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Technical Efficiency of Tomato Production: A Case Study of District Peshawar (Pakistan)

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Abstract: This study is designed to measure the mean technical efficiency of tomato production in district Peshawar of Khyber Pakhtunkhwa (Pakistan). Data from 120 tomato growers were collected using multistage sampling technique and was analyzed using Maximum Likelihood Estimation technique. The mean technical efficiency was found 92 percent implying that on average tomato growers were 92 percent efficient. The study further reveled that farmers have increasing returns to scale. Estimates of the inefficiency model shows that among various factors experience and age are the only factors that significantly affect the inefficiency of the farmers. Using formal and informal education farm technical efficiency may be increased. To take benefits of high technical efficiency and economies of scale, farming community should be motivated to increase their scale of operation. Farming community should also be trained in processing the tomato so that crop may be preserved to avoid commodity losses.

Key words: Technical efficiency · Stochastic Approach, Farmer's efficiency · Farmer's education

INTRODUCTION

The use of different resource combinations brings high variation in output among the farmers. The difference is not only among the farmers but there is a difference in output between what the farmers produce and what the agricultural research and experimental stations produce from the given resources and technology. Such variation in production among the farmers and the difference between output of farmer and the experimental stations shows that farmers don't use the resources efficiently [1]. According to Federal Bureau of Statistics [2] there is large variation in yield of tomato in different districts of the province of Khyber Pukhtunkhwa (KPK). The variation in average production ranges from 5.391 to 12.63 tons per hectare for top 11 tomato producing districts of KPK (Pakistan). Similarly the yield of tomato in KPK as compare to other provinces of Pakistan is very low. For the years 2005 to 2010 the average yield of tomato in Punjab, Sind, KPK and Baluchistan were 12.6, 7.4, 9.8, 11.4 tons per hectare respectively [3].

It is clear from the above statistics that yield in KPK is very low as compared to other provinces of Pakistan except Sind. The difference in yield among different districts of Khyber Pakhtunkhwa and low yield of Khyber Pakhtunkhwa as compared to other provinces shows that farmers do not make full use of available resource. On the other hand, Khan *et al.* have shown that food production at the district level ensures the food availability component of food security [4]. The above statistics necessitate that there is a need to analyze the efficiency level of tomato production and to find out the causes of low yield and variation that exist in the yield of tomato across the farmers.

Farrell split the economic efficiency into two component, i.e. technical efficiency and allocative efficiency [5] and used technical efficiency to measures the variation that exist among the farmer's production [6].

When there is measuring of technical efficiency there is actually measuring of gap between what farmers actually produces and what they can produce from the given resources and technology. This study attempted to

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measure the technical efficiency level of tomato production in KPK and to identify technical inefficiency factors of tomato production.

MATERIAL AND METHODS

Data: This study was conducted in Peshawar (Pakistan). Data was collected using multistage sampling technique. The observations regarding input used in the production process such as seed, fertilizer, tractor hours, labor hours and socioeconomic characteristics of farmers such as age of the farmer, literacy level of the farmer, farming experience etc. were taken through the interview.

Data were analyzed to measure the relationship between output and input used and to measure the mean technical efficiency and technical inefficiency in tomato production.

Model Specification: Two approaches have been used to measure the mean technical efficiency, i.e. (1) parametric and (2) non-parametric approach. Both approaches have their own merits and demerits. Major drawback in non-parametric approach is that all the deviations from the frontier are measured in terms of inefficiency which does not take into account the uncertainty effect. To overcome such deficiency Aigner *et al*. and Meeusen and Broeck developed the stochastic frontier production function that is also called as composite error model, for measuring the technical efficiency [7,8]. In this study the parametric stochastic frontier approach has been used for the analysis. It has also been used by a number of studies [9,10,11,12,13]. The stochastic frontier Cobb Douglas production function used for the measurement of technical efficiency is as follows:

$$Y_i = f(\beta, X) + \varepsilon_i \quad (1)$$

$$LnY_i = \beta_0 + Ln\beta_1X_1 + Ln\beta_2X_2 + Ln\beta_3X_3 + Ln\beta_4X_4 + Ln\beta_5X_5 + Ln\beta_6X_6 + Ln\beta_7X_7 + \varepsilon_i \quad (2)$$

Where

Y_i = Output obtained by ith farmer per hectare, X_1 = Area under tomato production, X_2 = No of seedlings per hectare, X_3 = Pesticide in liters per hectare, X4 = Fertilizer in Kg per hectare, X_5 = Labor days per hectare, X_6 = Tractor hours per hectare, X_7 = No. of Irrigation per hectare, ε_i = Composite error term that capture the noise of both, the error term and inefficiency component (V_i, U_i). Where V_i = Random variable having normal distribution and U_i = Non-negative random variable having half of the normal distribution which measures the technical inefficiency [11]. The modal used for the measurement of technical inefficiency is as follows:

$$U_i = (\alpha, Z) + W_i \quad (3)$$

$$U_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + W \quad (4)$$

Where

α = Vector of parameters, to be estimated, Z_1 = Education in Years, Z_2 = Total area Cultivated, Z_3 = Experience in Years, Z_4 = Credit (as a dummy variable), Z_5 = Age of the farmer, W_i = Random variable having normal distribution

Technical efficiency of individual farmer is defined as the ratio of observed output to the corresponding frontier output. The model used for technical efficiency is given as:

$$TE = Y_0 / Y_f = f(\beta, X) + (Vi + Ui) / f(\beta, X) + (Vi) \quad (5)$$

Where Y_0 is the observed and Y_f is the frontier output. TE takes the value between 0 and 1.

RESULTS AND DISCUSSION

The descriptive statistics of the variables that have been used to come up at the estimation of technical efficiency are shown in Table 1. The variable used in production function are: Area (Area under tomato production only) Seedling, Pesticide, Fertilizer, Labor, Tractor, Irrigation, Age, experience and education of farmer (socioeconomic characteristics) and Area cultivated (Area under tomato production plus area under other crops).

The Maximum likelihood estimates of the stochastic frontier Cobb Douglas production function has been shown in Table 2.

The results in Table 2 show that all the variables except Fertilizer significantly affect the farm yield. The return to scale analysis shows that a farmer has increasing return to scale. Thus there is a scope of boost in productivity and production by increasing the scale of operation.

Table 1: Summary Statistics of the Variables Used in the Stochastic Frontier Analysis

Variable	Unit	Minimum	Maximum	Mean	Std. Deviation
Yield	Kilograms	4940.00	17200	9749	3719.6
Area	Hectares	0.50	3.00	1.4317	0.59
Seedling	Numbers	1185.00	1892.00	1432.92	169.00
Pesticide	Liters	9.80	118.56	45.73	23.45
Fertilizer	Kilograms	247	22971	7547.48	5880.20
Labor	Man- days	123.50	489.06	285.28	83.86
Tractor	Hours	6	13	9.60	1.71
Irrigation	Numbers	11.00	24.00	17.28	3.16
Education	Years	0.00	12.00	4.67	2.65
Area Cultivated	Hectares	2.00	3	2.73	0.44
Experience	Years	9.00	48.00	33	9.58
Age	Years	22	66	44.46	11.04

Table 2: Maximum Likelihood Estimates of the Stochastic Frontier Production Function (Dependent variable = Yield)

Variables	Parameters	Coefficients	St. Error	Z value	P-Value
Intercept	β_0	3.676	0.715	5.14	.000
Ln Area	B_1	0.363	.0323	11.24	.000
Ln Seedling	B_2	0.310	0.098	3.15	.002
Ln Tractor	B_3	0.293	0.066	4.42	.000
Ln Pesticide	B_4	0.110	0.021	5.05	.000
Ln Fertilizer	B_5	-0.0005	0.007	-0.07	.941
Ln Irrigation	B_6	0.348	0.051	6.71	.000
Ln Labor	B_7	0.197	0.045	4.32	.000
RTS		$B_{1+} B_{2+} B_{3+} B_{4+} B_{5+} B_{6+} B_{7=}$ 1.6			

Table 3: Maximum Likelihood Estimates of the Inefficiency Effect Model

Variable	Parameters	Coefficient	St. Error	t value	P-Value
Intercept	α_0	-8.723	6.619	-1.32	0.188
Experience	α_4	-0.074	0.034	-2.17	0.030
Year of Schooling	α_3	-0.014	0.064	-0.23	0.821
Area Cultivated	α_2	3.35	2.00	1.67	0.094
Credit	α_1	-0.403	0.609	-0.66	0.508
Age	α_4	-0.065	0.029	-2.25	0.024

Table 4: Maximum Likelihood Estimates of the Variance Parameters

Variable	Parameters	Coefficients
Sigma Square	σ^2	0.0175756
Sigma V	σ^2_V	0.0019112
Sigma U	σ^2_u	0.0156643
Gama	Γ	0.89

Table 5: Frequency Distribution of Technical Efficiency of Potato Farmers

Technical efficiency	Frequency	Percentage
<0.90	28	23.44
0.90 -0.95	38	31.6
$\geq$0.95	54	45

Maximum = 0.99 Minimum = 0.72 Mean = 0.92

Table 6: Log Likelihood Test Ratio for Hypothesis Testing of Technical Inefficiency

1LH_0	Gamma γ equal to 0	127
LH_a	Gamma γ not equal to 0	151
Degree of freedom	No of Para specify to zero in Null Hypo	6
χ^2 Calculated	$\chi^2 = -2[LH_0 - LH_a]$	48
χ^2 Tabulated	5% level of sign, at 6 degree of freedom	12.59

The Maximum Likelihood estimates of the inefficiency model are shown in Table 3.

The estimates in Table 3 explain that Credit, Area cultivated and Year of schooling are insignificant, while Experience and Age have significant effect on farm technical inefficiency.

The Maximum Likelihood Estimates of the variance parameters are shown in Table 4.

The results of Maximum Likelihood estimates of variance parameters explain that variance parameter such as gamma that is the ratio of σ^2_u to the σ^2 (σ^2_u / σ^2) has value of (0.89) which shows that out of total variation in production 89 percent variation is due to technical inefficiency U_i while remaining 11 percent is due to the uncertainty V_i.

In the Talbe 5 frequency distribution of technical efficiency of tomato farmers is shown.

The mean technical efficiency calculated is 0.92 where it ranges from minimum value of 0.71 to maximum value of 0.99. Table 5 contains the frequency distribution of technical efficiency of the farmers in the study area, which shows that majority of the farmers that is about 45 percent have technical efficiency above 95 percent. The 23.44 percent of the sampled respondents have technical efficiency below 90 percent and 31.6 percent of the respondent's technical efficiency ranges from 90 to 95 percent.

The information of the Log Likelihood test Ratio has been shown in Table 6. The test is based on the information of LH_0 and LH_a, the degree of freedom, χ^2 calculated and χ^2 tabulated. If χ^2 calculated is greater the χ^2 tabulated then we will reject the hypothesis (there is no inefficiency in tomato production) and vice versa.

The results of likelihood test ratio shows that our χ^2 calculated is greater the χ^2 tabulated so we reject the hypothesis, i.e. there is no technical inefficiency.

CONCLUSION AND RECOMMENDATIONS

Stochastic frontier Cobb Douglas production function was used to measure the mean technical efficiency of the farmers by using parametric approach. The results have shown that mean technical efficiency was 92 percent explaining that farmers in the area are highly efficient in allocation of resources, but still there is a scope of increase in production by increasing their efficiency level. The socioeconomic characters such as age, years of schooling, credit, experience were analyzed which shows that experience and age are the factors that significantly affect farmer's technical inefficiency. The LR test shows that farm technical inefficiency exist in tomato production and there is a scope for increase in production by improving the farmer's efficiency. The return to scale analysis shows that farmers have increasing return to scale.

The results show that among various factors experience and age are the factors that significantly affect the farm technical inefficiency. The farmers can increase their level of efficiency by increasing their level of understanding of modern techniques of farming. In this regard extension agents can play a vital role in providing formal and informal education to the farming community. It will enhance their level of understanding of modern technique of farming. On the other hand government should facilitate the extension agents by providing more funding.

Based on the findings it has been observed that tomato farmers are highly efficient in allocating their resources and getting maximum production from given resources. On the other hand tomato farmers have increasing returns to scale and operate in stage first of the production process. To take benefits of high technical efficiency (92%) of farmers and economies of scale, farmers should be motivated to increase their scale of operation. Increasing the scale of operation will help to increase the level of production and productivity of farmers.

The high level of production will be beneficial for both consumers and producers if there is an efficient marketing structure otherwise there may be an opposite impact of high production. Tomato is perishable commodity and high production in the absence of market structure will not only deteriorate the farmers profit through low prices but will also result in commodity losses. In this regard extension agent can play a vital role by providing training to the farmers' community. It is relevant to how to process tomato so that the farmer can preserve the tomato and bring it into market at proper time, which will not only help the farming community to increase their profit but also help the consumers to get tomato products all the time in a year at considerable stable prices. It will result in welfare of the society in food security.

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