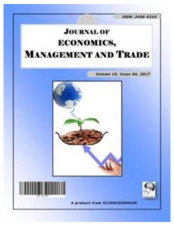

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Technical Efficiency and Its Determinants in Production of Cropping Systems in Kolar District, Karnataka

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Technical efficiency was examined by collecting data from Kolar district of Karnataka under four distinct groups viz., vegetable-based small (VS), vegetable-based large (VL), cereal-based small (CS) and cereal-based large (CL) cropping systems by adopting multistage purposive cum random sampling technique. Data Envelopment analysis (DEA) was used for estimating the technical efficiency and the results indicated that nearly 38.33 per cent of farms under assumption of constant returns to scale performed with the efficiency level equal to 0.9 or greater, i.e., 46 out of 120 farmers in the entire cropping system. Distribution of farms in three regions of production frontier revealed that majority of farms i.e., 70 per cent of the farms in VS, 60 per cent in VL, 77 per cent in CS and 67 per cent in CL systems were found to be operating in the region of increasing returns or the suboptimal region. The production scale of these farms can increased while decreasing costs, since they were performing below the optimum production scale.

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1. INTRODUCTION

Development of appropriate farming and cropping systems as applicable to resources of farmers and also to suite to different agro-ecological zones is the very important for present growth of Indian agriculture as well as during coming years. Efficiency under such scenarios plays an important role as resources are meager and opportunities for developing and adopting better technologies are dwindling [1]. Optimum use of inputs in farming particularly purchased inputs could possibly be achieved through multiple cropping and diversified farming system particularly vegetable-based farming.

Most farmers who practice subsistence farming particularly in cereal-based agriculture with low productivity operates under high inefficiencies (technical and allocative) because of lack of access of inputs as well as inadequate information on use of inputs. Further, low literacy levels limiting interpretation of such information to guide them in commercial production also contributed these inefficiencies. Of late, there is a significant shift towards the vegetable-based farming systems as vegetables provides improved nutrition and better income security to the farmers, which is evidenced in higher vegetable area [2]. Here, farmers' particularly small farmers need to efficiently utilize the limited resources in order to realize increased production and efficiency. Thus, increasing efficiency in cereals production system to sustain the subsistence agriculture and vegetable production system to enhance the income generation is a greater challenge to the scientific and farming communities. The present study is attempted to address some of these issues with the specific objectives of i) examining the profitability of vegetable-based vis-a vis cereal based cropping systems and ii) estimating e technical efficiency of production in various production systems including vegetables based cropping systems.

2. METHODOLOGY

2.1 Study Region and Data

In order to examine the hypothesis that cereal and vegetable based production as well as the scale effect does not influence the profit from production, farmers were classified in four groups viz., i) Vegetable-based Small (VS), ii) Vegetable-based large (VL) iii) Cereal-based small (CS) and iv) Cereal-based large (CL) cropping systems. Multi-stage cum random sampling technique was used to select farmers. In the first stage, the highest vegetable production district in Karnataka i.e, Kolar was selected as it contributes maximum to the total production. In the second stage, two talukas viz., Kolar and Mulbagal were purposively selected based on its significant contribution to the vegetable production. And in the final stage, 12 villages viz., Gandhinagar, Doddasala, Kodiramacahndra, Kallipura, Tamaka and Chikkasala villages in Kolar taluk and Virupakshi, Oorkunte, Gutlur, Varadaganahalli, Doddamadenahalli, Jimmanahalli villages in in Mulbagal taluk were selected, again based on its contribution to vegetable production and cereal production. A total of 120 farmers comprising 30 each in all four groups as specified above were collected from these villages by random method. Further, for analysis pupose, VS and VL cropping system groups were pooled to get vegetable-based cropping systems (VCS) and CS and CL groups to get cereal-based cropping systems (CCS).

Data were collected from both primary and secondary sources. Primary data required on the socio- economic characteristics, land holdings, inventory of implements and machinery, cost and returns of principal crops, non-farm income was collected from the randomly selected farmers for 2011-12 agricultural production period. The secondary data regarding cropping pattern, land utilization and general information of district were collected from Department of Statistics, Kolar.

2.2 Estimation of Technical Efficiency

Technical efficiency refers to the firm's ability to produce the maximum possible output from a given combination of inputs and technology. Several methods like ordinary least squares (OLS) regression, stochastic frontier analysis (SFA) and total factor productivity (TFP) indices using price-based index numbers (PIN), were used to estimate technical efficiency. Although OLS methods are well-known and easy to implement, however requires the specification of a functional form and provides information on average performance rather than frontier performance. While, SFA is an econometric technique that addresses this latter problem, by specifying a composed error term, with one part used to capture data noise and the other inefficiency. However, SFA methods still require a functional form to be specified, plus distribution forms for its composed error structure (Coelli and Battese 1996). PIN methods, such as the popular Tornqvist TFP index, suffer from the problem that it requires access to reliable price information (which is often difficult to obtain) and it does not explicitly accommodate scale effects. Of late, the popular method of estimating the maximum possible output has been the "*data envelopment analysis*" (DEA) advocated by Charnes et al. [3], Murthy et al. [4] which overcome most of these limitations and hence selected in the present study to examine the technical efficiency. The details are given below.

2.3 Data Envelopment Analysis

The DEA method is a frontier method that does not require specification of a functional form or a distributional form, and can accommodate scale issues. This approach was first used by Farrel [5] as a piecewise linear convex hull approach to frontier estimation and later by Boles [6] and Afriat [7]. This approach did not receive wide attention till the publication of paper of Charnes et al. [3], which coined the term data envelope analysis.

DEA was applied by using both classic models 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 assumption of constant returns to scale, the linear programming model for measuring the efficiency of farms are [8].

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

Where

y_i is a vector (*m x 1*) of output of the i^{th} Producing Farms (TPF)

x_i is a vector (*k x 1*) of inputs of the i^{th} TPF

Y is an output matrix (*n x m*) for n TPFs

X is an input matrix *(n x k*) for n TPFs

θ is the efficiency score, a scalar whose value will be the efficiency measure for the i^{th} TPF. If θ =1, TPF will be efficient; otherwise, it will be inefficient.

λ is a vector (*n x 1*) whose values are calculated to obtain the optimum solution. For an inefficient TPF, the λ values will be the weights used in the linear combination of other, efficient, TPFs, which influence the projection of the inefficient TPF on the calculated frontier.

The specification of constant returns is only suitable when the firms are working at optimum scale. Otherwise, measures of technical efficiency can be mistaken for scale efficiency, which considers all types of returns to production, i.e., increasing, constant and decreasing. Therefore, the CRS model is reformulated by imposing a convexity constraint. The measure of technical efficiency obtained in the model with variable returns is also named 'pure technical efficiency' as it is free of scale effects, and the following linear programming model estimates it:

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta \\ &\text{Subject to} \quad -y_i + Y\lambda \geq 0 \\ &\qquad\qquad\quad \theta x_i - X\lambda \geq 0 \\ &\qquad\qquad\quad N_1 \lambda = 1 \\ &\qquad\qquad\quad \lambda \geq 0 \end{aligned} \tag{2}$$

where N_1 is a vector (*n x 1*) of ones.

When there are differences between the values of the efficiency scores in the models CRS and VRS, scale inefficiency is confirmed, indicating that the return to scale is variable, i.e., it can be increasing or decreasing [9]. 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.

$$\theta_s = \theta_{CRS}(X_K, Y_K)/\theta_{VRS}(X_K, Y_K) \tag{3}$$

where

$\theta_{CRS}(X_K, Y_K)$ is the technical efficiency for the model with constant returns

$\theta_{VRS}(X_K, Y_K)$ is the technical efficiency for the model with variable returns

θ_s the scale efficiency.

It was pointed out that model (2) makes no distinction as to whether TPF is operating in the range of increasing or decreasing returns [8]. The only information that one has is that if the value obtained by calculating the scale efficiency in (3) is equal to one, the TPF will be operating with constant returns to scale. However, when θ_s

is smaller than one, increasing or decreasing returns 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), $N_1\lambda = 1$, is replaced by $N_1\lambda \leq 1$ for the case of non-increasing returns, or by $N_1\lambda \geq 1$, for the model with non-decreasing returns. Therefore, in this work, the following models were also used for measuring the nature of efficiency.

Non-increasing returns

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta \\ &\text{Subject to } -y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &N_1\lambda \leq 1 \\ &\lambda \geq 0 \end{aligned} \tag{4}$$

Non-decreasing returns

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta \\ &\text{Subject to } -y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &N_1\lambda \geq 1 \\ &\lambda \geq 0 \end{aligned} \tag{5}$$

It is to state here that all the models presented above should be solved *n* times, i.e., the model is solved for each TPF in the sample.

Gross return (Rs/ha) was used as a output (Y) in the present case and total men labour (man days), total women labour (woman days), farm yard manure (t), plant nutrients N (Kg), P (kg), K (kg) separately, capital inputs (Rs) on plant protection, other input costs and fixed input costs as inputs (X). The models were solved using the DEAP version 2.1 taking an input orientation to obtain the efficiency levels.

3. RESULTS AND DISCUSSION

3.1 Economic Feasibility of Cropping Systems

The profitability of different cropping systems are examined by estimating the per hectare net return as well as return on investment. To arrive-at these figures, the costs and returns of each farms were calculated separately for individual crops, totalled and finally divided with total farm acreage (Table 1). The gross return realised by the farmers in VCS (Rs 3,77,895/ha) is three and a half times higher than income realised by the farmers in CCS (Rs 1,00,153/ha). This substantial higher gross return is because crops included in the VCS systems are tomato, potato, cabbage, cauliflower, which are commercial in nature and provides higher income, which contribute more than 50 per cent to the total income. The net return realised was also higher because of the same reason though the costs are less in CCS. Thus, the farmers in VCS had earned a net return of Rs 1,68,697/ha compared to Rs 29,614/ha. Overall, a return of Rs 1.81 over the rupee of investment is higher in VCS than Rs 1.42 earned in CCS.

Between size groups, SF cropping system (small farmers- includes VS and CS) had realised higher gross income (Rs 2,56,954/ha) than the LF (large farmers- includes VL and CL) cropping systems (Rs 2,21,094/ha) and the net return is nearly 30 per cent higher in SF system (Rs 1,07,787/ha) than LF system (Rs 90,524). Both cropping systems include vegetable and cereal crops and factors that may have influence the production was scale and management efficiencies. As evident in many studies [11,12], the present study also confirms that small farmers are more efficient and realising higher returns than large farmers due to intensive nature of production. However, the difference in the rate of return for every rupee of investment is small (1.72 in SF against 1.69 in LF).

Identifying the best cropping system, which yields highest profit, would help for proper crop planning and budget allocation. VS cropping system with a gross profit of Rs 4, 09, 358/ha and a net return of Rs 1, 90, 179/ha has emerged as the best combination. Undoubtley, vegetable crop is the key in earning higher profit which was maximised by the managerial ability of the small farmers, that reflected in higher return than VL cropping system (gross return of Rs 3,46,432/ha and net rerun of Rs 1, 47, 214/ha). The gross return realised in CS and CL cropping systems are Rs 1,04,550/ha and Rs 95,757/ha., respectively. While the net return in these two systems were Rs 25, 395/ha and Rs 33,834/ha in that order. The return over the rupee spent on investment in cropping system is higher in VS cropping system (1.87) followed in VL (1.74), CL (1.55) and CS (1.32) cropping systems.

3.2 Technical Efficiency of Cropping Systems

Technical efficiency (TE) of the farms were estimated separately under different cropping systems by employing Data Envelop Analysis (DEA). The results of technical efficiency are presented under the following three sub heads.

Table 1. Economic feasibility analysis of vegetable-based cropping system vis-à-vis cereal-based cropping system in Kolar, Karnataka

	Cropping-based systems		Size-based systems		Cropping-size based systems			
	VC	CC	SF	LF	VS	VL	CS	CL
Total cost (Rs/ha)	209198	70539	149167	130570	219179	199218	79155	61923
Total Gross Return (Rs/ha)	377895	100153	256954	221094	409358	346432	104550	95757
Net Return (Rs/ha)	168697	29614	107787	90524	190179	147214	25395	33834
BCR (Rs/ha)	1.81	1.42	1.72	1.69	1.87	1.74	1.32	1.55

Table 2. Range of technical efficiency in various cropping systems in Kolar, Karnataka

TE score	Vegetable cropping systems						Cereal cropping systems						Pooled	
	VS		VL		VC		CS		CL		CC			
	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Up to 0.45	2	6.67	1	3.33	3	5.00	3	10.00	2	6.67	5	8.33	8	6.67
0.45 to 0.60	4	13.33	9	30.00	13	21.67	3	10.00	6	20.00	9	15.00	22	18.33
0.60 to 0.75	6	20.00	5	16.67	11	18.33	7	23.33	5	16.67	12	20.00	23	19.17
0.75 to 0.90	7	23.33	3	10.00	10	16.67	5	16.67	6	20.00	11	18.33	21	17.50
>0.90	11	36.67	12	40.00	23	38.33	12	40.00	11	36.67	23	38.33	46	38.33
Total	30	100.00	30	100.00	60	100.00	30	100.00	30	100.00	60	100.00	120	100
Average TE score	0.7983		0.7657		0.7820		0.7845		0.7659		0.7752		0.7786	

Table 3. Efficiency measures and descriptive statistics for producing farms according to scale of operations in Karnataka

Scale of operations	Efficient farms ($\theta \leq 0.90$)		Efficiency measures			
	No	%	Mean	Standard deviation	Max	Min
VS Cropping system						
Technical efficiency (Constant returns)	11	36.7	0.7801	0.2120	1	0.312
Technical efficiency (Variable returns)	22	73.3	0.9102	0.1127	1	0.638
Scale efficiency	18	60.0	0.8484	0.1746	1	0.348
VL Cropping system						
Technical efficiency (Constant returns)	12	40.0	0.7657	0.2143	1	0.383
Technical efficiency (Variable returns)	21	70.0	0.9181	0.1348	1	0.553
Scale efficiency	17	56.7	0.8284	0.1690	1	0.514
CS system						
Technical efficiency (Constant returns)	12	40.0	0.7845	0.2024	1	0.423
Technical efficiency (Variable returns)	23	76.7	0.9367	0.0876	1	0.743
Scale efficiency	17	56.7	0.8328	0.1815	1	0.446
CL system						
Technical efficiency (Constant returns)	11	36.7	0.7659	0.2217	1	0.303
Technical efficiency (Variable returns)	20	66.7	0.9532	0.0913	1	0.617
Scale efficiency	17	56.7	0.8036	0.2149	1	0.303

Table 4. Distribution of farms in different cropping systems according to the types of return among different scale of operations in Kolar district, Karnataka

Types of return	Increasing returns		Constant returns		Decreasing returns		Total	
	No.	%	No.	%	No.	%	No.	%
VS	21	70.0	8	26.7	1	3.3	30	100
VL	18	60.0	9	30.0	3	10.0	30	100
CS	23	76.7	7	23.3	0	0.0	30	100
CL	20	66.7	10	33.3	0	0.0	30	100
Total	82	68.34	34	28.33	4	3.33	120	100

3.2.1 Technical efficiency under constant returns to scale

Under constant returns to scale all farms are expected operating at optimum level due to perfect competition. The range of TE scores estimated as per the procedure explained earlier is presented in Table 2. To decide efficient farms, the cut-off score as per the criterion suggested by Ferreira (2005) is used i.e., farms that operated at 0.90 or more score were considered as 'efficient farms'. The explanation for this flexibility is to avoid compromising the analysis though a farm that stands out as being an outlier rather than for its true relative efficiency. Data recording errors and external factors were attributed for this flexibility.

Nearly 37 per cent of farms (11 out of 30 farms) in VS cropping system performed efficiently with TE score of 0.90 or higher), in other words, these farms are operating at maximum technical efficiency. Similarly, these values for the farms under VL, CS and CL cropping systems are 40, 40 and 37 per cent, respectively. Thus, 37 to 40 per cent of farms under four cropping system are performing at maximum technical efficiency. Even the distribution of farms in other grouping of technical efficiency among four groups are similar.

The average technical efficiency in VS cropping system was 79.83 per cent. This indicates that other farms in this group, which are not at the maximum efficiency level, can reduce the input level by average 20.17 per cent and still maintain same level of returns or there is a scope for increasing income by about 20.17 per cent by adopting the technology and techniques used by the best farmers. The average efficiency scores in VL, CS and CL cropping systems are 76.57, 78.45 and 76.59 per cent, respectively suggesting similar distribution. Thus, the marginal differences in average TE scores among four cropping systems pointed out that the level of inefficiency has not influenced by either the size of holding or the type of cropping systems.

3.2.2 Impact on technical efficiency due to variable returns to scale

The relaxation of constant returns to scale is necessitated, as all the vegetable/cereal - producing farms are not operating at optimum scale due to imperfect competition, constraint in finance, etc. Upon relaxation, the impact of production scale on the technical efficiency level will be visible. This can be achieved by the calculation of the model with variable returns to scale. Here also the efficiency of 90 per cent and less has considered as the cutoff point for inefficiency. The results of such relaxation are presented in Table 3.

The number of efficient farms (≥0.90) in VS cropping system increased to 73.3 per cent, which is almost two times more than the number of farms under constant returns scale (36.7 %). Even the average technical efficiency score increased to 91.0 per cent from 78.02 per cent. This difference between the means of TE obtained in two models indicates that 13 per cent of the total 21.98 per cent ascribed to technical inefficiency (constant returns) are caused by scale inefficiency. The extent of scale inefficiency in case of VL, CS and CL cropping systems are 15.24, 15.22 and 18.73 per cent, respectively.

Thus, the superior results in the model with variable returns is due to the fact that the model with constant returns to scale did not take into consideration the existence of scale inefficiency. The standard deviation of the mean in the model with variable returns was also lower than the one in the model with constant returns in all four category of cropping systems, which indicates concentration of farms in the highest efficiency levels.

If the measure of scale efficiency equals 0.9 or higher, the farmer will be performing at optimum scale. The results indicated that 18 out of 30 farmers in VS cropping systems (60%) were performing at optimum scale or were close to the optimum scale. The percent of farmers performing at optimum level in VL, CS and CL cropping systems are of identical values of 56.7 per cent i.e, 17 out of 30 farmers.

3.2.3 Distribution of farms in three regions of production frontier

In addition to knowing the number of efficient farms, extent of inefficiency and optimum scale of operation, it is also important to understand the distribution of farms in three regions of production frontier i.e, how many farms are under increasing, decreasing, or constant returns. The results are presented in Table 4. Nearly 70 per cent of the farms in VS cropping system, 60 per cent in VL system, 77 per cent in CS system nearly and 67 per cent in CL systems were found to be operating in the region of increasing returns or the suboptimal region. The production scale of these farms can increase while decreasing costs, since they were performing below the optimum production scale.

Nearly three per cent of farms in VS cropping system, 10 per cent in VL and none in both CS and CL cropping systems were found in the 'decreasing returns' region. This region is also called as 'supraoptimal', which means that the farms were performing above the optimum scale of production. In the constant region of frontier i.e., optimum scale of production, nearly 27 per cent of farms in VS cropping system, 30 per cent in VL, 23 per cent in CS and 33 per cent in CCCL cropping systems were found operating in this region.

Thus, there is a considerable increase in the number of farms that are operating in the increasing returns to scale especially in small farmers category both in vegetable and cereal based cropping systems and the production scale of these farms can increase while decreasing costs. For those with decreasing returns (very less in the present case), a reduction in the production level would imply an increase in technical efficiency, as they were spending more than they should on the growing different crops in the cropping system.

4. CONCLUSIONS AND POLICY IMPLICATIONS

It was observed that the vegetable-based small farming systems is emerged as the best combination for profit maximization, which renders action to include vegetable crop component in the cropping systems of the farmers. The results of the present study also show that majority of analyzed vegetable, cereal based farms of the state of Karnataka both in small, and large farmers' categories had technical inefficiencies. This calls for the action to correct inefficiency problems fundamental to the long-term sustainability of these farms. The results suggest that measures to increase efficiency should be applied to different factors, taking into account the particularities of each production scale group.

The level of technical efficiency and returns to scale indicated that the majority of the small farms group, need to increase production volume and therefore improve scale efficiency, because most of these farms have not achieved the optimum efficiency level, performing with increasing returns to scale. Further, it was observed that majority particularly in small farming system were found to be operating in the region of increasing returns or the suboptimal region and therefore, the production scale of these farms can increase while decreasing costs, since they were performing below the optimum production scale. The difference in the technical efficiency level between small and large farms is also related to the fact that large farms perform with larger production volumes and have better operating conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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