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ARTICLES

High Technical Efficiency of Farms in Two Different Agricultural Lands: A Study under Deterministic Production Frontier Approach

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I

Available evidence in the last few years reveals that technological package via its efficient utilisation may accelerate the pace of agricultural development in India. But there are large variations in input practices and output levels among farms in different regions within the country. Therefore, an analysis at the farm level is desirable to have a clear understanding of the existence of gap between actual and potential output of agricultural crops in different regions as well as within the same region of the country. This paper examines the extent of technical efficiency under different types of tenure and different farm sizes within the same region of West Bengal in two types of villages - one having high incidence of irrigational facilities and high-yielding varieties (HYV) technology in an area usually cropped twice (technologically advanced villages [TAV]) and the other having no irrigational facilities except rainwater and non-HYV technology in a mono-cropping area (technologically backward village [TBV]), because the estimates on the extent of inefficiencies could help to decide whether to improve or to develop new technology to raise productivity.

In this study we have tried to estimate the technical efficiency level of each individual farm employing Data Envelopment Analysis (DEA) approach under deterministic production frontier model with cross-sectional data for 80 sample farms from our field work on two different types of villages - TAV and TBV - in a particular area of West Bengal for the year 1995-96. It is said that the extent by which a farm lies below its production frontier which sets the limit to the range of maximum obtainable output is regarded as a measure of inefficiency under frontier production function approach (Neogi and Ghosh, 1998). The estimation of production frontiers has proceeded along two general paths - deterministic and stochastic. In the deterministic production frontier model, output is assumed to be bound from above by a non-stochastic (deterministic) production function so that all deviations from the frontier are attributed to inefficiency; the one-sided error component which is under the control of the farm captures deviations from the frontier due to inefficiency. Conversely, in a stochastic production frontier model, output is assumed to be bound

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by a stochastic frontier where disturbance term consists of two components-one component representing one-sided, which follows a half-normal distribution and the other is symmetric component, which captures random effects outside the control of the decision-maker including the statistical noise contained in every empirical relationship. The advantage of the stochastic frontier over deterministic frontier is that farm-specific efficiency and random error effect can be separated (Mythili and Shanmugam, 2000, pp. 16-17, Banik, 1994, p. 7). On the other hand, the advantage of deterministic approach is that the estimates of this approach have no statistical property (Neogi and Ghosh, 1998). Moreover, the deterministic frontier approach does not require a particular functional form (like Cobb-Douglas, CES or Translog) as stochastic one (Jha and Sahni, 1993, p. 13). Even, some studies doubt about yielding similar results in respect of efficiency in all functional forms for the stochastic frontier production function (Brown, 1957; Krishna and Sahota, 1991; Banik, 1994). In keeping with these features, we, however, attempted to use non-parametric approach for measuring the efficiency of individual farm under our sample. More importantly, Farrell (1957) carried out the first empirical study to measure technical efficiency for a cross-section of farms by using DEA approach under deterministic (non-parametric) frontier approach. He dichotomised efficiency into technical and allocative efficiency. Technical efficiency reflects the ability of a farm to obtain maximum output from a given set of inputs. Allocative efficiency points to the ability of a farm to use the inputs in optimal proportions given their respective prices. These two measures are then combined to provide a measure of economic efficiency. Following Farrell (1957), Aigner and Chu (1968) and Timmer (1971) extended this deterministic frontier approach. Later Aigner *et al.* (1977) and Meeusen and Broeck (1977) independently developed the stochastic (or econometric) frontier approach to measure technical efficiency using cross-sectional data. This stochastic frontier approach has been extended in various ways, such as specification of more general distribution for the residual term (truncated normal, exponential and gamma), consideration of panel data and measurement of technical efficiency using cost functions. But all these extensions require the functional form of the frontier and the distribution of the residual term to be specified. This can result in errors of mis-specification if the above specifications are incorrect (Mythili and Shanmugam, 2000, p. 24).

Despite the extension and development of stochastic frontier approach, the deterministic frontier approach, was later generalised to multiple outputs and reformulated as a mathematical programming problems by Charnes *et al.*, (1978, 1979, 1981) thus initiating the mathematical programming approach to efficiency measurement, known as Data Envelopment Analysis (DEA). While the model developed by Charnes *et al.* (1978) assumes constant returns to scale (CRS), the model was subsequently revised for variable returns to scale (VRS) by Banker *et al.* (1984). Our study presents one DEA model of technical efficiency following Banker *et al.* (1984) with deterministic production frontier approach. Under the frontier approach, although most of the recent studies in our country estimated technical efficiency (the ratio between observed and frontier output) in measuring efficiency level of individual firm/farm (Hazarika and Subramanian, 1999; Mitra, 1999; Mythili and Shanmugam, 2000; Shanmugam, 2003; Chattopadhay and Sengupta, 2001; Singh *et al*., 2002; Pillai, 2001; Panda, 1996; Neogi and Ghosh, 1998), most of the studies measure technical efficiency in stochastic frontier production function approach. However, there are some recent studies (like Chattopadhyay and Sengupta, 2001; Singh *et al*. 2002)[1] which measure technical efficiency of the individual farm by non-parametric DEA under CRS (Constant Returns to Scale) model. Our study also presents one non-parametric DEA under CRS (Constant Returns to Scale) model. Our study also presents one non-parametric DEA to measure technical efficiency for each individual farm by VRS model instead of CRS one. This is mainly because, among others, CRS technology does not envelop the data as closely as VRS (Lovell, 1993, p. 29).

This paper is divided into four sections. Section II discusses the survey design and methodology employed for our empirical exercise. Section III presents the empirical results. The concluding comments are made in Section IV.

II

SURVEY DESIGN AND METHODOLOGY

Our survey is carried out with data pertaining to 150 households from 4 villages of Habra Blcok-1 in the district of North 24 Parganas in West Bengal. For the selection of cultivating households, a two-stage sampling procedure was followed. In selecting the villages, a list of different villages located in the block was first obtained from the Agricultural Development Office and then two villages, usually cropped twice (10 to 15 per cent of land produces three crops) in the same plot of land every year were selected having the higher incidence of irrigation and HYV[2] facilities and the rest of the villages, having no irrigational facilities except rainwater and non-HYV technology were selected. For the selection of households in the second stage the lists of households were prepared separately for owner-cultivators, tenant cultivators and agricultural labourers from the Gram Panchayat Records of each village. Detailed lists of each category available from Gram Panchayat Records were then used to draw the sample of households for our study following the method of simple random sampling without replacement. Our sample covered 40 owner-cultivator households, 40 tenant - cultivator households[3] and 50 agricultural labour households consisting of 50 per cent in each type of households from each type of villages - Technologically Advanced (TAV) and Technologically Backward (TBV). We surveyed the villages throughout the year 1995-96.[4]

This exercise is based on 80 sample households - 40 owner cultivating households (20 from TAV and 20 from TBV) and 40 tenant cultivating households (20 from TAV and 20 from TBV). The survey aimed at collecting a whole variety of information about the farming activities of sampled households. These include the various items of cost of cultivation, output of various crops, credit, marketing of products, agricultural extension, etc. Various items of input cost including the human labour costs were accounted separately both in physical and in value terms in our study. Crop-wise output in physical units were collected and then valued at the prevailing market price. The major crops produced in this region are paddy (ordinary and HYV), jute, potato and lentil. Our sample households in unirrigated village produce ordinary paddy once a year in the same plot of land, whereas the major crops produced by the sample households in irrigated villages are both ordinary and HYV paddy in the same plot of land every year. The production of other crops except paddy (ordinary and HYV) is insignificant in our sample.[5] This paper attempts to estimate the efficiency of farms from a given set of physical inputs and physical outputs. In this analysis we have considered all the physical inputs classified into three categories irrigation,[6] material input[7] (except irrigation) and human labour[8] and total physical output of paddy (ordinary and HYV) - in two sample TAV and all the physical inputs classified into two categories - material input and human labour - and all physical output of ordinary paddy in sample TBV in agriculture in order to estimate, among others, the impact of irrigation and HYV technology on the basis of which we categorised the villages. We have taken paddy (ordinary and/or HYV) as output in this exercise for insignificant production of other crops. Our methodology is based on the framework of Data Envelopment Analysis (DEA), a non-parametric approach. This approach does not require any price data to estimate the technical efficiency of units, while with quantities and prices economic efficiency can be calculated (Lovell, 1993, p. 25). Since we are dealing with the production units of an unorganised sector (particularly in less developed countries like India) the data on prices are frequently questionable (Chattopadhyay and Sengupta, 2001).

Methodology

In order to measure the efficiency of farms in TAV and TBV in agriculture, the Data Envelopment Analysis (DEA), developed by Banker *et al.* (1984) has been used in our study. DEA methodology is described as a "mathematical programming model applied to observed data (that) provides a new way of obtaining empirical estimates of external relationships such as the production function and/or efficiency production possibility surfaces that are the cornerstones of modern economics" (Charnes *et al.,* 1978). Using DEA, it is possible to construct production frontier as well as to measure efficiency relative to the constructed frontiers. DEA truly envelops a data set; it does not "nearly" envelop a data set the way most econometric models do.

Let us assume there are 'n' decision-making units (DMUs) to be evaluated. Each DMU consumes varying amounts of 'm' different inputs to produce 's' different outputs. Let the respective input and output vectors be denoted by

$X = (x_1, x_2, \ldots, x_m)\ \varepsilon R^m_+$ and

$Y = (y_1, y_2, \ldots, y_s)\ \varepsilon R^2_+$, where

R^m_+ and R^S_+ denote positive orthonts of 'm' dimensional input and 's' dimensional output space respectively.

DEA analysis requires the solution of the following linear programming problem in Envelopment form:

$VRS_E\ (Y_1, X_1)$:

$\text{Min} - (\sum s_r + \sum e_i)$

λ_j, s_r, e_i

$s_r \geq 0;\ r = 1, 2, \ldots, s$

$e_i \geq 0\ \ i = 1, 2, \ldots, m$

Turning to the multiplier side,

$VRS_M\ (Y_1, X_1)$:

$$\max_{\mu r,\, vi,\, w} \quad \sum_{r=1}^{s} y_{r1}\, \mu_r - \sum_{i=1}^{m} x_{i1}\, v_i + w$$

Subject to (S.t): $\sum y_{rj}\, \mu_r - \sum x_{ij}\, v_i + w \leq 0$ for j=1, …., n.

$\mu_r \geq 1$ for r=1, ….s

$v_i \geq 1$ for i=1, ….m

The optimal solution to $VRS_E\ (Y_1, X_1)$ for DMU_2 consists of S-vector output slacks, s^1, the m-vector of excess inputs e^1 and n-vector λ^1. Vector λ^1 defines a point

$(Y_1, X_1) = (\sum \lambda_j^1\, Y_j,\ \lambda_j^1\, X_j)$, which

is a convex combination ($\sum \lambda_j^1 = 1$) of units that lie on a facet of the envelopment surface. $(Y_1, X_1) = (Y_1, X_1)$ of an efficient DMU_1. For inefficient DMU_1 (Y_1, X_1) is referred to as the projected point, where

$(Y_1, X_1) = (Y_1 + s^1, X_1 - e^1)$

The optimal solution to $VRS_M\ (Y_1, X_1)$ for DMU_1 is given by S-vector μ^1, the m-vector v^1 and the variable w^1. In the literature these values have been interpreted as virtual multipliers. Regarding the characterisation of efficiency, a decision-making unit, 1, is said to be efficient if it lies on the facet defining hyperplane $\mu^1 y - v^1 x + w^1 = 0$ of the envelopment surface; whereas inefficient DMU_2 lie below the closest supporting hyperplane.

We have considered inputs and output, mentioned earlier, in physical terms per acre for our study. Our DEA technique reports optimal solution for the Variable Returns to Scale (VRS) model for each DMU.

III

EMPIRICAL FINDINGS

Efficiency is measured as the ratio of weighted output (virtual output) to weighted input (virtual input), and can take the values between zero and one. Ideally one can treat farms with efficiency score equal to unity as efficient, while those less than one as inefficient. In other words, when the optimum values for the dual linear programmes for any Decision Making Unit (DMU) possesses zero value, the DMU is efficient which lies on the envelopment surface. In Table 1, we present the frequency distribution of farm by efficiency level. One observes very interesting results regarding the nature of efficiency of farms from the Table. Although most of the farms are ideally efficient, the efficiency scores of other farms do not differ much. No farm in the sample score efficiency level less than 0.98. It should be mentioned that Chattopadhyay and Sengupta (2001), in their studies comprising 100 owner and tenant cultivating households, observed that 74 per cent of the farms, which they categorised as efficient farms, scored efficiency greater than 80 per cent, but they excluded their most important input (irrigation) in measuring efficiency by the DEA technique which makes doubt of the validity of DEA test. Should they include, it is expected, their most efficient input within the given set of inputs for the given output, paddy, under DEA technique, it could have made a possibility to increase the efficiency level of the farms - both efficient and inefficient farms, and then the results of efficiency score of the farms of our findings might not differ much with Chattopadhyay and Sengupta (2001). But, more importantly, the results that all farms score high efficiency are valid not only in Technologically Advanced Villages (TAV) but also in Technologically Backward Villages (TBV) in agriculture. This might suggest that the diffusion of technological inputs in agriculture, like high incidence of irrigation and HYV technology together with high use of chemical fertiliser, is not so important in improving the efficiency level of the farm. It is also widely possible for a firm in a technologically backward area in agriculture, which is entirely dependent on rain water, non-HYV technology and low use of chemical fertiliser in a mono-cropping area, to produce maximum possible output from a given set of inputs (or the ‘best practice’ relationship between inputs and outputs - Cavaluzzo and Baldwin; 1993, p. 212). In other words, though crop produced in technologically backward villages bears low cost per unit of area compared with technologically advanced villages in agriculture, in respect of efficiency or productivity differentials they do not differ much.

TABLE 1. FREQUENCY DISTRIBUTION OF FARMING HOUSEHOLDS BY LEVEL OF EFFICIENCY OBTAINED FROM DATA ENVELOPMENT ANALYSIS

Levels of technical efficiency (per cent) (1)	Number of farms (2)
Upto 0.980	Nil
0.980 – 0.990	20
0.990 – 0.999	36
1.0	24
All	80

In Table 2, we present the frequency distribution of efficient[9] and inefficient farms among owners and tenants[10] in two types of villages - Technologically Advanced Villages (TAV) and Technologically Backward Villages (TBV) in agriculture. It shows that for TAV, most of the owner-cultivating farms (13 out of 20 cases) are efficient and they are efficient in most cases (13 out of 16 cases) compared with tenant-operated farms. Turning to TBV although tenant operated farms are efficient in most cases (6 out of 8) in relation to owner-operated farms, those efficient farms (6 cases) belong to only 30 per cent (6 out of 20 cases) of total tenant cultivating farms. Thus the results obtained in TBV show that both tenant and owner cultivators are inefficient in most of the cases. But for TAV, our findings seems to suggest the basic neo-classical logic of inherent inefficiency of tenant farms as propounded by Marshall (1920).

TABLE 2. FREQUENCY DISTRIBUTION OF EFFICIENT AND INEFFICIENT FARMS BY TYPES OF TENURE

Types of tenure	Efficient*		Inefficient[@]		Total	
	TAV	TBV	TAV	TBV	TAV	TBV
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Owner	13 (65.00)	2 (10.00)	7 (35.00)	18 (90.00)	20 (100.00)	20 (100.00)
Tenant	03 (15.00)	6 (30.00)	17 (85.00)	14 (70.00)	20 (100.00)	20 (100.00)
All	16 (40.00)	8 (20.00)	24 (60.00)	32 (80.00)	40 (100.00)	40 (100.00)

TAV and TBV represent technologically advanced villages and technologically backward villages in agriculture respectively. Figures in parentheses are percentages. *Farms with efficiency score equal to unity are treated as efficient farms. @ Farms with efficiency score less than unity but greater than or equal to zero are treated as inefficient farms.

Turning to the frequency distribution of efficient and inefficient farms by size-classes of holdings, Table 3 shows that according to the respective size-classes of holdings, irrespective of any tenancy type, all the farms of the lowest farm size (up to 1 acre) are efficient. But regarding the farm size (in acre) between 1.01 and 2.50, most of the farms are inefficient and the proportion of inefficient farms increases with the increase of farm size within these size-groups. On the other hand, either cent per cent or an overwhelming majority of the farms are efficient beyond farm size 2.51 and above. Considering all farm-sizes in both the types of villages together, it can be said that except for the lowest farm size where all farms are efficient, the proportion of efficient farm increases with the increase of farm size.

TABLE 3. FREQUENCY DISTRIBUTION OF EFFICIENT AND INEFFICIENT FARMS BY SIZE-CLASS OF HOLDINGS

Size-classes of holdings (in acres)	Efficient farms		Inefficient farms	
	TAV	TBV	TAV	TBV
(1)	(2)	(3)	(4)	(5)
Upto 1.00	100.00	-	-	100.00
1.01 – 1.50	33.00	-	66.67	100.00
1.51 – 2.00	18.18	11.11	81.82	88.89
2.01 – 2.50	9.09	10.00	90.91	90.00
2.51 – 3.00	100.00	42.86	-	57.14
3.01 – 5.00	75.00	28.57	25.00	71.43
Above 5.00	100.00	50.00	-	50.00
Total	40.00	20.00	60.00	80.00

We now present data on the distribution of farms separately for efficient and inefficient categories by size classes of holdings and types of tenure in TAV in Table 4. As per the size-group of holdings under owner-cultivating farms, the proportion of efficient farms almost increases with the increase of farm size; on the contrary, the proportion of inefficient farms almost decreases with the increase of farm size for owner-cultivating farms. Table 4 also shows that tenant farms are almost inefficient, whereas most of the owner-cultivating farms are efficient. For TBV, Table 5 shows that majority of the tenant and owner-cultivating farms are inefficient. But compared with owner-cultivating farms, the proportion of efficient farms are higher for tenant – cultivating farms. Regarding the relationship between efficiency/inefficiency and farm-size, no clear-cut pattern in discernible. We also conduct a χ^2 test to examine whether there is a significant difference in efficiency of farms on the basis of size-classes of holding between two types of villages - TAV and TBV. We test the null hypothesis H_0: there is no distinction in average efficiency level of farms between two types of villages on the basis of size classes of holdings, against the alternative hypothesis H_1: there is a distinction in average efficiency level of farms between two types of villages for same size classes of holdings.

TABLE 4. FREQUENCY DISTRIBUTION OF EFFICIENT AND INEFFICIENT FARMS BY SIZE-CLASS OF HOLDINGS AND TYPES OF TENURE IN TAV

(per cent)

Size-classes of holdings (in acres)	Efficient farms		Inefficient farms	
	Owners	Tenants	Owners	Tenants
(1)	(2)	(3)	(4)	(5)
Upto 1.00	50.00	50.00	-	-
1.01 – 1.50	33.33	-	50.00	16.67
1.51 – 2.00	18.18	-	9.09	72.73
2.01 – 2.50	9.09	-	27.27	63.64
2.51 – 3.00	66.67	33.33	-	-
3.01 – 5.00	75.00	-	-	25.00
Above 5.00	100.00	-	-	-
Total	32.50	7.50	17.50	42.50

TABLE 5. FREQUENCY DISTRIBUTION OF EFFICIENT AND INEFFICIENT FARMS BY SIZE-CLASS OF HOLDINGS AND TYPES OF TENURE IN TBV

(per cent)

Size-classes of holdings (in acres)	Efficient farms		Inefficient farms	
	Owners	Tenants	Owners	Tenants
(1)	(2)	(3)	(4)	(5)
Upto 1.00	-	-	100.00	-
1.01 – 1.50	-	-	25.00	75.00
1.51 – 2.00	-	11.11	55.56	33.33
2.01 – 2.50	-	10.00	50.00	40.00
2.51 – 3.00	-	42.86	28.57	28.57
3.01 – 5.00	14.29	14.29	42.85	28.57
Above 5.00	50.00	-	50.00	-
Total	5.00	15.00	45.00	35.00

The test statistic under H_0 is

$$\chi^2 = \sum_{i=1}^{n} \frac{(Oi-Ei)^2}{E_i} \text{ with df. (K-1) (L-1)}$$

where 0 = observed cell frequency; E = expected cell frequency; K = number of rows; L = number of columns. The expected frequency of any cell is given by

$$E = \frac{\text{Row total} \times \text{Column total}}{\text{Total frequency}}$$

As the difference of efficiency level between firms is close to 1 (between 0.98 and 1), the observed χ^2 is 0.0020. From table, $\chi^2_{0.01,6}$ = 16.812 and $\chi^2_{0.05,6}$ = 12.592. Thus, we see that χ^2 (observed) < $\chi^2_{0.01,6}$ or $\chi_{0.05,6}$ and H_0 is not rejected both at 1 and 5 per cent level of significance. We may conclude that there is no significant difference in the average efficiency of farms between two 1 types of villages on the basis of size-classes of holding.

We now turn to examine the factors responsible for the higher level of efficiency for all farms in both the types of villages. To this end, we present simple descriptive statistical analysis like mean (arithmetic) and standard deviation of all the variables except seed[11] (per acre) considered for the measurement of efficiency level of all farms (Table 6). It is important to mention here that there is no cost of irrigation and

TABLE 6. DESCRIPTIVE STATISTICAL ANALYSIS (MEAN AND STANDARD DEVIATION) OF THE VARIABLES CONSIDERED FOR EFFICIENCY TEST

	TAV				TBV			
	Owner		Tenant		Owner		Tenant	
Variables used per acre	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Production (in kg)	1,030.81	257.20	959.65	164.35	798.81*(*)	242.83	752.66*(*)	259.46
Irrigation (in hours)	93.20	68.90	87.26	62.32	-	-	-	-
Chemical fertiliser (in kg)	174.07	62.98	158.23	58.34	-	-	-	-
Others (in hours)†	417.61	126.64	402.31	111.23	389.28*(*)	104.25	371.13*(*)	95.17
Family labour (in hours) ‡	676.21	276.81	624.10	227.15	625.05*	194.40	631.55*	203.87
Hired labour (in hours)‡	1,106.70	904.23	970.13	847.38	641.18*(*)	511.27	685.16*(*)	583.13

†Others include cost of bullock/tractor and maintenance of implements. ‡ In the test, hours were converted into days dividing total hours by 6, because agricultural labour usually works 6 hours a day in the region we surveyed. * and (*) denote t values for the difference between (2) and (6) [or between (2) and (8)] and between (4) and (6) [or between (4) and (8)] Significant at 1 per cent level.

chemical fertiliser for farms in TBV. Table 6 shows no significant difference of means[12] for TAV and TBV relating to production (per acre) and its cost for almost all items (per acre) for both categories of cultivators. But the most important difference in cost at the mean level is observed for hired labour between cultivators in two types of villages. However, the comparison of basic statistical measurement like mean and standard deviation based on variables considered for the measurement of efficiency of farms under two types of villages suggests that higher (significant) mean of production (per unit) is associated with higher (significant) mean of cost (per unit) for farms in TAV, compared with TBV. Conversely, lower (significant) mean of production (per unit) is tied with lower (significant) mean of cost (per unit) in TBV. This result, however, suggests, higher efficiency score for all firms in both the villages calculated by non-parametric DEA, because technical efficiency points to a production unit's ability to obtain the maximum possible output from a given set of inputs or 'best practice' relationship between inputs and outputs.

IV

CONCLUSION

In this paper we have attempted to examine the extent of efficiency under different types of tenure and different farm sizes in two types of villages - Technologically Advanced Villages (TAV) in agriculture, having high incidence of irrigational and HYV facilities in an area usually cropped twice on the same plot of land every year and Technologically Backward Villages (TBV) having no irrigational (except rainwater) and HYV facilities in a mono-cropping area. This study seems to be important in that it tries to study whether the spread of modern agricultural technology like high incidence of irrigational and HYV facilities can bring about any change to the efficiency level of farm compared with an area which have no irrigational facility (except rain water) and HYV technology. Our analysis shows that the use of high technological inputs in agriculture is not so important in improving the efficiency level of the farms. It means that despite the use of low cost per unit of area in Technologically Backward Villages (TBV) in relation to the Technologically Advanced Villages (TAV), the efficiency level between those two types of villages do not differ much. It implies that it is also widely possible for a farm in a technologically backward area in agriculture to produce the maximum possible output from a given set of inputs or the farm is a 'best practice' farm (best practice relationship between inputs and outputs). However, treating farms with efficiency score equal to one as efficient (ideally efficient farm), our data show that owner-cultivating farms are efficient in TAV, whereas in most of the cases both tenant and owner-operated farms are inefficient in TBV. Considering all farm sizes in both the types of villages together, it can be said that except the lowest farm size where all farms are efficient, the proportion of efficient farm increases with the increase of farm size. But, more importantly, according to the score of efficiency, since the numerical scores between efficient and inefficient farms are very close to each other, the difference between efficient and inefficient farms under the size-classes of holdings among owners and tenants of our study based on the evidence of a particular region of West Bengal cannot, likely, to be established significantly. This might suggest that the only high use of technical inputs like irrigation, HYV seed, chemical fertiliser, per unit of land does not necessarily bring about maximum possible output for a given set of inputs, nor does it only make 'best practice' relationship between inputs and outputs. It is necessary to provide institutional support to the farmers of TAV by widening access to agricultural extension facilities like management and supervisory advantages to the farmers, technical training to the farmers and the like so that the farmers of TAV may use minimum modern agricultural inputs with low cost per unit of area in order to have maximum possible output.

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NOTES

1. Using DEA methodology Singh *et al.* (2002) also estimated the overall economic efficiency expressed in terms of cost efficiency, which is a measure of the combined extent to which technical and allocative change the cost of farm-level production.
2. Eighty-eight per cent and above of the net cultivable area in each village is irrigated as well as under HYV crop cultivation.
3. In our sample, owners are those farmers, who are owners of at least 72 per cent of land cultivated by them and tenants are those farmers who cultivate land 78 per cent or more of which is leased in from owners. The tenants of our sample were almost sharecroppers (49 out of 50 cases). We treat those farms as marginal, small and medium farms which belong to land between 0.01 and 2.50 acres, 2.51 and 5.00 acres and 5.01 and 10.00 acres respectively.
4. In 1989-90 we surveyed six villages (excluding the villages we surveyed in 1995-96) in Habra block under 25 Parganas district, West Bengal (Chattopadhyay and Sarker, 1993).
5. Out of 40 households in irrigated villages, 4 owner-cultivator and 2 tenant-cultivator households cultivated wheat, 3 owner-cultivator and 4 tenant-cultivator households cultivated potato in the year (1995-96) we surveyed.
6. Irrigation service (in hours) per acre.
7. Material cost (except irrigation) in physical terms includes manure and fertiliser input per acre (kg), seed input per acre (kg), input of bullock labour days per acre, expenditure on maintenance of implements (in hours) per acre.
8. Human labour includes both family and hired labour days per acre.
9. We treat farms with efficiency score equal to unity as efficient. It should be mentioned that if we take into account the effect of random events (such as natural holocausts, equipment failures, product defects, etc.), the difference between efficient and inefficient farms does not exist.
10. The tenant of our sample are almost sharecroppers. Although the tenants of our sample are not pure tenants, they cultivate land of which almost all lands (about four-fifths) are leased in from owners.
11. The application of seed (measured in kg per acre) as an input of production did not differ between cultivators under two types of villages. Hence the absolute values of mean and S.D. were the same for cultivators in both the types of villages.
12. To test the null hypothesis that means are equal, H_0: $\mu_1 = \mu_2$, against the alternative hypothesis H_1: $\mu_1 \neq \mu_2$, Fisher's 't' test was applied.

$$t = \frac{X_1 - X_2}{\sqrt{S_2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} \qquad t_{n1} + n_2 - 2 \text{ degrees of freedom}$$

where $$S^2 = \frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}$$

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