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JOURNAL OF THE INDIAN SOCIETY OF AGRICULTURAL STATISTICS 76(1) 2022 17–22

A Stochastic Frontier Production Function to Measure the Technical Efficiency of the Farmer of Apple (*Malus Pumila*) Production and Productivity

Rishabh Mohan, Chetan Kumar Saini, R.B. Singh and Neelash Patel

Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur

Received 24 November 2021; Revised 29 April 2022; Accepted 18 May 2022

SUMMARY

This paper estimates the Technical Efficiency (T.E.) of an apple-producing farmer in Jubbal and Kotkhai tahsil of Shimla district, using a stochastic Cobb-Douglas (CD) production frontier function. A stochastic frontier production function can be used for panel data of firms. The non-negative technical inefficiency effects are assumed to function firm-specific variables and vary over time. They are believed to be independently distributed as truncations of normal distributions with constant variance. The result shows the mean technical efficiency of Jubbal and Kotkhai tahsil Farmer is 66% and 70%. The mean technical efficiency is high for Kotkhai Farmer compared to Jubbal Farmer. Therefore, it is concluded that Kotkhai's farmers are more technically efficient than Jubbal with the same input. This suggests that Jubbal Farmer can potentially increase their productivity through more efficient use of information.

Keywords: Technical efficiency, Stochastic frontier function (SFF), Constraints, Simple size.

1. INTRODUCTION

As in the current scenario, there is exponential population growth, but the total cultivable area decreases. This results in the demand for higher productivity. However, the cost involved in the production should not be increased as the farmers are not accessible to the high value of capital. Thus, there is a need to adopt the latest technologies and utilize inputs efficiently. The current status of farmers' resource use is calculated by examining the efficiency. Thus, there is a need to find out the Technical Efficiency of farms.

Technical efficiency evaluates the farm's ability to obtain the maximum possible output from a given set of resources. The Cobb-Douglas production function assumes that all production techniques are identical across farms and each farmer is technically efficient, which is often untrue. Thus, it does not distinguish between farmers based on technological efficiency. The specification stochastic parametric frontier function recognizes component error term as the primary source of deviation from the production frontier. By definition, the stochastic frontier production function is $Y_i = F(X_i; \beta) \exp(V_i - U_i)$ i = 1, 2... n, where Y_i is the logarithm of the output of i^{th} farm; X_i is the logarithm of the corresponding vector of inputs; β is a vector of unknown parameters to be estimated; F denotes an appropriate functional form, V_i is the symmetric error component that accounts for random effects and exogenous shock; while U_i is a one-sided error component that measures technical inefficiency.

Frontier production functions and technical efficiency of individual firms have been considered in many papers in economic, statistical, and econometric journals. Many studies have been carried out using this approach to estimate T.E. and to determine factors that influence the efficiency of farmers, especially in the agricultural sector (Onumah and Acquah, 2010; Villano *et al.*, 2010; Nasiri and Singh, 2010; Kumbhakar

Corresponding author: Rishabh Mohan
E-mail address: rishabhmhn@gmail.com

et al., 2011; Oyewo, 2011; Edeh and Awoke, 2011). Bagi (1982) measured the technical efficiency of 193 farms in West Tennessee using a stochastic production function; Kalirajan and Shand (1985) estimated a Cobb-Douglas production frontier by using a maximum likelihood procedure for a sample of 91 paddy farmers from the Coimbatore district of Tamil Nadu in India. Battese *et al.* (1999) estimated the technical efficiency of cotton growers in the Vehari districts of Punjab by using a stochastic frontier production function model in which technical inefficiency effects were assumed to be the function of other observable variables related to the farming operations. Coelli *et al.* (2002) estimated Bangladeshi rice farmers' technical, allocated, cost, and scale efficiency using a non-parametric approach. Kumar *et al.* (1999) evaluated the production and marketing constraints of high-value crops in Himachal Pradesh for the year 1997. They found that more than 45 percent of the flower growers quoted a lack of reliable sources for the supply of propagating material.

2. MATERIAL AND METHODS

(i) Sampling and data collection

(ii) Nature and Source of Data

(iii) The study period

(iv) Materials

(v) Analytical tools and techniques

(i) Sampling and data collection

The sampling frame data was taken from The Jubbal, and Kotkhai Tehsils of Shimla selected based on agro-ecological potential and market access with 291 total farmers. The research is based on a sample of 50 farmers. The model was taken by simple random sampling from selected Tehsils.

(ii) Nature and Source of Data

The data for the study included both primary and secondary data. The preliminary data for the analysis was obtained from the sample farmers through the personal interview method, and secondary data was taken from the Department of Horticulture, Shimla.

(iii) The study period

The collected data pertained to the agricultural year 2017-18. As most of the respondents did not maintain the records of expenditure and receipts of apple production, the data collected were based on their memory of the respondents.

(iv) Materials

The frontier production function utilized for this study is as follows:

$$Y = b_0 + b_1 lnX_1 + b_2 lnX_2 + b_3 lnX_3 + b_4 lnX_4 + b_5 lnX_5 + V_i - U_i$$

where,

Y = Apple output (quintals/ha)

X_1 = Density of plants (No. of plantsha^{-1})

X_2 = Value of fertilizers used (Rs. ha^{-1})

X_3 = Value of plant protection chemicals used (Rs. ha^{-1})

X_4 = Organic manures used (kgs. ha^{-1})

X_5 = Total labour used (person days ha^{-1})

(v) Analytical tools and techniques

(1) Stochastic frontier production function analysis

Farrell (1957) introduced the concept of technical efficiency, which is based on the frontier production function. This function distinguishes technical and allocative efficiencies. Farrell proposed that efficiency should be measured relatively as a deviation from the best performance in a representative peer group.

Timmer (1971) modified this procedure in many ways, imposed a Cobb-Douglas type specification on the frontier, and evolved an output-based efficiency measure. The primary tool used for the analysis of this study was the stochastic production frontier. A Cobb-Douglas functional form was used to model the frontier appropriate structure specified for this study.

Suppose that a farm has a production plan ($Y°, X°$), where the first argument is the set of outputs and the second represents the set of inputs. Given a production function f(X), the farm is technically efficient if $Y°=f(X°)$ and technically inefficient if $Y°<f(X°)$. Therefore, parametric pairwise linear technology or a parametric function such as the Cobb- Douglas form.

This study uses the stochastic (or econometric) frontier production model for cross-sectional data. We define the frontier production function as the maximum feasible or potential output produced by a production unit such as a farm, given the level of inputs and technology. The actual production function (corresponding to the production unit's actual output) can be written as:

$$Qi = f(X_i; \beta) \exp(-u_i) \text{ and } 0 < u_i < \infty;\ i = 1, 2\ldots n. \quad (1)$$

Where

Q_i = represents the actual output for the i^{th} sample (production) unit;

X_i = is a vector of inputs, and

β =is a vector of technology parameters to be estimated;

f (X) = is the frontier production function

U_i = is a one-sided (non-negative) residual term.

If the production unit is inefficient, its actual output is less than the potential output. Therefore, we can treat the ratio of the actual production Q_i and the possible output f(X) as a measure of the technical efficiency of the production unit.

Using equation (1) above, we can write this measure as:

$$TE = Q_i / f(X_i; \beta) = \exp(-u_i) \quad (2)$$

The specification of stochastic parametric frontier recognizes component error term as the major source of deviation from production frontier. By definition, stochastic frontier production function is $Y_i = F(X_i; \beta) \exp(V_i - U_i)$ i = 1, 2... n

were,

Y_i = logarithm of the output of i^{th} farm;

X_i= logarithm of the corresponding vector of inputs;

β = a vector of unknown parameters to be estimated;

F = denotes an appropriate functional form,

V_i= symmetric error component that accounts for random effects and exogenous shock;

U_i= is a one-sided error component that measures technical inefficiency.

In the explicit form, the frontier production function utilized for this study is as follows:

$$Y = b_0 + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + V_i - U_i$$

The "production frontier" serves as one such standard in the case of T.E. T.E. can be defined as the ability and willingness of a production unit to Obtain the maximum possible output with a specified endowment of inputs (represented by a frontier production function), given the surrounding technology and environmental conditions.

a. Timmer's measure of economic efficiency

It is the ratio of actual output to the potential production on the production function given the level of input used on the i^{th} farm.

Timmer's measure of technical efficiency (%) = $Y_i / Y_i^* \times 100$

were,

Y_i = is the actual output of i^{th} farm

Y_i^*= is the maximum output obtainable by the i^{th} farm for a given level of inputs.

b. Estimation of potential output

The potential yield of apple is calculated based on technical efficiency measured through Timmer's measure of technical efficiency. It is the ratio of the average actual output level to the mean technical efficiency, which is given by

$$PY = \frac{AY}{MTE}$$

where,

PY = Potential output (qtls.ha^{-1})

AY = Average actual output (qtls.ha^{-1})

MTE = Mean technical efficiency

(2) Garrett's ranking technique

Garrett "s ranking technique is used to rank the constraints in apple production based on their importance. The order of the merit given by the respondents was converted into a percent position using the formula.

Per cent position = 100 * (Rij – 0.50)/ N_j

where, R_{ij} = Rank given for ith item by jth individual

N_j = Number of items ranked by jth individual

The percentage position of each rank was converted to scores by referring to the table given by Garrett and

Woodworth (1969). Then for each factor, the scores of individual respondents were summed up and divided by the total number of respondents for whom scores were gathered. The mean score for all the factors was ranked, following the decision criteria that the higher the value, the more important is the order of preference by respondents.

3. RESULTS AND DISCUSSION

Table 1 and 2 showed the mean technical efficiency of farm areas Jubbal and Kotkhai were 66% and 70%, respectively. It indicates that Kotkhai farmers were more Technically Efficient

Table 1. Technical efficiency of Farm-A (Jubbal)

Actual Yield	Predicted Yield	T. E
140	175.95	0.79
85	134.99	0.62
70	83.12	0.84
80	97.79	0.82
65	78.83	0.82
44	61.92	0.71
32	56.04	0.57
75	123.46	0.61
66	73.18	0.9
55	86.34	0.64
35	63.88	0.55
40	62.06	0.64
52	95.31	0.54
66	67.15	0.98
28	49.22	0.57
68	112.14	0.61
75	131.11	0.57
48	65.211	0.73
95	155.93	0.61
60	100.6	0.6
58	76.75	0.75
76	131.13	0.58
38	71.79	0.53
46	86.69	0.53
28	69.77	0.4
MEAN		**0.66**

Table 4 showed that the mean level of technical efficiency of apple-growing farmers is about 68%, with the minimum and maximum efficiency levels of about 40% and 99%, respectively.

Table 2. Technical efficiency of Farm-B (Kotkhai)

Actual Yield	Predicted Yield	T. E
70	100.92	0.69
25	43.33	0.58
70	72.44	0.96
48	57.84	0.83
42	62.4	0.67
75	101.94	0.73
35	48.76	0.72
80	84.69	0.94
65	79	0.82
52	95.17	0.55
66	66.72	0.99
50	66.6	0.75
30	62.61	0.47
45	82.13	0.54
76	130.81	0.58
28	52.9	0.52
45	61.21	0.73
35	53.51	0.65
55	59.64	0.92
35	62.54	0.56
48	68.33	0.7
40	60.74	0.66
60	90.59	0.66
56	87.02	0.64
45	68.32	0.66
MEAN		**0.7**

Table 3. Frontier production function coefficients

	Coefficients	Standard Error	t Stat
Intercept	-5.044	1.4416	-3.499
fertilizer	0.3082	0.0899	3.427
plant protection	0.1715	0.1178	1.4559
organic manure	0.2756	0.0886	3.11
plant density	0.1738	0.0498	3.4902
labor	-0.049	0.0957	-0.509

Table 4. Mean, Minimum & Maximum Technical efficiency of Farms

	Farm-A	Farm-B
N	25	25
Mean	0.66	0.7
Minimum	0.4	0.47
Maximum	0.98	0.99

Table 5 showed that the technical efficiency of 60% of farmers is below 70%, and 12% of farmers have more than 90% of technical efficiency. This means that most farmers are not more technically efficient, and only a few farmers are highly technically efficient and progressive. This shows a wide disparity among apple producer farmers in their level of technical efficiency, which may, in turn, indicate that there is room for improving the current status of apple production by enhancing the level of farmers' technical efficiency.

Table 5. Categorization of apple farms based on T.E.

Sl. No.	Efficiency range	Farm-A	Farm-B	Frequency (No. of farmers)	Percentage of total farms
1	Up to 0.70	16	14	30	60
2	0.71-0.75	2	4	6	12
3	0.76-0.80	2	1	3	6
4	0.81-0.85	3	2	5	10
5	0.86-0.90	0		0	0
6	> 0.90	2	4	6	12
7	Total	25	25	50	100

Table 6. Farm category-wise yield gap in apple production

Sl. No.	Particulars	Timmer's index	Average yield (QTLs/ ha)	Potential yield (QTLs/ ha)	Yield gap (QTLs/ ha)
1	Farm-A	0.66	61	92.43	31.43
2	Farm-B	0.7	51.04	72.81	21.77
3	Total farms	0.68	56.02	82.62	26.6

Extent up to which efficiency can be increased

The lack from which the particular farm is lagging to becoming perfectly technically efficient is the extent to which its efficiency can be increased.

Table 7. Mean T.E. and lag from perfect T.E.

	MTE	(1-MTE)
Farm-A	0.661753	0.338247
Farm-B	0.703197	0.296803

Thus 34% of Farm-A & 30% of Farm-B efficiency can be increased.

Production constraints of apple growers

The farmers were interviewed to elicit the problems faced them relating to various aspects of the production of the apple crop in the study area. Based on Garrett's score, among the various production constraints, inadequate irrigation water was the major production constraint (Rank I), followed by lack of timely inputs, inadequate supply of information, the incidence of pest and disease attacks, shortage of skilled labor, lack of wide yielding varieties, lack of equipment and machinery and increasing fertilizer prices.

Table 8. Garrett's mean score of various production constraints

Sl. No.	Production constraints	Mean score (n=50)	Rank
1	Inadequate irrigation water	75.65	I
2	Lack of timely inputs	60.97	II
3	Inadequate supply of inputs	57.32	III
4	Incidence of pest and disease attack	54.91	IV
5	Shortage of skilled labor	46.27	V
6	Lack of wide yielding varieties	45.82	VI
7	Lack of equipment and machinery	44.56	VII
8	Increasing fertilizer prices	40.66	VIII

4. CONCLUSION

1. The mean technical efficiency of the farmers was 68 percent which implied that there was scope to increase by 32 percent output. In this regard, the machinery may make efforts to enable the farms to achieve close to 100 percent technical efficiency.
2. Since there might be limited opportunities for raising the level of education of farmers in the short term, intensifying farmer training programs through various innovative and vocational education programs and extension delivery systems would be more practical in improving technical efficiency. The positive impact of education on technical efficiency will enhance the farmer's ability to receive and understand information relating to new agricultural technology.

ACKNOWLEDGEMENTS

The authors are grateful to the editor and referees for giving their cogent comments on the paper that have changed the shape of the article.

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