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Assessment of farm efficiency of beneficiary and non beneficiary pea farmers of KVK Rohru in Shimla district of Himachal Pradesh: The DEA Approach

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Abstract
A study was carried out in Shimla District of Himachal Pradesh to assess the farm efficiency of pea production in case of the beneficiary and non-beneficiary farmers. Multistage random sampling was used to collect the sample of 100 farmers. The DEA approach was used to assess the efficiency of the farmers. On an average the farmers were 82 percent technically efficient (CRS) in pea production. Tobit regression model was used to determine the factors affecting technical, allocative, scale and economic efficiency. The main factors used in the study were area under crop, education, farm size and government financial supports.

Keywords: DEA approach, technical efficiency, scale efficiency, allocative efficiency, Economic efficiency, Tobit regression model

Introduction

Farmers are generally considered rational decision-makers when it comes to making crucial choices regarding what to produce, how to produce, and the quantity to produce. However, it's important to acknowledge that the quality of these decisions varies among individuals and organizations. The characteristics and attributes of the decision-makers themselves play a significant role in shaping the quality of their decisions. Ultimately, the effectiveness of these decisions becomes evident in the operational efficiency of the farm. Efficiency in agricultural production is a critical aspect, particularly in the context of developing countries' agriculture, as highlighted by Radam and Latif in 1995. Farm efficiency has long been a subject of interest when studying farm operations. The performance of farmers in terms of production is not solely dependent on the physical resources and technology available to them; it is also influenced by the existing conditions and management practices on the farm. Various studies conducted in developing countries have consistently shown production efficiency levels ranging from 60 percent to 82 percent, irrespective of the type of crop or the region in question. (Rahman, 2003; Coelli *et al*., 2002; Wang *et al*., 1996) [14, 5, 17]. Achieving efficient resource utilization is a key indicator of enhanced agricultural production. Efficient utilization of inputs enables farmers to attain higher levels of production using the same amount of resources. Numerous studies conducted in different countries have demonstrated the significant potential for increasing agricultural output and profitability by enhancing productive efficiency (both technical and allocative) through the optimal utilization of existing resources, as highlighted by Rahman in 2002 [13]. Therefore, it is crucial to consider the factors influencing various aspects of efficiency so that a constructive approach can be developed to enhance the quality of decision-making in agriculture. This study specifically focuses on evaluating the efficiency of pea crop cultivation in Shimla district of Himachal Pradesh, as it is the primary vegetable crop in the region.

Methodology

This research was conducted within the Shimla district of Himachal Pradesh. To ensure a representative sample, a multistage random sampling approach was employed to choose the respondents. In the first stage, two blocks, specifically Jubbal-Kotkhai and Rohru, were randomly chosen from the total of 12 blocks within Shimla district. In the second stage, a list of villages located within these selected blocks was compiled, and then five villages from each block were randomly picked. For the third stage, a comprehensive list of all potential respondents from these ten selected villages was created. Subsequently, ten farmers were chosen randomly from each village, with an equal representation of five beneficiaries and five non-beneficiaries. Beneficiary are those who are linked with KVK through any training, workshops, cluster field line demonstrations and on farm trials and they are users of the technology disseminated through these trainings. In summary, the research involved a total sample size of 100 respondents, ensuring a balanced representation of beneficiary and non-beneficiary farmers in the study.

Statistical and Economic analysis

Technical, scale, economical and allocation efficiency were estimated through R-software using DEA technique.

Technical efficiency

Technical efficiency was assessed using Data Envelopment Analysis (DEA) with the R software. DEA is a non-parametric method for measuring efficiency that does not rely on assuming a production function, unlike Stochastic Frontier Analysis. It is important to note that neither of these methods is definitively superior to the other (Watkins, 2013) [16]. In DEA, the process involves creating an efficient frontier against which the inputs and outputs of Decision-Making Units (DMUs) are compared. In the context of DEA, a farm is considered a DMU. Farrell (1957) [8] introduced the concept of relative efficiency, which allows us to compare the efficiency of one DMU with another within a specific group. Farrell identified three types of efficiency: technical efficiency (TE), allocative efficiency (referred to as "price efficiency" by Farrell), and economic efficiency (referred to as "overall efficiency" by Farrell).

Technical efficiency (TE) relates to a DMU's ability to either maximize output from a given set of inputs or minimize inputs while achieving a specific output level. The former is known as output-oriented TE, while the latter is input-oriented TE. Allocative efficiency (AE) focuses on how efficiently a technically efficient DMU uses inputs to minimize production costs based on input prices. AE is calculated as the ratio of the DMU's minimum costs required to achieve a particular output level and the actual costs of the DMU, adjusted for TE. Economic efficiency (EE) combines both TE and AE (Farrell, 1957) [8]. Therefore, a DMU is economically efficient when it demonstrates both technical and allocative efficiency. Economic efficiency is computed as the ratio of the minimum feasible costs to the observed actual costs for a DMU. The inputs used for the study are mentioned below:

- Seed
- Fertilizer
- Manure
- Pesticide

The outputs are taken for the study are

Pea yield

The technical efficiency score of the n^{th} farm will be find out using following DEA linear programming formulation:

$$TE_n = \min_{\lambda_i\, \theta_n} \theta_n$$

s. t.

$$\sum_i^I \lambda_i\, X_{ij} - \theta_n X_{nj} \leq 0$$

$$\sum_i^I \lambda_i\, Y_{ik} - Y_{nk} \geq 0$$

$$\sum_i^I \lambda_i = 1$$

$$\lambda_i \geq 0$$

Where, subscript i, j and k are used for i^{th} farm, j^{th} input and k^{th} output. The symbol X denotes input while Y denotes output λ_i is the non-negative weight associated with i^{th} farm. When $\sum\lambda_i$ is set equal to one, then variable return to scale (VRS) prevails and when this constraint is omitted then constant returns to scale (CRS) prevails.

Economic efficiency

Following cost minimizing linear programming formulation was used.

$$MC_n = \min_{\lambda_i X*'_{nj}} \sum_{j=1}^{J} P_{nj} X*_{nj}$$

s. t.

$$\sum_i^I \lambda_i\, X_{ij} - \theta_n X*'_{nj} \leq 0$$

$$\sum_i^I \lambda_i\, Y_{ik} - Y_{nk} \geq 0$$

$$\sum_i^I \lambda_i = 1$$

$$\lambda_i \geq 0$$

Where, MC_n is the minimum cost for the n^{th} farm and P_{nj} is the price of j^{th} input for n^{th} farm.

Then economic efficiency was calculated as following

$$EE_n = \frac{\sum_{j=1}^{J} P_{nj} X*'_{nj}}{\sum_{j=1}^{J} P_{nj} X_{nj}}$$

Scale efficiency: It was computed as ratio of technical efficiency under VRS to CRS.

Allocative efficiency

Allocative efficiency was obtained by dividing the economic efficiency of the sample farm by the corresponding technical efficiency.

t-Test: two sample assuming unequal variance

To test the technical efficiency, allocative efficiency, economic efficiency, scale efficiencies of beneficiary and non-beneficiary farms unit is statistically different or not we applied t-test, two sample assuming unequal variance.

Hypothesis

H_0: The efficiencies (technical, allocative, economic, scale) are same in case of beneficiary and non-beneficiary sampled farmers.

H_1: The efficiencies of the beneficiary and non-beneficiary sampled farmers are not same.

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where, $\bar{x}_1$ and $\bar{x}_2$ are samples mean, s_1^2 and s_2^2 are sample variances and n_1 and n_2 are numbers of samples size of beneficiary and non-beneficiary farmers' samples, respectively.

Factors affecting farm efficiency of beneficiary and non-beneficiary farmers

The Tobit model, initially introduced by James Tobin (1958) [15], encompasses a censored regression framework in economic analysis (Hayashi, 2000) [9], and has been extensively studied in econometrics literature (Maddala and Lahiri, 2009) [10]. Given that the efficiency index obtained from data envelopment analysis (DEA) is constrained between 0 and 1, it is well-suited for simulation analysis to identify the determinants of technical efficiency, allocative efficiency, scale efficiency, and economic efficiency among farmers.

The regression model takes the form

$$Y_i^* = \beta X_i + \epsilon_i, \; i = 1, 2, 3, ..., N$$

Here, N represents the number of observations, Y_i is the dependent variable, X_i is a vector of independent variables, β is a vector of estimable parameters, βX_i denotes the scalar product of the two vectors, and ϵ_i is an error term that follows a normal distribution with zero mean and constant variance σ^2.

To explore the relationship between efficiency measurements and farmer characteristics, farm-level technical efficiency, allocative efficiency, scale efficiency, and economic efficiency scores are incorporated into the regression model. Based on existing literature, several variables have been identified to explain the levels of technical efficiency , scale efficiency, allocative efficiency and economic efficiency among farmers in the study area. These variables include family size, land area, literacy rate, and government financial support. These variables are justified for inclusion based on surveys and interviews conducted during the research, indicating their impact on farmer productivity. Consequently, the hypothesis of the study estimated that these variables also influence the levels of technical efficiency, scale efficiency, allocative efficiency, and economic efficiency among farmers in the study area.

Table 1: Technical, economic, scale and allocative efficiency of beneficiary and non beneficiary farmers in case of Pea

Peas						
Sr. No.	**Particulars**	**Beneficiary**	**Non beneficiary**	**t-value**	**Standard error**	**Significant difference**
1	Technical efficiency (crs)	0.83	0.81	3.206	0.312	*
2	Technical efficiency (vrs)	0.93	0.90	3.538	0.327	*
3	Scale efficiency	1.15	1.12	3.026	0.302	*
4	Economic efficiency	0.75	0.73	2.702	0.286	*
5	Allocative efficiency	0.80	0.57	6.61	0.447	*

(* shows the significant)

Table 1 illustrates that for the pea crop, there was significant difference in all the efficiencies of beneficiary and non-beneficiary framers. The mean TE (CRS) for the beneficiary farmers was higher (0.83) compared to the non-beneficiary farms (0.81) where beneficiary farmers were 83 percent technically efficient. TE (VRS) for the beneficiary farmers (0.93) was also significantly higher than that of the non-beneficiary farmers (0.90). The scale efficiency for the beneficiary farmers (1.15) is slightly higher than that of the non-beneficiary farmers (1.12). The beneficiary farmers were 75 percent economically efficient whereas non-beneficiary farmers were only 73 percent economically efficient which is less than beneficiary farmers. The allocative efficiency for the beneficiary farmers (0.80) was significantly higher than that of the non- beneficiary farms (0.57).

Factors Affecting Technical, Allocative, Economic and Scale Efficiency of Sampled Household

Factors affecting technical, allocative, economic and scale efficiency of Pea

Efficiency is influenced by a range of independent variables and their impact can vary. Some variables have a positive correlation with efficiency, meaning that an increase in these variables tends to result in an improvement in efficiency. On the other hand, certain variables exhibit a negative correlation with efficiency, indicating that an increase in these variables leads to a reduction in efficiency. The variables selected in the present study were family size, area, education and government financial support.

Table 2 shows that, out of all the factors, government support and education had the most effects on the economic efficiency in case of beneficiary farmers. Economic efficiency rises significantly by 0.007 and 0.11 units, respectively, for every unit increase in both the education level and the government support given to the beneficiary farmers. The size of the family and level of education have a significant impact in case of non-beneficiary farmers on economic efficiency. As the family size increases by one-unit, economic efficiency decreases by 0.03 units and if level of education increases by 1unit it will increase the economic efficiency by 0.005 units.

It is clear from Table 2 that the beneficiary farmers' education level and area under crop have a considerable impact on allocative efficiency. For every unit increase in the beneficiary farmers area under crop and educational level, the allocation efficiency increases significantly by 0.12 and 0.005 units, respectively. Similar to non-beneficiary farmers, education and crop area have a significant impact on allocative efficiency. When education level and crop area both rise by 1 unit, they are going to increase the allocative efficiency by 0.10 and 0.005 units, respectively.

In case of scale efficiency, the area under crop and the assistance provided by the government had a big impact in case of beneficiary farmers, when each of these factors increases by 1 unit, they will increase the scale efficiency by 0.25 and 0.16 units, respectively. The same factors have a negative impact in case of non- beneficiary farmers, if we increase both factors by one unit, the scale efficiency will decline by 0.27 and 0.14 units, respectively.

In terms of technical efficiency (crs), the education level and government support had a significant effect in case of beneficiary farmers, when these factors increases by 1 unit, they will rise the technical efficiency (crs) by 0.006 and 0.13

units, respectively. In case of non- beneficiary, area under crop and educational level has significant effect on technical efficiency (crs), if we increase both of the factors by one unit, technical efficiency (crs) will increase by 0.163 and 0.01 units, respectively.

In case of beneficiary farmers, educational level and government support had positive significant effect while area under crop had negative significant effect on technical efficiency (vrs). If we increase the crop area by one unit, then the technical efficiency (vrs) will decrease by 0.05 units while the increase in educational level and government support by 1 unit will increase the technical efficiency (vrs) by 0.003 and 0.09 units, respectively.

Table 2: Factors affecting technical, allocative, economic and scale efficiency of Peas

Dependent variable	Economic Efficiency		Allocative Efficiency		Scale Efficiency		Technical Efficiency (crs)		Technical Efficiency (vrs)	
	Beneficiary	Non beneficiary	Beneficiary	Non beneficiary	Beneficiary	Non beneficiary	Beneficiary	Non beneficiary	Beneficiary	Non beneficiary
Intercept	-0.0263	1.301562	1.279834	0.309872	2.07114	0.378421	0.12253	2.375227	0.665081	0.532233
Independent Variable										
Family size	0.018	-0.034*	0.00757	-0.004	-0.001	0.014	0.011	-0.008	-0.006	0.018*
	(0.013)	(0.019)	(0.012)	(0.013)	(0.018)	(0.016)	(0.011)	(0.010)	(0.006)	(0.009)
Area under crop	0.103	0.093	0.128*	0.107*	0.259**	-0.272***	0.012	0.163***	-0.054*	0.009
	(0.066)	(0.069)	(0.063)	(0.055)	(0.097)	(0.077)	(0.046)	(0.048)	(0.030)	(0.049)
Education	0.007**	0.005*	0.008**	0.005*	0.007	0.015	0.006***	0.017**	0.003**	0.003
	(0.002)	(0.002)	(0.003)	(0.002)	(0.004)	(0.009)	(0.002)	(0.006)	(0.001)	(0.002)
Govt financial support	0.113*	-0.024	0.042	-0.051	0.163*	-0.143*	0.131***	-0.052	0.094***	0.074*
	(0.060)	(0.062)	(0.058)	(0.043)	(0.085)	(0.068)	(0.044)	(0.041)	(0.031)	(0.035)
No. of Observations	33	25	33	25	33	25	33	25	33	25
log likelihood	10.039179	11.73856	10.88729	20.07049	-3.39956	14.66781	20.19361	22.50422	33.92653	25.89143

(Figures in parentheses denotes standard error)

***denotes significant at 1 percent level, ** significant at 5 percent level, *significant at 10 percent level

Conclusion

In case of pea crop, there was significant difference in all the efficiencies among beneficiary and non-beneficiary farmers. Beneficiary farmers were 83 percent technically efficient while non-beneficiary farmers were 81 percent technically efficient which is less as compared to beneficiary farmers. Significant factors affecting allocative efficiency were area under crop and education while significant factor affecting scale efficiency was area under crop. The similar findings were reported by Dhungana *et al*. (2004) [7], Akinbode *et al*. (2011) [3], Ajao *et al*. (2012) [2], Debebe *et al*. (2015) [6], Asghar *et al*. (2018) [4], Ahmed *et al*. (2015) [1] and Mukhtar *et al*. (2018) [11].

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