Chapter 5

Mechanized Vessels and Efficiency of Indian Marine Fishery

5.1 Introduction:

In the previous chapter, we have tried to analyze the performances of Indian Maritime states with the objective of resolving the apparently paradoxical situation relating to optimum marine resource exploitation. As we have already mentioned that many studies have reported that Indian marine fleet size is greater than the optimum, although, at the same time, we know that the estimated potential of marine resources has not been fully exploited. Analysis in the previous chapter help us to reveal the phenomenon that overexploitation of resources or overcrowding of vessels is a local phenomenon and not valid equally for all maritime states. But over employment of inputs (mechanized vessels in this case) in marine resource does affect the system adversely in many ways. Firstly, level of employment of inputs higher than the optimum implies inefficiency as it would fetch lesser amount of productions per unit of input. Secondly, inefficiency of the system is compounded by the fact that over crowding leads to over-exploitation of resources, which may consequently reduce the biomass stock even below the minimum level that is required for sustainable growth of renewable resource. Thus, over crowding of inputs leads to increase the level of harvest effort in a particular marine zone with many adverse consequences and makes the system inefficient in an accelerated speed. Table 4.5 (in the previous chapter) shows number of vessels in different maritime states. Fluctuations in the number of vessels in different years explain the inefficient allocation of vessels in different maritime states. In the previous chapter, we have identified maritime states where the number of mechanized vessels employed is more than the optimum requirement. However, mechanized vessels are not of same types. Several types of vessels of different size, lengths and capacity have been introduced in Indian Marine fishery according to the need of the industry as well as either to avoid or to match with the different statutory compulsions promulgated by the State and the Union Government time to time.

The Indian marine fishing activities were mostly confined to the coastal zone until mid 80's. After this period, the fishing zone was marginally extended beyond coastal zone for catching mostly deep-sea lobster, shrimps and also cephalopods. The major significant change that had been observed in Indian marine fishery (especially in the coastal region of south) was modernization program under Indo-Norwegian project by the Department of Agriculture, Government of India, in the 1950's. Successful implementation of the project not only changed individual boats into the mechanized one by the installation of inboard engines but introduction of mechanized boats of convenient new designs was also made possible later. Subsequently, in late 1970's Union Cabinet initiated introduction of medium sized outrigger trawlers along the upper east coast followed by import of 25 m length overall (LOA) trawlers essentially for marine shrimping. However, these were also equipped for stern trawling. Indigenously constructed similar trawlers and mini trawlers of 15m LOA range were introduced in Indian marine fishing in late 80's and after 80's respectively by private fishing enterprises for shrimping and purse seining in the coastal zone.

Indian EEZ was notified in 1976. The regulations to control fishing by foreign vessels in the EEZ were announced in 1981 by the Government of India. Larger vessels for marine fishing beyond coastal zone required huge investments which was not available with the Indian marine fishing industry. For this, before the declaration of EEZ and 1981 notification of GOI, Taiwanese fleet owners used their vessels capable of distant water fishing for harvesting in Indian waters. Declaration of EEZ and subsequent GOI notification (1981) did fail to deter Taiwanese in harvesting in the Indian Territory. Taiwanese took advantage of *Foreign Vessel Charter/Lease Joint Venture Scheme* of India and continued to access Indian EEZ resources through vessels registered in Hong Kong, Singapore or elsewhere. On the basis of the recommendations of *Murari Committee* (1994), the GOI abolished the scheme[19].

The process of liberalization of economy, formally declared in the early 1990's, permitted many new joint venture agreements for fishing in the Indian EEZ beyond 12 nautical miles of territorial waters (Kurien, 2000b). Meanwhile, the number of medium length Indian fleet of 23-27 m OAL operating in deep sea at present declined to 50 only from 195 (Fishing Chimes, 2003).

Scenario is completely different within 12 nautical miles of coastal zone. Here we have thousands of different types of fishing vessels- motorized and non-motorized traditional crafts, mechanized boats of different size and facilities. Numbers of mechanized boats are also increasing rapidly over the years as the following table-5.1 shows.

[19] 21 recommendations of Murari Committee were approved by the central cabinet on 27 September 1996. Among the major recommendations of the Murari Committee were: the formulation of marine fishing regulations in the entire Exclusive Economic Zone (EEZ), an end to joint ventures with foreign entities, banning foreign fishing vessels from Indian waters and cancelling all the fishing licences to foreign vessels issued by the commerce ministry

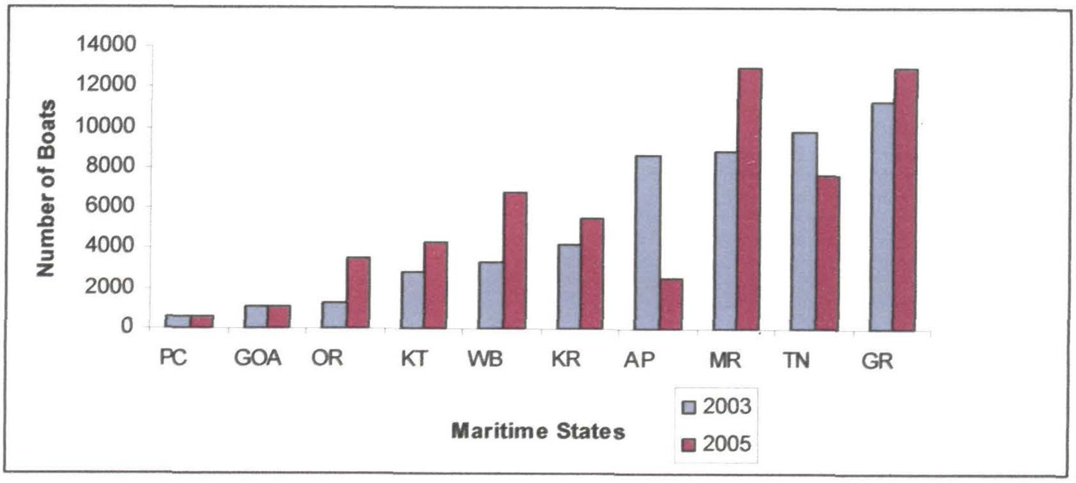
Table-5.1: Increment of the Numbers of Mechanized Boats Over The Years Within 12 Nautical Miles.

Year	No. of mechanized boats	Cumulative no of mechanized
1950-51	13	13
56-57	2142	2155
66-67	2500	4655
76-77	11345	16000
86-87	6906	22906
90-91	1366	24272
91-92	4737	29009
92-93	1307	30316
93-94	4532	34848
94-95	12070	46918
2004-05	6766	53684

Source: DAHD (1996); DAHD (2006).

As we have noticed that, in general, there are opposite trend with regards to fluctuations in fleet size in case of motorized and non-mechanized vessels with minor exception. In case of fleet size of mechanized vessel, we observed that fleet size increased in all states except AP & TN and size remained constant in case of GOA during the period 2003 to 2005. Number of motorized vessels similarly increased in all states except GOA. This increase in fleet size for mechanized and motorized vessels were compensated by the substantial decline in the number of non-mechanized vessels except WB and OR. In this respect WB and OR registered very exceptional pattern of increasing trend in all types of vessels. In the Fig-5.1, the fleet size fluctuations of mechanized crafts among the maritime states are shown.

Figure-5.1: **Number of Mechanized boats in Different Maritime States in 2003 & 2005**



Mechanized sector, in marine fisheries of India, occupies a special position for many reasons, like the amount of capital investment, the scale of operation, the access in deep sea, employment and skill of crew members, types of vessels, the amount of harvest, etc.

Basically, there are following five types of vessels within this mechanized group of vessels;

1. Trawlers
2. Dol-netter
3. Long-liners
4. Gill netters
5. Purse seiners

The target species, capacity of vessels, mode and styles of operation etc. of these vessels are different from each other. Areas of sea where these vessels are being used for harvesting are, therefore, also different.

In this chapter we will consider all these types of mechanized vessels as input for measuring efficiency of maritime states. This would help us to identify which areas of the Indian EEZ are over employed and with what type of vessels. This analysis may help us to framing an allocation principle of mechanized vessels.

Another feature, which is important with the advent of mechanized crafts, is involvement of skilled human resources. All these vessels are fitted with different modern gadgets and gears and, therefore, require skilled fishermen and crew. Performance of maritime state, therefore, also depends on the availability of human resources and their levels of skills. We, therefore, will consider availability of human resources as one of the determinants or inputs in this chapter. (We did not consider this category of inputs in the last chapter.)

There are three types of fishermen involved in production process (fishing) in each state: (i) full time fishermen, (ii) part-time fishermen and (iii) occasional fishermen.[20] We have combined these three different types of fishermen into one as *human resources* and used in the model as a single input, namely '*effective fishermen*' (X_6), which is obtained as weighted total of above three types and computed as follows.

[20]According to census classification (DAHD, 2006), any fisherman who spends more than 30 percent but less than 90 percent time in fishing activity is called part-time fisherman, whereas any fisherman who spends less than 30 percent time in fishing activity is called occasional fisherman.

Number of Effective fishermen (X_6) = 1.0 * number of fulltime fishermen + 0.6 * number of part-time fishermen + 0.2 * number of occasional fishermen.

Average time spent in fishing by each type of fishermen is used as weight-age. Finally, therefore, we have the following variables which we could consider as inputs:

X_1:	number of trawlers,
X_2:	number of dol-netters
X_3:	number of liners
X_4:	number of gill-netters
X_5:	number of purse-seines.
X_6:	effective fishermen

5.2 Selecting Determinants as Inputs in DEA Model:

While running the DEA here also we face the same problem of excess inputs than permitted. The number of DMU only being ten, we could not use all 6 variables together as inputs as it would create the problems involving degrees of freedom (Cooper, Sieford, Tone, 2004). Also there is certain interdependence between some variables which could have the same spurious effects. Here too we could employ at most two variables as inputs along with the output. As we did in previous chapter we would select only two variables from the set of six potential variables already mentioned. Our objective is to select any two variables whose joint contribution in output is relatively higher than any other group of two variables of the set and, at the same time, as explanatory variables those two would not form spurious relationship with the dependent variable. For this we adopt Frisch's Confluence Analysis method as before (Koutsoyiannis, A. 1977).

We assume the following regression relation

$$Y = f(X_j) \qquad \text{for} \qquad j = 1, 2, \ldots, 6,$$

Where X_j are determinants as stated above used as independent variables. We regress the dependent variable (in this case production of the year 2005) on each of the above six explanatory variables separately. We then examine the results of these elementary regressions on the basis of a priori and statistical criteria. We select the most plausible regression (the variable with maximum value of R^2) and introduce remaining variables gradually to examine their effects on coefficients, on their standard errors and on the overall R^2 and then classify the additional variable as useful, superfluous or detrimental.

In the year 2005, from the estimated equation $Y = \lambda + \lambda_j X_j$ for j =1, 2,.... 6, we find that for j = 1 (i.e. for the number of trawlers X_1), the goodness of fit is the highest (R^2 = 0.608). [λ_1, however appears to be insignificant by S.E. test (s (λ_1) < λ_1/2))]. The variables with next higher value of R^2 is X_6 (effective fishermen) and its value is R^2= 0.272. Introducing X_6 with X_1, R^2 improves to 0.639 and also coefficients do not change adversely and thus X_6 may be accepted as a useful explanatory variable. Next we introduce X_2 (number of dol-netters) with X_1. Although, the value of R^2 improves but the co-efficient changes its sign. Hence X_2 has a detrimental effect and we discard X_2.. Similarly, if we introduce X_3 with X_1 it has the same detrimental effect and thus we discard X_3 also. Introducing X_4 with X_1 however improves the value of R^2 to 0.612 and also the co-efficient does not change its sign. Hence X_4 also can be taken as useful variable along with X_1 which contributes positively for the production of the year 2005.

Following table shows the results of Frisch' Confluence analysis for the year 2005[21].

Table-5.2: Results of Frisch's Confluence Analysis for the year 2005

VARIABLES	X_1	X_2	X_3	X_4	X_5	X_6	R^2
X_1	0.051 (0.014)						0.608
X_2		0.029 (0.036)					0.075
X_3			0.114 (0.228)				0.030
X_4				0.017 (0.041)			0.022
X_5					-0.037 (0.356)		0.001
X_6						0.001 (0.001)	0.272
X_1, X_6	0.045 (0.017)					0.001 (-0.001)	0.639
X_1, X_4	0.05 (0.015)			0.007 (0.028)			0.612

Source: Computed by the author. Figures in parenthesis indicate SE of estimates

[21] Results of the combination which produce either detrimental or spurious relationship are not shown in any of the Frisch's' Confluence analysis table.

None of the other combination comes out as plausible. Hence, as we are constrained to consider only any two variables as determinants of the marine fishery output for the year 2005, we may consider either of the following two sets of variables:

(1) The number of trawlers ($\mathbf{X_1}$) and number of effective fishermen ($\mathbf{X_6}$)

(2) The number of trawlers ($\mathbf{X_1}$) and number of gill-netters ($\mathbf{X_4}$).

Efficiency of maritime states would, therefore, be analyzed by DEA initially with respect to each of six variables and subsequently with respect to above two sets (two variables in each set) identified as most effective by Frisch' Confluence Analysis.

5.3 Application of DEA:

Again we write down our output oriented BCC-O form which we are using for measuring the efficiency of the Indian maritime states considering the different mechanized boats.

$$\begin{aligned} &\text{Max} \quad \eta \\ &\textit{subject to} \\ &\quad X\lambda \leq x_0 \\ &\quad \eta y_0 - Y\lambda \leq 0 \\ &\quad e\lambda = 1 \\ &\quad \lambda \geq 0 \end{aligned}$$

Where, η is the efficiency score, **X**= input vectors specified as above, **Y**= fish production of each maritime state of the year 2005, $\mathbf{x_0}$ = virtual input combination, $\mathbf{y_0}$= virtual output. The above constraints can be written as shown below:

$$\begin{aligned} &x_0 - X\lambda - s^- = 0 \\ &\eta y_0 - Y\lambda + s^+ = 0 \\ &e\lambda = 1 \\ &\lambda \geq 0 \end{aligned}$$

Where s^- is the input excess and s^+ is the production shortfall. Condition of DEA efficiency demand that all the measures are to be satisfied simultaneously. These are

(i) Score (η) = 1

(ii) Input excess (s^-) = 0 and

(iii) Production shortfall (s^+) = 0.

5.3.1 Results of DEA considering each of the determinants as a single input:

Single input DEA results are shown in Tables 5.3, 5.4, 5.5, 5.6 and 5.7 representing Relative Scores, Relative Ranks, Excess Inputs (s^-), Production Shortfalls (s^+) and Peer States respectively.

It is important to note that for two maritime states, namely; WB & OR numbers of all types of vessels increases registering a tendency just opposite to the other maritime states (Table-4.2 of previous chapter). Results shown in table 5.3 exhibit that WB lies on the efficient frontier only with respect to trawler numbers while OR performs below the frontier for every input. The tendency of substantial increase in number of all types of vessels, therefore, did not appear to be beneficial for efficient performance of these two states. Table 5.5 shows that, for those two states - dol-netters, liners and gill netters are in excess of their corresponding peer state which in both cases is KR. It simply implies that WB produces the same output of KR with in excess of 1692 dol-netters, 56 liners and 3927 gill netters. Similarly, OR produces identical output of KR with excess dol-netters of 254, 18 liners and 1332 gill netters. The corresponding tables showing the optimum weights of input and output along with efficient frontier shown as bar graph is given in appendix – 8 to appendix -13 (taking effective fishermen, trawler, purse-seiner, dol-netter, liner and gillnetter respectively as individual input).

Table-5.3: Efficiency Scores of Maritime States for the Year 2005 with respect to Single DEA Input

DEA	RELATIVE SCORES (η)					
INPUT / DMU	EFFECTIVE FISHERMEN	TRAWLER	PURSE-SEINER	DOLNETER	LINER	GILL-NETTER
WB	0.557894	1	0.467964	0.36817	0.368169781	0.36816978
OR	0.217237	0.3749	0.216669	0.189288	0.189287979	0.18928798
AP	0.310752	0.5034	0.378505	0.297788	0.297788221	0.30046265
TN	0.555686	0.5557	0.573815	0.555686	0.555686099	0.5556861
PC	9.21E-02	1	2.56E-02	2.02E-02	0.132598039	4.57E-02
KR	1	1	1	1	1	1
KT	0.959602	0.5762	0.417814	0.417814	0.417813584	0.41781358
GOA	1	0.3717	0.152176	0.152176	1	1
MR	0.775885	0.5266	0.526612	0.526612	0.526612211	0.52661221
GR	1	0.7867	1	0.786748	1	0.78674798

Source: Computed by the author through DEA-Solver.

In case of AP, although it is inefficient with respect to every input, it has only 10 numbers of excess liners only. It does not have any other input as excess but it has to improve its production for each of the inputs to relocate itself on the efficient frontier. It implies that its peer states are achieving higher harvest with the same amount of input.

If we consider the individual states and individual results tables, then we see WB is only efficient with respect to the number of trawlers employed. For that case it has an efficiency score equal to 1 (table 5.3), it does not have any excess trawler (table 5.5) and also it does not have any production shortfall (table 5.6). Hence the situation in WB satisfies all the required conditions for optimality when trawlers are taken into consideration. Performance with regard to other inputs, however, it is lying below the frontier. It has excess dol-netters of 1692 numbers, excess liners of 56 numbers and excess gill-netters of 3927 numbers (table 5.5) when those are considered as single input. Production shortfall for WB is respectively are 156.4463, 224.45, 338.8, 338.8 and 338.8 thousand tonnes for inputs of effective fishermen, purse-seiner, dol-netter, liner and gill-netter (table 5.6). Utilization of these inputs in WB is inefficient because its peer state(s) GOA, GR & KR are utilizing their resources more efficiently.

Table-5.4: Relative Performance Ranks of the Maritime states for the year 2005 with respect to single DEA input

DEA INPUT / DMU	RANK					
	EFFECTIVE FISHERMEN	TRAWLER	PURSE-SEINER	DOLNETER	LINER	GILL-NETTER
WB	6	1	5	6	7	7
OR	9	9	8	8	9	9
AP	8	8	7	7	8	8
TN	7	6	3	3	4	4
PC	10	1	10	10	10	10
KR	**1**	1	1	1	1	**1**
KT	4	5	6	5	6	6
GOA	1	10	9	9	1	1
MR	5	7	4	4	5	5
GR	1	4	1	2	1	3

Source: Computed by the author through DEA-Solver

Similarly for the state OR, we can see that it is the worst performing state. Its rank is 8 for two individual inputs or 9 for four individual inputs (table5.4). It has excess dol-netters of 254 numbers, excess liners of 18 numbers and excess gill-netters of 1332 numbers (table 5.5), while each of those are considered as single input. Production improvement required for betterment of OR's performance are 365.731, 169.2664, 366.957, 434.72, 434.72 and 434.72 thousand tonnes respectively for inputs of effective fishermen, trawler, purse-seiner, dol-netter, liner and gillnetter (table 5.6). In these cases peer state(s) of OR are GR, WB & KR.

Table-5.5: Excess inputs used by the Maritime states for the year 2005 with respect to Single DEA Input

DEA	EXCESS INPUTS (s^-)					
INPUT / DMU	EFFECTIVE FISHERMEN	TRAWLER	PURSE-SEINER	DOLNETER	LINER	GILL-NETTER
WB	0	0	0	1692	56	3927
OR	0	0	0	254	18	1332
AP	0	0	0	0	10	0
TN	64723.6	1318	0	11	771	227
PC	0	0	0	0	0	0
KR	**0**	**0**	**0**	**0**	**0**	**0**
KT	0	0	451	0	18	826
GOA	0	0	142	0	0	0
MR	0	237	102	4409	243	2122
GR	0	4020	0	2425	0	1935

Source: Computed by the author through DEA-Solver

While considering the effective fishermen as input we find that the states GOA, KR & GR are utilizing their human resources efficiently and achieving optimum production. As we can see that these maritime states' score are 1 (table-5.3), excess number of fishermen for each of them is zero (table-5.5) and production shortfall is also nil (table-5.6). Only the state TN has excess of 64723 numbers of fishermen. Although the other states may not have excess fishermen but they must improve their production to become efficient. For the state TN, though it has reduced its number of mechanized crafts than previous year, but it is not sufficient. Its peer state in each case is KR and the result implies that TN has to reduce its number of trawlers, dol-netters, liners and gill-netters further by 1318, 11,771 and 227 (table

5.5) respectively for its performance improvement. With the less number of mechanized vessels, the state KR has better amount of harvest. Hence TN has to shade off these excess inputs to lift itself at the efficient frontier.

Table-5.6: Production improvement required by the Maritime states for the year 2005 with respect to Single DEA Input

DEA	PRODUCTION SHORTFALLS (s^{+}) (in thousand tonnes)					
INPUT / DMU	EFFECTIVE FISHERMEN	TRAWLER	PURSE-SEINER	DOLNETER	LINER	GILL-NETTER
WB	156.4463	0	224.45	338.8	338.8	338.8
OR	365.731	169.2664	366.957	434.72	434.72	434.72
AP	354.1695	157.5056	262.19	376.54	376.54	371.7671
TN	238.25	238.25	221.3093	238.25	238.25	238.25
PC	106.677	0	411.05	525.4	70.78	225.8997
KR	0	0	0	0	0	0
KT	9.431848	164.7839	312.18	312.18	312.18	312.18
GOA	0	137.9244	454.62	454.62	0	0
MR	81.5657	253.84	253.84	253.84	253.84	253.84
GR	0	114.35	0	114.35	0	114.35

Source: Computed by the author through DEA-Solver

As we can see from the tables that KR is the only state which is efficient with respect to each and every input. It is utilizing its resources optimally and efficiently. It has an efficiency score equal to 1 (table 5.3), it does not have any excess vessel of any type (table 5.5) and, also, it does not have any production shortfall (table 5.6) for any of the inputs. It is the best performing state when individual input is considered.

Although the state PC does not have any excess input, its rank is at the bottom with respect to each input barring trawlers. It needs to improve its production for inputs of effective fishermen, number of purse-seiners, number of dolnetters, number of liners, and number of gill-netters by 106.677, 411.05, 525.4, 70.78 and 225.8997 (table 5.6) thousand tonnes respectively. The state KT is also inefficient with respect to each input. It needs to reduce its inputs of purse seiners, liners and gill-netters by 451, 18 and 826 numbers respectively. Further it has to improve its production because its peer states are utilizing their inputs more efficiently. The state GOA is efficient with respect to three inputs. They are effective fishermen, liners and gill-netters. It has 142 excess purse-seiners and it needs to improve its production by 454.62 thousand tonnes with respect to the number of trawlers to become efficient.

Table-5.7: Peer States of the Maritime states for the year 2005 with respect to Single DEA Input

DEA	PEER STATES					
INPUT / DMU	EFFECTIVE FISHERMEN	TRAWLER	PURSE-SEINER	DOLNETER	LINER	GILL-NETTER
WB	GOA , GR	WB	GR	KR	KR	KR
OR	KR, GR	WB, KR	KR, GR	KR	KR	KR
AP	KR, GR	WB, KR	GR	KR	KR	KR, GOA
TN	KR	KR	KR, GR	KR	KR	KR
PC	GOA , GR	PC	GR	KR	GOA	KR, GOA
KR	KR	KR	KR	KR	KR	KR
KT	GOA , GR	WB, KR	KR	KR	KR	KR
GOA	GOA	WB, KR	KR	KR	GOA	GOA
MR	GOA , GR	KR	KR	KR	KR	KR
GR	GR	KR	GR	KR	GR	KR

Source: Computed by the author through DEA-Solver

The state MR has all types of mechanized crafts in excess. Although it does not have excess fishermen but its peer states GOA & GR are using their human resources more efficiently than MR. For all types of mechanized crafts KR is MR's peer state and thus MR needs to reduce its trawler number by 237, purse-seiners by 102 numbers and dol-netters by 4409, liners by 243 and gill-netters by 2122.

Lastly, the state GR is efficient with respect to the effective fishermen, purse-seiners and liners. It has excess trawlers, dolnetters and gill-netter of about 4020, 2425 and 1935 respectively. And for all the three above cases KR is its peer state.

5.3.2 Results of DEA with two inputs:

In section 5.2, we have discussed that the maximum number of input variables that we could incorporate in our DEA model is two. We have also found two sets of variables those predominantly contributes the harvest output. In this section we would now adopt single output two input DEA model to identify misallocation of inputs, if any, among the maritime states of India. Inputs and output of the present discussion are specified in the following table- 5.8.

Table-5.8: Input Output Combination for DEA as Determined by Frisch's Confluence Analysis

Output	Input(s)
Harvest	i) Number of trawlers ii) Number of effective fishermen
Harvest	i) Number of trawlers ii) Number of gill-netters

5.3.2.1 Trawlers and Effective Fishermen as Inputs:

We obtain DEA results with number of trawler(**X_1**), number of effective fishermen (**X_6**) as input against annual marine harvest. We find the efficiency of the maritime states (DMUs) and resource allocation in accordance to the application of **BBC-O** model specified in section 5.3. Results of DEA are given below in table-5.9. The corresponding tables showing the optimum weights of inputs and output along with efficient frontier shown as bar graph is given in appendix-14.

Table-5.9: Results of DEA of considering Number of trawlers (X_1) & Number of effective fishermen (X_6) as inputs

DMU	SCORE(η)	RANK	PRODUCTION SHORTFALL (s^+) (in thousand tonnes)	EXCESS INPUTS: TRAWLER (s_t^-)	EXCESS INPUTS: EFFECTIVE FISHERMEN(s_e^-)	PEER STATE(S)
WB	1	1	0	0	0	WB
OR	0.374862	10	169.266382	0	21588.55	WB,KR
AP	0.503428	9	157.5055991	0	34620.43	WB,KR
TN	0.555686	8	238.25	1318	64723.6	KR
PC	1	1	0	0	0	PC
KR	1	1	0	0	0	KR
KT	1	1	0	0	0	KT
GOA	1	1	0	0	0	GOA
MR	0.848478	7	50.42754418	0	0	KR,KT,GR
GR	1	1	0	0	0	GR

Source: Computed by the author through DEA-Solver

Results reveal that six DMUs, namely, WB, PC, KT GOA, KR and GR have scored unity. It implies that these states are lying on the efficient frontier. These states appear to be efficient as excess inputs (s_t^-, s_e^-), and production shortfall (s^+) are zero for all these states. For OR and AP only s_e^- is greater than zero. This implies that fishermen are employed more than the requirement in these two states. But in case of TN both inputs are excess of requirements. Results show that s_t^-=1318 and s_e^- = 64723.

Situation, however in another inefficient maritime state MR is different. Neither the trawler (s_t^-), not effective fishermen (s_e^-) are positive, but production shortfall s^+>0. It implies that input productivity is relatively less than KR, KT & GR- these are peer states of MR. In short, this analysis reveals that many fishers of these regions, namely, Orissa, Andhrapradesh and Tamilnadu, are operating inefficiently because of over employment of inputs and MR suffers from lesser productivity of both inputs. However, TN is the only state which employed 1318 trawlers in excess of optimum requirement.

5.3.2.2 Trawlers (X_1) and Gill-Netters (X_4) as Inputs:

We will now consider another set of variables as inputs, namely, trawlers (X_1) and gill-netters (X_4). Results of DEA are provided in the Table- 5.10. The corresponding tables showing the optimum weights of inputs and output along with efficient frontier shown as bar graph is given in appendix- 15.

Table-5.10: Results of DEA of considering trawlers (X_1) and gill-netters (X_4) as inputs.

DMU	SCORE(η)	RANK	PRODUCTION SHORTFALL (s^+) (in thousand tonnes)	EXCESS INPUTS TRAWLER (s_t^-)	EXCESS INPUTS GILLNETER (s_g^-)	PEER STATE(S)
WB	1	1	0	0	0	WB
OR	0.480198	10	109.87	0	0	WB, KR, GOA
AP	0.692372	6	70.95	0	0	WB, KR, GOA
TN	0.555686	8	238.25	1318	227	KR
PC	1	1	0	0	0	PC
KR	1	1	0	0	0	KR
KT	0.624441	7	134.74	0	0	WB, KR, GOA
GOA	1	1	0	0	0	GOA
MR	0.526612	9	253.84	237	2122	KR
GR	0.786748	5	114.35	4020	1935	KR

Source: Computed by the author through DEA-Solver

We observe that only four maritime states scored unity, namely, WB, PC, KR and GOA. Since input excess (s_t^-, s_g^-) and production shortfall (s^+) are zero, these states are lying on the efficient frontier. Out of remaining six maritime states, three states, namely, OR, AP and KT do not show any excess inputs but operating below the efficient frontier. It implies that productivity of trawlers and gill-netters in these three states are less than their corresponding peer states, namely, WB, KR and GOA.

However, other three states, namely, TN, MR and GR have employed both trawlers (s_t^-) and gill-netters (s_g^-) in excess of the requirement. DEA results show that 1318, 237 and 4020 trawlers and 227, 2122 and 1395 gill-netters are appeared to be excess in those three maritime zones. We find that, with respect to the harvest output of trawlers and gill-netters, six out of ten zones are operating at the level below the productivity level achieved by the peer states.

5.4 Comparison of the Results of single input with two inputs:

The results reveal that the maritime states' performances vary when we consider either trawler or fishermen as single input or trawler & fishermen together. The state WB remains efficient when we consider trawler as a single input or trawler & fishermen together as inputs but its efficiency declines if we only consider the fishermen only against output produced. In that case WB needs to improve its production by 79.25 percent (Table-5.6) in order to become efficient. For all the three cases the only efficient state is KR, i.e. the state KR is using its inputs efficiently, whether it is using it alone or together. It implies that the state Kerala has employed optimum number of trawlers & fishermen. The state PC has its similarity with WB. In PC their productivity of the fishermen is very low and thus they are ranked 10^{th}. They need to improve their production by 106.667 thousand tonnes to take themselves to efficient frontier. The states OR, AP & TN are performing very badly if we consider all the three different cases. In case of TN it has excess fishermen of 64723.6 numbers, it has excess trawlers of 1318 numbers and also it needs to improve its production to become efficient. The state AP is ranked 8^{th} if we consider trawlers only or only fishermen but its rank is lowered to 9 if we consider both together. In that case it also has excess effective fishermen of 34620.43 numbers and also need to improve its production by 157.5054 thousand tonnes. The state OR too shows similar effect if we consider both the inputs together. The state OR is ranked 9^{th} if we consider trawlers only or only fishermen but its rank is lowered to 10 if we consider both together. In that case it also has excess effective fishermen of 21588.55 numbers and also need to improve its production by 169.2664 thousand tonnes to become efficient. Efficient frontier with respect to the human resource employed in marine harvesting is formed by the states KR, GOA & GR only. All other states are lying below the frontier. However, only TN shows 64723.6 effective fishermen are in excess of the present requirement. In other states, the result of the study reveals that there exist no excess fishermen. Even then they are inefficient because their output is inadequate to justify the total crewmen (fishermen) employed. In order to be placed on the efficient frontier, these states must improve their productivity. Using similar levels of inputs the efficient states (peers) are producing better output than these states. The required level of improvement or production shortfall is shown in **table -5.6**. The implication of this is that the productivity per fishermen of these states is less than what it ought to be. Here also, the low level of biomass stock may be the reason.

A very interesting result is shown by the state KT. If we consider only trawler or only fishermen the state is inefficient in both the cases but when we consider trawler & fishermen together the state KT becomes efficient. This implies that joint effort of trawlers and fishermen has positive impact on productivity and both inputs are complementary to each other. The state MR also improves its score to 0.848478 if both the variables are taken together as inputs. But it still needs to improve its production to take itself to the efficient frontier. The states GOA and GR also showed interesting results. For both the states if we consider only trawler as input they appear to be inefficient. It indicates that GR needs to shade off 4020 numbers of trawlers to become efficient. Also they need to improve their production a notch. But when we consider only fishermen or trawler & fishermen together both the states become efficient. That implies, fishermen effectively improve the performances of the trawlers as well as the states of GOA & GR. The results show that some states when individual inputs are considered, they become inefficient but combining the other inputs they become efficient.

We have also run another DEA considering the number of trawlers and the number of gill-netters together as inputs. The results are in the following table.

When gill-netter (X_4) is considered along with trawler (X_1) four maritime states appear efficient, namely WB, PC, KR and GOA. Values of production shortfalls and excess inputs for the inefficient states are shown in table-5.10. The inefficient states TN, MR & GR has excess trawlers of 1318, 237 and 4020 numbers respectively and excess gill-netters of 227, 2122 and 1935 numbers respectively. They need to improve their production by 238.25 thousand tonnes, 253.84 thousand tonnes and 114.35 thousand tonnes respectively to become efficient. The state AP has improved its score as well as rank by the introduction of gill-netters with trawlers. Also its production enhancement requirement has lessened. That implies the state AP utilizes its resources better if it combines its inputs of trawlers and gill-netters together. But for the state KT it is exactly the opposite. Although KT improves its score from 0.576199 to 0.624441, its rank went down from 5 to 7. Also its production improvement went down from 164.7839 to 134.7448 thousand tonnes. It implies that, although the state KT betters its performance for itself when it combines gillnetes with trawlers but it is not enough or sufficient with respect to other states. The other states combine them better to achieve higher efficiency score and higher rank. Six out of ten maritime states (DMUs) being inefficient, it explains why the CPUE is declining in Indian Marine Fisheries. This also indicates how the situation can be improved if the estimation of biomass stock in these marine zones is available. Because, there are maritime states which are appeared as inefficient but do not show any excess fishing boats. The reason may be the insufficient biomass stock. If the stocks of biomass in these zones are found to be inadequate to cater the existing number of motorized crafts and gill-netters then excess crafts and gill-netters should be shifted to other zones. This would prevent the danger of overexploitation and would also solve the problem of declining CPUE.

5.5 Conclusion:

The result obtained in this chapter establishes the fact that there exists a paradoxical condition in Indian Marine Fishery. It also ascertained that Indian Marine Fishery has not been exploited to the fullest potential of the biomass stock because there are zones where there are massive production shortfalls. At the same time the result also justified the claims of some experts, who complained about over harvesting with use of excess crafts and gears. It could be stated that on the average, states are using excess inputs. They need to reduce the surplus inputs to become efficient.

The analysis of efficiency of Indian maritime states using different types of mechanized vessels as inputs seems to provide explanation of paradoxical situation of Indian Marine fishery. Results indicate that in majority of states labour productivity is very low although, DEA analysis shows, there are no excess fishermen. This low productivity seems to indicate the cause of not achieving the potential level of harvest. Result proves that there are unutilized resources in the form of excess effective fishermen which can be used for improvement of marine harvest productivity.

There are certain states, namely, TN, MR and GR where there are production shortfall as well as excess inputs of mechanized vessels. These are the states where overexploitation is happening as well as they have failed to reach the targeted potential. Some other maritime states, (KT, OR), where there are no excess inputs but production shortfall exists. This implies that they did fail to harvest their fullest potential. These states can enhance their production up to certain extent so that the targeted potential indicated by MSY can be achieved. The result in table 5.5 also proves that overcapacity exists in the form of excess numbers of different kind of mechanized fishing boats/ crafts which in turn can be termed as the cause of inefficiency. Therefore, restriction and regulation in the operation as well as licensing of new mechanized boats is an absolute necessary to enhance the efficiency and productivity of the maritime states. Also it follows that redistribution of excess mechanized crafts are required to achieve the target potential.

It is very important for the states to identify the types of mechanized boats which give them optimum harvest from their territorial waters. Each maritime state must concentrate on licensing those particular type of fishing crafts. For example, results reveal that for WB, trawlers and purse seiners are very effective rather than gill-netters, liners or dol-netters. For trawlers and purse-seiners WB achieved the score unity, having no excess input as well as no production shortfall. WB may consider giving more licenses to trawlers and purse-seiners instead of other mechanized boats. At the same time, it would be wise decision to relocate excess gill-netters, liners or dol-netters to other states, namely, GOA, PC.

The state KR projects itself as an ideal state for every kind of input and for every aspect. It does not have any excess input, and its production is also optimum for every type of mechanized boats. Hence the other states can follow Kerala (KR) model for betterment of their performances. Especially those states TN, AP, KT who share their boundary with Kerala, or has similarity in geographical location and continental shelf.