AN ANALYSIS OF TECHNICAL EFFICIENCY OF GROWING BITTER GOURD IN PAKISTANI PUNJAB

Khuda Bakhsh, Bashir Ahmad, Sarfraz Hassan and Zulfiqar Ahmad Gill[1]
Department of Environmental and Resource Economics, and
[1]Department of Development Economics, University of Agriculture, Faisalabad

Yield of vegetables can be enhanced substantially by improving level of technical efficiency without making additional cost. Keeping this in view, technical efficiency of growing bitter gourd in the two districts of Punjab was estimated. Data were gathered by employing purposive sampling technique from Faisalabad and Rahim Yar Khan Districts of Punjab, Pakistan during 2003. Stochastic frontier production function was used to estimate technical efficiency and its determinants. Cobb Douglas type production function was adopted to determine technical efficiency among bitter gourd growers. Results indicated that irrigation, labour and location were contributing towards higher yield whereas fertilizer was negatively related with yield in the production function. Inefficiency effect model showed that age of bitter gourd growers was positively related with technical inefficiency while family size, fertilizer and plant protection measures were found decreasing technical inefficiency. Average technical efficiency was 60 percent indicating that there exist a great potential to increase bitter gourd yield, with available resources and technology.
Keywords: Cobb douglas; frontier; stochastic production function; bitter gourd; Punjab

INTRODUCTION

Vegetable production in Pakistan is very low despite having surplus labour and fertile land suitable for growing a variety of vegetables in the country. Vegetable production in the country could be enhanced in three possible ways such as by allocating more area, by developing and adopting new technologies and by utilizing the available resources more efficiently. To increase area under vegetable production is much more difficult in the short duration of time, since it requires reallocation of cultivated area from major crops to vegetables demanding a change in cropping pattern which is virtually impossible. The second way to increase vegetable production is to develop and adopt latest technologies. Development and adoption of new innovation is a long term process and it needs more funds to be allocated for research and development. The third option of using available resources more efficiently becomes viable in the current situation. This says that increased vegetable production lies in improvement of vegetable productivity i.e. yield per unit area. Therefore, the ample scope exists for improving productivity i.e. output per unit of area.

Bitter gourd like other vegetables is a labour intensive enterprise, thus creating employment opportunities for semi-skilled and un-skilled labour force in the rural areas. On the other hand, this vegetable production not only generates higher returns in short duration but also supplements food consumption. In spite of all these facts, area allocated to bitter gourd is low compared to other major crops such as wheat, cotton, sugarcane, rice, potato, etc. Similarly, little research and development focus is given to vegetables in general and to bitter gourd in particular. Therefore, it is need of the time to conduct research studies in vegetable sector providing insights into factors contributing towards higher yield of vegetables. This could help farming community to allocate financial and other resources to high value vegetables.

Bitter gourd production could be made sustainable by making production system efficient, assessing the potential for and sources of future improvements. This can be achieved through measuring technical efficiency at the farm level, identifying important factors influencing level of technical efficiency. Therefore, the study in hand has been designed to determine technical efficiency in bitter gourd production and to identify factors responsible for various levels of technical efficiency. It would provide information to bitter gourd growers for fully exploiting available resources and technology to maximize yield and it will be helpful to policymakers to evolve policies to improve vegetable supply in the country.

MATERIALS AND METHODS

Sampling and source of data

Data for bitter gourd collected during 2003 was used to determine technical efficiency and its determinants. A four stage sample design was used for collection of information from the field. During first stage, two districts namely Faisalabad and Rahim Yar Khan were selected on the basis of share in total area of Punjab. Tehsils having a large number of bitter gourd growers were selected with the consultation of Department of Agriculture, Punjab, Pakistan. Two tehsils of Rahim Yar Khan district and one tehsil of Faisalabad district were chosen. After selecting the second stage units, third stage units were chosen from the units selected at the second stage. A list of villages where bitter gourd production was commonly practised was obtained from Department of Agriculture. These villages were arranged in a descending order on the basis of bitter gourd growers. Seven villages were selected from two tehsils of Rahim Yar Khan district and three villages from that of Faisalabad district. The fourth stage sampling units were bitter gourd growers. A list of farmers growing bitter gourd was prepared and necessary information was obtained. This list of farm respondents served as frame for fourth stage sampling. Bitter gourd growers were selected using purposive sampling technique from each of the selected villages.

Data were gathered on various aspects of bitter gourd cultivation. Survey data contained information on socio-economic characteristics of the farmers, land tenure status, management practices, input-output quantities, etc. A total of 90 bitter gourd growers, 45 from each district were interviewed to collect detailed information relating to bitter gourd cultivation.

Analytical framework

Stochastic frontier production function method has been used in the present study due to the fact that random shocks are more prevalent in vegetable production in general and bitter gourd in particular. Stochastic frontier production function method incorporates random shocks and measurement error separately. Effects of random shocks and measurement errors are independently estimated while determining technical efficiency (Parikh and Shah, 1994; Parikh *et al.*, 1995; Battese and Hassan, 1999; Hassan, 2004).

Cobb Douglas type production function was used in this study despite its well known limitations due to its ease of computation and interpretation (Battese, 1992; Bravo-Ureta and Pinheiro, 1993; Battese and Hassan, 1999; Hassan, 2004).

The empirical Cobb Douglas type model is as under:

$$\ln \mathrm{Y}_i = \beta_0 + \sum_{i=1}^{7} \beta_i \ln \chi_i + \upsilon_i - \mu_i \qquad i = 1, 2, \ldots n \qquad (1)$$

where Y_i is yield (kg) per acre for the *i*-th farm. Out of seven independent variables, six inputs and one dummy variable for location are included in the production function. X_t is a vector of k inputs used in the bitter gourd production. The independent variables are defined as under:

χ_{1i} shows number of tractor hours used for land preparation. Tractor hour include all hours required for ploughing, planking, leveling and planting for preparing one acre of land for bitter gourd cultivation. Quantity of seed (kg) per acre is represented by χ_{2i}. χ_{3i} represents the cost incurred on plant protection measures (Rupees) including cost of pesticide, fungicide and weedicide. χ_{4i} represents number of hours required to irrigate one acre of land. Total number of labour hours used to perform various farming activities on the i-th farm is indicated by χ_{5i}. Labour input includes family labour, permanent hired labour and casual hired labour. χ_{6i} shows the NPK nutrients, (kg per acre). To incorporate geographical effects into the production function, dummy variable for location is included and it is shown by χ_{7i}. It is taken as one if the respondent belongs to Faisalabad district and otherwise as zero.

β_0, β_i are unknown parameters to be estimated. v_i is a random error accounting for measurement errors and other random factors outside the control of a farm enterprise and it is assumed that it is independent and identically distributed (i.i.d) normal variable with mean zero and constant variance, $\sigma^2{}_v$, independent of the μ_i's. The μ_i's show the technical inefficiency effects and they are associated with technical inefficiency of farm enterprise. u_i's are non-negative random variables, associated with technical inefficiency of production of the farmers, assumed to be independently distributed, such that the technical inefficiency effect for the i-th farmer growing bitter gourd is obtained by truncation (at zero) of the normal distribution with mean μ_i, and variance σ^2, such that

$$\mu_i = Z_i \delta + w_i \qquad (2)$$

where Z_{1i} represents the age of bitter gourd growers in years. Age of the respondents is taken into account as a proxy for experience. It is expected that the effect of age on technical efficiency could be positive or negative as described by Coelli (1996). Z_{2i} represents schooling years. Z_{3i} represents family size (in number) of the farmers growing bitter gourd. Z_{4i} is a dummy variable indicating the tenancy status of the growers (if the farmer is cultivating his own land, then it has the value of one, otherwise zero). Z_{5i} represents the total farm area operated by bitter gourd growers in acres. To determine the impact of extension services on technical efficiency, a dummy variable is introduced in the inefficiency effect model and it is represented by Z_{6i}. It is taken as 1 if bitter gourd growers claimed lack of extension services, otherwise zero. The impact of services provided by input dealers especially of those dealing in pesticide products is taken into account in the same fashion represented by Z_{7i}. Environmental contaminating variables such as plant protection measures and inorganic fertilizer are used to estimate the extent of effect of these variables on technical efficiency. Z_{8i} represents cost of plant protection measures (Rupees per acre) and cost of fertilizer (Rupees per acre) is shown by Z_{9i}. The δs are unknown parameters to be estimated. w_i is an error term independent and identically distributed. The mean values of variables included in the stochastic production frontier and inefficiency effect model are presented in Table 1.

Table 1. Descriptive statistics of variables included in the model.

Variable	Mean	Standard deviation
Land preparation (tractor hours/acre)	5.96	2.08
Seed (kg/acre)	2.76	0.96
PPM (Rs/acre)	1763.97	1395.31
Irrigation (Hours/acre)	31.87	10.20
Labour (Hours/acre)	462.69	211.24
NPK (kg/acre)	140.87	60.08
Age (years)	35.71	13.27
Schooling years	3.74	4.14
Family size (no.)	6.21	2.62
Owners (no.)	34	
Farm area (acre)	9.43	13.15
Lack of extension services	28	
Contact with input dealers	25	
Cost of fertilizer (Rs/acre)	2403	1274
Yield (kg/acre)	2858	1079

RESULTS AND DISCUSSION

The maximum likelihood estimates (MLE) of Cobb Douglas type production function and inefficiency effect model were estimated using computer software, FRONTIER 4.1, developed by Coelli (1996). Table 2 indicates the estimates of ordinary least squares (OLS) and MLE of Cobb Douglas type production function along with estimates of determinants of technical inefficiency effect model. OLS method was found inappropriate for the given data on the basis of generalized likelihood ratio test statistic.

Results show that out of seven independent variables, only two variables are statistically significant using asymptotic t-test in case of OLS estimates whereas in the case of MLE estimates, four estimates are significantly different from zero according to an asymptotic t-test. These variables include irrigation, labour, fertilizer and geographical location (district dummy). Since Cobb Douglas type production function is used, the estimates directly represent elasticities of independent variables. The highest elasticity is estimated for fertilizer, however, the sign is negative implying that a one percent increase in the use of fertilizer would reduce bitter gourd yield by 0.31 percent. This is due to the fact that most of the bitter gourd growers were making use of only nitrogenous fertilizer and the use of this type of fertilizer was above the required level. Shafiq and Rehman (2000) estimated the similar effect of fertilizer on cotton crop in Pakistan. Other important variable is dummy variable depicting the difference of location. The coefficient of this dummy variable is positive showing that bitter gourd growers of Faisalabad district were getting higher yield compared to those of Rahim Yar Khan district. Other important variable in term of elasticity is irrigation. The elasticity of this variable is 0.14 implying that a one percent increase in irrigation hours would enhance bitter gourd yield by 0.14 percent. This result is consistent with those of Battese, *et al.* (1993) and Ahmad, *et al.* (1999). Labour hours used in various farming practices also has substantial impact on bitter gourd yield. The elasticity of this variable shows that yield could be enhanced up to 0.13 percent by increasing labour hours by one percent. The reason for this increase in yield is due to better cultural practices in bitter gourd production. This elasticity is consistent with those of Battese, *et al.* (1993) and Hassan (2004).

Estimates of technical inefficiency effect model are determined using equation 1 and 2 with the help of FRONTIER 4.1. Nine variables were incorporated to ascertain determinants of technical inefficiency. Out of these variables, four variables are significantly different from zero according to an asymptotic t-test. Family size, cost of plant protection measures and cost of fertilizer variables have expected signs and statistically significant using asymptotic t-test. However, the age of the bitter gourd growers is positively related with level of technical inefficiency. This suggests that the older

Table 2. Maximum Likelihood Estimates for Parameters of CD Stochastic Frontier Production Function and Inefficiency Model for Bitter Gourd Growers

Variables	Estimates	
	OLS	MLE
Constant	6.18* (0.87)	8.94* (0.70)
ln (Land preparation)	-0.23*** (0.20)	-0.23 (0.27)
ln (Seed)	0.07 (0.13)	0.16 (0.12)
ln (PPM)	0.01 (0.16)	-0.003 (0.01)
ln (Irrigation)	-0.05 (0.14)	0.14*** (0.11)
ln (Labour)	0.36* (0.10)	0.13*** (0.11)
ln (NPK)	-0.01 (0.11)	-0.31** (0.11)
District dummy	-0.03 (0.16)	0.21*** (0.12)
Inefficiency Effect Model		
Constant		0.71 (0.51)
Age of the respondent		0.02* (0.00)
Schooling year		0.01 (0.02)
Family size		-0.09* (0.03)
Owners dummy		0.09 (0.13)
Farm area		0.0003 (0.007)
Lack of extension services		0.14 (0.19)
Contact with input dealers		-0.003 (0.21)
Cost of PPM		-0.0002* (0.0001)
Cost of fertilizer		-0.0002* (0.0001)
Variance Parameters		
σ^2	0.18	0.37** (0.13)
γ		0.99* (0.00)
Log likelihood function	-45.31	-28.135

Figures in parenthesis are standard errors

*, ** and *** indicate one, five and fifteen percent level of significance, respectively

bitter gourd growers are technically more inefficient and this result is in line with that of Parikh, *et al.* (1995). Coelli (1996) concludes that as the farmers becomes older; they could be more traditional and conservative and, therefore, show less willingness to adopt new practices.

Since bitter gourd cultivation is labour intensive as indicated in Table 1, the negative sign for family size variable is according to our expectation and this result is in line with those of Parikh, *et al.* (1995), Coelli, *et al.* (2002) and Dhungana, *et al.* (2004). Cost of plant protection measures and cost of fertilizer variables, proxy for environmental contamination have negative coefficients on level of technical inefficiency. Hadri and Whittaker (1999) and Giannakas, *et al.* (2001) found a negative relationship between level of technical inefficiency and the environmental contaminating variables.

The estimates for the variance parameters σ^2 and γ are significantly different from zero. This indicates statistical confirmation of our presumption that there are differences in technical efficiency among farmers. The share of this one-sided error in total variance (γ) is 0.99 percent of the two variances. These results indicate that the technical inefficiency effects are significant in bitter gourd production.

Distribution of technical efficiency

The estimated technical efficiency of bitter gourd growers is in the range of 0.11 to 0.99 with a mean of 0.60. This implies that there exist a great potential to increase per acre yield of bitter gourd. It is also found that only 21 percent farmers were operating above 80 percent level of technical efficiency and 29 percent of total farmers were found having technical efficiency level in the range of 60 to 80 percent while 50 percent growers were operating below 60 percent technical efficiency level (Table 3). This shows that a large number of bitter gourd farms in the sample faced severe technical inefficiency problems. The mean technical efficiency estimated in this study is low than those of Amara, *et al.* (1999) for potato (80.27 percent) in Canada and Bakhsh, *et al.* (2006) for potato (76 percent) in Pakistan.

Table 3. Frequency distribution of technical efficiency estimates.

Technical efficiency levels	Frequency of farmers
<0.40	18 (20)
0.40-0.60	27 (30)
0.60-0.80	26 (29)
>0.80	19 (21)
Mean	0.60
Minimum	0.11
Maximum	0.99

Figures in parentheses are percentages

The findings of the study indicate that bitter gourd growing farmers are not making right combination of available inputs and technology to obtain maximum yield. If the potential of available resources is fully exploited the yield could be increased by 40 percent as the mean technical efficiency was estimated as 60 percent in our study.

SUMMARY AND CONCLUSIONS

Results of the stochastic frontier production function and technical inefficiency effect model indicated that production elasticity for the NPK nutrients variable was higher (-0.31) compared to those of dummy for location (0.21), irrigation (0.14) and labour (0.13). Fertilizer (NPK nutrients) variable had negative sign implying that this variable was decreasing bitter gourd yield. All other inputs had positive elasticities, but statistically non-significant according to an asymptotic t-test.

An attempt was made to ascertain the factors affecting technical inefficiency in bitter gourd production. Results showed that age of the farmer was increasing technical inefficiency due to traditional and conservative behaviour of the older farmers towards adoption of new technology. Family size and environmental contaminating variables were negatively related with level of technical inefficiency. The mean technical efficiency averaged 60 percent indicating that the resources were inefficiently exploited. On the basis of results, it is concluded that bitter gourd growers could increase yield by 40 percent if they make use of the right combination of available resources and technology.

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