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Aswathy N
Central Marine Fisheries Research Institute, Kochi, Kerala, India

R Narayana Kumar
Central Marine Fisheries Research Institute, Kochi, Kerala, India

Somy Kuriakose
Central Marine Fisheries Research Institute, Kochi, Kerala, India

Rekha J Nair
Central Marine Fisheries Research Institute, Kochi, Kerala, India

Correspondence
Aswathy N
Central Marine Fisheries Research Institute, Kochi, Kerala, India

Total factor productivity growth of trawl fishing in Kerala state, India

Aswathy N, R Narayana Kumar, Somy Kuriakose and Rekha J Nair

Abstract
Trawlers are the prominent fishing units in the mechanized fishing sector of Kerala state in the south west coast of India contributing 40% of the landings. The trawl catch in the state declined from 0.27 million tonnes in 1997 to 0.21 million tonnes in 2015. Increase in fishing power of trawlers with expansion in engine, gear capacities and overall length resulted in extending fishing trips from singleday to multiday and diversification of species caught. The paper discusses the technological changes and its impacts on sustainability of trawl operations in Kerala for the period 1997 to 2015 using total factor productivity analysis.
The capacity of engines increased from 90hp to 550 hp during 1997- 2015 resulting in increased use of fuel in the fishing sector. There was fivefold increase in diesel cost and eight fold increase in ice cost in absolute terms when compared to less than two fold increase in average fish price during 1997-2015. The total factor productivity analysis revealed negative growth during 1997-2015 indicating that technological change has resulted in economic unsustainability in the production system.

Keywords: economic efficiency, technological change, total factor productivity, trawlers

Introduction

The state of Kerala in the southwest coast of India contributes 16% of marine fish landings in India. There was reduction in total marine fish catch in the state from 0.58 million tonnes in 1997 [1] to 0.48 million tonnes in 2015 [2]. Trawlers are the prominent fishing units in the mechanized sector in the state contributing 40% of the landings. Trawl fishing in Kerala was initiated under the Norwegian project at Sakthikulangara in 1960s with the aim of modernizing marine fishing sector of Kerala. Trawling on a commercial scale was first initiated in India in Cochin in the 60s and later spread to other parts of the country. The number of trawlers in Kerala increased from 2630 in 1980 [3] to 4,484 in 1998 [4] and again declined to 3,678 in 2010 [5].
The trawl fishing sector in Kerala witnessed drastic changes over the years in terms of technological advancements and regulatory measures. In 1987, Government of Kerala introduced ban on monsoon trawling which resulted in the complete ban on trawlers from fishing during the monsoon months for varying periods from 45 to 60 days since 1988. In 1997 multiday trawling was introduced in Kerala. The fishing vessels which were undertaking singleday fishing trips started multiday fishing with increase in OAL of vessel up to 60' and horsepower up to 180hp. With the reduction in the catches of shrimps and cephalopods targeted by trawlers, high speed engines with horse power up to 350 hp were introduced in 2007 to improve the fishing capacity and catch diversification. The horsepower of engines were later increased upto 550hp in 2015. Several controversies also followed with introduction of high speed engines and consequent increase in its capacity. A section of mechanised category fishermen themselves were against the use of high speed engines in the fishing sector due to the high diesel requirements. In this context the present study was undertaken to assess the impact of technological advancements on the economic efficiency and sustainability of trawl fishing in India.
The impact of technology on economic sustainability of trawl fishing in Kerala was analysed using total factor productivity analysis. Previous studies on the productivity measurement of fishing fleets using index number approach includes Squires [6, 7] on measuring productivity in the Pacific Coast Trawl Fishery; Jin *et al*. [8] in the New England Ground fish Fishery using Malqmist productivity indices; Felthoven and Paul [9]; Fox *et al*. [10] in Australian fisheries; Hannesson [11] in Norwegian fisheries; Squires *et al*. [12] in Korean tuna purse seine fishery

operating in the Pacific Ocean; Felthoven *et al.* [13] in the Alaskan pollock fishery; Eggert and Tveterås [14] in Icelandic, Norwegian and Swedish fisheries; Divisia Tornqvist indices by Kumar *et al.* 2004 [15] and Aswathy *et al.* [16]; Lowe index by O'Donnell [17] Walden *et al.* [18] in US catch share fisheries and Fissel *et al*. [19] in Alaska, head and gut factory trawlers.

2. Methods

The data on year wise trawl catch and effort were obtained from CMFRI for the period 1997-2015. Costs and revenues of fishing units were obtained from various publications of CMFRI (Aswathy *et al.* [20], Narayanakumar *et al*. [21] and also from data base of Socio-Economic Evaluation and Technology Transfer Division(SEETTD) of CMFRI**.**

The impact of technological change on economic sustainability of marine fishing was analysed using total factor productivity analysis. In economics literature multi-factor productivity (total factor productivity) or TFP is defined as a ratio of aggregate outputs to aggregate inputs. Output and input changes can be measured by constructing output and input quantity indices. A change in multi-factor productivity (MFP) measures changes in outputs and inputs between two time periods. MFP may improve either by harvesting more fish with the same amount of inputs or by harvesting the same amount of fish using fewer inputs.

For fishing fleets, TFP can be affected by changes in target species biomass. Biomass is an important input for the fishery production process, but its level and change between time periods is beyond the control of individual vessels in the fishery [7]

Fisher index, Divisia index, Lowe or Laspeyres index are the most commonly used indices for productivity measurement. For longrun analysis chain indices are better than fixed weight indices and hence Tornqvist index which is a discrete approximation of Divisia index was used in the present analysis. The inputs used for working out TFP were fuel, labour and ice. Since time series of biomass data was not available it was not included as a variable in working out input index. The output index was calculated by grouping the resources into 14 resource groups. The study period was purposively divided into two periods consisting of 1997-2006 period coinciding with initiation of multiday fishing and 2007-15 coinciding with introduction of high speed imported engines to study the impact of technologies.

2.1 Divisia-Torqvist indexing method

The output index is worked out as follows;

$$\text{Output index} = \Pi_j \left(Q_{jt}/Q_{jt-1}\right)^{(R_{jt}+R_{jt-1})^{1/}2} \qquad (1)$$

Where Q_{jt} and Q_{jt-1} are the quantities of resource j at time t and t-1 R_{jt} and R_{jt-1} are the shares of resource j in total revenue at time t and t-1 t is the number of years.

In each period, Qjt/Qjt-1 in equation (1) gives the index relative to the previous period. A series of annual changes are 'chained' together to express the index relative to a base year by multiplication. The input index is also worked out based on the following equation;

$$\text{Input index} = \Pi_j \left(X_{it}/X_{it-1}\right)^{(S_{it}+S_{it-1})^{1/2}} \qquad (2)$$

Where X_{it} and X_{it-1} are the quantities of input i at time t and t-1

S_{it} and S_{it-1} are the shares of input i in total cost at time t and t-1

t is the number of years [22]

Compound Annual Growth Rate of TFP index measures the total factor productivity growth for the period under study.

3. Results and Discussion

Trawlers of various size classes are operated in Kerala. Trawlers with overall length (OAL) <35 ft made of wood with engine capacities of 60-90hp undertook singleday fishing trips only. Vessels with more than 61ft OAL made of steel undertook multiday fishing trips of more than 6days duration. The horsepower of engine increased from 60 hp in 1980 to 550 hp in 2015(Table 1). The multiday fishing units introduced in the year 1997 used indigenous Leyland engines of capacity 110 hp which was later increased upto 180 hp. High speed engines started operating in the year 2007 which were imported from China, USA and Japan with engine capacity of 350hp which was later increased to 550 hp in 2015 and these units undertook multiday fishing trips up to 12 days duration.

Table 1: General particulars of trawlers in Kerala

Size categories	Duration of fishing trip	Hp of engine
<35ft	SD	60-90
40-60ft	MD(2-5 days or more) with Indigenous engines	110-180
>61ft	MD(>6 days)with High speed engines	350-550

3.1 Growth in catch, effort and Catch Per Unit effort (CPUE) of trawlers

The catch per unit effort of singleday trawlers declined from 0.33 tonnes during 1997-2006 to 0.23 tonnes during 2007-15 period. In the case of multiday trawlers, the CPUE showed a slight decline of 1.15tonnes in 1997-2006 to 1.13tonnes in 2007-15. Analysis of growth in catch and effort of trawlers showed that there was positive growth in fishing effort of multiday trawlers during 1997-2006 (3.44%) and negative growth during 2007-15 period. In the case of single day trawlers fishing effort showed a declining trend in both the periods. The catch of multiday trawler showed a growth of 6.36% during 1997-2006 and 9.17% during 2007-15 period. For singleday trawlers, the catch declined in both the periods (Table 2).

Table 2: Growth in catch and effort of trawlers (CGR %)

Period	Fishing effort(units)			Catch		
	Multiday day	Single day	Total trawl	Multiday day	Single day	Total trawl
1997-2006	-3.45	-11.65	-8.79	6.36	-16.72	-3.25
2007-15	-1.48	-8.39	-5.33	9.18	-7.83	5.04

3.2 Growth in nominal and real value of trawl catch

The nominal value of fish catch was deflated by using wholesale price index (2004-05=100) to compare the real value of trawl catch in different periods.

The fish production by trawlers showed a negative growth during 1997-2006 and positive growth during 2007-15 period.

The value of catch showed positive growth in nominal terms in both 1997-2006 and 2007-15 periods. However in real terms, the growth was negative during 1997-2006 period. The weighted average fish price increased from Rs.37/kg in 1997 to Rs. 142/kg in 2015 in nominal terms and from Rs.52/kg to Rs.80/kg in real terms during the same period (Table 3).

Table 3: Growth in Nominal and real value of trawl catch (1997-2015)

Years	Q(t)	Nominal value (Rs. million)	Real Value (Rs. million)
1997	273814	10079	14193
2000	217089	11943	14452
2005	177395	11041	10681
2010	159179	13080	9337
2015	209129	29679	16765
CGR(1997-2015)	-0.66	6.28	0.61
CGR(1997-2006)	-3.25	2.43	-2.30
CGR(2007-2015)	5.04	15.06	8.27

3.3 Total factor productivity analysis

The total factor productivity analysis using Divisia-Tornqvist indexing method showed that output index with a negative growth during 1997-2006 period and positive growth during 2007-15 period. The input index showed negative growth during 1997-2006 and positive growth during 2007-15 period. Eventhough the output index growth was positive during 2007-15 period, the high input index growth made the TFP growth negative which indicated the economic inefficiency in input use in the trawl fishing sector in Kerala. During 1999-2000 and 2001-2002 period TFP showed considerable increase with reduction in input index and increase in output index. From 2005-06 to 2009-10 TFP declined with decrease in both output and input indices. From 2011 onwards TFP declined with increase in input indices more than the increase in output indices (Table 4).

Table 4: Output input and TFP indices

Period	Output index	Input index	TFP index
1998	100	100	100
1999	81.61	87.61	93.16
2000	96.91	63.15	153.45
2001	82.29	80.25	102.54
2002	90.09	78.10	115.34
2003	79.94	74.66	107.07
2004	85.23	75.72	112.57
2005	74.25	66.04	112.44
2006	76.39	79.06	96.62
2007	64.96	106.75	60.85
2008	69.62	105.84	65.78
2009	68.26	94.60	72.16
2010	58.97	97.22	60.66
2011	78.23	109.37	71.53
2012	87.21	140.78	61.95
2013	68.17	117.67	57.93
2014	82.74	134.48	61.53
2015	71.48	114.03	62.68
1997-2015	-1.46	3.21	-4.53
1997-2006	-2.71	-2.46	-0.25
2007-2015	2.17	3.03	-0.83

The estimated diesel use increased from 90 million litres from 1997 to 2007 and then to 189 million litres in 2014. The ice used increased from 0.2 million tonnes in 1997 to one million tonnes in 2015. The labour use increased from 3.4 million mandays in 1997 to 4.6 million mandays in 2015. In real terms, the diesel cost increased fivefold from Rs.1136 million in 1997 to Rs.6213 million in 2015. The ice cost increased from Rs.97 to 802 million. The labour cost declined from Rs.4197 million to Rs.3260 million with reduction in mandays during 1997 to 2015 period. Even though the fish production from the trawl fishing sector increased during 1997-2015 period with the introduction of multiday fishing and high speed engines, these technological changes proved to be highly capital intensive with increased use of fuel and ice and lower economic efficiency. There is an exponential growth in the engine capacity of trawlers above 18m OAL in the state which eventhough contributed to increased fishing power of the trawlers, resulted in high fuel use and increased greenhouse gas emissions [23]. Hence there is an urgent need to optimize and regulate the engine power of trawlers in the state to conserve fuel and reduce greenhouse gas emissions.

4. Conclusion

Technological change in terms of multiday fishing and introduction of high speed engines resulted in economic unsustainability of trawl fishing in Kerala. Eventhough the fish production has increased with introduction of high speed engines, there was less than two-fold increase in the prices received by the fishermen in real terms when compared to the fivefold increase in diesel costs and eight-fold increase in ice costs in the same period. This clearly indicated that the growth in fishing costs higher than the growth in earnings, which is an alarming situation considering the economic sustainability of fishing and hence efforts are necessary to improve the economic efficiency by reducing the input costs. In addition, the decline in the overall marine catches in the state when compared to increased catches of trawlers indicated the possibility of exploitation of other fishing units. With increased fishing power, the trawlers are able to catch pelagic resources which are targeted by other gears also. Hence the socio-economic impact of trawling using high speed engines on other fishing gears also requires attention in future studies.

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