

An Economic Analysis of Technical Efficiency In Rice Production: Data Envelopment Analysis (DEA) Approach

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ABSTRACT

The agricultural productivity and production are continued to be at low level despite the use of critical inputs may be due to the resource-use inefficiency in the paddy farms. Keeping this in view an attempt has been made in this paper to estimate the technical efficiency across the farm sizes (small, medium and big) and villages (irrigated, tailed-irrigated and non-irrigated) under study in Bargarh district of Orissa by using Data Envelopment Analysis (DEA). It is found from the study that the productivity is often affected by the resource-use and technical inefficiencies of farms even though the small farms were comparatively found less technically inefficient compared to others and hence appropriate adjustment mechanism may be suggested for improvement in efficiency and productivity.

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Introduction

The level of efficiency of a farmer in his production process is difficult to assess unless one is sure of the prevailing conditions in which he operates. For instance, a farmer may not be allocating his resources optimally due to resource constraints or the prevailing uncertainty with regard to price/yield and perhaps due to the lack of ready access to resources. Under such circumstances, he cannot be termed inefficient merely because he does not operate at the point where profit is maximized; profit maximisation may not be his final objective. On the other hand, a farmer may be using all the inputs in required quantities, but may not be realizing the potential output due to improper management. In such cases, a comparison of output in relation to the level of inputs used reveals the true picture of efficiency. This is referred to as 'technical efficiency' which is the maximum possible yield achievable with a given level of input used (Jayaram *et al.*, 1992). Technical efficiency can also be defined as the farm's ability to obtain the maximum output from a given set of resources (Farrell, 1957).

In other words technical efficiency of a farm can be defined as the ability and willingness of the farm to obtain the maximum possible output with a specified endowment of inputs (represented by a frontier production function), given the technology and environmental conditions surrounding the farm (Mythili G. *et al.*, 2000). As pointed out by Little *et al* (1987) comparison of indexes of technical efficiency of individual enterprises provides information on the relative as well as absolute levels of total factor productivity. For this reason measurement as well as interpretation of the technical efficiency of the individual farms in the area under study is an important exercise to do (Banik Arindaam, 1994).

A number of empirical study have been undertaken to measure the technical efficiency by using cross-section data with the help of both parametric and non-parametric techniques. In this regard the deterministic and stochastic frontier approach were used very popularly (Farrell, 1957), (Aigner and Chu, 1986), (Timmer, 1971), (Aigner, *et al*, 1977), (Meeuen and Broeck, 1977). A number of comprehensive work has

been undertaken in this context by considering also the panel data approach and measurement of technical efficiency using cost functions (Forsund *et al*, 1980), (Bauer, 1990), (Battese, 1992) (Greene, 1993), (Kaliranjan and Shand, 1994) and (Kumbhakar, *et al*, 1997). However, only a few studies (Kaliranjan, 1981, Tadesse and Krishnamoorthy, 1997, Kaliranjan and Shand, 1994; Mythil and Shanmugam, 2000) have been carried out to measure technical efficiency of rice production in India using the cross-section data. The present study uses the nonparametric technique of Data Envelopment Analysis (DEA) to measure the technical efficiency of the farms cultivating rice for three different villages with different agrarian conditions of Bargarh district of Orissa during the agricultural year 2009-2010.

Objective of the Study

The objective of the present study is to estimate the technical efficiency across different sizes of rice growing farms (both owner and tenant farms) and villages under study so as to suggest for improvement in efficiency and productivity through appropriate adjustment mechanism of significant resources.

Data Base and Methodology

The present study is based on the primary source of data collected on the basis of a pre-designed questionnaire from 474 farm households of three different villages located in three different blocks with varied irrigation status under Bargarh district of Orissa during the agricultural year 2009-10.

The study district is basically comprised of two distinct agro climatic zones such as canal irrigation (under Hirakud dam canal system) and rain-fed zone. Further, the canal irrigation zone is divided into two parts viz., head-end and tail-end. There is adequate supply of water at the head-ends of the canals, with a corresponding shortage at the tail-ends. Based on the agronomic and socio-economic characteristics of both the zones two villages from canal irrigation zone [one from head-end(V-1) and another from tail-end(V-2)] and one village (V-3) from rain-fed zone (enjoys only one crop i.e.Kharif) have been selected for the present study. The rice (paddy) cultivation is the mainstay in the area under study not because it is their staple food but for their livelihood too.

Instead of sampling, the data has been collected on census basis (i.e. whole farm households) in each of the three villages selected purposively for better understanding of the differential pattern of behaviour across the farm sizes and villages under study. The selected farm sizes were classified into three size groups on the basis of operated area viz., Small (Up to 5.00

acres), Medium (5.01 acres to 10 acres) and Large (10.01 acres and above).

There are 192 (Small-84, Medium-52 and Large-56), 139 (Small-86, Medium-24 and Large-29) and 143 (Small-82, Medium-53 and Large-8) number of farm households considered for the purpose of present study from the villages V-1, V-2 and V-3 respectively. The total sample size constitutes 474 number of farm households (All-V). The Data Envelopment Analysis (DEA) has been used as an analytical tool to estimate the technical efficiency across the farms and villages under study.

For the present study, we have taken production of rice(paddy) per acre (in rupees) as the output (Y) of the farm. The different inputs considered for the analysis are as follows:

X1 = Bullock/Machine labour used per acre (in Rupees), X2 = Human labour used per acre (in Rupees), X3 = Quantity of Seeds used per acre (in Rupees) , X4 = Chemical fertiliser used per acre (in Rupees), X5 = Irrigation expenses (from all sources such as canal and other sources) per acre (in Rupees) , X6 = Plant protection measures used per acre (in Rupees), X7 = Agricultural credit per acre (in Rupees) , X8 = Total area under rice (in Acre)

All the variables except the last one are measured in monetary term (rupees). The last variable 'area under rice' is measured in acre.

Socio-economic conditions of the Villages under study-A brief outline

Out of the three villages chosen for the purpose two villages are in irrigated area. One of the irrigated village(V-1) in the head-end and the other in tail-end (V-2) are virtually enjoying 75 to 80 per cent and 45 to 50 per cent coverage from the Hirakud canal system respectively. Rice (Paddy) is the dominant crop in these villages. Literacy and supporting public infrastructure are found moderate and good respectively in these villages. Tenancy is found moderate in both the villages. About one-third of the households mostly depend on agricultural labour in these villages. There is wide spread attached labour among medium and large farm employers. The dominant form of the rental contract is a fixed rent in kind. The use of tractor is fairly high. Private money-lenders are active in these villages. Further, there are traders who also provide credit in kind (i.e. fertilizer and other agriculture inputs) not only to marginal and small farm households but also to medium and large farmers and the recovery of such credit made in terms of purchasing paddy from them after harvest. In other words interlinked credit market (input-output) is

found in these villages. This may be one of the reasons for selling of their marketable surplus (paddy) to the private traders despite the existence regulated market system.

The third village is situated in the dry tract of the district. In this village there is virtually no irrigation facility except some local irrigation sources such as Katas, Ponds and Mundas. As reported all together there are fifteen Katas, Ponds and Munda of small, medium sizes. Out of these fifteen, ten Katas and Ponds are managed by the Block Development Authority and the rest five Mundas of small size are personally owned by some five medium and large farmers. As virtually there is no irrigation, these Katas, Ponds and Mundas supply water during the Kharif crop for a week or so. Those farmers whose land is situated below these Katas or Ponds have the advantage of using water during Kharif, in case of a shortage of rainfall. Large farmers do keep farm servants to supplement their work. Rice (Paddy) is the dominant crop during Kharif season only in this village, because this is a single rice-cropped area being dry village. Hence, compared to the wet villages, there are a variety of crops, including pulses, grown in the dry village. The extent of tenancy is also moderate in this village. The use of tractor for cultivation is relatively low. Private money-lenders do their business actively in this village. In this village also the traders are providing output linked inputs credit. Most of the farmers sold their surplus paddy to the private traders in the village only at the prevailing price in and around the village.

Technical Efficiency and Data Envelopment Analysis

Currently, two methods are used to measure the technical efficiency (TE); econometric estimation of production frontiers and non-parametric approach of production frontier popularly known as data envelopment analysis (DEA). The econometric approach of estimating TE assumes an explicit functional form for the underlying production technology. In contrast, DEA, originally pioneered by Charnes et al. (1978), does not require any underlying assumptions. It enables one to obtain extremal relations such as the production function and/or production possibility surfaces. Instead of trying to fit a regression plane, it floats piece wise – linear/Cobb-Douglas (log-linear) surface to rest on the top of the observations (Seiford et al. 1990). Econometric frontier approaches both deterministic and stochastic are subject to specification error. Further, the number of parameters to be estimated may become a problem in the stochastic frontier approach, especially in cases where there are large number of inputs and outputs. Relative to the parametric frontier approaches; non-parametric frontier approaches have the advantage of minimal specification error but do not allow for measurement error or random shocks. The non-

parametric frontier models have the advantage of being suitable for analysis of discrete data. This avoids the approximation error introduced in the parametric models which presume continuity. Further, computationally though the non-parametric approaches are less demanding than the stochastic frontier approaches, but they provide an enormous amount of disaggregated information.

Concept of Technology and Technical Efficiency

The extent by which a farm lies below its production frontier, which sets the limit to the range of maximum obtainable output, can be regarded as the measure of technical inefficiency. The concept of technology and output oriented technical efficiency can be well explained with the help of Figure-2.3.1, involving single input (X) and single output (Y).

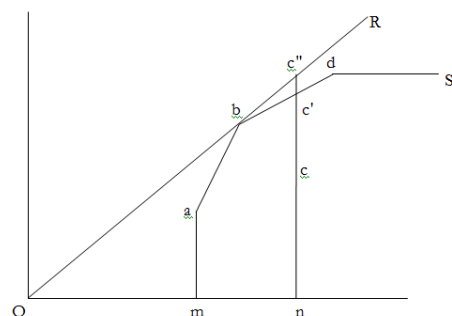


Figure: 1. Measure of Output Technical Efficiency

Consider a village consisting of four firms – a,b,c and d. Given the free disposability of inputs and convexity condition, the free disposal convex hull of the observed input-output vectors provides us an inner approximation to the true underlying production possibility set. It additionally, one assumes constant returns to scale (CRS), all non-negative input-output bundle will also be feasible. The production possibility set becomes a convex cone. By convexity, all points in the convex hull of the points a, b, c and d (i.e. all convex combinations of these points) represent feasible input – output combinations. The free disposal convex hull is the set of points bounded by the horizontal axis and the broken line mabd – extension. Under Variable returns to scale (VRS), all points in this region represent feasible input-output combinations. Under CRS, however, all radial extension and (non-negative) contraction of feasible input-output bundles are also feasible. Thus the CRS production possibility set is the cone formed by the horizontal axis and the ray OR through the point b. As it can be seen from the Fig.1, farm c is technically inefficient as it is laying below the frontier of the technology. The output-oriented technical efficiency is

measured by the amount by which output could be increased without requiring extra inputs. In other words, it is the ratio of actual output to potential output (i.e. y/y^* where Y^* is the frontier or potential output associated with the level of input x of the farm). Hence the technical efficiency of the farm c is the ratio nc/nc' under CRS and the ratio nc/nc' under VRS.

Let us consider a sample of J number of agricultural farms also be known as DMUs (Decision Making Units) Let B denotes $J \times M$ matrix of observed outputs and A denotes the $J \times N$ matrix of observed inputs. Individual elements of M , denoted by y_{jm} measures the quantity of m th output produced by the j th DMU, while the individual elements of N , denoted by x_{jn} , measure the employment level n th input j th DMU, at particular period of time. A production technology transforming input vector x to output y can be constructed from the data as:

The reference frontier (or technology) in period t is constructed from the data as:

$$S^t = (x^t, y^t): y_m^t \leq \sum_{k=1}^K Z^{k,t} y_m^{k,t};$$

$$\sum_{k=1}^K Z^{k,t} x_n^{k,t} \leq x_n^t; Z^{k,t} \geq 0 \quad (1)$$

Which exhibits constant returns to scale and strong disposability of inputs and outputs (Fare et al 1994). Following Sidney Afriat (1972), the assumption of CRS can be relaxed and one may allow for variable returns to scale by putting the following restriction in (1) (Banker et al, 1984):

$$\sum_{k=1}^K Z^{k,t} = 1 \quad (2)$$

where, $Z^{k,t}$ is an intensity variable indicating at what intensity a particular activity (farm) may be employed in production.

The distance function seeks the reciprocal of the greatest proportional increase in output(s) given input(s), such that output is still feasible.

Following Shepherd (1970) and Fare (1998), the output distance function in time period t is defined as:

$$D_o^t = \min \theta : (X^t, \frac{1}{\theta} y^t) \in S^t \quad (3)$$

It completely characterizes the technology $D_o^t \leq 1$,

if and only if $(x^t, y^t) \in St$. In addition, $D_o^t = 1$, if and only if (x^t, y^t) is on the boundary or frontier of the technology. This function is reciprocal to Farrell's (1970) output oriented measures of technical efficiency i.e. the reciprocal of the maximum proportional expansion of the output vector, y^t , given the input vector, x^t .

Calculation of Distance Function: A Linear Programming Problem

The output distance function under CRS technology is calculated by following linear programming problem:

$$\{ D_o^t(x^t, y^t) \}^{-1} = \max \theta$$

$$\text{Subject to } \sum_{k=1}^K Z^{k,t} x_n^{k,t} \leq x_n^{k',t}, \quad n=1, 2, \dots, N$$

$$\sum_{k=1}^K Z^{k,t} y_m^{k,t} \geq y_m^{k',t} \theta, \quad m=1, 2, \dots, M$$

$$Z^{k,t} \geq 0, \quad k=1, 2, \dots, K \quad (4)$$

The output distance function under VRS technology can be calculated by putting the restriction (2) in the above LP problem.

In this study, each farm is treated as a separate DMU (Decision making unit). The Number of DMUs $k=474$, for the study area of Bargarh district of Orissa. The number of inputs $n=8$, the number of outputs $m=1$. The decision variables are the shadow prices i.e., Z_1, Z_2, \dots, Z_{474} . The expansion factor is θ in the output-oriented model. We are required to maximise the objective function D_o subject to respective constraint as given in the model. The model given in equation (4) is run separately for each DMU and as such 474 linear programming problems are solved to obtain the efficiency estimate of all the DMUs.

Input Reducing (IR) BCC Model

The inefficient DMU can be made fully efficient by projection into a point on the envelopment surface. The particular point of projection selected is dependent upon the type of the model selected. In the input-reducing model, the focus is on the maximal movement towards the frontier through proportional reduction of inputs. The output-increasing model focuses on the maximal movement towards the frontier through

proportional augmentation of outputs. However, the present study deals with the IR model.

The linear programmes for the BCC (Banker, et al. 1984) input-reducing model are given below:

$$\text{Min } \theta - \epsilon \left(\sum_{n=1}^M e_n + \sum_{m=1}^s s_m \right) \quad (5)$$

Subject to

$$\sum_{k=1}^K z^k x_n^{k,t} + e_n = \theta x_n^{k,t}$$

$n=1, 2, \dots, N$

$$\sum_{k=1}^K z^k x_n^{k,t} - s_m = y_m^{k,t}$$

$m=1, 2, \dots, M$

$$\sum_{k=1}^K z^k = 1$$

$$\theta, z^k, e_n, s_m \geq 0 \quad (6)$$

where $s =$ the total no. of output variable

$e_n =$ excess or surplus of input n used by DMU k

Results and Discussion

The BCC efficiency scores are evaluated for a number of individual farms of the area under study consisting of different agrarian conditions, during the period 1999-2000 (Agricultural year). An efficiency score for each farm is computed relative to all other farms and itself. In other words, the efficiency of farm 1 for example is compared relative to efficiency characteristics of all other 473 observations in the given year.

The efficiency scores of all the farms in the sample so obtained are used to find out the average efficiency scores across different farm sizes and among different villages situated in different agro-climatic zones of the district under study. The overall averages have been calculated by using the weighted arithmetic mean.

The average technical efficiency (T.E.) scores vary across farm sizes and villages as it is evident from Table-1.

On an average the efficiency score varies from 81.01 per cent in large farms to 93.06% in case of small

farms. Similarly, it varies from 86.07% in V-2 to 87.96% in V-1 and 91.69 in V-3. As one can observe from the above table, the small farms are technically more efficient than those of medium and large farms in all the villages. However, the mean technical efficiency as shown in Table-1 implies that on an average, the realized output can be increased by 19% in large farms, 15% in medium farms and 7% in small farms, similarly it is around 12% in V-1, 14% in V-2, and 8% in V-3 respectively without any additional resources. Various factors may be responsible for the observed differences in efficiencies which need further analysis.

Table: 1. Average T.E. Scores Across farm sizes and Villages (in percentage)

	V-1	V-2	V-3	All-V
Small	92.86	89.56	96.96	93.07
Medium	83.27	83.63	87.41	85.04
Large	84.98	77.73	66.14	81.10
Overall average	87.96	86.07	91.70	88.53

Table-2 shows that the average efficiency scores vary across different farm sizes in case of both the owner farms and owner-tenant/tenant farms.

However, it can be observed from the table that on an average the owner-tenant/tenant farms are slightly more efficient than the owner-farms. But across villages on an average the owner-farms are slightly more efficient than owner-tenant/tenant farms in case of V-2 and V-3 i.e. 87.54% and 92.26% respectively. Further, it is observed that in both the cases of owner-farms and tenant farms in all the villages the small farms are on an average more technically efficient than medium and large farms.

The frequency distribution of technical efficiency (T.E.) of individual farms for each villages (V-1, V-2, V-3) and entire sample farms (All-V) separately with size-wise details of small, medium and large farms as well as owner, owner-tenant and tenant farms are presented in Table 3 to 6 respectively.

Table: 2. Average T.E. Scores of owner farms and Owner-Tenant/tenant Farm (in %)

	V-1	V-2	V-3	All-V
Owner farms	92.25(S)	89.95(S)	96.31(S)	92.21(S)
	82.53(M)	80.93(M)	85.6(M)	82.93(M)
	82.76(L)	81.31(L)	66.31(L)	80.83(L)
	87.20(A)	87.54(A)	92.66(A)	88.48(A)
Owner-tenant/tenant farms	95.46(S)	-	98.29(S)	97.23(S)
	92.19(M)	88.14(M)	88.32(M)	88.61(M)
	87.04(L)	75.22(L)	65.98(L)	81.33(L)
	90.21(A)	79.69(A)	91.04(A)	88.66(A)
Overall average	87.96	86.07	91.70	88.53

Table: 3. Frequency Distribution of T. E. of Individual Farms: V-1 (irrigated village)

Range of Efficiency Score (%)	All Farms	Small Farms	Medium Farms	Large Farms	Owner Farms	Owner-Tenant/Tenant Farms
Below 10.00	-	-				
10.00-20.00	-	-				
30.00-40.00	-	-				
40.00-50.00	-	-				
50.00-60.00	-	-				
60.00-70.00	2 (1.04)	-	-	2 (3.57)	1 (0.70)	1 (2.04)
70.00-80.00	29 (15.10)	2 (2.38)	15 (28.85)	12 (21.43)	24 (16.78)	5 (10.20)
80.00-90.00	84 (43.75)	27 (32.15)	32 (61.54)	25 (44.64)	67 (46.85)	17 (34.69)
90.00-100.00	45 (23.44)	29 (34.52)	3 (5.77)	13 (23.21)	33 (23.08)	12 (24.50)
100.00	32 (16.67)	26 (30.95)	2 (3.84)	4 (7.15)	18 (12.59)	14 (28.57)
Total	192 (100)	84 (100)	52 (100)	56 (100)	143 (100)	49 (100)

Table: 4. Frequency Distribution of T.E. of Individual Farms: V-2 (tailed-irrigated village)

Range of Efficiency Score (%)	All Farms	Small Farms	Medium Farms	Large Farms	Owner Farms	Owner-Tenant/Tenant Farms
Below 10.00	-	-	-	-	-	-
10.00-20.00	-	-	-	-	-	-
30.00-40.00	-	-	-	-	-	-
40.00-50.00	-	-	-	-	-	-
50.00-60.00	-	-	-	-	-	-
60.00-70.00	5 (3.6)	-	2 (8.33)	3 (10.34)	3 (2.65)	2 (7.69)
70.00-80.00	56 (40.29)	27 (31.4)	11 (45.83)	18 (62.08)	40 (35.4)	16 (61.54)
80.00-90.00	21 (15.11)	12 (3.95)	4 (16.67)	5 (17.24)	18 (15.93)	3 (11.54)
90.00-100.00	12 (8.63)	12 (3.95)	-	-	12 (10.62)	-
100.00	45 (32.37)	35 (40.7)	7 (29.17)	3 (10.34)	40 (35.4)	5 (19.23)
Total	139 (100)	86 (100)	24 (100)	29 (100)	113 (100)	26 (100)

Table: 5. Frequency Distribution of T.E. of Individual Farms: V-3 (Non-irrigated village)

Range of Efficiency Score (%)	All Farms	Small Farms	Medium Farms	Large Farms	Owner Farms	Owner-Tenant/Tenant Farms
Below 10.00	-	-	-	-	-	-
10.00-20.00	-	-	-	-	-	-
30.00-40.00	-	-	-	-	-	-
40.00-50.00	-	-	-	-	-	-
50.00-60.00	-	-	-	-	-	-
60.00-70.00	7 (4.896)	-	-	7 (87.5)	4 (5.2)	3 (4.55)
70.00-80.00	21 (14.69)	9 (10.97)	11 (20.75)	1 (12.5)	13 (16.88)	8 (12.12)
80.00-90.00	25 (17.48)	2 (2.44)	23 (43.4)	-	9 (11.69)	16 (24.24)
90.00-100.00	13 (9.09)	3 (3.66)	10 (18.87)	-	8 (10.39)	5 (7.58)
100.00	77 (53.85)	68 (82.93)	9 (16.98)	-	43 (55.84)	34 (51.51)
Total	143 (100)	82 (100)	53 (100)	8 (100)	77 (100)	66 (100)

Table: 6. Frequency Distribution of T.E. of Individual Farms: All Village

Range of Efficiency Score (%)	All Farms	Small Farms	Medium Farms	Large Farms	Owner Farms	Owner-Tenant/Tenant Farms
Below 10.00	-	-	-	-	-	-
10.00-20.00	-	-	-	-	-	-
30.00-40.00	-	-	-	-	-	-
40.00-50.00	-	-	-	-	-	-
50.00-60.00	-	-	-	-	-	-
60.00-70.00	14 (2.95)	-	2 (1.55)	12 (12.9)	8 (2.4)	6 (4.25)
70.00-80.00	106 (22.36)	38 (15.08)	37 (28.68)	31 (33.33)	77 (23.12)	29 (20.57)
80.00-90.00	130 (27.43)	41 (16.27)	59 (45.74)	30 (32.26)	94 (28.33)	36 (25.53)
90.00-100.00	70 (14.77)	44 (17.46)	13 (10.08)	13 (13.98)	53 (15.92)	17 (12.06)
100.00	154 (32.49)	129 (51.19)	18 (13.95)	7 (7.53)	101 (30.33)	53 (37.59)
Total	474 (100)	252 (100)	129 (100)	93 (100)	333 (100)	141 (100)

The result shows a moderate variation in the level of technical efficiencies across farms in all the villages i.e. the minimum range being 60 to 70 per cent and maximum technical efficiency being 100 per cent. As one can see from table-3, in our sample of 192, 32 (16.67%) have a technical efficiency of 100 per cent, of which 26 (81.25%) are small farms. The other 160 (83.33%) of the total farms have the technical efficiency ranging from more than 60% to less than 100%. Out of the total small farms (84), 26 (30.95%) have technical efficiency of 100% and other have below 100%, but out of total large farms (56) only 4 (7.15%) have technical efficiency of 100%. Similarly, out of the total owner farms (143) and owner-tenant/tenant farms (49), 18 (12.59%) and 14 (28.57%) respectively have technical efficiency of 100%. It can be observed from this table that the percentage of small farms having technical efficiency of 100% is higher than the percentage of medium and large farms.

Similarly, from Table 4 it can be observed that in V-2 also the percentage of small farms (having technical efficiency of 100%) of the total farms are more (i.e. 35 out of total 45) under 100% score category compared to other farm sizes. It is also observed that the percentage of owner farms of total owners (i.e. 35.4%) is higher than that of percentage of tenant farms of total tenant farms (i.e. 19.23) under 100% technical efficiency score.

Similarly, it can be observed from the Table 5 that in V-3 the percentage of small farms of the total farms having technical efficiency of 100% are more (i.e. 68 out

of 77) compared to other farm-sizes, finding an interesting result that no large farm is under technical efficiency score of 100%. It is also observed that the percentage of owner farms of the total owner farms (i.e. 55.84%) is higher than that of the percentage of owner-tenant/tenant farms of the total tenant farms (i.e. 51.51) under the technical efficiency score of 100%. In the similar way considering the entire sample farms as shown in Table 6 it can be observed that out of 154 farms having technical efficiency of 100% 129 farms are small farms. But out of 474 farms 154 (32.49%) are only having technical efficiency of 100% and other 67.51% are below 100% (i.e. 2.95, 22.36, 27.43, 14.77% for 60-70, 70-80, 80-90 & 90-100% score range respectively). So there exists ample scope for increasing the technical efficiency of the sample farms as a group. It is also observed that the percentage of owner farms of total owner farms (i.e. 30.33) is less than that of the percentage of owner-tenant/tenant farms of the total tenant farms (i.e. 37.59) having technical efficiency of 100%. This may be the influence of V-1 on the result of total sample farms.

One comes to the conclusion from the above discussion that the small farms are technically more efficient than that of medium and large farms in all the villages i.e. V-1 (irrigated), V-2 (tailed-irrigated) and V-3 (Non-irrigated) and also in the entire sample farms. This finding further supports the result of Banik (1994) in this context, even though the methodology and area under study is different than that of Banik. His area of study

was confined to a sample of irrigated farms only and methodology was stochastic frontier production function.

It is also observed that the owner-tenant/tenant farms are technically more efficient than owner farms in V-1 (irrigated area), this finding again supports in one or other way to the result of Banik (1994). On the contrary the owner farms are technically mere efficient than that of owner-tenant/tenant farms in V-2 (tailed irrigated area) and V-3 (non-irrigated area). But in the case of entire sample farms the owner-tenant/tenant farms are technically more efficient than that of owner farms. This may be due to the influence of the result of V-1 in this regard.

Potential Improvements of Inputs

The potential improvement of various inputs for 474 sample farms individually calculated based on the BCC (IR) model (i.e. output oriented measure of potential improvement of various inputs). In other words, the quantum of each input used excessively has been worked out for each individual farm (i.e. the difference of input use at Actual and Frontier level by the farms) given the level of output. For segregation of the result across the farm sizes in different villages separately the average value of actual and frontier input usages has been calculated for each inputs. The percentage of potential improvement (PI) of each input is calculated by adopting the formula

$$\text{Percentage of PI} = \left[\frac{\text{Actual } x_i - \text{frontier } x_i}{\text{Actual } x_i} \right] \times 100,$$

where $i=x_1 \dots x_8$ and the result is compared across farm sizes and villages for policy implication at the end. This analysis is undertaken with a view to provide a feedback to the productivity management (with regard to input use), in rice cultivation in the area under study. In other words, from this analysis it can be inferred that to produce a given level of output, how much input a farm is actually using, and how much the farm is ought to be used if he operates at frontier level. This provides the way of potential improvement to be done in the input usage to reach to its optimum usage. Thus, here the measure of technical efficiency compares the actual level of input used to the level at which it would be used by farm 'i' to obtain the same output 'y', but at the efficient level.

Table-7, shows the percentage of average potential improvement (P.I.) of various inputs across farm sizes and villages.

Table: 7. Average P.I. of various Inputs across farm sizes and Villages (in Percentage)

Unit name	Y	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈
V-1									
Small	0	13.52	10.10	8.43	13.83	21.39	16.56	32.33	11.78
Medium	0	16.73	21.29	16.89	35.21	35.57	52.90	59.82	46.39
Large	0	15.44	22.91	15.07	29.11	35.90	43.39	44.19	57.87
All	0	14.95	16.87	12.66	24.08	30.28	34.23	43.24	34.59
V-2									
Small	0	13.29	14.26	12.23	19.17	37.55	24.31	36.91	15.47
Medium	0	19.95	23.82	21.27	29.75	56.19	46.55	36.27	54.96
Large	0	25.16	24.82	26.07	35.96	78.60	61.24	56.88	81.62
All	0	16.92	18.12	16.68	24.50	49.33	35.86	40.97	36.09
V-3									
Small	0	41.20	5.46	15.36	5.78	10.92	32.49	77.76	59.71
Medium	0	30.24	12.69	19.55	55.59	71.62	15.02	52.35	73.84
Large	0	56.51	33.86	33.86	57.79	95.85	33.86	75.29	76.29
All	0	38.00	9.73	17.95	21.15	38.17	26.09	68.21	65.87
All-V									
Small	0	22.45	10.01	11.98	13.03	23.50	24.39	48.68	28.63
Medium	0	22.88	18.23	18.80	42.57	54.43	36.15	52.37	59.26
Large	0	22.01	24.45	20.11	33.71	54.37	48.14	50.82	66.86
All	0	30.74	14.93	18.60	32.63	46.04	33.16	60.49	64.27

Note: 1) average efficiency score of different farm sizes have been calculated by using arithmetic mean, whereas, the overall averages have been calculated by using weighted combined mean.

2) the average value of actual and frontier x_i (where $i=1, \dots, 8$) are taken in account for percentage of Average PI

A perusal of actual and frontier usage of inputs in the production of rice (Table7) indicated that all the factors under consideration were used at levels higher than the frontier level by all the size groups. The table reveals that the percentage of the quantum of excess use of inputs in the production of rice increases with the increase in farm size. It is also discussed earlier that the small farmers are more technically efficient than medium and large farmers and also the number of small farms under 100% of technical efficiency score (where Actual x_i =frontier x_i) is more than that of medium and large farms. Thus, the percentage of wastage is less in small farms in case of all the inputs in all the three villages under study. But still there is scope for potential improvement in input usage by all size groups in all the villages. In other words, if the farms were technically efficient on an average they could have saved different inputs level: viz. $X_1, X_2, X_3, X_4, X_5, X_6, X_7$ and X_8 by 14.95, 16.87, 12.66, 24.08, 30.28, 34.23, 43.24 and 34.59 per cent respectively in V-1 (irrigated village). 16.92, 18.12, 16.68, 24.50, 49.33, 35.86, 40.97 and 36.09 per cent of the above said inputs respectively in V-2 (tailed irrigated village) and similarly 38, 9.73, 17.95, 27.15, 38.17, 26.09, 68.21 and 65.87 per cent respectively in V-3, 30.74, 14.93, 18.60, 32.63, 46.04, 33.16, 60.49 and 64.27 per cent of the said inputs respectively in case of entire sample to achieve the current level of output. Similarly, while analysing the same across the farm sizes it is found that the percentage of excess use of all the inputs under study, varies directly with the farm size. In other words the percentage of excess use of inputs is less in case of small farms compared to medium and large farms in all the villages as well as in the entire sample (Table-7). This may be due to the relatively higher technical efficiency of small farms over other size group (Table-4, 5 & 6 respectively).

Conclusion

Thus, from the foregoing analysis it is apparent that the resource use in rice cultivation in the study area leaves ample scope for improvement for all size groups in all the villages. Further, the medium and large farmers may be advised to achieve the resource-use efficiency effectively so as to raise their technical efficiency for realizing better output. By a better organisation of resources, a considerable amount of resources (i.e. inputs including land input) can be saved

without affecting the achievement of the current level of production of rice per acre. Thus, the importance of productivity management in rice cultivation in terms of improving technical efficiency of the farmers by proper management and judicious utilisation of the resources is a matter of prime concern today.

References

- [1] Afriat, S.N., "Efficiency Estimation of Production Functions" *International Economic Review*, 13(3),1972, 568-598.
- [2] Aigner, D.J. and S.F. Chu, "On Estimating the Industrial Production", *The American Economic Review*, Vol.58(4), 1968, 826-839.
- [3] Banik, A., "Farm Size, Factor Productivity and Returns to Scale under Different Types of Water Management", *Economic and Political Weekly*, 1994,175-183.
- [4] Banik, A., "Technical Efficiency of Irrigated Farms in a Village of Bangladesh", *Indian Journal of Agricultural Economics*, Vol.49(1),1994,70-77.
- [5] Banker, R.D., Charnes, A. and Cooper, W.W., "Some Model for Estimating Technical and Scale Efficiencies in Data Envelopment Analysis", *Management Science*, 30(9),1984, 1078-1092.
- [6] Charnes, A., Cooper, W.W., Rhodes, E., "Measuring the Efficiency of Decision Making Units", *European Journal of Operational Research*, 2 (6),1978, 429-444.
- [7] Fare R., Grosskop F.S. and Lovell C.A.K., "Production Frontiers", Cambridge University Press, Cambridge, 1994.
- [8] Farrell, M.J., "The Measurement of Productivity Efficiency" *Journal of Royal Statistical Society*, 120 (3), 1957,253-281.
- [9] Greene, W.H., *The Measurement of Productive Efficiency: Techniques and Applications*, Oxford University Press, London, 68-119 (1993).
- [10] Jayaram, H., Chandrashekar, G.S. & Achoth, L., "An economic analysis of technical efficiency in rice cultivation in Mandya: Some Issues in resource pricing", *Ind. J. Agri. Econ.*, Vol.47, No.4, p.671-676 (1992).
- [11] Kalirajan, K.P. & Shand, R.T., "On modeling agricultural entrepreneurship", *Ind. J. Agri. Econ.*, Vol.49, No.1, p.79-87 (1994).
- [12] Kalirajan, K.P. and R.T. Shand, *Economics in Disequilibrium: An Approach from the Frontier*. Macmillan India Ltd., New Delhi (1994).

- [13] Meeusen, W. and J. Van den Broeck, "Efficiency Estimation from Cobb-Douglash Production Function with composed error" *International Economic Review*, 18(2),1977,435-444.
- [14] Mythili, G., Shananugam, K.R., "Technical efficiency of rice growers in Tamil Nadu: A study based on Panel data", *Indian Journal of Agricultural Economics*, 55(1),2000,15-25.
- [15] Seiford, L.M., Thrall, R.M., "Recent Development in DEA:The Mathematical Programme Approach to Frontier Analysis", *Journal of Econometrics*, 46, 1990,7-38.
- [16] Timmer, C.P., "Using a probabilistic Frontier Production Function to Measure Technical Efficiency", *Journal of Political Economy*, 79, 1971,776-794.