Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(1): 803-807
Received: 08-11-2017
Accepted: 09-12-2017

V Kathiravan
Assistant Professor, Agricultural Economics, the Indian Agriculture College, Radhapuram, Tirunelveli, Tamil Nadu, India

D David Rajasekar
Professor, Department of Agricultural Economics, AC & RI, Madurai, Tamil Nadu, India

S Saranya
M.Sc Scholar, Department of Agricultural Economics, AC & RI, Madurai, Tamil Nadu, India

Correspondence
V Kathiravan
Assistant Professor, Agricultural Economics, The Indian Agriculture College, Radhapuram, Tirunelveli, Tamil Nadu, India

Data envelopment analysis to estimate technical and scale efficiency of irrigated and dry farms in Salem district of Tamil Nadu

V Kathiravan, D David Rajasekar and S Saranya

Abstract
The study is focused to analyse the technical and scale efficiency of irrigated and dry farms in overall production of crops in Salem District of Tamil Nadu. The input oriented Data Envelopment Analysis (DEA) was applied to estimate technical, pure technical and scale efficiency of the farms. A random sampling procedure was used to select 180 sample respondents. The Data Envelopment Analysis was used to examine the technical and scale efficiency of different crop enterprises under irrigated and dry farm situations. The study revealed that the technical inefficiency was less in irrigated farms than in dry farms. Similarly the scale inefficiency was found high in dry farms than in irrigated farms. Even though differences exist in mean technical and scale efficiency among dry and irrigated farms. The findings of the study could be helpful to farming community and policy makers to undertake necessary action to improve the current level of technical and scale efficiency in the study area.

Keywords: data envelopment analysis, technical efficiency, scale efficiency, constant return to scale, variable return to scale, input slack

Introduction

One of themain reasons for low productivity in agriculture is the inability of farmers to fully exploit the available technologies, resulting in lower efficiencies of production. The overall production of food grains declined from 259.29 million tonnes in 2011-12 to 252.22 million tonnes in 2015-16. Likewise, the production of pulses declined from 17.09 million tonnes in 2011-12 to 16.47 million tonnes. In oil seeds the production declined from 29.80 million tonnes in 2011-12 to 25.30 million tonnes in 2015-16.The decline in production of sugarcane were from 361.04 million tonnes in 2011-12 to 352.16 million tonnes in 2015-16. In contrast, the rate of population growth was significantly higher than the rate of production, thus offsetting the gains from food grain production at present, which in turn, may lead to scarcity of food grains for the ever expanding population in the years to come. (Pocket Book of Agricultural Statistics, Directorate of Economics & Statistics, 2016). Thus, increasing the efficiency in production assumes greater significance in attaining potential output of the farms. Further, the examination of existing gap between the potential and actual yields on the farm, given the technology and resource endowment of farmers, would provide a better understanding of the yield gap along with the causative factors. Thus, technical efficiency (TE) is an indicator of productivity differences across farms. It may help in exploring the potentiality of the existing technology. Therefore, enhancing the technical efficiency at farm level is the key to meet the requirement of food grains for the growing population in near future. With this end in view, the present study focuses on measuring the efficiency of irrigated and dry farms in Salem District of Tamil Nadu state in India. The study may use to the policymakers in identifying appropriate policies and strategies to improve efficiency of farms.

Methodology

Salem District was selected purposively as the universe of the study. A random sampling method was adopted to select the sample farms. At the first stage, out of 20 blocks 6 blocks in Salem district were purposively selected. At the second stage, all the revenue villages in each of the selected blocks were arranged in the ascending order based on the gross cropped area for the year 2015-16 and three revenue villages from each of the selected 6 blocks were selected at random. At the third stage the lists of farmers were prepared separately for each of the selected 18 villages and arranged in alphabetical order. Then, 10 farmers were selected at random from the farmer lists of each of the villages selected, thus, constituting a total sample size of 180 farmers. The selected sample respondents were personally contacted and the required primary data were collected through personal interview method by using the pre tested interview schedule.

Tools of Analysis

Technical efficiency is the ratio of output to input and it stands for the ability of a farm to produce maximal output from the given resources available in the farm. The Data Envelopment Analysis was used to examine the technical and scale efficiency of different crop enterprises under irrigated and dry farm situations. The DEA method is the frontier method that does not require specification of a functional or distributional form, and can accommodate scale issues. Data Envelopment Analysis (DEA) is a non-parametric model. It does not necessitate assumptions about the production function and the error term distribution, and therefore potential misspecifications are avoided.

Model Specification

In the present case, the DEA method was preferred because data noise was less of an issue as most of the variable in crop production were included and because of this, it has the ability to readily produced rich information on technical efficiency, scale efficiency and peers.

The DEA was applied by using both classic model CRS (Constant Returns to Scale) and VRS (Variable Returns to Scale) with input orientation, in which one seeks input minimization to obtain a particular product level.

Under the assumption of constant returns to scale, the following input oriented linear programming model was used to measure the overall technical efficiency of farms (Coelli *et.al*., 1998):

$$\begin{aligned} &\text{Min } \theta, \lambda\ \theta \\ &\text{Subject to } -y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &\lambda \geq 0 \qquad \ldots\ (1) \end{aligned}$$

Where,

y i is a vector (m x 1) of output of the i th farm,

x i is vector (k x1) of inputs of the i th farm,

Y is a output matrix (n x m) for ‘n’ number of farms,

X is the input matrix (n x k) for ‘n’ number of farms,

θ is the efficiency score, a scalar whose value will be the efficiency measure for each i^{th} farm. If $\theta = 1$, crop producing farms will be efficient; otherwise, it will be inefficient, and

λ is a vector (n x 1) whose values are calculated to obtain the optimum solution.

For an inefficient crop producing farms λ values will be weights used in the linear combination of other, efficient crop producing farms, which influenced the projection of the inefficient crop producing farms on calculated the frontier.

The specification of constant returns is only suitable when the firms work at the optimum scale. Otherwise, the measures of technical efficiency can be mistaken for scale efficiency, which considers all the types of returns to production, i.e., increasing, constant and decreasing. Therefore, CRS model was reformulated by imposing the convexity constraint. The measure of technical efficiency obtained in the model with variable return is also named as “pure technical efficiency”, as it is free from scale effects. Thus, the VRS model to measure the pure technical efficiency is specified as the following linear programming model (Banker and Cooper, 1984) [1]:

$$\begin{aligned} &\text{Min}_{\theta, \lambda}\ \theta \\ &\text{Subject to} \\ &-y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &N1\lambda = 1 \\ &\lambda \geq 0 \qquad \ldots\ (2) \end{aligned}$$

Where,

N1 is a vector (n x 1) of ones.

When there are differences between the values of efficiency scores in the models CRS and VRS, scale inefficiency is confirmed, indicating that return to scale is variable, i.e. it can be increasing or decreasing (Fare and Grosskopf, 1994). The scale efficiency values for each analyzed unit can be obtained by the ratio between the scores for technical efficiency with constant and variable returns as follows:

$$\theta s = \theta CRS(XK, YK) / \theta VRS(XK, YK) \qquad \ldots\ (3)$$

Where,

$\theta CRS\ (XK, YK)$ = Technical efficiency for the model with constant returns,

$\theta VRS\ (XK, YK)$ = Technical efficiency for the model with variable returns, and

θs = Scale efficiency.

It is pointed out that model (2) makes no distinction as to whether crop producing farms is operating in the range of increasing or decreasing returns (Coelli *et al*., 1998). The only information one has is that if the value obtained by calculating in the scale efficiency in Equation (3) is equal to one, the crop producing farms will be operating with constant returns to scale. However, when θs is smaller than one, increasing or decreasing return can occur. Therefore, to understand the nature of scale inefficiency, it is necessary to consider another problem of linear programming, i.e. the convexity constraint of model (2), where $N1\lambda = 1$, is replaced by $N1\lambda \leq 1$ for the case of non-increasing returns, or by $N1\lambda \geq 1$, for the model with non-decreasing returns. Therefore, in the present study, the following models were also used for measuring the nature of efficiency.

Non-increasing returns

$$\begin{aligned} &\text{Min } \theta, \lambda\ \theta \\ &\text{Subject to } -y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &N1\lambda \leq 1 \\ &\lambda \geq 0 \qquad \ldots\ (4) \end{aligned}$$

Non-decreasing returns

$$\begin{aligned} &\text{Min } \theta, \lambda\ \theta \\ &\text{Subject to } -y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &N1\lambda \geq 1 \\ &\lambda \geq 0 \qquad \ldots\ (5) \end{aligned}$$

It is to be stated here that all the above model should be solved ‘n’ times, i.e. the model should be solved for each crop producing farms in the sample.

The net income from different crops cultivated by the individual farmer was taken as the output variable in DEA model and expressed as rupees per farm. The input variables (X) include human labour in days, farmyard manure in tonnes, nitrogen in Kg, phosphorus in Kg, potash in Kg, machine power in machine hours and cost of plant protection chemicals in rupees.

Results and Discussion

Technical and Scale Efficiency of Irrigated Farms

The results of the Data Envelopment Analysis for the irrigated farms in Salem district is furnished in Table 1.

Of the total 97 irrigated farms in Salem district, 24.74 per cent (24 farms) were found to operate with the overall technical efficiency of more than 0.90 under constant returns to scale (CRS) and the rest 73 farms constituting 75.25 per cent of farms were technically inefficient with respect to input allocation in crop production. The overall technical efficiency of irrigated farms ranged from 0.55 to 1.00 with the mean efficiency of 0.80.

The result indicated that the 73 farms (75.25 per cent) which did not operate at the maximum efficiency level could reduce the present level of input usage by 20 per cent and could still maintain the same level of production as achieved by 24.74 per cent of the technically efficient irrigated farms in the region.

Table 1: Technical and Scale Efficiency of Irrigated Farms

S. no	Descriptive Statistics	CRSTE	VRTSTE	SE
Total Farms -97				
	No. of Efficient Farmers (More than 0.90)	24 (24.74)	43 (44.32)	21 (21.64)
1	Mean	0.80	0.92	0.76
2	Standard Deviation	0.21	0.12	0.13
3	Minimum	0.55	0.72	0.59
4	Maximum	1.00	1.00	1.00

Note: Figures in parentheses are percentage to total farmers in respective farm size; CRSTE- Technical Efficiency under Constant Returns to Scale; VRSTE- Technical Efficiency under Variable Returns to Scale; SE - Scale Efficiency

The pure technical efficiency as calculated by using variable returns to scale model ranged from 0.72 to 1.00 with mean efficiency score of 0.92. Relaxing the assumption of constant returns to scale and using the convexity model with the assumption of variable returns to scale indicated that the irrigated farms with pure technical efficiency score more than 90 per cent of efficiency increased from 24.74 per cent to 44.32 per cent and the mean technical efficiency increased from 0.80 to 0.92 as compared to constant returns to scale model, because pure technical efficiency calculated is devoid of scale effects and the difference between technical efficiency under constant returns to scale and variable return to scale stands for scale inefficiency.

About 21.64 per cent of the irrigated farms were found with the scale efficiency of more than 0.90 and the rest 78.36 per cent were operating in a less than optimal size. The scale efficiency among irrigated farms ranged between 0.59 and 1.00 with mean scale efficiency score of 0.76. The above result indicated that 78.36 per cent of irrigated farms which were operating in less than optimal size (scale inefficiency) could increase their scale efficiency by 24 per cent by operating in optimal scale under current technology. This would enable the irrigated farms to operate in optimal scale and would increase the productivity and income from irrigated farms in the region.

Scale of Operation in Irrigated Farms

Scale of operation of irrigated farms as furnished in Figure 1. revealed that 31.42 per cent of farms were operating under decreasing returns to scale (supra optimal level), 45.25 per cent operating under increasing returns to scale (sub optimal level) and 24.33 per cent operating under constant returns to scale (optimal farms).

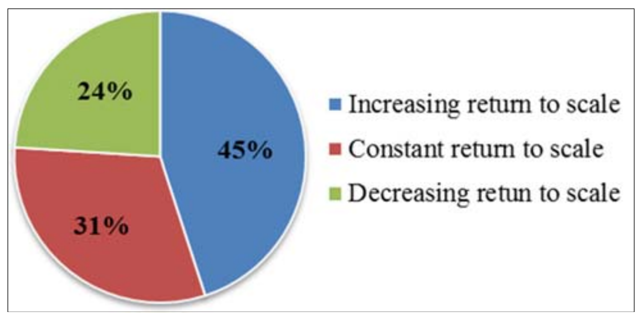

Fig 1: Scale of operations in irrigated

Input Slacks in Irrigated Farms

The mean input slacks, mean input usage and the percentage of excess inputs available in irrigated farms are presented in Table 2.

Table 2: Mean Input Usage and Mean Input Slacks in irrigated Farms

S. No	Inputs	Mean input slack	Mean input used	Excess input (in per cent)
1.	Farm Yard Manure in Tonnes/ ha	0.40	10.90	3.66
2.	Labour in Man days/ha	4.93	159.34	3.09
3.	Machine hours in Hrs/ha	0.81	19.69	4.11
4.	Nitrogen in Kg/ha	5.27	177.54	2.96
5.	Phosphorus in Kg/ha	10.32	134.5	7.67
6.	Potash in Kg/ha	10.73	130.18	8.24
7.	Plant Protection in Rs/ha	143.56	1980.12	7.25

A slack indicates excess of an input available in a farm, so that the farm could reduce its expenditure on this input by the amount of slack without reducing its output. The greatest slack was found in potash (8.24 per cent) followed by phosphorus (7.67 per cent), plant protection chemicals (7.25 per cent), machine hours (4.11 per cent), farmyard manure with (3.66 per cent), labour (3.09 per cent) and nitrogen (2.96 per cent), in the irrigated farms. The above results indicated that a farm could reduce its expenditure on these inputs by the amount of slack without reducing its output.

Technical and Scale Efficiency of Dry Farms

The results of the Data Envelopment Analysis for the dry farms in Salem district is furnished in Table 3.

Of the total 64 dry farms in Salem district, 20.31 per cent (13 farms) were found to operate with the overall technical efficiency of more than 0.90 under constant returns to scale (CRS) and the rest 51 dry farms constituting 79.69 per cent of farms were technically inefficient with respect to input allocation in crop production. The overall technical efficiency of dry farms ranged from 0.56 to 1.00 with the mean efficiency of 0.79.

The result indicated that the 51 dry farms (79.69 per cent) which did not operate at the maximum efficiency level could reduce the present level of input usage by 21 per cent and could still maintain the same level of production as achieved by 20.31 per cent of the technically efficient dry farms in the region.

The pure technical efficiency as calculated by using variable returns to scale model ranged from 0.69 to 1.00 with mean efficiency score of 0.90. Relaxing the assumption of constant returns to scale and using the convexity model with the assumption of variable returns to scale indicated that the dry farms with pure technical efficiency score more than 90 per cent of efficiency had increased from 79 per cent to 90 per cent and the mean technical efficiency increased from 0.79 per cent to 0.90 as compared to constant returns to scale model, because pure technical efficiency calculated is devoid of scale effects and the difference between technical efficiency under constant returns to scale and variable return to scale stands for scale inefficiency.

Table 3: Technical and Scale Efficiency in Dry Farms

S. No	Descriptive Statistics	CRSTE	VRTSTE	SE
Total Farms -64				
	No. of Efficient Farmers (More than 0.90)	13 (20.31)	33 (51.56)	14 (21.87)
1	Mean	0.79	0.90	0.85
2	Standard Deviation	0.15	0.24	0.14
3	Minimum	0.56	0.69	0.53
4	Maximum	1.00	1.00	1.00

Note: Figures in parentheses are percentage to total farmers in respective farm size; CRSTE- Technical Efficiency under Constant Returns to Scale; VRSTE- Technical Efficiency under Variable Returns to Scale; SE - Scale Efficiency.

About 21.87 per cent of the dry farms were found with the scale efficiency of more than 0.90 and the rest 78.13 per cent were operating in a less than optimal scale size. The scale efficiency among dry farms ranged between 0.53 and 1.00 with mean scale efficiency score of 0.85. The above result indicated that 78.13 per cent of dry farms which were operating in a less than optimal size (scale inefficiency) could increase their scale efficiency by 15 per cent by operating in optimal scale under current technology. This would enable the dry farms to operate in optimal size, and to increase their farm productivity and income in the region.

Scale of Operation in dry Farms

Scale of operation of dry farms as furnished in Figure 2. revealed that 21.03 per cent of farms were operating under decreasing returns to scale (supra optimal level) and 52.46 per cent operating under increasing returns to scale (sub optimal level) and 26.51 per cent operating under constant returns to scale (optimal farms).

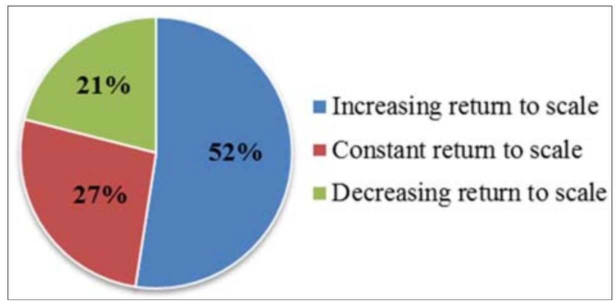

Fig 2: Scale of Operations in dry farms

Input Slacks in Dry Farms

The mean input slacks, mean input usage and the percentage of excess inputs available in dry farms of Salem district are presented in Table 4.

Table 4: Mean Input Usage and Mean Input Slacks in Dry Farms

S. No.	Inputs	Mean input slack	Mean input used	Excess input (in per cent)
1	Seed in Kg/ha	0.234	14.77	1.58
2	Farm Yard Manure in Tonnes/ ha	0.96	12.58	7.63
3	Labour in Man days/ha	2.44	55.71	4.37
4	Machine hours in Hrs/ha	0.259	11.91	2.17
5	Nitrogen in Kg/ha	5.653	64.54	8.76
6	Phosphorus in kg/ha	1.39	40.05	3.47
7	Potash in kg/ha	1.439	40.80	3.52

A slack indicates excess of an input available in a farm, so that the farm could reduce its expenditure on this input by the amount of slack without reducing its output. The greatest slack was found in nitrogen with (8.76) followed by farmyard manure (7.63 per cent), labour in man days (4.37 per cent), potash (3.52 per cent), phosphorus (3.47 per cent), seed (1.58 per cent) and machine hours (2.17 per cent) in the dry farms. The above results indicated that a farm could reduce its expenditure on these inputs by the amount of slack without reducing its output.

Conclusion

The study revealed that the technical inefficiency was less in irrigated farms than in dry farms. Similarly the scale inefficiency was found high in dry farms than in irrigated farms. Even though differences exist in mean technical and scale efficiency among dry and irrigated farms. The technically inefficient farms could improve their technical efficiency by adopting the best practices of technically efficient farms in the region. Similarly the scale inefficient farms could improve their productivity and income by operating in the optimal size.

References

1. Banker RD, Charnes A, *et al*. Some models for estimating technical and scale inefficiencies in data envelopment analysis, Management Science. 1984; 30(9):1078-1092.
2. Deshpande RS, Bhende MJ. Land Resources and Policy in Karnataka, Working Paper 132, Institute for Social and Economic Change, Nagarbhavi, Bangalore, 2003.
3. Murthy Sreenivasa D, Sudha M, Hegde MR, Dakshinamoorthy V. Technical Efficiency and its Determinants in Tomato Production in Karnataka, India: Data Envelopment Analysi (DEA) Approach. Agricultural Economics Research Review. 2009; 22:215-224.

4. Nasurudeen P. Efficiencies of Rice Production in Union Territory of Pondicherry. Agricultural Economics Research Review. 2009; 22:361-364.
5. Orhan Gunduz, Vedat Ceyhan, Kemal Esengun. Measuring the technical and economic efficiencies of the dry apricot farms in Turkey. Journal of Food, Agriculture & Environment. 2011; 9(1):319-324.
6. Srivastava, Prasad B. A study of Income, Saving and Investment on Small, Medium and Large Farms of Rudrapur Block of Nainital District. Agricultural Situation in India. 1989; 39(1):10.
7. Umanath M, David Rajasekar D. Data Envelopment Analysis to Estimate Technical and Scale Efficiency of Farms in Periyar-Vaigai Irrigation System of Tamil Nadu, India. Indian Journal of Science and Technology. 2013; 6(10):5331-5336.