Data envelopment anaylsis in estimating economic efficiency of farm credit for adopting good agricultural practices in mango cultivation in Tamil Nadu, India

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Good agricultural practices (GAPs) in mango production are essential to enable farm produce to be internationally competitive with sufficient institutional credit. Economic efficiency of 0.45 and 0.68 respectively for conventional and GAP farms in Krishnagiri district of Tamil Nadu, India implies that there is scope to increase mango output by 55% and 32% respectively, by optimum allocation of resources. The highest return invested by GAP borrowers might be due to efficient use of resource and GAPs. The extension workers should develop strategies to increase income through adoption of GAPs, efficient use of resources and strengthening the loan delivery mechanism to enhance mango production.

Keywords: Data envelopment analysis, economic efficiency, farm credit, good agricultural practices, mango cultivation.

AGRICULTURAL investment when appropriately structured, can lead to capital deepening, technology transfer and accelerate broader economic development of India. Being the second largest producer of horticultural crops[1], India is in a position to the supply to worldwide market. However, shortage of planting material, infrastructure constraints and lack of proper post-harvest management facilities prevent it from becoming a reliable exporter[2]. The challenge today is to recast horticulture in the new environment of globalization, rising prices, growing domestic demand and more private sector involvement[3]. The high capital cost involved in establishing an orchard or a plantation, or rejuvenation of existing old unproductive plantations poses serious constraints in area expansion under perennial crops, as it requires more investments. The institutional credit has been conceived to play a pivotal role in the agricultural development of India[4]. The substantial credit supply by the money-lending institutions enabled rapid infrastructural growth across the country and improved the absorption capacity of the farm credit as well. The situation becomes all the more difficult in view of the large number of small holdings devoted to these crops, which are essentially owned by the poor farmers, who have no means to invest nor can afford to face the burden of credit, even if available[5]. This calls for liberalized credit facilities in easy instalments for repayment in the form of soft loans to small and marginal farmers to be introduced if the benefits of the horticulture industry are to be fully exploited.

India is renowned for its diverse collection of mango types, each with its own distinct flavour, texture and aroma[6]. The Indian mango is a special product that substantiates the high standards of quality and bountiful nutrients packed in it. The country is the largest producer and also a prominent exporter of fresh mangoes worldwide. India has exported 27,872.78 MT of fresh mangoes worth Rs 327.45 crores during 2021–22 (ref. 7). Mechanization, diversification and commercialization of horticulture, and the changing demand patterns have resulted in increased area and production under mango. Although credit has played a vital role in mango production, there is regional and farm-categorywise disparity. Few farmers with better resource endowments and access to financial and other institutions have benefitted, while the others have not so. Furthermore, multiplicity of lending institutions together with the liberal deployment of credit for mango production through various on-going schemes, including micro-financing has saved rural-dwellers from the clutches of money-lenders. The market potential can also be realized by reforming agricultural practices and making the produce internationally competitive in quality and food safety. To enable farm produce to be internationally competitive, innovative farming practices incorporating the concept of globally accepted good agricultural practices (GAPs) within the framework of commercial agricultural production for long-term improvement and sustainability are essential. In addition to improving the yield and quality of the products, GAPs also have environmental and social dimensions. Implementation of GAPs would promote optimum utilization of agricultural inputs such as pesticides,

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Table 1. Sample villages and number of mango producers

Block	Village	Conventional borrowers	Conventional non-borrowers	GAP borrowers	Total
Bargur	Kullanoor	10	10	10	30
	Pochampalli	10	10	10	30
	Kosapatti	10	10	10	30
Kaveripattinam	Malathampatti	10	10	10	30
	Panagamutlu	10	10	10	30
	Kadhampatti	10	10	10	30
Mathur	Kunnathur	10	10	10	30
	Rangampatti	10	10	10	30
	Sivampatti	10	10	10	30
Total		90	90	90	270

fertilizers, water and eco-friendly agriculture. The social dimension would be to protect the health of agricultural workers against improper use of chemicals and pesticides. It is an opportune time to promote GAPs when the second generation of reforms in agriculture which would have a critical impact on Indian agriculture, has been planned by the Indian Government of India (GoI). In this context, the need for affordable, sufficient and timely supply of institutional credit to adopt the GAPs has assumed critical importance. By encouraging cooperatives, GoI is also helping farmers to reduce the risk of farming by encouraging them to do bulk purchase of inputs and selling of yields, as well as negotiate jointly for credit from financial institutions that are willing to use the wealth of numbers as a form of collateral. The crop loan system or the production-oriented system of lending is conceived as the most appropriate mechanism for mass disbursement of production credit. In this context, the present study was taken up to evaluate the impact of credit or owned capital on returns to investment and also to farm investment.

Methodology

Krishnagiri district in Tamil Nadu is a prominent region is involved in mango cultivation and fruit-processing activity. The area under mango cultivation in the district is about 30,885 ha, with a total production of four lakh tonnes per annum[8]. The National Horticultural Mission, GoI, has already identified the potential in this region, and has identified Krishnagiri for promoting mango cultivation. Hence, it was decided to study the economics and credit impact of mango cultivation in this district. Among the ten blocks in Krishnagiri district, Bargur, Kaveripattinam and Mathur blocks were selected for this study, as production and processing are concentrated in these blocks. The sample mango farmers who borrowed credit for crop production purposes during 2017–18 from institutional sources of credit were classified as borrower farms and the sample farmers who did not borrow credit from any source and who used up their own savings were classified as non-borrower farms. These two categories of mango farmers adopted conventional mango cultivation practices. The third category of mango farmers was referred to as GAP farmers, adopted GAPs during the study period. All GAP farmers were borrowers in the study area and there were no farms without credit under GAPs. All farms were certified for GAPs by the concerned processing firms. The total number of 270 mango farms were selected from Bargur, Kaveripattinam and Mathur blocks of Krishnagiri. From each block, three villages were selected and for each of selected villages a sample of 30 mango growers were selected at random. Among these 30 farmers, 10 each were selected from conventional borrowers, conventional non-borrowers and GAP farmers respectively. The sample size of the conventional borrowers, conventional non-borrowers and GAP farmers was fixed at 90 each (Table 1).

Tools of analysis

The data collected were coded, processed and classified into tables in order to bring out generalization of facts from which meaningful inference could be drawn. Based on the survey, mango-producing period of the sample farms was fixed at 20 years for conventional borrowers, 15 years for conventional non-borrowers and 30 years for GAP farmers. Data envelopment analysis (DEA) was employed to study the technical efficiency of GAP farmers over conventional farmers.

Data envelopment analysis

DEA is a methodology of measuring the relative efficiency of decision-making units[9]. It is a linear programing technique which uses input and output data for a set of mango farms to constructs non-parametric, piece-wise linear production frontier for each farm in the sample. The frontier surface is constructed by the solution of a sequence of linear programing problems for each farm in the sample. An output-oriented DEA model is used to construct the production frontier. It seeks the maximum proportional increase in output, given the levels of input. Production function is defined as the relationship that describes the maximum possible

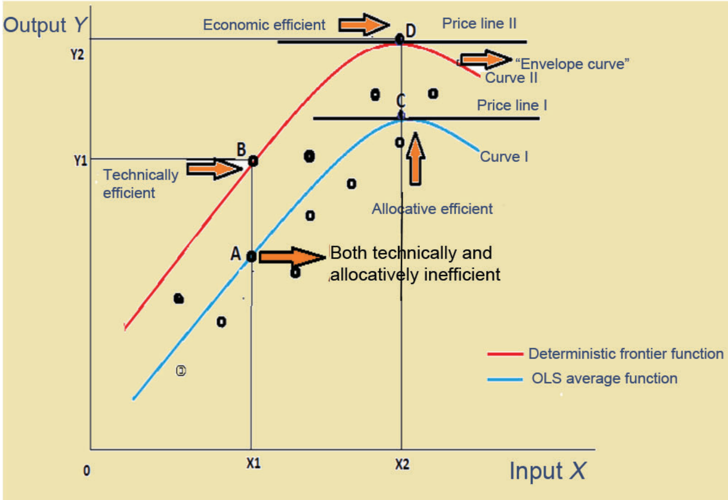

Figure 1. Schematic presentation of the stochastic frontier and average production function.

output for a given combination of inputs[10]. A production function estimated by the ordinary least squares (OLS) method shows an average response and does not represent the frontier. Deterministic approach is used in which a cost frontier is estimated by using linear programing, requiring all observations laid on or above the cost frontier[11]. Farrell's cost frontier was transformed into a production frontier[12]. It is noted that all observations lay on or below the production frontier. Since the outliers under a deterministic approach affect the results, the deterministic frontier was converted into a probabilistic frontier function[13–15]. This approach deletes outlier observations or extreme observations until the estimated coefficients are established and hence, the above probabilistic approach has been used in this study.

Measuring technical efficiency

Using the OLS technique is the general means by which production functions are estimated. It results in the specification of 'average production function', represented by curve I in Figure 1 (OLS average function) for the factor–product situations. The envelope curve (curve II, Figure 1) often referred to as 'maximum technologically possible output' function (deterministic frontier) bring about the theoretical definition of a production function[16].

Let the production function is defined as the envelope curve

$$Y_i = f(X_i). \tag{1}$$

Then the jth farm output may be specified as

$$Y_j = f(X_i) + u_j, \qquad u_j \leq 0, \tag{2}$$

where u_j is the difference between the output obtained by the jth farmer (Y_j) and output estimated from the envelope curve in eq. (1). By definition, eq. (1) is a maximum technologically possible output (MTPO) which implies that u for farm j will be negative or zero. If the farm uses best practice techniques and maximizes output for a given bundle of inputs, then it lies on the MTPO and u_j will be zero (point B, Figure 1). If a farmer does not employ best practice techniques, u_j will be negative, and the farm will lie below the MTPO (point A in Figure 1). The magnitude of u_j will vary among farmers, depending on their individual technical efficiency. A higher value of u_j indicates higher technical inefficiency. If u_j is zero, then the farmer is perfectly technically efficient. The deterministic frontier is defined as the maximum output attainable from a given set of measured inputs and technology.

Empirical model for measuring efficiency in mango farms

The estimated Cobb–Douglas production function is estimated as

$$\ln(Y) = \beta_0 + \beta_1 \ln A + \beta_2 \ln M + \beta_3 \ln F + \beta_4 \ln L + \beta_5 \ln P + e, \tag{3}$$

where Y is the yield per hectare (kg), A the age of the mango tree (years), M the farmyard manure (tonnes), F the fertilizer used (kg), L the labour (man days) and P is the plant protection chemicals (kg).

The production function in eq. (3) was first estimated by the OLS method. It was transformed into a deterministic frontier production function as follows:

The objective function is to minimize

$$\beta_0(1) + \beta_1 \ln \overline{A} + \beta_2 \ln \overline{M} + \beta_3 \ln \overline{F} + \beta_4 \ln \overline{L} + \beta_5 \ln \overline{P} + e. \tag{4}$$

Subject to

$$\beta_0(1) + \beta_1 \ln A_1 + \beta_2 \ln M_1 + \beta_3 \ln F_1 + \beta_4 \ln L_1 + \beta_5 \ln P_1 \geq Y_1$$

$$\beta_0(1) + \beta_1 \ln A_2 + \beta_2 \ln M_2 + \beta_3 \ln F_2 + \beta_4 \ln L_2 + \beta_5 \ln P_2 \geq Y_2$$

$$\beta_0(1) + \beta_1 \ln A_{90} + \beta_2 \ln M_{90} + \beta_3 \ln F_{90} + \beta_4 \ln L_{90} + \beta_5 \ln P_{90} \geq Y_{90} \quad (5)$$

where $\overline{A}$, $\overline{M}$, $\overline{F}$, $\overline{L}$ and $\overline{P}$ are the mean values of the respective inputs. The deterministic function coefficients used in estimating efficiencies were obtained from eq. (4) after deleting outlier observations until the estimated efficiencies were stabilized. In the analysis, stabilization was obtained after deleting five observations one by one.

From the deterministic function coefficient, farm specific technical efficiency (TE) was estimated as follows

$$TE = AF_i/MF_i, \quad (6)$$

where AF_i is the actual farm output and MF_i is the maximum possible output which is estimated by substituting the resources of the ith farm into the deterministic frontier production function. Farm-specific allocative efficiency (AE_{ji}) in the use of a factor (j) is

$$AE_{ji} = MF_i/OF_i,$$

where MF_i is the maximum possible output estimated by substituting the resources of the ith farm into the deterministic frontier production function. OF_i is the output as the optimum level of jth input, with all other inputs remaining at the level at which the ith farm used them. The optimum input level is estimated by equating marginal value product of an input with its marginal cost.

The allocative efficiency (AE_i) of all inputs on the ith farm was estimated to be

$$AE_i = MF_i/GF_i, \quad (7)$$

where MF_i is the maximum possible output estimated by substituting the resources of the ith farm into the deterministic frontier production function. GF_i is the farm output at the optimum level of all inputs.

Individually, these efficiency measures are averaged over a number of observations to arrive at a single value for measuring technical and allocative efficiency. Farm-specific economic efficiency (EE) was estimated as follows

$$EE = TE \times AE. \quad (8)$$

Economic inefficiency was calculated by deducting the value of EE from one.

Results and discussion

DEA was employed to determine which of the mango farms were most efficient, and to identify specific inefficiencies of the other farms. The core part of DEA analysis lies in finding the best mango producing potential for each sample mango producing farms. All the producers can then be combined to form a composite producer with composite inputs and composite outputs. Since this composite producer does not necessarily exist, it is called a best producer. The producer is considered as efficient if best output is more than the actual output for a given input level. This is known as output-oriented technical efficiency.

OLS, deterministic Cobb–Douglas production frontier for mango conventional borrower farms

In case of conventional borrower farms, the regression coefficients in Table 2 clearly indicate that the marginal effects of factors affecting mango productivity vary between the two estimating procedures, demonstrating the importance of allowing for threshold effects of the explanatory factors.

It could be inferred from the OLS estimation that the plant protection chemicals influenced the output more at 10% significant level when compared to other inputs used in mango production. The coefficients value of plant protection chemicals was 0.29, which shows their major contribution to the total yield. The plant protection chemicals have been used by farmers to control weeds and insects, and their remarkable increases in agricultural products have been reported[17]. Farmyard manure influences mango yield at 5% significance level. The number of saplings, plant protection chemicals and labour influenced mango yield at 10% significance level, except fertilizers, which was not significant. These four variables showed less contribution to mango yield when compared to plant protection chemicals in the category of conventional borrower farms. In this category, most of the coefficients in the deterministic frontier function have shifted, implying that the frontier envelop shifts vertically. The deterministic frontier function shows response to the best practice of progressive farmers in the category of conventional farmers.

OLS, deterministic Cobb–Douglas production frontier for mango GAP borrower farms

The OLS estimates for GAP borrower farms revealed that the number of saplings, farmyard manure, fertilizers and labour were significant factors for production, except plant protection chemicals in these sample mango farms (Table 3). This might be due to under-use of resources by the

Table 2. Estimates of ordinary least squares (OLS), deterministic Cobb–Douglas production frontier for mango conventional borrower farms

Parameter	Average function estimated through OLS	Deterministic frontier estimated using data envelopment analysis (DEA)
Intercept	0.3658	0.3301
Number of saplings	0.1431*	0.1515
Farmyard manure	0.1701**	0.1782
Fertilizers	0.1643^{NS}	0.1725
Plant protection chemicals	0.2903*	0.3061
Labour	0.1489*	0.1594
N	90	90

**Significant at 5%; *Significant at 10% and NS, Nonsignificant.

Table 3. Estimates of OLS, deterministic Cobb–Douglas production frontier for mango good agricultural practices (GAP) borrower farms

Parameter	Average function estimated through OLS	Deterministic frontier estimated using DEA
Intercept	0.5823	0.4822
Number of saplings	0.2764*	0.2928
Farmyard manure	0.3808**	0.3904
Fertilizers	0.1123*	0.1212
Plant protection chemicals	0.2493^{NS}	0.2613
Labour	0.3268***	0.3409
N	90	90

***Significant at 1%; **Significant at 5%; *Significant at 10% and NS, Nonsignificant.

'average' farmers. These 'average' farmers operate in the first stage of the production curve and so input elasticities are significant. The OLS function shows the response of the 'average' farmers, while the frontier function shows the response of the 'best practice' farmers. In addition, most of the coefficients in the deterministic frontier function have shifted, implying that the frontier envelop shifts vertically. The deterministic frontier function shows the response to the best practice of the progressive farmers.

Efficiency coefficients in sample mango conventional borrower farms

From the deterministic function using DEA farm-specific technical efficiency, allocative efficiency and economic efficiency for conventional borrower farms were estimated.

The mean technical efficiency estimated for conventional borrower farms was 0.64 (Table 4). Therefore, the technical inefficiency was 0.36. The mean technical efficiency of the DEA models indicate that there is substantial inefficiency for the conventional borrower mango farms in the sample, which confirms the expectations. It reveals that there is 36% potential for increasing mango yield at the existing level of resources by adopting the technology followed by frontier farms. It also highlights the need to strengthen the existing farm extension services so that the available conventional practices could be disseminated from progressive farms to average farms. The overall allocative efficiency was 0.71 and allocative inefficiency was 0.29, which shows that the output could be increased by 29% by optimum allocation of all inputs. Economic efficiency was 0.45 for conventional borrower farms, which implies that there is scope to increase mango output by 0.55% by adopting the conventional practices of progressive farms and by optimum allocation of all resources.

Efficiency coefficients in sample mango GAP farms

The deterministic frontier function was selected for estimating efficiency measures, since it was also selected for outliers. From the deterministic function using DAE, farm-specific technical efficiency, allocative efficiency and economic efficiency for GAP borrower farms were estimated.

Table 5 shows that the technical efficiency estimated for GAP farms is 0.89. Therefore, the technical inefficiency is 0.11. The mean technical efficiencies of the DEA models indicate that there is substantial inefficiency for the GAP mango farms in the sample, which confirms the expectations. It reveals that there is 11% potential for increasing mango yield at the existing level of resources by adopting the technology followed by frontier farms. It also highlights the need to strengthen the existing farm extension services so that the available GAPs could be disseminated from the progressive farms to 'average' farms. The overall allocative efficiency was 0.76 and allocative inefficiency was 0.24, which shows that the output could be increased by 24% by optimum allocation of all inputs. Economic efficiency was 0.68 for GAP borrower farms, which implies that

Table 4. Efficiency coefficients in sample mango conventional borrower farms

Efficiency categories	Efficiency coefficient	Inefficiency coefficient
Technical efficiency	0.6391	0.3609
Allocative efficiency	0.7104	0.2896
Economic efficiency	0.4540	0.5460

Table 5. Efficiency coefficients in sample mango GAP barrower farms

Efficiency categories	Efficiency coefficient	Inefficiency coefficient
Technical efficiency	0.8862	0.1138
Allocative efficiency	0.7644	0.2356
Economic efficiency	0.6774	0.3226

Table 6. Number of conventional borrower mango farms under different efficiency measures

Efficiency categories	<60%	60–80%	>80%	Total
Technical efficiency	27 (30.00)	62 (68.89)	1 (1.11)	90 (100.00)
Allocative efficiency	41 (45.56)	48 (53.33)	1 (1.11)	90 (100.00)
Economic efficiency	67 (74.44)	21 (23.33)	2 (2.22)	90 (100.00)

Figures in parenthesis indicate percentage of the total.

there is scope to increase mango output by 32% by adopting GAPs of progressive farms and optimum allocation of all resources.

Conventional borrower mango farms under different efficiency measures

Table 6 shows the number of conventional borrower mango farms under different efficiency measures. It can be clearly seen that there are 27 farms under the category of technical efficiency less than 60%. More number of conventional borrower farms (i.e.) 68.89% of the total conventional farms, attained technical efficiency of 60–80% and only one farm was under the category of greater than 80% of technical efficiency. In case of allocative efficiency, only one farm was coming under the category of technical efficiency greater than 80%. Also, 45.56% and 53.33% of the farms belonged to the category of less than 60% and 60–80% respectively. Table 6 also reveals that 74.44%, 23.33% and 2.22% of the conventional farms are economically efficient at less than 60%, 60–80% and greater than 80% respectively.

GAP borrower mango farms under different efficiency measures

Table 7 shows the number of GAP borrower mango farms under different efficiency measures. There are no farms were under the category of technical efficiency less than 60%. More number of GAP borrower farms (i.e.) 78.89% of the total GAP farms, attained technical efficiency greater than 80%. In case of allocative efficiency, only two farms are under the category of technical efficiency less than 60%. Also, 34.44% and 63.33% of the farms belong to the category of 60–80% and greater than 80% respectively. Table 7 also shows that 4.44%, 40% and 55.56% of the GAP farms are economically efficient at less than 60%, 60–80% and greater than 80% respectively. More than 60% of the farmers show scale efficiency, which indicates that majority of the farmers do not operate at the optimal scale; they operate far away from the efficiency frontier[18].

Conclusion

The role of credit in mango cultivation has been significant. In modern agriculture, farming has become complex and needs careful planning to achieve success. Transformation of traditional farming to modern commercialization farming needs credit availability. Access to credit for more mango farmers, and appropriate quantity and quality of agricultural credit are crucial for realizing the full potential of mango cultivation as a profitable activity. The results of this study clearly depict that improvement in credit supply for mango cultivation could considerably help increase income from a given set of resources. The extension workers should analyse the resource position of the farms and suggest suitable solutions to increase farming efficiency of progressive farms by adopting GAPs and optimum allocation of all resources. Since economic efficiency is 0.45 for conventional borrower farms and 0.68 for GAP borrower farms, this implies that there is scope to increase mango output in the study area. The cost structure of the crop may be used by the bankers as guidelines for fixing the scale of finance. The role of credit can be further enhanced

Table 7. Number of GAP borrower mango farms under different efficiency measures

Efficiency categories	<60%	60–80%	>80%	Total
Technical efficiency	0 (0.00)	19 (21.11)	71 (78.89)	90 (100.00)
Allocative efficiency	2 (2.22)	31 (34.44)	57 (63.33)	90 (100.00)
Economic efficiency	4 (4.44)	36 (40.00)	50 (55.56)	90 (100.00)

Figures in parenthesis indicate percentage of the total.

by greater financial inclusion involving region-specific market participants, and credit suppliers ranging from public sector banks, cooperative banks, private sector banks and micro-credit suppliers, especially self-help groups.

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