.65	-13.77	-261.47	14.68	-17.81	28.27	13.66	2.07
Plant protection	-3145.75	895.03	-3.51	-13359.50	878.87	-15.20	-16001.39	1114.31	-14.36	-76646.29	1002.51	-76.45
Labour	702.84	91.09	7.72	784.99	89.60	8.76	1016.41	111.03	9.15	1172.62	104.09	11.27
Irrigation	541.98	8.05	67.36	5.25	6.24	0.84	-23.40	9.51	-2.46	21.71	6.08	3.57

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 brinjal in Bilaspur district of Chhattisgarh

Variables	Co-efficient (β_i)	APP	MPP	Output unit prices (Py)	VMP_i	P_i	Allocative efficiency (VMP_i / P_i)
Land size	0.04	182.91	7.13	886.67	6324.95	6421.56	0.98
Seed	0.02	852.95	15.35	886.67	13613.05	13904.51	0.98
Fertilizer	-0.19	0.53	-0.10	886.67	-89.80	13.96	-6.43
Agrochemicals	-0.02	154.45	-3.71	886.67	-3286.62	1013.17	-3.24
Labour	0.69	0.90	0.62	886.67	546.60	101.05	5.41
Irrigation	-0.003	1.55	-0.005	886.67	-4.12	8.17	-0.50

If A.E. =1 then the input is optimally / efficiently used and if A.E. < or > then input is inefficiently used utilisation of agro-chemicals by all the farms as values were less than unity. The allocative efficiency values for the input labour were computed as 7.72, 8.76, 9.15 and 11.27 on marginal to large farm, respectively. This showed under utilization of input labour as the values observed greater than unity. The allocative efficiency values for the input irrigation were computed as 67.36, 0.84, -2.46 and 3.57 on marginal to large farms, respectively. The values were greater than unity on marginal and large farms showed under utilisation of this resource on these farms. Whereas, values less than unity as on small and medium farms portrayed over utilisation of same input on both the farms.

The study found that most of the resources were over utilized by marginal to medium farms whereas, large farm under utilzed the most of the resources. This study suggested that to get maximum production of brinjal marginal farm needed to decrease the use of input land size, seed, fertilzer and agrochemicals and increase the labour and irrigation. Whereas, small and medium farms needed to reduce the use of seed, fertilizer, agro-chemicals and irrigation and increase the use of land size and labour. Large farm needed to reduce the use of input land size and agro-chemicals and increase the use of inputs seed, fertlizer, labour and irrigation.

Table 5 presented allocative efficiency observed in production of brinjal. The analysis of this study indicated allocative efficiency values as 0.98, 0.98, -6.43, -3.24, 5.41 and -0.50 for land size seed, fertilizer, agro-chemicals, labour and irrigation inputs, respectively. By these results it was found that land size, seed, fertilizer, agro-chemicals and irrigation inputs with allocative efficiency values were below one and that portrayed over utilisation of these inputs. Whereas, only labour was with allocative efficiency greater than one indicating under utilized input. The under utilization of labour was also reported by Suresh and Reddy (2006).

Conclusion :

The return to scale on marginal, small and medium farms valued positive but less than unity showing decreasing returns to scale. Whereas, large farm valued return to scale greater than one having production surface of stage one.

The study found labour to be the most important factor in brinjal production to increase the production. The return to scale valued 0.58 showing an indication to take the decision on alteration of technology. The mean level of technical efficiency indicated an average shortfall of output by 3.9 per cent to the maximum possible level of output.

The study found that inputs land size, seed, fertilizer, agro-chemicals and irrigation were over utilized and only labour was under utilized as production of brinjal in study area facing the problem of labour availability. The study suggested that decrease the over utilized resources and increase the under utilized resource *i.e.* labour to maximize the profit.

Authors' affiliations :

K.N.S. BANAFAR AND A.K. GAURAHA, Department of Agricultural Economics, College of Agriculture, Krishak Nagar, RAIPUR (C.G.) INDIA
Email: banafarkns1959@gmail.com; ajaygauraha15@gmail.com

G. CHANDRAKAR, Department of Agricultural Statistics and Social Science, College of Agriculture, Krishak Nagar, RAIPUR (C.G.) INDIA
Email: chandrakar.gayatri6@gmail.com

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