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An economic analysis of factors affecting efficiency of KVK adopted and non-adopted farmers in Chhattisgarh: A DEA approach

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Abstract
In this study, an attempt was made to identify the various socio economic and ecological factors of Krishi Vigyan Kendra (KVK) adopted and non- adopted farmers determining the Technical Efficiency levels in district. The study revealed that Tobit regression showed the variation was related to farm-specific attributes such as adoption status, caste, literacy, family size, age, nonfarm income, land holding, fertilizer quantity and variety type. In case of economic efficiency independent variable caste and fertilizer quantity were significant. In case of allocative efficiency independent variable family size was positively significant. Scale efficiency crop variety and land holding significant and technical efficiency variable adoption status and land holding were significant.

Keywords: allocative efficiency, economic efficiency, DEA approach, scale efficiency, technical efficiency, Tobit regression

Introduction
Improvement in farm economic efficiency is very important factor of productivity growth especially in developing economies, where resources are meager and opportunities for developing and adopting better technologies have lately started dwindling. The concept of efficiency is the core of economic theory. The crucial role of efficiency in increasing agricultural output has been widely recognized by researcher and policy makers alike.
The study used DEA approach. Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontiers It is used to empirically measure productive efficiency of decision making units (DMUs). Although DEA has a strong link to production theory in economics, the tool is also used for benchmarking in operations management, where a set of measures is selected to benchmark the performance of manufacturing and service operations. In benchmarking, the efficient DMUs, as defined by DEA, May not necessarily form a "production frontier", but rather lead to a "best-practice frontier"

Significance of the study
Most of the researchers used to measure efficiency differentials among farms with simple measures, such as yield per hectare and cost per unit of output, which are easy to calculate and understand, but tell us very little about the reasons for any observed differences among farms. Yield-per-hectare figures are of little use when the amounts of non-land inputs used (such as labour and fertilizer) differ among farms. Cost per unit of output generally addresses the problems with yield comparisons, but they can also be quite misleading measures of performance when input prices differ across geographical regions. Furthermore, simple cost comparisons do not tell us what portion of the cost difference is due to inefficient use of the given input bundle (technical inefficiency) and what part is due to the incorrect choice of input ratios, given the input prices faced by the farmer (allocative inefficiency). In addition, neither yield nor unit cost measures tell us anything about the existence, or otherwise, of scale economies. So in this study, an attempt was made to avoid the problems inherent in these simple measures were taken by constructing non-parametric production frontiers using data envelopment analysis (DEA) and then used them to produce a range of efficiency measures. Here four different measures: technical efficiency, allocative efficiency, economic efficiency and scale efficiency.

Objective
To know the factors affecting Technical, allocative, economic and scale efficiency selected farmers.

Methodology
Since the study was based on a sample of KVK adopted farmers, a list of 45 adopted farmers was obtained, and equal numbers of non-adopted farmers were selected by proportionate random sampling method from the vicinity of adopted farmers to minimize the difference in various characteristics of farm, farmers and the environment faced by them thereof. The study was based on primary data collected from various sample respondents. Primary data were collected using pretested interview schedule and personal interview of selected respondents by survey method. The required secondary data were collected from the annual report and other publications of Krishi Vigyan Kendra. The collected primary data pertained to the agricultural year 2018-2019.The analysis of data was done using different analytical tools, keeping in view the objective of the study.

Technical efficiency
The technical efficiency was examined by Data Envelopment Analysis (DEA) using R software. The DEA method is a non-parametric approach to measurement of efficiency. It does not assume a production function like Stochastic Frontier Analysis does. However, neither of the two can be said as better to the other (Watkins, 2013) [8]. DEA consists in preparing an efficient frontier with which to compare the inputs and outputs of the DMUs. In the terminology of DEA, a farm is a decision making unit (DMU). Technical efficiency (TE) refers to the ability of a DMU to produce the maximum feasible output from a given bundle of inputs, or the minimum feasible amounts of inputs to produce a given level of output. The former definition is referred to as output-oriented TE, while the latter definition is referred to as input-oriented TE. Allocative efficiency (AE) refers to the ability of a technically efficient DMU to use inputs in proportions that minimize production costs given input prices. Allocative efficiency is calculated as the ratio of the minimum costs required by the DMU to produce a given level of outputs and the actual costs of the DMU adjusted for TE. Economic efficiency (EE) is the product of both TE and AE. Thus, a DMU is economically efficient if it is both technically and allocatively efficient. Economic efficiency is calculated as the ratio of the minimum feasible costs and the actual observed costs for a DMU.
The technical efficiency score of the nth farm was found out using following DEA linear programming formulation:

$$TE_n = min\lambda,\theta n\ \theta_n$$
s. t.
$$\sum_{i}^{I} \lambda i Xij - \theta_n Xnj \leq 0$$
$$\sum_{i}^{I} \lambda i Y\,ik - Y\,nk \geq 0$$
$$\sum_{i}^{I} \lambda i = 1$$
$$\lambda i \geq 0$$

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 λi is the non-negative weight associated with i^{th} farm. When ∑ λi 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.

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

Economic efficiency: Economic efficiency was found out by cost minimizing linear programming formulation.

$$MC_n = min\lambda i X*'nj \sum_{j=1} P\,nj\ X*nj$$
s. t.
$$\sum_{i}^{I} \lambda i Xij - \theta_n X*'nj \leq 0$$
$$\sum_{i}^{I} \lambda i Y\,ik - Y\,nk \geq 0$$
$$\sum_{i}^{I} \lambda i = 1$$
$$\lambda i \geq 0$$

Where Mcn is the minimum cost for the nth farm and Pnj is the price of jth input for nth farm. Then economic efficiency would be calculated as following

$$EEn = \frac{\sum_{j=1} P\,nj\ X*'nj}{\sum_{j=1} P\,nj\ Xnj}$$

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

Tobit regression: Tobit regression was used to find out factors affecting technical and economic efficiency of adopted and non-adopted farmers in the district.

Result
Factors affecting economic, allocative, scale and technical efficiency of adopted and non-adopted farmers
To examine the factors affecting the gross return of adopted and non-adopted farmers a Tobit regression model was fitted. The value of intercept means without considering all the variables included on the model the farmer got this value as return.
Upon increasing area under crop by one acre the allocative efficiency decrease by 0.017 units and technical efficiency (vrs) increases by 0.194 units.
When area irrigated increases by one acre the economic efficiency decreases by 0.018 units and technical efficiency (vrs) also decreases by 0.186 units.
Compare to non-adopted farmers, adopted farmers economic efficiency is higher by 0.075 units and positively significant at 0.1 percent level of significant that means if farmer is adopted by KVK his economic efficiency increases by 0.075 units. The Scale efficiency of adopted farmers is higher by 0.092 units than non-adopted farmers. The technical efficiency (vrs) of adopted farmers is also higher by 0.05 units compare to non-adopted farmers and technical efficiency (crs) of adopted farmers is higher by 0.006 units than non-adopted farmers.

The family size increases by one unit the allocative efficiency increases by 0.052 units and positively significant on an average while other thing held constant and have positive influence and technical efficiency (vrs) increases by 0.029 units and technical efficiency (crs) decreases by 0.016 units on an average while other thing held constant.

The economic efficiency for a farmer belonging to ST caste is higher by 0.301 units compare to the farmers belonging to rest of the caste.

One unit increasing in fertilizer quantity (kg acre^{-1}) increases the economic efficiency by 0.0009 units and positively significant on an average while other thing held constant and allocative efficiency decreases by 0.0009 units. Scale efficiency increases by 0.007 units.

One unit increasing in variety type swarna increases the scale efficiency by 0.301 units and positively significant on an average while other thing held constant.

The economic efficiency for medium land holder farmer is less by 0.179 units and scale efficiency higher by 0.137 units and technical efficiency (crs) is less by 0.098 units on an average while other thing held constant.

The economic efficiency for small land holder is less by 0.209 units and scale efficiency higher by 0.310 units same as technical efficiency (crs) higher b 0.204 units and positively significant on an average while other thing held constant.

The technical efficiency (crs) for machine to inventory ratio of farmers is less by 0.071 units on an average while other thing held constant.

The economic efficiency for a farmer belonging to literacy middle school is less by 0.174 units compare to the farmers belonging to rest of the education level.

The economic efficiency for a farmer belonging to literacy high school is less by 0.096 units compare to the farmers belonging to rest of the education level.

The Allocative efficiency for variable age is less by 0.006 units, scale efficiency is higher by 0.006 units positively significant and technical efficiency (crs) is higher by 0.004 units on an average while other thing held constant.

Upon increasing nonfarm income1 (Rs 1001-10000) by one unit the scale efficiency increase by 0.307 units and technical efficiency (vrs) increases by 0.097 units on an average while other thing held constant.

When non-farm income 2 (Rs 10001-50000) increases by one unit the scale efficiency increases by 0.207 units and technical efficiency (vrs) also increases by 0.157 unit.

The R Square was significant and Economic efficiency, allocative efficiency and scale efficiency, technical efficiency VRS and technical efficiency CRS were respectively 0.25, 0.94, 0.19, 0.20 and 0.23 which indicate a fairly good fit of the regression model.

Determinants of economic, allocative, scale and technical Efficiency

Dependent Variable	EE	AE	SE	TE (VRS)	TE (CRS)
Intercept	0.926*** (7.21)	1.217***(5.92)	0.117 (0.40)	0.484 (4.68)	0.816*** (12.68)
Independent Variable	Regression Coefficient				
Area under crop (acre)	-	-0.017* (-2.34)	-	0.194 (1.95)	-
Area irrigated (acre)	-0.018** (-2.90)	-	-	-0.186 (-1.88)	-
Adoption status Yes (Dummy)	0.075* (2.24)	-	0.092 (2.04)	0.050 (0.65)	0.006 (0.18)
Family size (number)	-	0.052** (2.76)	-	0.029 (2.89)	-0.016* (-2.19)
Caste ST (Dummy)	0.301* (2.58)	-	-	_	-
Fertilizerquantity (kg acre^{-1})	0.0009*** (-4.68)	-0.0009` (-1.66)	0.0007 (1.64)	-	-
Variety type swarna	-	-	0.301` (1.71)	-	-
Landholding Medium (Dummy)	-0.179** (-2.97)	-	0.137` (1.74)	-	-0.098* (-2.26)
Land holding Small (Dummy)	-0.209** (-2.67)	-	0.310*** (3.71)	-	0.204*** (-4.82)
Machine to inventory ratio	-	-	-	-	-0.071* (-2.02)
Literacy Middle school (Dummy)	-0.174** (-3.36)	-	-	-	-
Literacy High school (Dummy)	-0.096* (-2.11)	-	-	-	-
Age	-	-0.006 (-1.43)	0.006* (2.31)	0.004 (1.90)	-
Nonfarm income1 (Rs.1001- 50000) (Dummy)	-	-	0.307*** (4.01)	0.097 (1.89)	-
Nonfarm income2 (Rs.50001-100000) (Dummy)	-	-	0.207* (2.27)	0.157 (2.63)	-
R^2 Adjusted	0.255	0.940	0.197	0.207	0.236
F statistic (F critical)	3.549 (1.880)	2.848 (2.323)	3.427 (1.999)	3.587 (1.999)	6.502 (2.323)
No. of Observations	90	90	90	90	90
AIC	-367.28	-191.64	-225.33	-303.96	-326.5

Figures in parenthesis are calculated t-values. Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Conclusion

A censored regression or Tobit model was used. Efficiency measures are regressed on area under crop, area irrigated, adoption status, family size, caste ST, Fertilizer quantity, variety type swarna, land holding small and medium, machine to inventory ratio, Literacy middle school and high school, age and nonfarm income 1 and 2. In case of Economic efficiency measures are regressed on area irrigated, adoption status, Caste ST, Fertilizer quantity, land holding small and medium, Literacy middle school and high school and intercept representing adoption status no, Caste SC, OBC, GEN, Land holding large, literacy graduation above and illiterate and non farm income 0 and 3. In case of allocative efficiency measures are regressed on area under cultivation, adoption yes, family size, fertilizer quantity and age and intercept representing adoption status no. In case of scale efficiency measures are regressed on fertilizer, variety type swarna, land holding medium and small, age and non-farm income 1 and 2. In case of Technical efficiency (CRS) efficiency measures are regressed on adoption status, family size, land holding medium and small and machine to inventory and intercept representing adoption status no and land holding large. The findings were supported with the work of Dhungana *et al.* (2004) [6], Akinbode *et al.* (2011) [3], Ajao *et al.* (2012) [2] Debebe *et al.* (2015) [5], Asghar *et al.* (2018) [4], Ahmed *et al.* (2015) [1] and Mukhtar *et al.* (2018) [7].

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