International Journal of Mathematical Archive-5(12), 2014, 31-39
Available online through www.ijma.info ISSN 2229 – 5046

MEASURING TECHNICAL EFFICIENCY OF TURMERIC PRODUCTION USING PARAMETRIC STOCHASTIC FRONTIER MODELS

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(Received On: 23-11-14; Revised & Accepted On: 29-12-14)

ABSTRACT

Measurement and comparison of Technical Efficiency Score (TES) of Turmeric production plays a major role in the present study. Two stochastic frontier models viz., Cobb-Douglas Normal Half-Normal Stochastic Frontier Model (CDNHNSFM) and Cobb-Douglas Normal Exponential Stochastic Frontier Model (CDNESFM) have been used to measure TES. Among the 180 turmeric farms considered, the number of farms having TES above 95% using CDNHNSFM and CDNESFM were 75% and 52% respectively. The higher mean TES was given by CDNESFM (95.79) than CDNHNSFM (94.24). Although CDHNSFM showed higher mean technical efficiency score, CDNESFM, which recorded higher correlation coefficient (0.786) and lower chi-square value (1.1712) between the observed efficiency and expected efficiency is considered as a better model to estimate the technical efficiency for the sample under study.

Keywords: *Stochastic Frontier Model, Technical Efficiency Score (TES), Productivity.*

INTRODUCTION

Efficiency plays a major role in increasing productivity. Growth, especially in developing economies, is determined by resources and opportunities. Due to inadequate adoption of sophisticated technologies, growth is found to be dwindling. Developing economies like India can benefit a great deal from inefficiency studies, which shows that it is still possible to raise productivity by improving efficiency. Estimates on the extent of inefficiency can also help to decide whether to improve efficiency or to develop new technology. Moreover, efficiency of a farm refers to its performance in the utilization of resources at its disposal. Thus, it is important to know how well the resources are being utilized and what possibilities exist for improving the production using the existing resources and technology (Ahluwalia, 1996).

Many agricultural scientists and farm experts have endorsed the view that the performance of agriculture is yet to reach its potential level. Available evidences in the last few years revealed that technological package *via* its efficient utilization may accelerate the pace of agricultural development in India and so in raising the living standards of the rural population (Jai Singh *et al.,* 2002). However, there are large variations in input practices and output levels among farms in different regions within the country. Therefore, an analysis at the farm level is desirable to have a clear understanding of the existence of the gap between actual output and potential output of agricultural crops in different regions as well as within the same region of the country (Debnarayan and Sudpita, 2004; Mythili and Shanmugam, 2000, Battese *et al*.,2004). Farmers in the developing countries fail to exploit full potential of a technology (Kalirajan and Shand, 1989; Bravo-Ureta and Evenson, 1994; Shanmugam, 2003; Battese, 1992; Battese and Coelli, 1992). An estimate on the extent of technical inefficiency can also help to decide whether to improve efficiency or to develop new technology to raise agricultural production (Reddy and Sen, 2004; Debdas and Arabinda Das, 2006).

Turmeric (*Curcuma longa*) is a golden crop native to India which fetches foreign currency in terms of exports. It is one of the oldest spices and had been used in India since ages. The world production of turmeric stands at around 8, 00,000 tonnes in which India holds a share of 75-80 percent approximately. India also holds the top position in the list of world's leading exporters. To sustain this level, variations input practices and output levels among farms in different regions within the country should be minimized. As no attempt has been made so for to measure the efficiency of the crop like turmeric using Cobb-Douglas Stochastic Frontier Models, the present study has been formulated to measure technical efficiency of turmeric production in northwestern region of Tamil Nadu.

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The study is presented in five sections. Section I describes the data base and variables used. Section II discusses the frontier models used to measure technical efficiency score of turmeric farms considered for the present study. An attempt has been made to measure technical efficiency in section III using the two chosen models. Section IV dealt with the correlation and Chi-Square analysis of technical efficiency measurements of two selected models and compared the technical efficiency scores. The final section summarizes the results and brings out their implications.

I. DATA AND VARIABLES

The present study is based on the data pertaining to 180 households from 18 villages of Coimbatore and Erode districts, Tamil Nadu, India. For the selection of Turmeric growing households, two stage sampling procedure was followed. Among the total 38 blocks of Coimbatore and Erode districts six blocks viz., *Thondamuthur*, *Avinashi*, *Annur*, *Andhiyur*, *Bhavani and Kodumudi* were selected based on the irrigation facilities, soil texture and farmers' holdings. Among the 180 farmers chosen for the study, 143 farmers have more than 11 years of farming experience and 37 farmers have less than 10 years of farming experience.

Summary statistics of the variables gathered from 180 farmers observed from North Western region of Tamil Nadu state are reported in Table 1. The average turmeric production was 2423 kg, which ranged from 1800 kg to 3000 kg. Human labour was high with mean value of Rs. 7252 followed by seed (Rs. 4514), fertilizer (Rs.3530), manure (Rs.3494), post harvest expenditure (Rs.2488), machinery (Rs. 957) and pesticide (Rs. 430).

Table-1. Summary statistics of survey variables

Variable	Sample mean	Standard Deviation	Minimum	Maximum
Turmeric output (Kg.)	2423.33	196.29	1800.00	3000.00
Seed (Rhizome) (Rs.)	4514.44	265.10	3850.00	4950.00
Human Labour (Rs.)	7252.58	676.79	5240.00	10400.00
Machine (Rs.)	957.78	258.93	500.00	1750.00
Manure (organic) (Rs.)	3494.44	878.02	2000.00	6000.00
Fertilizer (inorganic) (Rs.)	3530.00	1629.55	1300.00	7655.00
Pesticide (Rs.)	430.37	106.78	110.00	710.00
Post harvest (Rs.)	2488.56	301.50	1645.00	4050.00

II. FRONTIER MODELS

The Stochastic Frontier Production function (SFPF) was proposed by Aigner *et al.*, (1977). This function differs from the average production function in the sense that it has two components, one to account for technical inefficiency and the other to permit random events that affect production (Forsund *et al.*, 1980; Seung *et al*., 2007; Mon-Chi Lio and Jin-Li Hu, 2009; Andrew Barnes, 2008; Kumbhakar *et al*., 2008; Schmidt and Lovell, 1980; Bauer, 1990 and Battese, 1992) provided excellent surveys of the literature on frontier analysis. An appropriate formulation of a stochastic frontier model in terms of a general production function for the i-th production unit is

$y_i = f(x_i, \beta)\exp(v_i - u_i)$ where v_i is the two sided noise component, u_i is the non-negative technical inefficiency component of the error term. The noise component v_i is assumed to be identically and independently distributed (*i.i.d.*) and symmetric, distributed independently of u_i.

Two combinations of assumptions on distributions over the error terms have been considered in the present study. They are,

(i) $v_i \sim i.i.d.\ N(0,\sigma_v^2)$ and $u_i \sim i.i.d.\ N^+ (0,\sigma_u^2)$, that is non-negative half-normal.
(ii) $v_i \sim i..i.d.\ N(0,\sigma_v^2)$ and $u_i \sim i.i.d.$ exponential.

In the present paper, two stochastic frontier models viz., Cobb-Douglas normal half-normal stochastic frontier model (CDNHNSFM) and Cobb-Douglas normal exponential stochastic frontier model (CDNESFM) have been used to measure technical efficiency. The advantage of using the stochastic frontier model is the introduction of a disturbance term representing noise, measurement error and exogenous shock beyond the control of farms in addition to the efficiency component. Ordinary Least Square (OLS) estimate procedure and Maximum Likelihood Estimation (MLE) procedure have been employed to obtain parameter estimates.

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Considering seven inputs *viz*., seed (Sed), human labour (Hum), machinery (Mac), manure (Man), fertiliser (Fer), pesticide (Pes) and post harvest expenditure (Pht), the Cobb-Douglas production function can be specified as

$$\ln\ y = \beta_0 + \beta_1 \ln Mac + \beta_2 \ln Man + \beta_3 \ln Sed + \beta_4 \ln Hum + \beta_5 \ln Fer + \beta_6 \ln Pes + \beta_7 \ln Pht + v - u.$$

Normal Half-Normal Stochastic Frontier Model (NHNSFM)

The parameters of v and u can be estimated for NHNSFM by maximising the following log-likelihood function

$$\ln L[\beta, \sigma^2, \lambda] = -\frac{N}{2}\ln 2\pi - \frac{N}{2}\ln\sigma^2 - \frac{1}{2}\sum_{i=1}^{N}\left(\frac{y_i - x_i^{'}\beta}{\sigma}\right)^2 + \sum_{i=1}^{N}\left\{\ln\Phi\left(\frac{-(y_i - x_i^{'}\beta)\lambda}{\sigma}\right)\right\}$$

where Φ is the standard normal cdf.

The technical efficiency of sample turmeric farms using NHNSFM is obtained from the formula (Jondrow et al., 1982)

$$E[u_i / \varepsilon_i] = \sigma_* \left[\frac{\phi\left(\frac{\varepsilon_i\lambda}{\sigma}\right)}{1-\Phi\left(\frac{\varepsilon_i\lambda}{\sigma}\right)} - \frac{\varepsilon_i\lambda}{\sigma}\right]$$

where $\sigma_* = \frac{\sigma_u \sigma_v}{\sigma}$.

Normal Exponential Stochastic Frontier Model (NESFM)

The parameters of v and u can be estimated for NESFM by maximising the following log-likelihood function

$$\ln L = -\frac{N}{2}\ln\sigma_u^2 + \sum_{i=1}^{N}\left\{\ln\left(1-\Phi\left(\frac{\varepsilon_i}{\sigma_v} + \frac{1}{\lambda}\right)\right)\right\} + \frac{N}{2\lambda^2} + \sum_{i=1}^{N}\frac{\varepsilon_i}{\sigma_v\lambda}$$

where Φ is the standard normal cdf.

Once the parameters are estimated the technical efficiency of sample turmeric farms using NESFM is obtained using the formula

$$E[u_i / \varepsilon_i] = \sigma_v \left[\frac{\phi\left(\frac{\varepsilon}{\sigma_v} + \frac{1}{\lambda}\right)}{1-\Phi\left(\frac{\varepsilon}{\sigma_v} + \frac{1}{\lambda}\right)} - \left(\frac{\varepsilon}{\sigma_v} + \frac{1}{\lambda}\right)\right]$$

III. MEASUREMENT OF TECHNICAL EFFICIENCY

The present study is aimed at collecting the whole variety of information about cultivation activities of turmeric in the sample households and the technical efficiency has been measured. Measuring technical efficiency of farms by estimating frontier models is the latest econometric method developed (Bauer, 1990). The primary data collected on turmeric production from north western region of Tamil Nadu were analysed with reference to each of the specific objectives of the study. Based on the models discussed in the methodology, Ordinary Least Square estimates and MLE techniques were employed to estimate the parameters of the Cobb-Douglas production function using the software package LIMDEP 7.0.

Cobb-Douglas normal half normal stochastic frontier model (CDNHNSFM)

Estimation of Frontier Production Function

The Cobb-Douglas production function model considered for the study involved a total of seven independent variables. Ordinary least squares (OLS) estimates of the parameters of stochastic frontier model, which showed the average performance of the 180 sample farms, are presented in Table 2.

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With the R^2 value of 0.59, the inputs used in the model were able to explain 59% of the variation in the turmeric production using Cobb-Douglas stochastic frontier models. In OLS estimates the coefficient values of the inputs human labour, manure and fertilizer were of positive value and so were allocated efficiently. In fact, the input manure was of one per cent significant level together with the positive coefficient, thus played a major role in turmeric production. The inputs seed and post harvest expenditure were of five per cent and one per cent

Table-2. Ordinary Least Square Estimates of the Cobb-Douglas Stochastic Frontier Model

Variables	Parameters	Coefficients
Constant	β_0	7.873**
ln_{Sed}	β_1	-0.187*
ln_{Hum}	β_2	0.045
ln_{Mac}	β_3	-0.002
ln_{Man}	β_4	0.272**
ln_{Fer}	β_5	0.013
ln_{Pes}	β_6	-0.026
ln_{Pht}	β_7	-0.135**

* Significant at 5% level $R^2 = 0.596$
** Significant at 1% level N = 180

significant levels respectively and both had negative coefficient value denoting inefficient allocation of these resources. Therefore, for better output of turmeric production seed and post harvest expenditure should have an efficient allocation.The maximum likelihood estimates of the stochastic frontier models is presented in Table 3.

Table-3. Maximum Likelihood Estimates of the Cobb-Douglas Stochastic Frontier Models

Variables	Parameters	Coefficients	
		CDNHNSFM	CDNESFM
Constant	β_0	7.736**	7.725**
ln_{Sed}	β_1	-0.140	-0.140
ln_{Hum}	β_2	0.033	0.043
ln_{Mac}	β_3	0.010	0.011
ln_{Man}	β_4	0.244**	0.232**
ln_{Fer}	β_5	0.015	0.013
ln_{Pes}	β_6	-0.021	-0.022
ln_{Pht}	β_7	-0.134**	-0.131**
$\lambda = \frac{\sigma_u}{\sigma_v}$		2.490**	1.2282
$\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$		0.08136**	0.0562
Log- likelihood		272.964	272.7200
Estimated variances of the underlying variables			
V		0.00092	0.00126
U		0.00570	0.00190
E		0.00662	0.00316
γ = Var(u)/Var (ε)		0.86103	0.60127

* Significant at 5% level
** Significant at 1 % level

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In MLE estimates, both manure and post harvest expenditure (pht) showed one per cent significant level. Manure was allocated efficiently whereas the post harvest expenditure was more than the required allocation. So it should be minimized for better output. By the specification of the likelihood function, the difference between the production function estimated by the OLS and MLE can be statistically shown by the one per cent significant level of λ.

The presence of technical inefficiency was shown by the significant level of the parameter λ. From Table 3, the estimates of the error variances σ_u^2 and σ_v^2 were 0.00570 and 0.00092 respectively. Therefore, it was clearly seen that the variance of one- sided error, σ_u^2 was larger than the variance of random error, σ_v^2. Thus the value of λ= 2.49 of more than one showed the dominant share of the estimated variance of the one-sided error term,u, over the estimated variance of the whole error term. Thus, a greater part of the residual variation in output was associated with the variation in technical inefficiency rather than with measurement error which is associated with uncontrollable factors related to the production process.

Both the variables λ and σ enter the output of almost all farms positively and significantly. The estimate of γ, viz., 0.86 using CDNHNSFM and 0.60 using CDNESFM indicated that the difference between observed and frontier output were primarily due to the factors which were 86 per cent and 60 per cent respectively under the control of farms rather than with 'measurement error' which is associated with uncontrollable factors related to the production process.

Estimation of Technical Efficiency

Farm specific TES were estimated for both models using the software package Frontier 4.0 and are presented in Table 4 and Table 5. The frequency distribution of farm-specific technical efficiency scores using CDNHNSFM and CDNESFM are depicted in Table 6 which indicated less variation in the level of technical efficiency across sample farms. The model CDNESFM concluded that the highest number of farms (134) were found in the most efficient class 95-100 percent followed by 90- 95 per cent class (36 farms) and 85-90 per cent class (5 farms).

Surprisingly both models predicted 2.7 per cent of farms in an efficiency level between 80-85 per cent. No farms operated in the efficiency score below 80 per cent using Cobb-Douglas normal exponential stochastic frontier model.

However, CDNESFM indicated that technical efficiency score of sample farms ranged between 82.45 per cent to 99.02 per cent with an average of 95.79 per cent. The analysis indicated that there was a scope to increase physical production of turmeric by 95.79 per cent with the judicious use of existing resources and technology. Surprisingly, none of the farms in the sample data scored an efficiency score above 95 per cent using the non-parametric model Data Envelopment Analysis (Mary Louis and John Joel, 2010).

The minimum estimated efficiency using CDNHNSFM was 81.89 per cent and that of the maximum was 98.97 per cent. The mean level of technical efficiency was 94.24 per cent implying that sample farmers realized only 94.24 per cent of their technical abilities.

Table-4. Farm Specific Technical Efficiency of Cobb-Douglas Normal Half-Normal Stochastic Frontier Model

Farms	Values	Farms	Values	Farms	Values	Farms	Values
F1	0.971	F46	0.975	F91	0.964	F136	0.952
F2	0.837	F47	0.949	F92	0.969	F137	0.951
F3	0.924	F48	0.912	F93	0.968	F138	0.983
F4	0.973	F49	0.921	F94	0.958	F139	0.882
F5	0.979	F50	0.974	F95	0.942	F140	0.964
F6	0.946	F51	0.973	F96	0.965	F141	0.967
F7	0.952	F52	0.979	F97	0.972	F142	0.921
F8	0.973	F53	0.988	F98	0.971	F143	0.958
F9	0.990	F54	0.886	F99	0.949	F144	0.915
F10	0.969	F55	0.985	F100	0.950	F145	0.977
F11	0.926	F56	0.965	F101	0.978	F146	0.945
F12	0.899	F57	0.965	F102	0.980	F147	0.919
F13	0.872	F58	0.980	F103	0.983	F148	0.935
F14	0.904	F59	0.883	F104	0.894	F149	0.945
F15	0.862	F60	0.971	F105	0.900	F150	0.977
F16	0.900	F61	0.973	F106	0.981	F151	0.947
F17	0.981	F62	0.901	F107	0.981	F152	0.952
F18	0.860	F63	0.971	F108	0.983	F153	0.948
F19	0.911	F64	0.886	F109	0.982	F154	0.963

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F20	0.926	F65	0.970	F110	0.983	F155	0.906
F21	0.908	F66	0.953	F111	0.962	F156	0.951
F22	0.919	F67	0.931	F112	0.956	F157	0.936
F23	0.887	F68	0.879	F113	0.971	F158	0.949
F24	0.936	F69	0.946	F114	0.932	F159	0.938
F25	0.822	F70	0.893	F115	0.977	F160	0.934
F26	0.975	F71	0.904	F116	0.966	F161	0.980
F27	0.953	F72	0.984	F117	0.956	F162	0.963
F28	0.833	F73	0.925	F118	0.954	F163	0.951
F29	0.914	F74	0.936	F119	0.923	F164	0.963
F30	0.819	F75	0.967	F120	0.930	F165	0.966
F31	0.837	F76	0.943	F121	0.896	F166	0.956
F32	0.956	F77	0.986	F122	0.966	F167	0.982
F33	0.973	F78	0.950	F123	0.966	F168	0.925
F34	0.983	F79	0.967	F124	0.935	F169	0.946
F35	0.955	F80	0.945	F125	0.949	F170	0.929
F36	0.965	F81	0.947	F126	0.933	F171	0.887
F37	0.965	F82	0.955	F127	0.925	F172	0.957
F38	0.980	F83	0.971	F128	0.932	F173	0.942
F39	0.883	F84	0.966	F129	0.900	F174	0.892
F40	0.950	F85	0.876	F130	0.917	F175	0.928
F41	0.947	F86	0.868	F131	0.967	F176	0.925
F42	0.960	F87	0.964	F132	0.982	F177	0.926
F43	0.981	F88	0.967	F133	0.956	F178	0.954
F44	0.914	F89	0.925	F134	0.959	F179	0.929
F45	0.969	F90	0.966	F135	0.950	F180	0.940

Maximum TE = 0.9898 Minimum TE = 0.8189 Mean TE = 0.9424

Table-5. Farm Specific Technical Efficiency of Cobb-Douglas Normal Exponential Stochastic Frontier Model

Farms	Values	Farms	Values	Farms	Values	Farms	Values
F1	0.979	F46	0.982	F91	0.975	F136	0.969
F2	0.847	F47	0.967	F92	0.979	F137	0.969
F3	0.946	F48	0.937	F93	0.978	F138	0.987
F4	0.980	F49	0.947	F94	0.972	F139	0.904
F5	0.984	F50	0.981	F95	0.963	F140	0.977
F6	0.964	F51	0.981	F96	0.976	F141	0.978
F7	0.968	F52	0.984	F97	0.980	F142	0.947
F8	0.980	F53	0.989	F98	0.979	F143	0.973
F9	0.990	F54	0.909	F99	0.968	F144	0.942
F10	0.978	F55	0.987	F100	0.968	F145	0.983
F11	0.950	F56	0.977	F101	0.984	F146	0.965
F12	0.923	F57	0.977	F102	0.985	F147	0.947
F13	0.892	F58	0.985	F103	0.986	F148	0.957
F14	0.928	F59	0.904	F104	0.912	F149	0.965
F15	0.876	F60	0.980	F105	0.920	F150	0.983
F16	0.920	F61	0.981	F106	0.985	F151	0.966
F17	0.985	F62	0.928	F107	0.985	F152	0.970
F18	0.880	F63	0.979	F108	0.986	F153	0.967
F19	0.936	F64	0.910	F109	0.985	F154	0.975
F20	0.947	F65	0.979	F110	0.986	F155	0.933
F21	0.931	F66	0.970	F111	0.974	F156	0.969
F22	0.939	F67	0.954	F112	0.971	F157	0.957
F23	0.910	F68	0.901	F113	0.980	F158	0.968
F24	0.955	F69	0.966	F114	0.956	F159	0.961
F25	0.829	F70	0.920	F115	0.983	F160	0.958
F26	0.981	F71	0.928	F116	0.977	F161	0.985
F27	0.967	F72	0.987	F117	0.972	F162	0.976
F28	0.842	F73	0.951	F118	0.971	F163	0.969
F29	0.935	F74	0.958	F119	0.950	F164	0.976
F30	0.825	F75	0.977	F120	0.955	F165	0.977
F31	0.846	F76	0.963	F121	0.923	F166	0.973
F32	0.970	F77	0.988	F122	0.977	F167	0.986
F33	0.980	F78	0.967	F123	0.977	F168	0.951
F34	0.986	F79	0.977	F124	0.958	F169	0.967

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F35	0.970	F80	0.965	F125	0.967	F170	0.955
F36	0.977	F81	0.966	F126	0.958	F171	0.913
F37	0.977	F82	0.971	F127	0.951	F172	0.972
F38	0.985	F83	0.980	F128	0.956	F173	0.965
F39	0.904	F84	0.977	F129	0.926	F174	0.920
F40	0.969	F85	0.897	F130	0.944	F175	0.954
F41	0.966	F86	0.887	F131	0.977	F176	0.951
F42	0.974	F87	0.976	F132	0.986	F177	0.952
F43	0.985	F88	0.978	F133	0.973	F178	0.972
F44	0.939	F89	0.950	F134	0.975	F179	0.955
F45	0.978	F90	0.977	F135	0.968	F180	0.963

Maximum TE = 0.9903 Minimum TE = 0.8246 Mean TE = 0.9579

Table-6. Frequency distribution of farm specific technical efficiency estimates using Cobb- Douglas Stochastic rontier Models

Efficiency Scores (per cent)	No. of farms		Percentage	
	CDNHNSFM	CDNESFM	CDNHNSFM	CDNESFM
Below 80	-	-	-	-
80 – 85	5	5	2.78	2.78
85 – 90	20	5	11.11	2.78
90 – 95	61	36	33.89	20.00
95 – 100	94	134	52.22	74.44

The frequency distribution of the farm specific technical efficiency score using CDNHNSFM showed less variation in the level of technical efficiency across farms. About 48 per cent farms operate below the technical efficiency score of 0.95 indicating scope to increase turmeric production by 95 per cent. However, higher per cent of sample farmers were in the efficiency level of above 0.95 using CDNHNSFM.

Table-7. Increasing Technical Efficiency Potential of Turmeric Production using Stochastic Frontier Models

Model	Mean TE	Maximum TE	Mean potential to increase TE
CDNHNSFM	94.24	98.98	4.79
CDNESFM	95.79	99.03	3.30

The percentage of farms having technical efficiency score above 95 per cent was about 74 per cent using CDNESFM and was 52 per cent using CNHNSFM. Thus, CDNESFM performed well for the sample turmeric data. Moreover, the higher mean technical efficiency was given by CDNEFM (95.79) than CDNHNSFM (94.24). In this discussion also CDNEFM performed as a better model for the sample turmeric data. However, the average potential of increasing turmeric production through technical efficiency improvement across various turmeric farming systems revealed that there is a higher mean potential to increase technical efficiency of sample turmeric farms given by CDNHNSFM (4.79) than CDNEFM (3.30) as shown in Table 7. On comparing the correlation coefficients of the two models under study, it was found that correlation coefficients between observed efficiency and expected efficiency was greater, viz., 0.786, for CDNESFM than CDNHNSFM (0.755). Moreover, it was found from Table 8. that Chi-square value was lesser for CDNESFM (1.1712) than CDNHNSFM (1.5306). Hence, the difference between the observed efficiency and the technical efficiency was lesser for CDNESFM than CDNHNSFM. From the above observations, it is concluded, even though CDHNSFM showed higher mean technical efficiency score, CDNESFM, which recorded higher correlation coefficient and least Chi-square value is considered as a better model to estimate the technical efficiency for the sample under study.

Table-8. Statistical Association of the Models Under Study

Model	Correlation Coefficient	Chi-square value
CDNHNSFM	0.755	1.5306
CDNESFM	0.786	1.1712

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Empirically estimated Cobb-Douglas normal half- normal production function:

The estimated Cobb-Douglas normal half- normal production function is given as below:

$$\text{PROD} = (7.736)\,Sed^{-0.140}Hum^{0.033}Mac^{0.010}Man^{0.244}Fer^{0.015}Pes^{-0.021}Pht^{-0.134}$$

Empirically estimated Cobb-Douglas normal exponential production function:

The estimated Cobb-Douglas normal exponential production function is given as follows:

$$\text{PROD} = (7.725)\,Sed^{-0.140}Hum^{0.043}Mac^{0.011}Man^{0.232}Fer^{0.013}Pes^{-0.022}Pht^{-0.131}$$

CONCLUSION

The present study suggested that technical efficiency is high in turmeric production yet no farm has reported 100 percent technical efficiency score. Therefore, there is scope for improving technical efficiency and production consequently. Moreover, in no farm the technical efficiency index was less than 58 per cent using any of the models under study. Thus, there was on an average about 18 to 20 per cent technical inefficiency in turmeric production. By removing the inefficiencies, the yield gap could be bridged and production could be improved even in the present status of available technology. The most efficient farms identified within each of the turmeric farming systems can serve as model farms for improving efficiency of turmeric production in the study area.

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Source of support: Nil, Conflict of interest: None Declared

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