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Technical efficiency of fenugreek production in the semi arid region of Rajasthan, India: A stochastic frontier approach

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This paper examines the technical efficiency of fenugreek production in Rajasthan and also identifies key variables affecting technical efficiency using primary data collected from 120 randomly selected fenugreek cultivating farmers by applying a stochastic frontier analysis (SFA). The results obtained in an empirical model indicated that mean technical efficiency of all categories of farmers was 70%. This suggests that still there is scope for increasing the output by 30% with the same level of input uses. Small farmers were found to be more efficient in terms of judicious and timely application of irrigation and fertilizers as well as reaping more yields. Around 50% of the farmers attained a technical efficiency more than 80% because of employing the uniform cultivation practices. The results of the technical inefficiency effects model suggest that age, education and contact with extension agencies positively influenced technical efficiency of fenugreek cultivation.

Key words: Cobb-Douglas production function, fenugreek cultivation, semi-arid region, stochastic frontier analysis (SFA), technical efficiency.

INTRODUCTION

Seed spices constitute an important group of agricultural commodities and play a significant role in our national economy. Historically, India has always been recognized as a land of spices. Major seed spices are coriander, cumin, fennel and fenugreek (NRCSS, 2007). Among these spices, fenugreek *(Trigonella foenum graecum)* commonly known as *methi,* in Hindi has been used as a culinary spice, a flavoring agent and as a medicinal plant for centuries (Mathur and Choudhry, 2009). It is cultivated abundantly in India and the country contributes around 70 to 80% of the worlds' export share of fenugreek (Pruthi, 2001; Agarwal et al., 2001). Presently, Rajasthan, Gujarat, Uttarakhand and Uttar Pradesh are the leading states for fenugreek production. Rajasthan accounts for around 87% of the total area and 75% of the total production of fenugreek in the country (Indiastat, 2012). In spite of significant progress achieved during the last two decades in seed spices production in India, the average productivity of these crops is still low as compared to the best yields at the national and global level, indicating that there is a scope to enhance yields of different seed spice crops and their quality. More specifically, in case of fenugreek, the leading state in productivity is Uttarakhand (6525 kg ha^{-1}), followed by

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Gujarat (2654 kg ha^{-1}). However, in terms of productivity, even after having the highest area under fenugreek in the country, Rajasthan occupies the fourth rank with a productivity of 1061 kg ha^{-1} only which is below the national average (1239 kg ha^{-1}). This is basically because of a significant gap between actual and potential yield of crop which is still grown by the traditional system of cultivation (Singh and Singh, 2013). There is, therefore, a need for minimizing the yield gap by enhancing the technical efficiency of the producers. The motivation for undertaking the study stemmed from the hypothesis that there exists an immense scope for improving the productivity of fenugreek production by technological advancement or by enhancing the technical efficiency that is, getting maximum yield from given level of inputs. In this regard, it is necessary to quantify current levels of technical efficiency so as to estimate losses in production that could be attributed to inefficiencies in production process due to differences in socio-economic characteristics and management practices. There is a plethora of empirical work on the efficiency of seed spices production in India. This paper deals with estimation of technical efficiency of fenugreek production and also identifies the key variables determining inefficiency. This study will contribute to the technical efficiency literature, especially for spices in general and seed spices in particular.

MATERIALS AND METHODS

Data and sampling framework

The Sikar district of Rajasthan State, which is located in the semi-arid part of the state was selected purposively for the study on the account of being one of the leading districts in fenugreek production in the state. Out of seven *tehsils*, two viz. Sikar and Sri Madhopur were selected randomly and from each of them, two villages chosen for the study. Finally, from all the four villages, 40 farmers from each category that is, small, medium and large were selected. Thus, the final data set encompasses a total of 120 observations. The data was collected by personal interview of the selected respondents using a pre-tested schedule designed particularly for this study.

Analytical tool

The two most commonly used techniques for estimating a production frontier and predicting maximum possible farm output are data envelopment analysis (DEA) and stochastic frontier analysis (SFA) (Coelli, 1996a, 1996b; Kontodimopoulos et al., 2010). Stochastic production frontiers were first developed by Aigner et al. (1977) and Meeusen and van den (1977). The specification allows for a non-negative random component in the error term to generate a measure of technical inefficiency, or the ratio of actual to expected maximum output, given inputs and the existing technology. DEA is a non-parametric approach that involves the use of linear programming to construct a frontier. It does not require assumptions concerning the form of the production function (Coelli, 1996b). The best practice production function is created empirically from observed input and output. It does not identify the difference between technical inefficiency and random error (Admassie and Matambalya, 2002; Vu, 2003; Coelli et al., 2005). On the other hand SFA is a parametric approach, where the form of the production function is assumed to be known or is estimated statistically. It also allows other parameters of the production technology to be explored (Coelli, 1996a; Greene, 2003; Coelli et al., 2005). The advantages of this approach are that hypotheses can be tested with statistical rigour, and that relationships between input and output follow known functional forms. SFA enables the simultaneous estimation of technical efficiency and a technical inefficiency effects model (Admassie and Matambalya, 2002; Coelli et al., 2005). The technical efficiency of a farm is a comparative measure of how well it actually processes inputs to achieve its outputs, as compared to its maximum potential for doing so, as represented by its production possibility frontier. Thus, technical efficiency of the farm is its ability to transform multiple resources into output. A farm is said to be technically inefficient if it operates below the frontier. The coefficients of the production frontier and technical inefficiency effects model can be measured using the maximum likelihood method under the assumption of a normal distribution for U_i (Coelli et al., 2005; Tran et al., 2008). The appropriateness of the stochastic frontier approach can be tested by calculating the value of the parameter γ which contains a value between 0 and 1 and depends on two variance parameters of the stochastic frontier function. This is defined as follows (Battese and Corra, 1977; Coelli et al., 2005):

$$\gamma = \frac{\sigma_u^2}{\sigma^2}$$

Where, $\sigma^2 = \sigma_v^2 + \sigma_u^2$, where σ_v^2 and σ_u^2 are variances of the noise and inefficiency effects. If the value γ is close to zero deviations from the frontier are attributed to noise, whereas a value close to unity indicates that deviations are ascribed to technical inefficiency (Coelli et al., 2005; Tran et al., 2008).

Model

A Cob-Douglas production function using the cross-sectional data may be expressed as follows (Coelli 1996a):

$$y_i = \beta_0 + \beta_1 ln\, x_1 + \beta_2 ln\, x_2 + \beta_3 ln\, x_3 + \beta_4 ln\, x_4 + \beta_5 ln\, x_{i5} + (v_i - u_i); i = 1,2, \dots \dots \dots N$$

$y =$ Yield (kg ha^{-1}), $x_1 =$ Seed rate (kg ha^{-1}), $x_2 =$ Machinery use (Man-days ha^{-1}), $x_3 =$ Human labour (hour ha^{-1}), $x_4 =$ Urea (kg ha^{-1}), $x_5 =$ DAP (kg ha^{-1}a).

Technical inefficiency model

$$u_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 D_1 + \delta_3 Z_4 + \delta_5 D_2$$

Z_1=Age of the household head (years), Z_2= Education level of the household head (average number of schooling years), Z_3= Family size (number of family member who are more 14 and less than 60 years), Z_4=Farm size (ha) , D_1= Dummy variable (1, if contact with extension worker, otherwise zero), D_2= Dummy variable (1, if resides at farm, otherwise zero).

The parameters of the stochastic frontier production function model were estimated by the maximum likelihood estimation (MLE) method using FRONTIER Version 4.1 (Coelli, 1996a).

Hypothesis tests

The estimation of a stochastic frontier production function can be used to test the validation of three hypotheses as follows: (1)

Table 1. Summary statistics of variables of stochastic frontier product (per ha).

Variable	Units	Small		Medium		Large		Overall	
		mean	SD	mean	SD	mean	SD	mean	SD
Output	kg	1888	7.75	1560	7.87	1272	6.67	1576	7.81
Human labour	Man-days	70.52	11.04	67.54	12.36	59.70	10.12	65.97	12.03
Machine use	hour	23.81	19.29	21.33	3.00	20.95	3.42	22.04	11.46
Irrigation	hour	69.74	7.92	48.74	22.19	43.05	8.69	53.84	18.6
Seed	kg	26.04	10.05	28.84	9.10	22.66	4.01	25.87	8.5
Urea	kg	38.84	11.35	26.78	9.35	25.71	9.27	30.44	10.66
DAP	kg	29.98	7.67	27.99	8.7	26.02	8.41	28.00	8.36

Source: field survey.

adequacy of the Cobb-Douglas production functional form; (2) absence of technical inefficiency effects; and (3) insignificance of joint inefficiency variables. Formal hypotheses tests associated with the stochastic production function and technical inefficiency effects models are presented in Tables 2, 3 and 4, respectively. Three hypothesis tests are conducted by using the generalised likelihood-ratio test (LR test), which can be defined as (Coelli et al., 2005; Tran et al., 2008; Amornkitvikai and Harvie, 2011):

$$\lambda = -2\{\mathrm{Log}\ [\mathrm{L}(H_0)] - Log[L(H_1)]$$

Where, $\mathrm{L}(H_0)$ and $L(H_1)$ are the values of a log-likelihood function for the frontier model under the null hypothesis H_0 and the alternative hypothesis H_1 . The LR test statistic contains an asymptotic chi-square (χ^2) distribution with parameters equal to the number of restricted parameters imposed under the null hypothesis(H_0), except hypotheses (2) and (3) which contain a mixture of a chi-square (χ^2) distribution (Kodde and Palm, 1986). Hypotheses (2) and (3) involve the restriction that λ is equal to zero which defines a value on the boundary of the parameter space (Coelli, 1996a). The paper estimates technical efficiency of fenugreek farming in the arid zone of Rajasthan, with the following hypotheses: The technical efficiency of fenugreek cultivating farms is invariant to farm-size; and technical inefficiency is dominated by random factors beyond the control of farmers.

RESULTS AND DISCUSSION

The mean level of output and input usages are presented in Table 1. The mean use of human labour, machinery and irrigation use were 66 man-days, 22 and 54 h per ha, respectively. Similarly, average amount of seed, urea and DAP applied were 26, 30 and 28 kg per ha, respectively. Highest level of output (1888 kg) was obtained at small farms and declines with increasing in farm sizes with average output of 1576 kg ha^{-1}. Analysis of socio-economic characteristics of the respondents revealed that the average farm size of small, medium and large farmer was to the extent of 1.17, 2.93 and 6.06 ha, respectively with overall size of 3.36 ha in the study area. The education level was observed to be 6.3 (Table 2).

Overall, around 60% of the farmers were in regular contact with extension personnel or agency. Among different categories, around 72% of the large farmers, highest among the three, had contact with an extension personnel or agency. About 37% of the farmers had their residence at the farm itself (*Dhani** - a local word which means dwelling at the farm).

Testing hypotheses

The first null hypothesis explores $H_0: \gamma = 0$, which specifies that the technical inefficiency effects are not present in the model that is, fenugreek producing farms are perfectly efficient and have no room for efficiency improvement. The resulting likelihood ratio test of 54.84 leads to rejection of the null hypotheses in favour of the presence of inefficiency effects in the model at 5% level of significance (Table 3). Thus, the traditional average response function is not an adequate representation of the data and inclusion of the technical inefficiency term is a significant addition to the model. The second null hypothesis is regarding the distribution assumption that the inefficiency component of the random error term follows. H_0: μ = 0, specifies that a simpler half-normal distribution is an adequate representation of the data, given the specifications of the generalized truncated-normal distribution. The test statistic of 6.19 leads to rejection of the null hypothesis at 1% level of significance and therefore truncated normal distribution is more appropriate for the fenugreek producing farmers. The third null hypothesis which was tested is; $H_0 : \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$ implying that the farm-level technical inefficiencies are not affected by the farm-oriented variables included in the inefficiency model. This hypothesis is also rejected, implying the variables present in the inefficiency model have collectively significant contribution in explaining technical inefficiency effects. However, it has expected sign that is, negative, but it was statistically insignificant. The high value of gamma (0.915) indicated the presence of inefficiency in the production of crop. This significance higher value of gamma indicates the appropriateness of applying SFA model. If the coefficient of gamma was not significant, an OLS function would have been sufficient, as the

Table 2. Socio-economic variables of the sample farmers.

Particulars	Units	Small	Medium	Large	Overall
Age	Number of years	46.5	48.5	48.7	47.9
Education	Average number of schooling years	5.6	5.6	7.6	6.3
Extension	% farm having contact to extension personnel/agency	53	56	72	60
Family size	Number of working persons in family	4.00	5.00	4.00	4.00
Farm size	ha	1.17	2.93	6.06	3.36
Residence	% farmers living at farm	46	30	34	37

Source: field survey.

Table 3. Different hypotheses, respective decisions and their implications.

Null hypothesis	Test statistic	Decision	Implication
$H_o : \gamma = 0$	54.84**	Rejected	Use stochastic frontier model instead of ordinary least square model
$H_o : \mu = 0$	6.19***	Rejected	Assume truncated normal distribution
$H_0 : \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$	251.90***	Rejected	Include joint inefficiency determining variables

component technical inefficiency is small (Battese and Coelli, 1995). About 92% of the difference between the observed and the frontier value productivity was due to the presence of inefficiency, mainly through the non-judicious use of resources, which was under the control of sample farmers.

Parameter estimates of stochastic production frontier

The maximum likelihood estimates of stochastic production frontier for Cobb-Douglas form under truncated-normal distribution of u_i have been presented in Table 4. The variables having positive and significant coefficients were irrigation, DAP and urea use. This implies that there is potential for increasing fenugreek production by raising the quantity of some inputs. Irrigation, particularly, is an important input which enhances the fertilizer use efficiency. More precisely, one per cent increase in the use of irrigation, urea and DAP will result into 0.14, 0.01 and 0.26% increase in the output.

Thus, it seems that irrigation-fertilizer interaction has a positive impact on the yield. The variable seed was observed to be with a negative coefficient (but statistically insignificant) which shows that seeds are being over-utilized. The summation of the coefficients is less than one which indicates that at present, in general, farmers were observed to be working at decreasing returns to scale which amounts to saying that use of some inputs exceeded scale efficient level of quantities for the existing technology.

Determinants of inefficiency

Age of the farmer exhibited a negative coefficient which is significant at 1% level (Table 4). This implies that with an increase in age the technical inefficiency declines. The results of this study support the findings of Bravo-Ureta and Pinheiro (1997); Abdulai and Eberlin (2001) and Mondal et al. (2012). It further reveals that experienced farmers are relatively more efficient or had a better understanding of resource uses with respect to amount and combination of inputs along with timing of their application. Education also was found to have a negative effect on the technical inefficiency which means schooling has a positive bearing on the technical efficiency, since education enhances the decision making capability and understating about the technical know-how (Kaura et al, 2010). The education not only helps in better crop management decisions but also facilitate in availing better agricultural related services (Tilak, 1993). Similarly, contact with an extension person/agency had a positive impact on the technical efficiency and farmers get to know about the suitable variety, pest and disease control measures and agronomic practices etc. Coefficient associated with the farm size had a positive sign which shows that large farms are technically inefficient than their smaller counterparts. This is mainly attributed to non-uniform and insufficient application of irrigation water given the same duration of electricity supply to farms. Therefore, large farmers with a single tube-well are forced to prioritize irrigation to wheat, which occupies a large area in cropping pattern of large farmers as compared to smaller farms. Therefore, timely availability

Table 4. Maximum likelihood estimates of stochastic frontier model.

Parameter	Coefficient	Standard error
Stochastic production frontier		
Intercept	1.203	0.349
Seed	-0.046	0.043
Human labour	0.051	0.063
Irrigation	0.137**	0.056
Machinery use	0.041	0.043
Urea	0.091*	0.055
DAP	0.261***	0.050
Inefficiency effects		
Intercept	1.197	0.346
Age	-0.202***	0.031
Education	-0.009*	0.005
Extension contact	-0.215***	0.020
Family size	0.199***	0.118
Farm size	0.007*	0.013
Residence status	-0.007	0.013
Variance parameter		
Sigma-squared	0.064**	0.013
Gamma	0.915***	0.022

***, ** and * indicate the level of significance at 1, 5 and 10%.

Table 5. Descriptive statistics of technical efficiency.

Particular	Small	Medium	Large	Overall
Mean	0.78	0.69	0.63	0.70
Standard deviation	0.28	0.30	0.26	0.28
Minimum	0.17	0.17	0.15	0.15
Maximum	0.98	0.98	0.99	0.99

The null hypothesis, $H_0 : \overline{X_s} = \overline{X_m} = \overline{X_l}$, which was rejected at 5% level of significance. This null hypothesis suggests that mean technical efficiency scores are same for all farm categories. $\overline{X_s}$, $\overline{X_m}$ and $\overline{X_l}$ stand for the mean technical efficiency scores for small, medium and large farmers, respectively.

of water also provides incentive, especially to smaller farms, to apply fertilizers for fenugreek production, which in turn results in higher yield/ higher technical efficiency. In case of variable 'residence at farm', it was expected that farmer dwelling in a *Dhani* would be more efficient as they can start their farm work early in the morning and also can do the same late in the evening, since the farmers residing in village have to travel to their farm every day.

Mean technical efficiency and frequency distribution of farmers

The mean technical efficiency score was estimated to be 78, 69 and 63% for the small, medium and large farmers, respectively (Table 5). The mean technical efficiency scores were also different from each other at five percent level of significance. The overall average technical efficiency score was found to be 70% in the study area. This shows that there still exists a scope for increasing the output by 30% with the same levels of input. The minimum and maximum technical efficiency score were 15 and 99%, respectively.

Table 6 presents the distribution of farmers in different groups of technical efficiency ranges. Overall, in the region, around 52% fall in the higher efficiency range which indicates that farmers are following uniform practices for fenugreek cultivation. Further, about 72.5, 50.0 and 32.5% of small, medium and large farmers, respectively

Table 6. Distribution of farmers in different ranges of technical efficiencies (% farmers).

Particular	Small	Medium	Large	Overall
0-20	5.0	12.5	10.0	9.2
20-40	17.5	12.5	17.5	15.8
40-60	2.5	10.0	20.0	10.8
60-80	2.5	15.0	20.0	12.5
>80	72.5	50.0	32.5	51.7
Total	100	100	100	100.0

The null hypothesis, H_0 **:** F(S)=F(M)=F(L), which was rejected at 5% level of significance. This null hypothesis suggests that frequency distribution of all the farm categories is same. F(S), F (M) and F (L) stand for the frequency distribution of farmers belonging small, medium and large farmers.

were observed to be in a more than 80% of technical efficiency range. The F-test showed that the distribution of farmers in defined ranges is significantly different among one another at five percent level of significance.

Conclusions

The average technical efficiency in fenugreek production was observed to be 70%. This implies that there is scope for increasing the output by 30% with the same level of input uses. Further, smaller farmers were observed to be more efficient than the larger famers. The higher technical efficiency is mainly attributable to irrigation which in turn enhances fertilizer use efficiency. In general, farmers were found to be working at decreasing returns to scale which implies that quantities of some inputs exceeded scale efficient level of input uses as for the existing technology. This provides scope for optimal use of some inputs that would lead towards minimizing the cost of production and hence enhance efficiency. Experienced, educated farmers and those in contact with extension worker/agency are more efficient. There is a need to speed up extension programmes for the better production and use of scarce inputs. Since irrigation has a positive impact on the production, use of micro-irrigation, since the state is facing ever depleting level of groundwater, will ensure better utilization of scarce groundwater resources as well as sustainable production of crop.

Conflict of Interest

The authors have not declared any conflict of interest.

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