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Estimation of Revenue-Based Fishing Capacity of Trawlers Using Data Envelopment Analysis

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Abstract

Excess fishing capacity is a major problem of marine capture fisheries both at national and global level which needs urgent attention in the view of resource sustainability. Data Envelopment Analysis (DEA) was applied to estimate the revenue-based fishing capacity using the input and output data of the trawl fishing operations in Ernakulam district, Kerala, India. The analysis used trip-based panel data collected from 10 trawlers comprising of 370 data sets for one year period. The quantitative and economic input and output indicators were collected using the customized logbook. It was found that the trawl fishery operates at 85 % and 74 % of their capacity utilization and technical efficiency levels respectively. The economic utilization of capacity was estimated at 74 percent. The study revealed that the vessels with high technical efficiency also resulted in low economic efficiency indicating ample scope for improving the revenue-based capacity levels. The factors determining the fishing capacity were assessed using Multiple Linear Regression Analysis (MLRA). The results revealed that fishing capacity of trawl fishery is significantly determined by engine power. Deriving the effective fishing capacity is possible when economic parameters are taken into consideration while formulating the policy decisions of fisheries management.

Keywords: Revenue-based fishing capacity, data envelopment analysis, technical efficiency, economic efficiency, trawlers

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Introduction

Indian marine fisheries sector contributes 3.05 million tonnes of fish production and also employs 14 million people either directly or indirectly in the year 2021-22 (FRAD, CMFRI, 2021). Indian fishing fleet is growing both in numbers and cumulative power leading to excess fishing capacity. This coupled with the open access nature of ocean waters have led to sustainability issues in marine fishing in terms of reduced catch per effort. The single-day trawling has shifted to multi-day trawling in many fishing grounds. The major drivers for the increase in fishing capacity are the increasing demand for fish both in regional and international domains, government subsidies, technological advancement in crafts and gear, and overcapitalization (Zhang et al., 2018).

Globally, excess fishing capacity is one of the major issues in fisheries. In response to the FAO's International Plan of Action for Management (IPAM) towards tacking excess fishing capacity, several countries initiated serious steps for estimating fishing capacity. It is a focus research area globally. The excess fishing capacity affects domestic fishery world-wide (FAO, 2000). In India, mechanized fishing crafts constituted 25.8 % of fishing crafts, of which the major proportion is by trawlers (71.5 %) (Anon, 2020). The fishing capacity in terms of fleet size has increased in India during the last few decades (Madhu, 2018). Therefore, it is essential to limit the excess fishing capacity in the marine fishing sector for which a comprehensive assessment needs to be carried out. Many countries had initiated measures to tackle the excess fishing capacity, but with limited success due to regional issues. In India, the efforts on similar lines have already started.

Besides physical factors, economic factors also need be considered as an integral part while assessing the excess capacity and the reasons thereof. But, in practice, the availability of appropriate data is the limiting factor (Fare et al., 2000). Lindebo et al. (2007) mentioned that it is difficult to estimate the fishing capacity using economic factors unless the data on the economic factors are kept available and accessible. Hence, generally, the fishing capacity analysis is limited to measuring physical capacity (FAO, 2000). An effective understanding of investment is required towards anticipating capacity fluctuations, but it fluctuates over time and space which makes it tough for developing appropriate policies (FAO, 2001).

Previous studies measuring fishing capacity were largely on quantitative (physical) basis using only quantitative inputs such as gross tonnage and engine power rather than measuring economic fishing capacity. Efforts to streamline fishing capacity of mechanized sector with special emphasis on trawlers were initiated on revenue basis (economic terms). The exploitation of fishing capacity can be controlled on the basis of fishing capacity which is useful for policy decisions on fishing capacity management.

The excess capacity that exists in marine fisheries pose threat to the overall resource sustainability as well as the economic viability of the fishing fleets (FAO, 1998) which has worsened over the years (Ravi et al., 2014). In India, the share of mechanized fishing fleets has increased from 14 % to 25 % during the years 1985 to 2005 (Boopendranath, 2007). In 1985, Kalawar Committee had recommended for restricting the fishing effort in the trawl sector of Kerala to 1,145 vessels to maximise sustainablility (Xavier, 2014). Kurup & Devaraj (2000) determined the optimum fishing fleet size for the mechanized trawlers as 10,998.

Ravi et al. (2014) described the structural changes occurring in the marine mechanized trawling sector in India. Aswathy et al. (2011) reported decreasing profits of trawl fishery operations over the years. However, a comprehensive study on revenue-based fishing capacity is not available in India. Such a study would be useful to formulate fishery policy to reduce the overcapacity and for sustainable utilisation of fishery resources. The policies should be of combination of output-based measures with input control for effective management of fishing capacity (Ward et al., 2004). In this context, this study aims at estimating revenue-based fishing capacity using DEA and also to determine the factors that influence the fishing capacity (efficiency). This study incorporates mainly economic data for the estimation of fishing capacity.

Materials and Methods

The study was carried out in Ernakulam district in Kerala, one of the prominent trawl fishing centres. Data covering mechanised trawlers from Cochin Fisheries Harbour (CFH), Ernakulam, was collected for a period of one year, from January to December during the year 2017, excluding the trawl ban period. A total of 370 trip-wise datasets from 10 trawl vessels were collected from the logbooks prepared for the purpose. Both cross-sectional (vessel parameters) and trip-wise panel data (operational details) on quantitative and economic aspects were collected.

The categorization of trawlers was carried out according to Edwin et al., 2014. The trawl vessels ranging between 16.5–22.5 m were selected for the study. The first questionnaire was for collecting the vessel characteristics, while the second questionnaire was exclusively for panel data on input and output indicators. Data on vessel size (LoA), engine power (HP), duration of fishing (days), time spent on fishing (hours), crew members (numbers), quantity of fuel (litres) and quantity of ice (kgs) were collected. The catch per trip was selected as the output indicator (Jeyanthi, 2022). In addition, same input and output indicators in economic (cost) terms have been employed to estimate revenue-based fishing capacity.

In this study, DEA was used to analyse the efficiency and revenue-based capacity of the trawl fishery following FAO (2003). DEA is a mathematical programming technique for estimating technical efficiency and capacity utilization. DEA is used for performance measurement and to evaluate relative efficiency of decision-making units (DMUs). According to FAO (2003), DEA is the most appropriate tool for estimating fishing capacity especially in multi-species fisheries. Each trawl vessel is treated as a single decision-making unit (DMUs). The capacity utilization of vessels i.e., the relative efficiency score, is obtained by solving the linear programming model using DEA (Banker et al, 1984; FAO, 2003; Nga et al., 2020; Nga et al, 2021).

The DEA method was previously employed to study fishing capacity in several fishing systems viz., the Malaysian purse seine fishery (Kirkley & Squires, 1999), US Northwest Atlantic Sea Scallop fishery, Atlantic inshore groundfish fishery, Pacific salmon fishery, the total world capture fisheries (Hsu, 1999) and Danish gillnet fleet (Vestergaard et al., 2003).

Based on the efficiency score values, the trawl fishery is post-classified into efficient or inefficient. A multiple linear regression analysis was used to determine the factors associated with the fishing capacity (Chakkappan & Das, 2016). The multiple linear regression analysis used in the present study can be written as:

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta 4 x_4 + \beta 5 D_1 = \epsilon$$

Where,

Y_i - Technical efficency scores

x_1 - Skipper experience (yrs.)

x_2 - Education of skipper

x_3 - Fleet size (LoA) (in m.)

x_4 - Engine power (HP)

D_1 - Fishing days (dummy) (1 if multiday fishing, 0 otherwise)

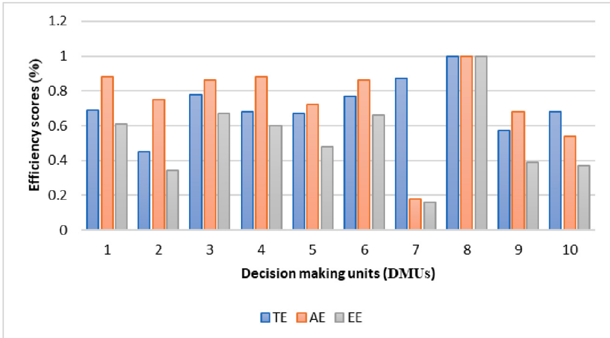
β_0 - constant

$\beta_1, \beta_2, \ldots\ldots \beta_5$ - estimated co-efficients

The multiple linear regression analysis includes both socio-economic and vessel-related variables as independent variables and technical efficiency scores as the dependent variable.

Results and Discussion

Trawl fishery is a capital-intensive fishing activity. It was estimated that the average capital investment on trawl fishing units accounted for Rs. 41.54 lakhs, Rs. 5.25 lakhs and Rs. 14.3 lakhs on craft, gears (nets) and engine, respectively. The average operational expenses per trip of trawl fishing included Rs. 45,653, Rs. 37,459, Rs. 1,978, Rs. 7,235, Rs. 5,100 and Rs. 1,500 on fuel, crew, repair and maintenance, ice, ration and water, respectively. Table 1 and 2 represent the average of economic input and output indicators of the trawl fishery of 10 DMUs. These indicators form the basis for the revenue-based fishing capacity estimation using DEA. Among the total input cost, fuel, wages for crew and ice were



** TE- Technical efficiency, AE – Allocative efficiency, EE -Economic efficiency*

Fig. 1. Technical, Economic and Allocative efficiency levels of trawl fishery

Table 1. Quantitative input and output indicators of trawl fishery (mean)

Indicators *Input indicators*	DMU 1	DMU 2	DMU 3	DMU 4	DMU 5	DMU 6	DMU 7	DMU 8	DMU 9	DMU 10	Pooled
Fuel (litres)	815.63	1010	1323.53	782.5	797.3	786.84	630.95	772.5	1000	967.2	888.645
Crew (numbers)	7	6	6	7	7	7	6	6	7	6	6.5
Ice (blocks)	100	100	107	100	100	100	100	65	98	98	96.8
Water (lit.)	2015	2000	2000	2000	2030	2000	2000	1261	1950	1980	1923.6
Time spent on fishing (hours)	105	97	117	123	140	129	113	110	112	124	117
Duration of fishing (days)	5	5	6	6	6	5	6	5	5	6	5.5
Output indicator Catch (Kgs.)	866.56	1015.93	1038.77	893.55	767.7	1337.58	1039.38	1017.69	1460.81	1234.5	1067.247

* DMUs – Decision Making Units

Table 2. Economic input and output indicators of trawl fishery (mean)

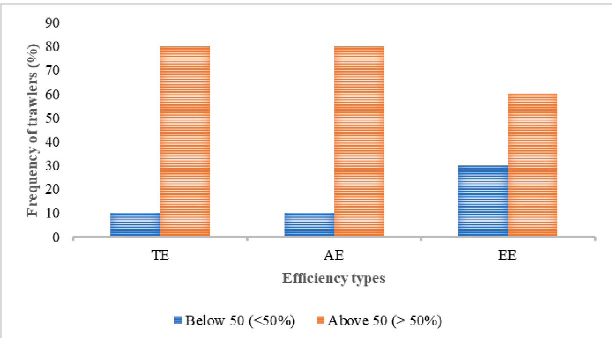
Indicators	DMU 1	DMU 2	DMU 3	DMU 4	DMU 5	DMU 6	DMU 7	DMU 8	DMU 9	DMU 10	Pooled
Input indicators											
Fuel cost (Rs.)	43979.31	48798.29	49950.82	41698.75	42320.81	41938.13	36947.62	44451.5	45186.68	44923.25	44019.52
Wages & Bata (Rs.)	29188.4	33852.93	35734.77	37950.15	33611.62	34758.15	29568.24	23137.4	32145.27	23457.45	31340.44
Ice cost (Rs.)	7240.63	7291.67	7761.41	7192.5	7227.12	7202.03	5338.12	7067.5	7124.25	7240.45	7068.568
Ration charges (Rs.)	5000	4825	4750	4850	4785	4950	5000	4860	4790	4855	4866.5
Cost of maintenance (Rs.)	1266.25	1091.67	1523.5	1104.5	962.45	1092.11	1674.62	1602.5	1077.84	1151.52	1254.696
Output indicator											
Catch (Rs.)	107966.1	180379.3	116147.2	88835.75	83159.46	147702.9	113335.5	126880.24	140591	92125	119712.2

* DMUs – Decision Making Units

the major components. The results are in confirmation with Hassan & Sathiadhas (2009), which reported that the fuel and labour accounted for about 40 % and 39 %, respectively in single day trawlers, while the same in multi-day trawl fishing was 62 % and 22 %, respectively.

The mean capacity utilized by the trawlers was 0.72 which implied that the technical efficiency of the trawlers could be increased by another 28 %. The economic efficiency of trawlers was 0.53, implying that it can be increased further by 47 % (Fig. 1).

It was found that certain vessels that operate with high technical efficiency performed poor in terms of economic efficiency. A unique feature observed while comparing the Technical Efficiency (TE) and Economic efficiency (EE) was that 21 percent of trawlers that operate with high technical efficiency



** TE- Technical efficiency, AE – Allocative efficiency, EE -Economic efficiency*

Fig. 2. Categorisation of trawlers according to efficiency level

did not have economic efficiency levels. This is an indication of the low economic profitability of the trawl fishery which leads to the increasing fishing capacity levels. This ultimately impacts fishermen's income and livelihood (Guillen & Maynou, 2016). Introducing community participation in fisheries management and encouraging 'co-operative fishing' rather than 'competitive fishing' could be a probable solution for high economic profitability levels (Sathiadhas, 1998).

The DMUs were categorized into two categories: poorly performed (below 50 %) and well performed (above 50 %) (Fig. 2). Out of the units studied, it was observed that the technical and allocative efficiency of "above 50 %" category of trawlers showed high technical efficiency than economic efficiency. In the same way, the economic efficiency of 30 % of DMUs in the "below 50" category also showed high economic efficiency than technical and allocative efficiency levels. This could be due to increasing capital investments on capital assets viz., crafts, gears and engine power (Carvalho et al., 2020).

Table 3. Details of capacity and economic utilization (Mean)

Particulars	Efficiency scores
Capacity Utilisation	0.85
Technical Efficiency	0.74
Economic Utilisation	0.63
Full capacity	15 % DMUs
No. of observations	370

Trawl fishery is the major mechanized sector that contributed significantly to fish landings and seafood export. But, the trawl fishery operates at 85 % and 74 % of their capacity utilization and technical efficiency levels, respectively (Table 3). The economic utilisation of capacity was 63 % which is 22 % lower than the capacity utilisation at quantitative measures. The DMU operations belonging to trawl fishery at full capacity (100 %) was estimated at only 15 %. A similar study on capacity and economic utilisation of Danish North Sea trawlers reported that 38 % of the vessels operating at full capacity are not reaching full economic capacity levels (Lindebo et al. 2007). Due to practical difficulties in collecting the data, studies on the economic measurement of capacity were limited in number (Walden & Kirkey, 2000). A positive relationship between capacity adjustments and vessel profitability has also been derived by Zhang et al. (2018).

From the regression analysis (Table 4), it was revealed that only engine power is associated with fishing capacity. The skipper's experience, education and fleet size did not turn out to be significant variables.

Table 4. Results of Multiple Linear Regression Analysis

Variable	Co-efficient	t-value
Constant (β_0)	1.054	0.205
Socio-economic variables		
Skipper experience (in yrs) (β_1)	-0.004	0.674
Education of skipper (β_2)	-0.002	0.590
Vessel-related variables		
Fleet size (LoA in m) (β_3)	-0.014	0.149
Engine power (in HP) (β_4)	-0.001*	0.084
Dummy variable (D_1)	0.001	0.978
F- value	12.73	
Adjusted R^2	26.81 %	

* Significance at 10 % level

This estimated the revenue-based fishing capacity of trawl fishery in Kerala. The fishing capacity was estimated based on technical, allocative and economic efficiency levels using DEA. Among the trawlers, 72 % of the DMUs showed high technical efficiency, but operating below the economic efficiency levels. The result is helpful in identifying efficiently performing trawlers from low efficient trawlers in quantitative and economic terms. The economic utilization of capacity was 63 %. Fishing capacity of trawler was found to be associated with engine power. The excessive use of inputs was not associated with efficiency, perhaps due to high competition in open waters. Hence, there is a need for an economic approach towards estimation of fishing capacity and policies for effective management needs special attention.

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