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Research Note

Economic Efficiency of Ring Seiners Operated off Munambam Coast of Kerala Using Data Envelopment Analysis[§]

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Abstract

This paper has presented the economic efficiency, which includes technical as well as allocative efficiency, of ring seiners operating off the Munambam fishing harbour in Kerala. The model applied was the input-oriented Constant Return to Scale (CRS) Data Envelopment Analysis (DEA) with one output and six input variables. The analysis is based on a sample of 300 trips of 15 ring seine fishing vessels. The minimizing input-oriented CRS DEA results have indicated that the average technical efficiency and allocative efficiency of ring seiners operating off the Munambam coast is 53 per cent and 76 per cent, respectively. The overall economic efficiency of ring seiners has been found to be 40 per cent, ranging from 14.62 per cent to 100 per cent for individual DMUs (Decision Making Units). This study has found that the cost on fuel is highest (68%) in the total operational cost.

Key words: Input-use efficiency, data envelopment analysis, technical inefficiency, linear programming, economic efficiency, ring seiners, Kerala

JEL Classification: C67, C61, Q16

Introduction

Technology development and adoption are the tools for improving efficiency and production in the fisheries sector. However, in spite of wide adoption of a technology, it is not necessary that it is being utilized optimally. From the technological and economic point of view, the question to be answered is how best the technological inputs are being utilized. To understand the level of efficiency in the use of any technology, data envelopment analysis (DEA) is a powerful tool and can be effectively used. It is an optimization technique and is being widely applied to evaluate the performance and efficiency of different sectors like transportation, hospitals, banks, industries, etc. (Charnes *et al*., 1994). It can also be used to measure the efficiency in the fishing industry.

In the case of a fishing vessel, if along with the increase in returns the costs also increases, the economic efficiency may decline from year to year. By simple economic logic, for better efficiency, the costs have to be kept under control. Using DEA models, we can estimate the actual vessel efficiency and the extent of input inefficiencies.

The efficiencies like technical, allocative and cost are worked out within a particular group or sample. According to Farrell (1957), the efficiency of any firm or unit consists of two components: technical efficiency, which means the ability of a firm to obtain maximum output from a given set of inputs, and allocative efficiency, which means the ability of a firm to use the inputs in optimal proportions, given their respective prices. In general, the technical efficiency

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using DEA is measured in two ways: (I) input-oriented, in which the potential of firm to reduce input-use for producing a given level of output is measured, and (II) output-oriented, in which the potential of increasing output with the given level of input-use is measured (Coelli, 1996; Johansson, 2005).

The term data envelope analysis (DEA) was coined by Charnes *et al.* (1978) and the proposed model had an input orientation and assumed constant return to scale (CRS). In this paper, DEA has been used to study the economic efficiency of ring seiners operating off the coast of Munamabam in the Ernakulam district of Kerala. Ring seiners are fishing systems operated by traditional fishermen and the uniqueness of the system is the gear, ring seines. They also play a very significant role in the fisheries sector in Kerala contributing about 56 per cent to the total marine fish production of the state (CMFRI, 2012). The DEA relies on building the best possible production function from the inputs and outputs of a group of similar units (Ramanathan, 2003). It is estimated with reference to the sample of selected or studied units or in other words, the group and the technical efficiency is the possible way the given inputs are converted into outputs relative to the best decision-making units (DMU) in the group.

The best unit operates at 100 per cent technical efficiency and the DMU with lower technical efficiency works at a percentage less than 100. The costs of inputs do not play any part in technical efficiency and this is factored in the allocative efficiency. Allocative efficiency is related to the cost of inputs in relation to the output, and equilibrium condition is that marginal cost equals average revenue. A DMU allocative efficiency is with regard to the allocation of inputs vis-à-vis its price for a given level of output, so as to minimize the costs of production. Also, in terms of percentages, the higher the percentage, the better is the cost minimization with respect to the particular DMU. The cost efficiency refers to the product of technical and allocative efficiencies, expressed as a percentage. This paper has examined the efficiency from the point of view of inputs at the existing level of production in the ring seine fisheries sector, because the output tends to be unpredictable in the marine fisheries.

Materials and Method

The data were collected from 15 ring seiners operating off Munambam fishing harbour in Kerala during the period July 2009 to June 2012. Each of the 15 crafts was considered as one DMU. Twenty sets of repeated observations over the study period for the 15 ring seiners, totalling 300 fishing trip observations, were taken for the analysis. The information on fish catch and input usage was collected from the craft operators. The quantity of fish catch was taken as the output variable and the input variables were craft (length in feet), fuel (litres), crew (number) and number of trips. To compute cost efficiency, the costs of inputs were taken into account.

The general statistics of ring seiners operated in Munambam fishing harbour are given in Table 1. The crafts were in the size class of 60-78 feet, fitted with inboard engines. The average crew size was 44. The group was fairly homogeneous as far as the type and area of operation was concerned.

Table 1. General information on the selected ring seiners operating off Munambam fishing harbour in Kerala

Vessel statistics	Min.	Mean	Max.	Standard deviation
Catch quantity (kg)	250	2720	9000	1747
Total catch value (₹)	3000	28990	110000	16322
Length (feet)	60.0	70.97	78.0	5.3
Storage capacity (kg)	2000	2865	3500	449
Depth of operation (m)	7.3	19.1	49.4	9.4
Trips per month (No.)	11	20	26	3
Diesel use (L)	70	166	270	38
Kerosene use (L)	40	153	322	55
Oil use (L)	1.0	2.5	4.0	0.7
Crew (No.)	33	44	55	4

Table 2. Correlation among the inputs used in ring seiners

Particulars	Boat (feet)	Fuel (L)	Crew (No.)
Boat (feet)	1		
Fuel (L)	0.09	1	
Crew (No.)	0.13	0.16	1

Table 2 shows that the correlation co-efficient between the length of a boat and fuel consumption was 0.09 and with crew number, it was 0.13. Similarly, the correlation coefficient between the quantity of fuel used and crew number was 0.16. Hence, it may be concluded that there was little correlation among the inputs used for ring seiners operating in the Munambam fishing harbour.

Data Envelopment Analysis Model

In general, the DEA is a deterministic approach, non-parametric in nature which is used for measuring the efficiency. In contrast with the Stochastic Frontier Approach, no assumptions regarding the functional form of the production function or the distribution of the error-term need to be made (Subhash, 2004; Coelli, 1996; Cooper *et al*., 2007; Andreu and Grunnewald, 2006). The DEA model selected for the study was a cost efficient input-oriented constant return to scale model (Coelli, 2008) as the output, i.e., the quantity of fish catch could not be controlled. On the basis of data collected over a period of time, the study aimed to minimize the inputs for achieving the level of catch. The production frontier in the DEA approach was constructed using linear programming methods. The term ‘envelopment’ is derived from the production frontier that envelops the set of observations. For each DMU, the given inputs and output were taken into account and the value of the efficiency score for the i^{th} DMU was arrived, the value being ≤ 1, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU.

The term ‘Efficiency’ is the ability of a firm to obtain maximum (minimum) outputs (inputs) from a given set of inputs (outputs), whereas cost-efficiency requires achieving the lowest possible cost, given the current prices and firm outputs. Figure 1 depicts the concept of cost efficiency where there are twelve DMUs labelled as A, B, C, . . ., L and M with two inputs and a single constant output with their respective prices. The input price ratio is reflected by the slope of the iso-cost-line NN$^{/}$ and the curve line connecting the points from ‘A’ to ‘M’ DMUs is the frontier line. The concept of frontier is especially important for the analysis of efficiency, because we measure efficiency as the relative distance to the frontier. For instance, the DMUs like B, D, G, I and K that are technically inefficient, operate at points in the interior of the shaded region, while DMUs that are technically efficient, operate somewhere along the technology defined by the frontier. So every package of inputs along the

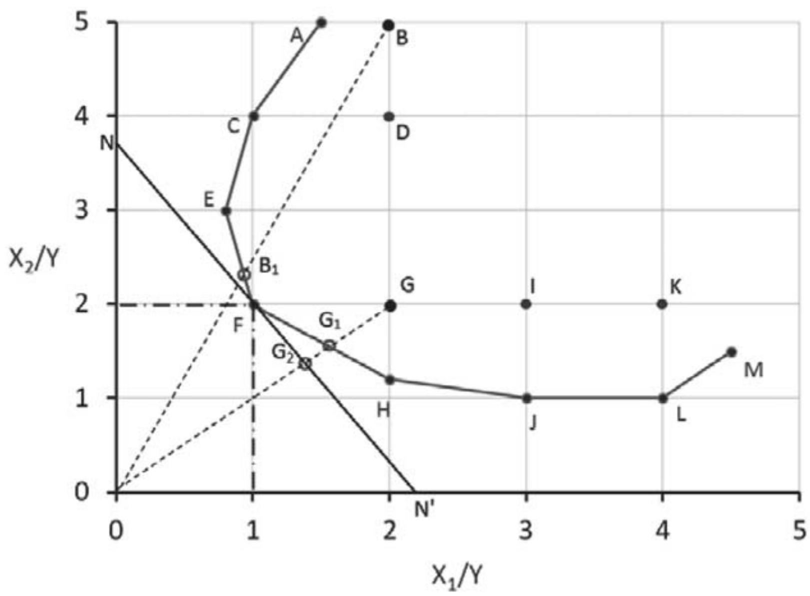

Figure 1. Cost efficiency method of DEA constant return to scale (Input-oriented)

frontier line is considered technically efficient, while any point above and to the right of the frontier is technically inefficient producer, i.e. the DMU produces the same amount of output, but with greater amounts of both inputs. For example, at point G the measure of radial efficiency identifies the two points, G_1 and G_2 (Farrell, 1957) and defines the 'technical efficiency', 'allocative efficiency' and 'cost efficiency' as $\frac{d(O,G_1)}{d(O,G)}$, $\frac{d(O,G_2)}{d(O,G_1)}$ and $\frac{d(O,G_2)}{d(O,G)}$, respectively. The multiplicative interaction of both technical efficiency (TE) and allocative efficiency (AE), termed as overall economic efficiency (EE), is calculated as per Equation (1):

$$EE = TE \times AE = \frac{d(O,G_1)}{d(O,G)} \times \frac{d(O,G_2)}{d(O,G_1)} = \frac{d(O,G_2)}{d(O,G)} \quad \ldots(1)$$

Each observation included one output, i.e. the total quantity of fish catch (Y) per trip in kilograms. In the input category, six variables were included, and these were: boat length (X_1) in feet, crew (X_2) in numbers, fishing trips (X_3) in No. of days per trip, diesel used (X_4) in litres, kerosene used (X_5) in litres and oil used (X_6) in litres. The unit prices of the six inputs were also used in the calculation of cost-DEA functions. Under this approach, CRS model was applied to the data with input orientation.

In the input-oriented DEA model, the data were on six inputs (K) and one output (M) on each of N ring seiners, each ring seiner technically called as a DMU. Using the linear programming method to derive the envelopment form of input-oriented DEA model, the technical efficiency is obtained by Equation (2):

$$\begin{aligned} & min_{\theta,\lambda}\ \theta, \\ & \text{Subject to } -y_i + Y\lambda \geq 0, \\ & \theta x_i + X\lambda \geq 0, \\ & \lambda \geq 0 \end{aligned} \quad \ldots(2)$$

where, θ is a scalar and λ is a N×1 vector of constraints. This envelopment form involves fewer constraints than the multiplier form $[(K + M) < (N + 1)]$, the value of θ is the efficiency score for the i[th] DMU. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU, according to the Farrell (1957) definition.

To calculate cost efficiency, prices of all the six inputs were used to study the behavioural objective, such as cost minimization or profit maximization. For this, the mathematical form of cost minimization DEA as represented in Equation (3) can be used:

$$\begin{aligned} & min_{\lambda,x_i^*}\ w_i' x_i^*, \\ & \text{Subject to } -y_i + Y\lambda \geq 0, \\ & x_i^* - X\lambda \geq 0, \\ & \lambda \geq 0 \end{aligned} \quad \ldots(3)$$

where, w_i is a vector of input prices for the i[th] DMU and x_i^* is the cost minimizing vector of input quantities for the i^{th} DMU, given the input price w_i and the output level y_i. The total cost efficiency (CE) or economic efficiency of the i^{th} DMU is calculated by Equation (4):

$$CE = w_i' x_i^* / w_i' x_i \quad \ldots(4)$$

It is the ratio of minimum cost and observed cost. Using Equation (1), the allocative efficiency (AE) can be calculated as:

AE = CE/TE.

Results and Discussion

Figure 2 represents the price-quantity relationship of the production (fish catch) obtained by the ring seine. The price elasticity co-efficient for the quantity catch (ε_p) is 0.38. It is greater than zero and less than one, which means the price response to fish supply is considerably less elastic. In the case of marine fisheries, the price of fish is decided by the quantity of fish catch landed, while in most other commodities the causality is from changes in demand (Nielsen, 2005; Arnason, 2006). In this case, supply creates the demand, i.e., the causality is supply, and even if there is more demand, it will not lead to more supply or landings. The declining linear trend line is like a typical demand curve, i.e. the quantity of fish catch is inversely proportional to its price (as in Equation 5).

$$Q = 2531.9 - 46.907\ (P) \quad \ldots(5)$$

The operational cost of ring seiners operating off Munambam harbour was worked out as ₹ 17,757 (Table 3) in which fuel cost was 68 per cent and included cost of diesel, kerosene and oil at approximately ₹ 12000 per fishing operation. After deducting the operating

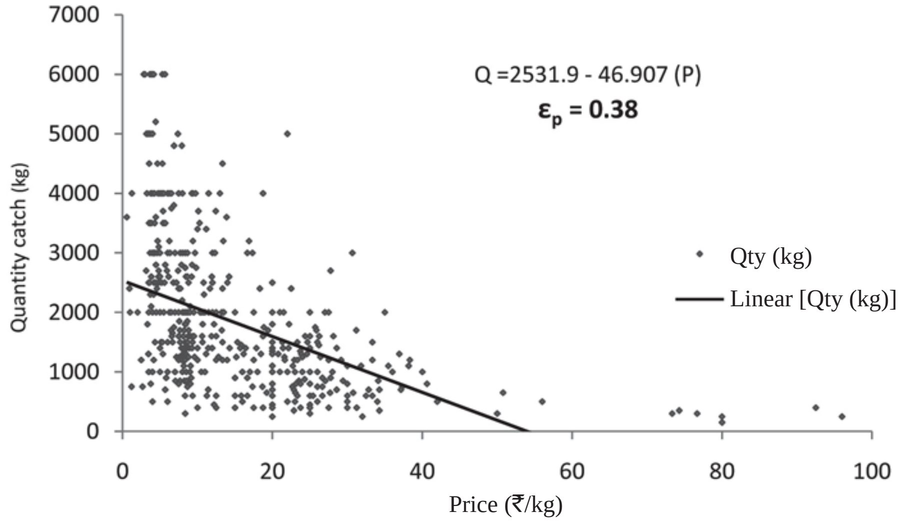

Figure 2. Price – quantity relationship of fish catch by ring seiners in Kerala

Table 3. Operational cost of ring seiners in Munambam coast, Ernakulam, Kerala

Particulars	Mean cost (₹)	Percentage of total cost
Diesel	6990	39.36
Kerosene	4893	27.56
Oil	246	1.39
Toll	101	0.57
Cleaning	704	3.96
Repairing	2425	13.66
Ration	1430	8.05
Other expenses (ice, bata)	968	5.45
Operating cost	17757	100
Gross value of catch	28990	
Net value of catch	11233	
Crew share (40%)	4493	
Owner's share (60%)	6740	

cost from the gross value of the catch, the net value of fish catch was arrived. The normal wage sharing observed in the ring seine sector (Dhiju das *et al.*, 2012) between crew and owner was 40:60. Based on this ratio, the boat owner received ₹ 6700, whereas the crew share was ₹ 4500 per trip. It was shared by around 40 crew members of the craft, and therefore the share per crew member was very low.

The analysis revealed that the average technical efficiency rating (θ) of ring seiners operating off Munambam coast was 0.53, which means that, on an average, the ring seiners were catching fish at about 53 per cent (Table 4) of the potential frontier production levels at the present state of technology and input levels. Further, this also indicates that the crafts should be able to reduce their inputs by 47 per cent (Figure 3) and still will have the same level of production. The crafts are using comparatively more inputs than necessary which included the size of craft, crew, fuel, etc. in relation to the quantity of catch (production). The technical efficiency score of individual DMUs ranged from 0.17 to 1 and 3 DMUs had a TE score equal to 1. Allocative efficiency is with regard to the allocation of inputs *vis-a-vis* its price, so as to minimize the cost of production, and it was 76 per cent overall, with individual efficiencies ranging from 25 per cent to 100 per cent.

The cost efficiency ranged from 15 per cent to 100 per cent for individual DMUs (Table 4). The policymakers can play an important role in promoting economies of scale and developing technical skills of labour which will lead to higher efficiency levels among ring seiner operating fishing vessels in the Munambam coast.

One of the important measures of efficiency is the cost efficiency (CE). Normally, the value of CE is equal to or less than 1. The results revealed that the overall cost efficiency was about 0.40 (Table 4, Column 4),

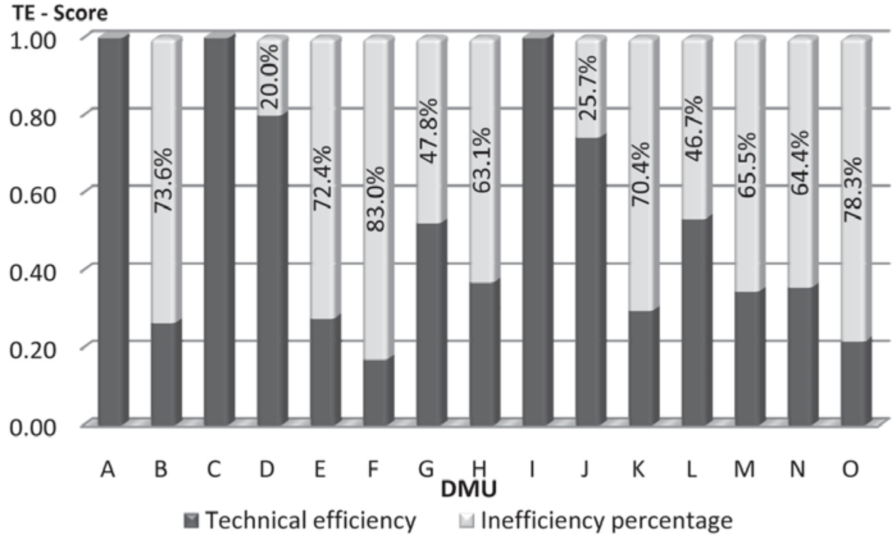

Figure 3. Technical inefficiency of ring seiners in Munambam coast, Ernakulam, Kerala

Table 4. Technical efficiency, allocative efficiency and economic efficiency scores of ring seiners operating off Munambam coast, Ernakulam, Kerala

DMU	Technical efficiency (θ)	Allocative efficiency	Economic efficiency
A	1.00*	0.47	0.47
B	0.26	0.61	0.16
C	1.00*	0.53	0.53
D	0.8	0.25	0.20
E	0.28	0.68	0.19
F	0.17	0.86	0.15
G	0.52	0.92	0.48
H	0.37	0.9	0.33
I	1.00*	1.00*	1.00*
J	0.74	0.81	0.60
K	0.3	0.9	0.27
L	0.53	0.99*	0.53
M	0.35	0.81	0.28
N	0.36	0.75	0.27
O	0.22	0.92	0.20
Overall	0.53	0.76	0.40

Note: * indicates the fully efficient DMUs

which is less than 1. It indicates the excessive input usage in ring seiner operated off the Munambam coast and also mis-allocation of considerable amount of input mix in the light of input cost. This suggests that the long-term efficiency could be improved through proper management of resource allocation. Three DMUs (individual ring seiners) have shown more than 50 per cent cost efficiency and particularly the Ith DMU ideal point is one of the observed DMUs with cost efficiency equal to 1.

Conclusions

Though resource-use or input-use control is regarded necessary for achieving high resource-use efficiency, under practical situations, it has been observed that productive resources or inputs are generally used as optimally as possible, depending on factors like competition within the sector and the availability of resources. The fishermen tend to go in for bigger craft and gear and more power usage due to increasing competition. The production *per se* does not primarily affect such decisions. However, in the long-run, this tends to be uneconomical and may result in losses. The long-term sustainability aspect has to be kept in mind for such decision-making and thus, the need for allocation of resources efficiently. The basic assumption in DEA is this efficiency in allocation of resources.

Using a homogeneous group of ring seiners (DMUs) having similar input resource use, this study has observed a huge difference in the efficiency among the DMUs within the group. The DEA has revealed that there exists technical inefficiency of 47 per cent in the input usage. This implies that there is overuse of inputs and it can be reduced to attain the maximum levels of output. In addition, there is allocative inefficiency calculated in terms of input cost of 24 per cent and this also can be reduced to get maximum revenue by minimizing the cost. These two inefficiencies have to be corrected to attain the overall 100 per cent economic efficiency of ring seiners within the DMUs. Further, the overall economic efficiency of ring seiners is 40 per cent. The study has indicated that nearly double the optimum effort is being used by the ring seiners operating off the Munambam coast which would be uneconomical or not feasible in the long-run. A better monitoring and management can lead to better utilization of inputs even with retaining the current levels of production, considering that fuel costs alone constitute 68 per cent of the total operational costs, due to the use of high power engines and increasing fuel costs.

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