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Technical Efficiency of Fish Farms in West Bengal: Nature, Extent and Implications§

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Abstract

In this study, undertaken in West Bengal, the concept of meta-frontier data envelopment analysis (DEA) has been carried out to examine whether there is any systematic difference in the technical efficiency (TE) of fish farms of different size-classes categorized on various socio-economic conditions. Efforts have also been made to identify the influence of those characteristics on TE score using regression analysis. The study has revealed that the overall mean TE is 62.8 per cent, which indicates that on average, the realized fish output can be raised by 37 per cent in the state with the existing technology and resources. Wide variations in TE scores have been found when farms were categorized on the basis of size, region, ownership pattern or proprietorship. The farm experience, ownership and sole proprietorship are the most important determinants of TE. However, pond size and education have not depicted any significant relationship with TE. In order to improve the efficiency of fish culture, location-specific development strategies, long-term leasing policies, and participatory extension support should be adopted in West Bengal.

Key words: Technical efficiency, fish farms, leasing policy, fish culture, data envelopment analysis, West Bengal

JEL Classification: Q22, Q15

Introduction

India commands a place of pride in fish production in the world. Growing at an average annual rate of 5.12 per cent, the fish production in the country increased to 9.06 million tonnes in 2012-13, enhancing availability of fish to 9.96 kg per capita. This growth in fish production has been possible due to quantum jump in inland fish production, especially pond aquaculture, which is now growing at the average annual rate of 6.87 per cent (GoI, 2014). Under the assumptions of 5 per cent GDP growth and at least 50 per cent of the population consuming fish, it is predicted that by 2030 demand for fish will reach to about 15.30 million tonnes, of which about 90 per cent is expected to be met from the freshwater sources (World Bank, 2013). In order to achieve such a target, efficiency in production of fish needs to be enhanced.

The efficiency can be increased through either introduction of new technology, which will shift production frontier upward, or utilization of existing technology to its full potential, which will maximize output given the set of inputs and technology. But, boarding on new technologies is meaningless, if farmers are found tardy regarding adoption of a new technology (Kumar *et al*., 2005; Katiha *et al*., 2005).

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In the case of fish production in India, it is found that there are only few regions which are able to specialize in intensive culture practices on a highly commercial basis. As a consequence, production performance of aquaculture sector has followed an uneven path and a large gap exists in productivity and efficiency (Ayyappan, 2008; Kumar *et al.*, 2008). Hence, improvement in technical efficiency is the key for meeting the growing fish demand in the coming years.

Again, there is no denying the fact that technical efficiency of a farm depends not only on the inputs it uses and output it produces, but also on several other factors, such as infrastructural facilities, region, level of education and technical knowledge, work culture, pond size, etc. It is difficult to incorporate those factors into the production frontier to examine their effects on efficiency, though important (Rao *et al.*, 2003; O'donnell *et al.*, 2008; Narla and Zala, 2010). Against such a backdrop, group-efficiency analysis might reveal more concrete results if it is carried out separately for different groups. Also, a definite conclusion can be drawn if it is found that a particular group of farmers is more efficient vis-a-vis other farmers. Hence, the present study has examined the systematic differences in the TE of fish farms of different groups categorized by various socio-economic conditions using the concept of meta-frontier data envelopment analysis (Hayami, 1969; Hayami and Ruttan, 1970). Efforts have also been made to identify the influence of socio-economic and farm characteristics on the TE score by conducting multiple regression analysis.

Data and Methodology

Data Collection

The study is based on the primary data collected through field survey in West Bengal during 2008-09. Excluding hill and terai regions, one district was selected from each zones (old alluvial region, red and laterite zone, new alluvial region, and coastal and saline zone) of West Bengal. At the second stage, three blocks from each district and then two villages from each block were randomly chosen. At the final stage, a comprehensive list of pond or tank owners from each village in the selected blocks was prepared. In case of non-fulfillment of this condition in a particular village, a cluster of villages with two or more contiguous villages was constituted. From each village or cluster, five fish farmers each from small (having ponds of < 0.5 acre), medium (having ponds of 0.5-5.0 acres) and large (having ponds of > 5 acres) groups were selected randomly. In this way, a total of 30 pond-owner households were selected from each block leading to a total sample of 360 units. The study was conducted on the basis of an open-ended and exploratory research design and data were collected using the pre-designed structured questionnaires.

The fish farmers produce different types of fish species using seeds of each category. The output was expressed as the aggregated nominal value of total fish produced, of all the species taken together, instead of each species from the group individually. Aggregation had to be done because of the inability or unwillingness on the part of fish farmers to provide detailed information about the use of different species of fish seed or fish output.

Analytical Framework

The study has used meta-frontier data envelopment analysis (DEA) models. The DEA calculates the frontier production function of a set of decision-making units (DMUs) and evaluates the relative technical efficiency of each unit, thereby allowing a distinction between efficient and inefficient DMUs. The DMUs identified as 'best practice units' (i.e. those determining the frontier) are given a rating of one, whereas the degree of technical inefficiency of the other DMUs is calculated on the basis of the Euclidian distance of their input –output ratio from the frontier (Charnes *et al.,* 1978).

Technical Efficiency (TE) represents the ability of a DMU to produce maximum output given a set of inputs and technology (output-oriented) or, alternatively, to achieve maximum feasible reductions in input quantities given the input prices and output (input-oriented), thereby producing output optimally (Farrell, 1957). In this study, input-oriented DEA seemed appropriate, given the fact that aquaculture farms have more control over inputs than output levels (Sharma *et al.*, 1999; Kumar *et al.*, 2010). Also, from utility-maximization point of view, most poor farmers tend to be risk averse. Their predominant goal is economic survival. They trade-off lower risk against higher profit or disutility of increasing risk. Adequate stability of output and income and the avoidance of major short-term losses take precedence over profit maximization (NCAP, 2008; Misra, 2011). As a result, optimal use of inputs, rather than output maximization, appears to be more rational strategy for the fish farmers. Again, since both input- and output-oriented measures give the same numerical figure for TE score, the interpretations remain the same, irrespective of the methods chosen (Färe *et al.*, 1994; Kumar *et al.,* 2004).

In meta-frontier analysis, the performance of each individual fish farm in the sample is measured against two different frontiers — one based on farms from all the different groups in the sample and the other based only on farms from the group to which it belongs. The first can be regarded as the *grand* frontier and the other as the *group* frontier. The index set may be defined as: $I = [\{1, 2, \ldots, N\}$, where each observed data point is an element of I. Now consider a partition $I = \bigcup I_r$, where I_r includes observations only from the group r. Then, under the standard assumptions of convexity and free disposability of inputs *(x)* and outputs *(y)*, the empirically constructed group and grand production possibility sets, respectively are:

$$S^r = \{(x,y): x \geq \sum_{j \in I_r} \lambda_j x^j;\ y \leq \sum_{j \in I_r} \lambda_j y^j;$$

$$\sum_{j = I_r} \lambda_j = 1\ ;\ \lambda_j \geq 0\ \ (j \in I_r)\} \qquad \text{(for group r)}$$

and

$$S^G = \{(x,y): x \geq \sum_{j \in \cup I_r} \lambda_j x^j;\ y \leq \sum_{j \in \cup I_r} \lambda_j x^j;_{\ j}$$

$$\sum_{j \in \cup I_r} \lambda_j = 1;\ \lambda_j \geq 0;\ (j \in \cup I_r)\}$$

It may be noted that while each S^r is a subset of S^G, the later is bigger than the union of the individual group production possibility sets.

Model Specification

For the overall or grand efficiency of fish farms in the sample, the following linear programming problem was solved, including all the 360 farms:

$$\underset{\lambda^j, \theta^j}{Minimize}\ \theta_G^j$$

Subject to

$$\sum_{j=1}^{360} \lambda^j Y^j \geq Y_0^j \quad \text{(output constraints)}$$

$$\sum_{j=1}^{360} \lambda^j Y^j \geq Y_0^j \quad \text{(inputs constraints, } k\text{)}$$

$$\sum_{j=1}^{360} \lambda^j = 1$$

$$\lambda^j \geq 0,\ j = 1, 2, \ldots, 360$$

where,

θ_G^j = Dual of the variable indicating proportional increase in output possible by the farm *j*; or grand technical efficiency, TE_G^j,

λ^j = The weight or intensity variable (or, shadow price) used to derive all possible linear combinations of sample observations,

Y_0^j = Actual output produced by the farm *j*, and

X_k^0 = Actual input-use by the farm *j*.

Similarly, the relevant DEA model for group *r* with N_r fish farms in the sample was given by:

$$\underset{\lambda^j, \theta^j}{Minimize}\ \theta_r^j$$

Subject to

$$\sum_j \lambda^j Y^j \geq Y_0^j \quad \text{(output constraints)}$$

$$\sum_j \lambda^j X_k^j \leq \theta_r^j X_k^0 \quad \text{(inputs constraints, } k\text{)}$$

$$\sum_j \lambda^j = 1,$$

$$\lambda^j \geq 0,\ j = 1, 2, 3, \ldots, N_r$$

where, θ_r^j is the dual of the variable indicating proportional increase in output possible by the farm *j*; or the group technical efficiency, TE_r^j.

A point-wise measure of technical efficiency of group *r* relative to the grand frontier evaluated at the input-output data of the farm *j* is:

$$\beta_r^j = \frac{TE_G^j}{TE_r^j}$$

An overall measure of the efficiency of group *r* is:

$$TE(r) = (\prod_{j \in r} \beta_r^j)^{1/N\,r}$$

where, N_r is the number of farms in group *r*. Clearly, for any fish farms *j* in a group *r*, TE_G^j is a measure of its performance relative to other farms within the same group. On the other hand, β is a measure of its performance compared to all the groups in the study (Coelli, 1996).

Determinants of Technical Efficiency

The exclusive focus on a single criterion (say, size of fish farm) may hide the consequences of variations in other characteristics (say, location of farm or age of farmers). The partial effect of differences in any one category can be accurately measured only within a multiple regression model incorporating all the relevant explanatory variables. In this study, the influence of socio-economic and farm characteristics was examined by regressing them on the (grand) TE score. The dependent variable was the measured level of TE score of an individual fish farm. The variables 'coastal and saline zone' (CSZ), 'old alluvial region' (OAR) and 'red and laterite zone' (RLZ) were the locational dummies. The category 'new alluvial region' (NAR) was treated as the reference group. In the tenure classification, owned (OWN) was the dummy variable for fish farming in owned ponds, whereas leased-in (LEASED) ponds constituted the reference category. In the organization type category, the dummy variables identified the farms as individual proprietorship (PROP 1) and joint proprietorship (PROP 2). Farms under proprietorship of more than two partners (PROP MORE) constituted the reference group. Apart from various categorical variables, size of ponds and age, education and experience of the farmers were also included as the regressors. The pond size was measured by the nominal value in acres. The age, experience and schooling of the fish farmers were measured in years (Table 1). The (grand) technical efficiency scores generated from meta-frontier DEA model were regressed using following model:

$$TE_i = \alpha_0 + \alpha_1(CSZ) + \alpha_2(OAR) + \alpha_3(RLZ) + \alpha_4(OWNED) + \alpha_5(PROP\ 1) + \alpha_6(PROP\ 2) + \alpha_7(SIZE) + \alpha_8(EDU) + \alpha_9(EXP) + \alpha_{10}(AGE) + e_i$$

where, α_0 is a constant and e_i is the error-term.

Results and Discussion

Distribution of Technical and Scale Efficiency Scores

The estimated TE score under CRS technology for the sample farms, given in Table 2, varies from 0.27 to 1.0, with a sample average of 0.628. It implies that on an average, the fish-farms can reduce input-use to the extent of 37.2 per cent without compromising on the level of output. The share of farms producing fish optimally is only 7.5 per cent in the total sample. A good number of farms are, therefore, operating below the potential and therefore, there are significant possibilities to increase the TE level of fish producers. The share of fish-farms having technical efficiency less

Table 1. Description of variables used in multiple regression analysis

Type of independent variables	Operational definition
Location dummies	New Alluvial Region = 0, Coastal and Saline Zone = 1, Old Alluvial Region = 2, Red and Laterite Zone = 3
Tenure dummy	Leased = 0, Owned = 1
Proprietorship dummies	More than 2 partners = 0, Individual = 1, Two partners = 2
Pond size	Area of pond (acre)
Education	Number of years in schooling
Experience of farmers	Number of years in fish farming
Age of farmers	Years

Table 2. Distribution of efficiency score of fish farms in West Bengal

Efficiency score (%)	Technical efficiency	
	Number of farms	Percentages to total farmers
Less than 50	68	18.89
50-70	196	54.44
More than 70 but less than 90	69	19.17
"Best Practice" farms (TE = 1)	27	7.50
Efficiency score less than average	221	61.3

Note: The minimum TE score was 0.271 and the overall mean TE score was 0.628.

than 50 per cent (TE score < 0.5) is 19 per cent. The distribution of efficiency scores shows that TE concentration is more in the sixtieth percentiles (52%), and the rests have almost equal distribution between lower and upper area of mean TE scores.

The difference in TE has another important implication. The worst-performing farms (having TE score of 0.27) can increase their efficacy regarding input-use up to 73 per cent (and thereby can reach the optimum TE score of one) just by sharing their own experience and implementing the input management strategy of best practice farms, without even getting institutional support. Thus, the way to manage eliminate technical inefficiency in fish farming in West Bengal is adoption of best farming practices and input application management of efficient farms.

A perusal of Table 2 also reveals that the best practices in fish culture have not been percolated widely in the sample area, leading to reasonable variations in technical efficiency scores. The interaction with the sample farmers led to the conclusion that the fish culture practices being adopted were not according to the recommended schedule. A large number of sample farmers even expressed their unawareness about the different steps of scientific culture practices.

Actual vs Technically Efficient Input Applications

To assess the input-use efficiency of fish-farmers, a comparison was made between actual (observed) quantities of inputs being used and the corresponding optimal (potential) quantities revealed from the technical efficiency exercise. The required amount of inputs was calculated for the actual level of output. It was found from Table 3 that the average actual usage of majority of inputs was lower than the theoretical levels. Table 3 also shows that use of fish fingerlings should be raised by 33.7 per cent on an average to satisfy the present level of production. Small farms have been found more rational regarding use of fish seed, but medium and large farms should reduce the seed-use by 27 per cent and 53 per cent, respectively to produce the existing level of output. The small farms could have faced financial constraints causing low use of this most important input, but large farms are overshooting fingerlings in order to receive high returns. However, in order to stay in best practice level, almost all the farms should raise their use of seed input.

It has also been found that farms, in general, have underutilized feed and over-applied labour and fertilizer. Accordingly, feed-use should be increased by 1193 kg/acre (more than 78%) in order to achieve the frontier level of production. But, to maintain the present level of production, farms should reduce fish feed up to 6 per cent. The tendency to use excess feed is highest among the large farms. Side by side, the sample farms have over-applied fertilizer and labour. More than 39 per cent use of fertilizers can be minimized for actual level of output. Small farms alone can reduce it by more than 50 per cent. Though, slight increase in fertilizer-use (only 4%) is required to be the best practice farm. Fertilization in excess of the required level may be due to the excessive usage of organic fertilizers like cow dung or oil cake. Another significant observation is that labour-use is more than the recommended (optimal) level, irrespective of the pond-size and farms, can reduce labour-use by more than 66 per cent. The existence of surplus labour (difference between labour actually used and labour required for the existing output level) is highest in small farms, followed by large and medium farms. As labour

Table 3. Mean actual versus technically efficient input-output applications in fish farms

Input-Output	Size of fish-farm (acre)			
	Small	Medium	Large	All
Actual use of seeds (No./acre)	3671	5929	9037	6212
Optimum use of inputs (No./acre)	5458	7217	8128	6934
Seeds required for actual output level	3379	4661	5898	4646
	(-08.64)	(-27.20)	(-53.22)	(-33.71)
Actual use of feed (kg/acre)	1271	1686	1712	1522
Potential use of feed (kg/acre)	2189	2853	3103	2715
Feed required for actual output level	1357	1873	1911	1632
	(06.33)	(09.98)	(10.41)	(06.74)
Actual use of fertilizers (kg/acre)	1037	1125	1705	1289
Potential use of fertilizers (kg/acre)	858	1274	1554	1228
Fertilizers required for actual output level	691	833	1254	926
	(-50.07)	(-35.05)	(-35.96)	(-39.20)
Actual use of labour (humandays/acre)	173	168	264	201
Potential use of labour (humandays/acre)	104	154	204	154
Labour required for actual output level	86	112	165	121
	(-101.16)	(-50.00)	(-60.00)	(-66.11)
Actual amount of fish produced (kg/acre)	1082	1846	2017	1648
Potential amount of fish output (kg/acre)	1739	2835	3290	2924
Change required to achieve optimal production	657	989	1273	1276
	(60.72)	(53.57)	(63.11)	(59.13)

Note: Figures within the parentheses indicate percentage change of respective total.

cost becomes minimal due to the use of family and off-agricultural based labour, farms were overshooting the input without considering its adverse impact on production.

The technically efficient fish output level per acre is estimated to be 2924 kg as against the actual production of 1648 kg. The theoretical optimum suggests that production of fish could be increased by 1276 kg (59% of actual production) if the technically efficient input quantities are applied by the farms. The changes in outputs across different pond size groups, given in Table 3, show that small farms could have increased fish production by 60 per cent with the TE inputs level. By matching the actual input-mix with the optimum, the large pond operators can increase production up to 63 per cent. More than half of the present production can be raised additionally in case of medium farms. All these facts signify that these irrational input-mix being practised by the sample farms may be most significant reason behind the low level of technical efficiency. Consultations with government officials revealed that extension services had been geared several times at the village level. The attendance rate of adopters was also high. Still, production is far from expectation. Actually, the adaptation of farmers to local knowledge systems and different social and cultural contexts had compelled the farmers to manipulate the acquired scientific knowledge along with their own conventional wisdom to adopt only a part of the package of practices. As a result, ultimate production has been affected adversely.

Technical Efficiency under Varying Conditions

Wide variations in TE scores reveal the fact that there is no "one size fits all" model for aquaculture development. Actually, all the observed fish farms may not have access to the same production technology. Rather, different farms or categories of farms may apply different production technologies due to variety of geographical, institutional, social or other factors. Building a single production frontier based on all the data points would, in such cases, result in an

Table 4. Mean technical efficiency of different fish farms-size Classes for different regions

Region	Criterion	Farm-size class		
		Small	Medium	Large
South 24 Parganas	% of farms	25	25	25
(Coastal and Saline Zone)	Grand TE	0.657	0.64	0.632
	Group TE	0.752	0.764	0.734
	CV (in %)	45.25	112.59	56.23
Hoogly	% of farms	25	25	25
(Old Alluvial Region)	Grand TE	0.517	0.605	0.631
	Group TE	0.713	0.721	0.713
	CV (in %)	81.36	78.33	214.35
Bankura	% of farms	25	25	25
(Red and Laterite Zone)	Grand TE	0.705	0.703	0.611
	Group TE	0.797	0.803	0.736
	CV (in %)	154.20	38.29	44.0
Murshidabad	% of farms	25	25	25
(New Alluvial Region)	Grand TE	0.609	0.632	0.578
	Group TE	0.682	0.724	0.729
	CV (in %)	68.29	92.35	139.71
Overall	% of farms	100	100	100
	Grand TE	0.622	0.651	0.613
	Group TE	0.736	0.753	0.728

Note: CV indicates coefficient of variation in individual TE score within the respective group.

inappropriate best-practice technology. A way to measure the impact of production technological heterogeneity across such groups (say, region, proprietorship or ownership) is to build a specific frontier for each group relative to its 'grand' frontier. The results, derived from such meta-frontier production function approach, reveal some interesting facts.

Size-wise Variations in Regional Level TE

The performance of each fish farm in the sample was measured against two different frontiers — one based on the farms of entire region, i.e. 360 fish farmers, and the other based only on the farms from region to which they belonged. The first was regarded as the state or *grand* frontier and the other as the *group* frontier or regional frontier. In the sample, four districts were taken as representatives of four agro-climatic zones. The summary results of TE of each farm evaluated on the basis of grand and regional frontiers are given in Table 4. To find regional variations, the average TE score was computed for each region. The result, in this case, appeared ambiguous. In the case of Coastal and Saline Zone and New Alluvial Region, medium-size pond owners can culture fish more efficiently than large and small farmers. But, in the Old Alluvial Region, large fish farms were found more technically efficient than medium and small farms. In the Red and Laterite Zone, medium fish farms were most efficient when measured with respect to group frontier. But, when all the farmers were taken into consideration, the medium fish farms appeared less efficient than small farms. Also, large fish farms in the New Alluvial Region were found technically more efficient than medium-size farms. Overall, medium fish farms in the Red and Laterite Zone, when analyzed within the group, appeared most efficient among all the farms taken together. On judging by the coefficient of variation (CV), medium (38.29%) and large-size farmers (44.20%) in the Red and Laterite Zone and small farms (45.25%) in the Coastal and Saline Zone depicted the lowest degree of variability in technical efficiency. In contrast, large farms in the Old Alluvial Region were, though more efficient than medium and small farms, showed much greater variability in efficiency (214%)

Table 5. Mean technical efficiency of different fish farm size classes for different tenure Status

Tenure status	Criterion	Farm-size class		
		Small	Medium	Large
Owned	% of farms	71.67	60.44	29.93
	Grand TE	0.423	0.434	0.411
	Group TE	0.727	0.743	0.743
	CV (in %)	25.25	52.59	76.23
	Group efficiency	0.846	0.853	0.822
Leased	% of farms	28.33	39.56	70.03
	Grand TE	0.523	0.564	0.498
	Group TE	0.615	0.593	0.598
	CV (in %)	68.29	92.35	139.71
	Group efficiency	0.348	0.453	0.446

Note: CV indicates coefficient of variation in individual TE score within the respective group.

within the group. Thus, based on highest mean and lowest variability in the efficiency levels, the medium-size pond owners in the Red and Laterite Zone appeared to have performed better.

Size-wise Variations in Technical Efficiency according to Tenure Status

The variations in TE were also observed according to the tenure status of fish farms. Preponderance of owner-operated farms, the unique characteristics of West Bengal, was also observed in the present study. The owner-operated farms are those where family labour makes up 50 per cent or more of the total labour employed in fish production. Usually, fish farmers in West Bengal own such ponds by either inheritance or dig ponds to culture fisheries. The tenant farms are those which fish farmers use on lease from their relatives, friends, irrigation and fisheries department of the government or panchayat. It was observed that preponderance of owner-operated farms and attaching of relatively less importance to the leasing-out system could be accounted for by two reasons. One, with the advent of new technology of composite intensive fish culture, self-cultivation is being considered by the owners as a paying proposition. Two, because of a series of tenancy legislations in recent years, giving more rights to tenants, the owners have become more apprehensive of losing the occupancy rights in their leased-out water units. Now, as is evident from Table 5, owner operation in fish culture had higher group efficiency than leased-in farms. It is true for all farm-size classes under study. The group efficiency for leased-in farms ranged from as low as 0.348 for small farms to 0.453 for medium farms and 0.446 for large farms. On the other hand, the group efficiency for small farms under owner operation was as high as 0.727. The owner operation had led to the same level of group efficiency (0.743) for both medium and large farms. Another interesting observation is that technical efficiency seems to be neutral to scale in both cases, owned and leased-in. This implies that ponds owned and operated by the enterprising fish farmers may yield higher production, irrespective of the size of water units. The low technical efficiency of leased-in farms in the study area might be due to short duration of the lease, as it was found that the majority of the water units (61.67%) were leased-in for a short period of one year. Also, most of the tenure arrangements were oral and eviction of lessees was quite frequent. The absence of long-term leasing policy is a genuine hindrance. The uncertainty attached with short-duration leasing normally dampens the fish farmers' motivation and is not congenial for good production.

Size-wise Variations in Technical Efficiency according to Proprietorship

Another interesting feature, which might have policy implications, was that farms depicted wide variations in terms of proprietorships. Water units in the study area were being operated by individuals, either singly or jointly. Co-operatives or local bodies, having multiple proprietorships, were also engaged in fish cultivation on the sample ponds. Sole private operations (49.59%) and joint operations (28.1%) were the major agencies. A significant proportion of water units was being operated by more than two partners, particularly in the large and medium size water units (31.9% and 42.2%, respectively). It was also observed that yield was lower in water units with larger number of shareholders. However, no clear pattern was visible regarding the relation between proprietorship and scale of operation. In the case of single operation, large farms had the highest group efficiency (0.904), followed by medium (0.819) and small (0.765) farms. The group efficiencies in case of joint operations were marginally low compared to those of sole operations, but in that case, small farmers performed better with the highest

Table 6. Mean technical efficiency of different fish farm-sizes under proprietorship

Proprietorship status	Criterion	Fish farm-size class		
		Small	Medium	Large
Sole proprietorship	% of farms	31.67	26.87	25.85
	Grand TE	0.689	0.678	0.646
	Group TE	0.765	0.819	0.711
	CV (in %)	25.76	44.16	23.89
	Group efficiency	0.822	0.857	0.904
Joint operation	% of farms	55.83	50.75	42.18
	Grand TE	0.569	0.587	0.498
	Group TE	0.577	0.611	0.597
	CV (in %)	55.61	67.43	35.67
	Group efficiency	0.633	0.589	0.587
More than 2 partners	% of farms	12.5	42.18	31.97
	Grand TE	0.511	0.507	0.479
	Group TE	0.547	0.597	0.607
	CV (in %)	12.34	109.45	76.72
	Group efficiency	0.511	0.506	0.521

Note: CV = Coefficient of variation in individual TE score within the respective group.

group efficiency score (0.633) and lowest degree of variability (CV = 12.5%). The large farms performed marginally better when more than two partners operated those farms. Thus it may be concluded that technical efficiencies in the case of single proprietorship had a clear edge over others. Actually, the water units under sole operation have the benefits of close supervision, better monitoring and sincere regulation by the family members themselves. On the other hand, jointly-owned water units face the constraints like disinterested shareholders, absentee shareholders, family conflicts among shareholders and unequal economic status of shareholders. All these constraints were found to hinder the adoption of modern fish culture practices and improvement of ponds.

Determinants of Technical Efficiency – Multiple Regression Results

The variations in TE score were also observed according to various farm-specific variables like age of farmers, number of years in schooling or experience in carp culture. Such variations have important implications on production enhancement and human development strategies. The influence of these variables was examined by regressing them on the (grand) TE score.

The regression estimates for different locational and farm-specific variables are given in Table 7. Many of the variables have the expected signs and are significant at 5 per cent or lower level. For example, the Old Alluvial Region (OAR) has the highest average level of (group) TE, exceeding the corresponding measure for overall by 0.139 (Table 4) and has lowest variability in the levels of efficiency. In the regression analysis reported in Table 7, the coefficient of OAR dummy variable is only 0.046. Moreover, it is not even statistically significant. By contrast, such difference for the Red and Laterite Zone (RLZ) is 0.079 in Table 4 and the estimated coefficient of the RLZ dummy variable in Table 7 is comparable being at 0.115, and significant at one per cent level. This shows that controlling other factors sometimes (though not always) could portray a different picture about technological differences across the regions.

The ownership has a positive and significant coefficient (0.152), indicating that TE is high on the owner-operated farms. In other words, leased-in farms are less efficient than owned farms. This result is in confrontation with that developed in the meta-frontier analysis. Again, the effect of extent of proprietorship on TE has shown interesting results. The culture operation under single proprietorship had significantly influenced the TE and its coefficient was 0.134 and

Table 7. Regression results explaining (grand) technical efficiency score using different location, ownership and farm-specific variables

Independent variables	Estimated coefficient	Standard error
CSZ	0.045**	0.00342
OAR	0.046	0.02765
RLZ	0.115***	0.00217
OWNED	0.152**	0.00022
PROP 1	0.134***	0.01630
PROP 2	- 0.033**	0.00300
SIZE (10^6)	0.003*	0.00016
EDU (10^2)	0.012	0.00007
EXP (10^2)	0.071*	0.00453
AGE (10^2)	- 0.036**	0.02458
Constant	0.238***	0.04783
R^2 (in %)	26.24	
Adjusted R^2 (in %)	24.46	
F-test	54.24**	

Note: *, ** and *** indicate significance at 10 per cent, 5 per cent and 1 per cent levels, respectively in a two-tailed test

was significant at one per cent level of probability. In the case of joint operation, the coefficient became significantly negative (-0.033). Hence, it may be concluded that multiple ownerships are affecting the farm efficiency adversely in the study area. Experience in fish farming, on the other side, had depicted a positive influence on TE and it is significant at 10 per cent probability level. But the estimated coefficient for education is 0.012 and it is not even statistically significant. The age had shown a negative influence on TE and it is statistically significant, indicating that old farmers are not affable for higher productivity. The result has significant implications for human resource development strategy.

The association between farm-size and TE was positive and significant, but was weak as estimated coefficient was only 0.003 and had also no adequate statistical significance. The result implies that the large farms are more efficient, but it is not always true. Actually, the majority of the fish farms in West Bengal are small and often lack capital to invest for enhancing yield. They need policy support in terms of credit, technical knowledge and extension services.

Conclusions and Policy Implications

Despite continuous growth in aquaculture in the selected zones of West Bengal, the potential for growth in aquaculture is still far from exhausted. The study has observed wide variations in the level of technical efficiency scores among the sample fish farms. More than 60 per cent of the sample farms are operating below the average level of technical efficiency and this may be due to the mismanagement regarding input mix. Overall, a reduction of 37 per cent input-use is possible for the farms to maintain the existing level of production. It indicates that technologies developed in the government laboratories and trainings provided through extension services have either not been adopted by the fish farmers or they are adopting only a part of the recommended package of technology. Actually, the technologies for utilizing the resources need not always be based on intensive commercial operations; rather they should be based on the application of basic aquaculture principles, their adaptation to local knowledge systems and the different social contexts. The deviation from this rationality has compelled the farmers to manipulate their acquired scientific knowledge along with their own conventional wisdom to adopt only a part of the package of practices. As a result, ultimate production and the resultant TE have been affected adversely. And therefore, production could be significantly increased through more efficient use of the existing inputs and technology by making extension approach more participatory and farmers-driven so that efficiency in production can percolate widely. Fish Farmers can also be motivated through success stories of adoption.

Again, since the regional level variations in TE score have been found widespread, it is suggested that development strategies should be more location- or community-specific, taking into account the different development potentials as well as constraints of each area or community. From this point of view, district level development plans would be highly effective in increasing efficiencies of the farmers. In this study, medium fish farms of Red and Laterite Zone have been found most efficient. Hence, successful farmers from this zone can also be included in the extension services delivery in the remaining zones.

The study has also found that short duration of lease period is dampening the farmers' motivation in

West Bengal. There should be legal policies to safeguard the interests of the lessees by framing suitable tenancy legislations. There should be long-term comprehensive lease arrangements. Such arrangements not only increase production but also provide a full time avocation or employment to the unemployed rural youth.

To overcome the multiple ownership problems, for which efficiency scores have been found to be least, some amount of business element should be introduced in the management of multi-owned ponds. If a pond is found unutilized for a certain period, wholly or partly, the government may take it over and give it to an aspirant who intends to cultivate it.

The multiple regression analysis has revealed that experience in fish cultivation has a positive influence and the age of fish farmers has a negative impact on TE. Also, the estimated coefficient for education has not been found statistically significant. The endogenous knowledge acquired through experience in carp farming helps the farmers in enhancing their productivity. Side-by-side, it should also be taken into consideration that mere spending days in farming could not enhance endogenous knowledge (as age has a negative impact). The result, to some extent, is in contradiction with the well-documented role of human resources in improving the efficiency in aquaculture (Dey *et al.*, 2004; Kumar *et al.*, 2004). Human capital should be developed by appropriate and comprehensive extension and research strategies.

Along with these, there is a need for diversification of species from the present dependence on carps. Small indigenous species (SIS) can be used as fish seeds along with carp to enhance productivity and efficiency.

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