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Estimating technical efficiency on Saudi Arabia fishing methods: A case study of the red sea

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Abstract
The Red Sea is one of the major fisheries for fish production in Saudi Arabia, where production represented 28.42% of the total fish production (90 thousand tons) in 2012. Despite the expand of water area and increase the number of fishers and boats (traditional and industrial) fishing in the Red Sea, but the fish production was decreased from 31.05 tons in 1988 to 25.56 thousand tons in 2012. This indicates the existence of deficiencies in the use of mechanical strength and quantity economic resources of fish available fisheries in the Sea Red. We used Data Envelopment Analysis (DEA) (which is a linear programming method of non-parametric), to estimate the technical efficiency of fishing methods (Trollins, Gillnet, and Traps) in the Red Sea and the impact of achieving optimum technical efficiency of fish production in the Red Sea.

Keywords: Fish Production, Fishing Methods, Technical Efficiency, the Red Sea

1. Introduction
Fish meat is one of the critical food in Saudi Arabia. Fish contains most of the animal proteins, fats, vitamins, and minerals. It also contains about 20% of its weight animal protein similar in composition to the amino acids of the chicken protein. The advantage of beef protein superiority of the degree of benefit. Fish also have fat ratios that vary in variety. Fat is about 0.8% in grouper and about 7% in sardines [1]. Despite the expansion of the coast of Saudi Arabia to more than 2,900 kilometers on the Red Sea and the Arabian Gulf, but the production of fish does not meet the growing consumer particular needs. Therefore the government had to expand imports of fishery products, where increased from 38.7 thousand tons with a value of 214 million SR ($57.1 million) in 1990 to 163.4 thousand tons valued at 1172.7 million SR ($312.72 million) in 2012 [2].

The Red Sea is one of the major fisheries in Saudi Arabia for fish production, where production represented 28.42% of the total fish production (90 thousand tons) in 2012. Despite the expand of water fishing area and increase the number of fishers and fishing boats (traditional and industrial) in the Red Sea, but fish production decreased from 31.05 thousand tons in 1988 to 25.56 thousand tons in 2012 [2]. This indicates the existence of a failure in the use of mechanical strength and economic resources amount of available fishers at the Red Sea. One manifestation of this failing was decreasing the fishing boat productivity of 8.24 tons/boat in 1990 to 3.03 tons/boat in 2012. It is known that low productivity means lower technical efficiency, which increases the loss of economic resources of fish and the consequent increase of production costs for fish in the Red Sea fisheries.

There were some studies discussed the fishing in the Red Sea [3, 4, 5]. The using of the fishing methods in the Red Sea lead to the researcher focus on the increasing of the production, but less of them focus on the efficiency of using these methods. In our study, we investigate the efficiency of using the fishing methods in the Red Sea by DEA.

1.1 Research objectives
This study aims to measure the technical efficiency of the methods of fishing at marine fisheries of the Red Sea, through the following objectives:

1. Study the current status of fish production in the various marine fishery of the Red Sea at Saudi Arabia during the period 1990- 2012.
2. Measure the technical efficiency of the methods of fishing in marine fishery Red Sea and

The impact of achieving optimal technical efficiency on fish production in marine fishery the Red Sea during the period 2007- 2012.

2. Study methodology

This study is based on measuring the methods of technical efficiency working at the marine fishery Red Sea on Data Envelopment Analysis (DEA). DEA is a non-parametric linear programming method that creates envelope includes data using Piecewise -Linear Frontier [6]. The model was estimated under a constant and variable return to scale. This is because the hypothesis of constant return to scale be preferred on DEA model when all fishing methods work at optimal size. There are several factors that inhibit the production units to achieve the optimum sizes such as imperfect competition and funding constraints. The use of the constant returns to scale assumption in the DEA model when all production units are not working in the level of optimal sizes, which resulting in confusion between technical efficiency and scale efficiency. To separate between the impact of technology and the size in measuring the efficiency, we used variable returns to scale model. The linear programming model used to measure the technical efficiency of the methods of fishing under variable returns to scale as following [7, 8]:

$$Min_{\theta,\lambda}\theta^{VRS}$$
$$S.t.$$
$$Y\lambda - y \geq 0$$
$$\theta_i - X\lambda \geq 0$$
$$i = 1, 2, \ldots, n$$
$$N_1\lambda = 1$$
$$\lambda \geq 0$$

Whereas:

θ^{VRS}: technical efficiency (TE) of the productivity unit.

λ: Constants vector of NX1.

θ_i: The efficiency degree earned from the productive unit, which arranged i .

X: Represents the vector to minimize production costs per unit.

y: Represents the rate of production.

Notes that if $\theta=1$ then the production unit work efficiently, and the unit produces at the optimal level of production possibilities frontier (PPF) curve. If the $\theta \leq 1$ production unit is located under the optimum level of the productive possibilities frontier curve, which considered technically to be inefficient [9]. Finally, this study is based on secondary data published in the statistical data on fisheries in the Kingdom of Saudi Arabia issued by the Marine Fisheries Department, by the Ministry of Agriculture.

2.1. Research concepts

This research includes a set of concepts and terms as the following:

2.1.1. Fishing Boats industrial and traditional

Industrial fishing boats refer to boats more than 9 meters in length and have modern equipment such as fish finders, electronic navigation equipment, and modern telecommunications facilities, in addition to fishing cranes and equipment with high efficiency. As for traditional fishing boats refer to boats ranging in length between 5-20 meters and equipped with an engine allow for a boat trip extends for two days, but without telecommunication facilities, fish finders equipment, and other modern fishing equipment [2].

2.2.2. Fishers and fishing workers

The fishers refer to both traditional, investors and temporary fishers, in addition to on-foot fishers. The traditional fishers refer to an individual Saudi citizen who engages himself on board one of his traditional fishing boats. The investor fishers refer to an individual Saudi citizen or the company who invest their money in marine fisheries with modern fishing boats. The temporary fishers refer to a son (who is less than 18 years of age) of the traditional fishers who engage with parents in the marine fisheries sectors. The on-foot fishers refer to an individual Saudi citizen who engages on foot in marine fisheries without owns fishing boats. Finally, fishery workers refer to an individual who is working in the marine fisheries sector as a worker on a fishing boat, regardless of their nationality [2].

2.2.3. Fishing effort

Fishing effort of trolling fisheries refer to the number of threads in use during a fishing trip. The fishing effort of the Gillnet fishery refers to the number of throwing Gillnet during a fishing trip regardless of the size and type of Gillnet. Finally, fishing effort of trap fishery (named Gargours) refers to the number of Gargours traps collected from the sea during a fishing trip regardless of the Gargours size of the trap and its duration in the sea [2].

3. Results and Discussion

3.1. The status of the fish production of the Red Sea fisheries

We examine the status of fish production in the Red Sea fisheries during the period 1990- 2012. We found from tables (1 and 2) results as follows:

1. The number of traditional boats operating in Red Sea fisheries increased from 3491 boats in 1990 to 8258 boats in 2012, which increased the number of traditional boats working in the Red Sea fisheries with an annual growth rate of 4.2% during the study period. Also, the number of modern boats operating in Red Sea fisheries increased during the study period with an annual growth rate of 4.4%. However, the fishing boat productivity decreased with an annual rate of 5%.
2. The numbers of fishers working and the number of workers in the Red Sea fisheries increased at an annual growth rate of 4.1% and 4.1%, respectively, during the study period. However, the fishers productivity decreased by 10.49 tons/Hunter in 1990 to 3.75 tons/Hunter in 2012, which decreased at an annual rate of 4.9%.
3. Despite the increasing numbers of boats, traditional and industrial fishing and the number of fishers and fishing workers in the Red Sea, but the fish production in Red Sea fisheries decreased from 29.27 thousand tons in 1990 to 25.56 thousand tons in 2012, a decrease at an average annual decrease of 0.7% during the study period. This was due to overfishing phenomenon that led to the failure to keep up with the rate of fishing natural growth rate. The Red Sea fisheries contributed at about 39.43% of the average total fish production of Saudi Arabia of 65.07 thousand tons, while the Arabian Gulf and fish farms contributed about 45.21%, 14.05%, respectively, during the study period.

Despite the increase in the number of boats, fishers, fishery

workers, and the fisher's production, there were decreasing in the productivity of boats and fishers. This means that the use of these methods is not optimized for optimal productivity.

3.2. Technical efficiency of the fishing methods in Red Sea fisheries for the Kingdom of Saudi Arabia

The technical efficiency knows as a measure of the productive capacity unit's ability to achieve maximum possible production of the available resources. The value of technical efficiency is between zero and one. The productivity of the unit can achieve full technical efficiency when the coefficient reaches one [10, 11]. Table (3) show the estimation of technical efficiency for different fishing methods in the Red Sea during the period from 2007 to 2012. The result show under of the constant returns to scale for the average technical efficiency of the method of fishing trolling between the minimum 0.608 in Aseer region and a maximum 0.902 for Tabuk and Medina regions, with an average of 0.754. This means that could increase fish production by 24.6% without any increase in economic Fishery resources. Thus, the method of using the fishing trolling method lose the number of economic Fishery resources, which resulting fish production cost increased by 24.6% during the period 2007-2012. Under of variable returns to scale, the average technical efficiency of the fishing trolling method ranged between the minimum 0.929 in Aseer region and a maximum 0.985 for the rest of the region, with an average of 0.966. This means that it could increase fish production by 3.4% without any increase in economic Fishery resources, and thus this method loses some of the economic fishery resources, resulted in an increase in the cost of fish production by 3.4% during the period 2007-2012.

The Gillnet fishing method shown that in under of the constant returns to scale the average technical efficiency ranged between the minimum 0.393 in Aseer region and a maximum reached 0.970 for Tabuk and Medina regions, with an average of 0.773, which means increased fish production by 22.7% without any increase in economic Fishery resources. Thus the method of using Gillnets loses a measure of the economic fishery resources, which increased the cost of fish production by 22.7% during the period 2007-2012. Under variable returns to scale, the average technical efficiency of the Gillnet fishing method reached between the minimum 0.425 in Aseer region and maximum 0.988 for Tabuk and Medina regions, with an average of 0.790, which could increase fish production by 21% without any increase in economic Fishery resources, and thus loses an amount of the economic fishery resources, resulting in an increase in a cost of fish production by 21% during the period 2007-2012.

Finally, the fishing trap (Gargours) method, under of the constant of returns to scale, the average of technical efficiency were between the minimum 0.311 in Mecca region and a maximum equal to one for Tabuk and Medina regions, with an average of 0.655. This means that could be increased fish production by 34.5% without any increase in economic Fishery resources, which loses an amount of the economic fishery resources, thus increases the cost of fish production by 34.5% during the period 2007-2012. However, under variable returns to scale the average technical efficiency of the fishing trap method ranged between the minimum 0.666 in Mecca region and a maximum reached one for the regions of Tabuk and Medina, with an average of 0.833. This means that can be increased fish production by 16.7% without any increase in economic Fishery resources, and thus the method of using the fishing trap method loses an amount of the economic fishery resources, increasing a cost of fish production by 16.7% during the period 2007-2012.

On the other hand, the average of technical efficiency of the fishing methods in the Red Sea fisheries under the constant and variable returns to scale 0.728 and 0.863 respectively, during the period from 2007 to 2012, which could increase the production of fishing methods by 27.2% 13.7% without any increase in the number of resources used in the fish production. Under of achieving optimum of technical efficiency of the fishing methods were expected to increase the average fish production in Red Sea fisheries by 26.33 thousand tons during the period 2007- 2012 to 33.49, 29.94 thousand tons under the constant and variable returns to scale for each respectively. In order to increase fish production of Red Sea fisheries, this study recommends the need to achieve the optimum technical efficiency of the fishing methods in the Red Sea through the optimal use of fish resources and the use of technical methods in detecting fish gathering sites and eliminating the phenomenon of overfishing.

4. Conclusion

The Red Sea is one of the major fisheries for fish production in Saudi Arabia, where production represented 28.42% of the total fish production (90 thousand tons) in 2012. Despite the expand of water area and increase the number of fishers and boats (traditional and industrial) fishing in the Red Sea, but the fish production was decreased from 31.05 tons in 1988 to 25.56 thousand tons in 2012. This indicates the existence of deficiencies in the use of mechanical strength and quantity economic resources of fish available fisheries in the Sea Red. We used Data Envelopment Analysis (DEA) (which is a linear programming method of non-parametric), to estimate the technical efficiency of fishing methods (Trollins, Gillnet, and Traps) in the Red Sea and the impact of achieving optimum technical efficiency of fish production in the Red Sea.

This study adopted in achieving its goals on secondary data published in Fisheries statistical by the marine fisheries management by statistics of the Ministry of Agriculture Agency for Fisheries. It also relied on Data Envelopment Analysis, which is a linear programming method of non-parametric.

This study resulted in a set of results, including (1) The average technical efficiency of the methods of fishing fisheries the Red Sea under constant and variable returns to scale 0.759, 0.806 for each respectively during the period from 2007 to 2012, and this means that it can increase the production of fishing methods by 24.1%, 19.4% under constant and variable returns to scale for each of them in a row without any increase in the number of resources used in the production of fish, (2) underachieve full technical efficiency of fishing methods, expected to increase the average fish production of the Red Sea fisheries of 26.33 thousand tons during the period 2007- 2012 to 32.68, 31.44 thousand tons under constant and variable returns to scale for each respectively, (3) the study recommends the need to achieve full technical efficiency of fishing methods in the Red Sea, through the optimal use of fishery resources and follow the techniques in the detection of places of gatherings fish and getting rid of the phenomenon of overfishing.

Table 1: Trend model of fishing methods in the Red Sea area during the period 1990-2012.

Statement	Growth rate%	F	R^2	Model	Average
Number of fishing boats in the Red Sea					
Traditional	4.2	66.59	0.76	$Ln\ Y_1 = 8.335 + 0.042T$ $(116.96)^{**}\ (8.16)^{**}$	7273.1
Industrial	4.4	76.52	0.78	$Ln\ Y_2 = 4.826 + 0.044T$ $(62.95)^{**}\ (8.75)^{**}$	134.3
sssTotal	4.2	67.79	0.76	$Ln\ Y_3 = 8.398 + 0.042T$ $(118.24)^{**}\ (8.23)^{**}$	7407.3
The number of fishers and fishery workers in the Red Sea					
Fishers	4.1	112.26	0.84	$Ln\ Y_1 = 8.068 + 0.044T$ $(130.39)^{**}\ (10.60)^{**}$	5442.5
Fishery Workers	4.1	28.52	0.58	$Ln\ Y_2 = 8.488 + 0.041T$ $(80.86)^{**}\ (5.34)^{**}$	8062.7
Total	4.0	49.68	0.70	$Ln\ Y_3 = 8.982 + 0.040T$ $(114.33)^{**}\ (7.05)^{**}$	13505.1

** Significant when the probability level of 1%.
Source: Collected and calculated from the data available in the Ministry of Agriculture, Marine Fisheries Department. Fisheries Statistic Data of Saudi Arabia, period 1990- 2014.

Table 2: Trend equations of the development of fish production of the most critical marine fishery in Saudi Arabia and the productivity of the fishing boats and fishers during the period 1990-2012.

Statement	Growth rate%	F	R^2	Model	Average 1000 tons	The relative Importance %
Fisheries production of Saudi Arabia						
Red Sea	-0.7	12.12	0.55	$Y_1 = 84.18 - 1.62T + 0.06T^2$ $(18.80)^{**}\ (-4.68)^{**}\ (4.10)^{**}$	25.66	39.43
Arabian Gulf	6.4	232.46	0.92	$Ln\ Y_2 = 2.521 + 0.064T$ $(48.64)^{**}\ (15.25)^{**}$	29.42	45.21
Fish farms	-21.4	1.94	0.18	$Ln\ Y_3 = 2.094 - 0.214T$ $(1.80)^{ns}\ (-1.39)^{ns}$	9.14	14.05
Total fish production	3.5	196.09	0.90	$Ln\ Y_4 = 3.721 + 0.035T$ $(107.47)^{**}\ (14.00)^{**}$	65.07	100
Productivity boats and fishers						
Fishing boats	-5.0	37.72	0.64	$Ln\ Y_5 = 1.098 - 0.080T$ $(16.76)^{**}\ (-6.14)^{**}$	3.95 Tons/boat	
Fishers	-4.9	47.61	0.69	$Ln\ Y_6 = 2.175 - 0.049T$ $(22.17)^{**}\ (-6.90)^{**}$	5.29 Tons/hunter	

Source: Collected and calculated from the data available in the Ministry of Agriculture, Marine Fisheries Department. Fisheries Statistic Data of Saudi Arabia, period 1990-2014.
** Significant when the probability level of 1%, *is* not significant.

Table 3: Technical efficiency of the fishing methods in the Red Sea fisheries under the constant and variable returns to scale during the period 2007-2012.

Zone	Year	Constant returns to scale			Variable Returns to scale		
		Trolling	Gillnet	Trap (Gargours)	Trolling	Gillnet	Trap (Gargours)
Tabuk and Medina	2007	0.876	0.998	1.000	.977	0.998	1.000
	2008	.879	0.997	1.000	1.000	1.000	1.000
	2009	.877	1.000	1.000	0.986	1.000	1.000
	2010	0.876	1.000	1.000	.962	1.000	1.000
	2011	1.000	0.938	1.000	1.000	0.960	1.000
	2012	0.903	.888	1.000	.983	.967	1.000
	Average	0.902	0.970	1.000	0.985	.988	1.000
Mecca	2007	.754	0.996	0.314	0.986	0.998	0.314
	2008	.754	0.998	0.315	1.000	1.000	.353
	2009	.754	0.999	.313	0.992	1.000	.851
	2010	.754	1.000	0.314	.982	1.000	0.802
	2011	.844	0.859	.287	1.000	0.859	.896
	2012	0.660	0.884	0.322	0.950	0.885	.781
	Average	0.753	0.956	0.311	0.985	.957	0.666
Aseer	2007	.631	0.302	-	.959	0.302	-
	2008	.631	0.301	-	.921	0.301	-
	2009	0.630	0.302	-	0.940	0.302	-
	2010	0.632	0.301	-	1.000	0.302	-
	2011	0.530	0.571	-	.755	.665	-
	2012	.592	0.581	-	1.000	0.677	-
	Average	0.608	0.393	-	0.929	0.425	-
The average public areas		.754	.773	0.655	.966	0.790	.833
The overall average of the methods		.728			0.863		

Source: Collected and calculated from the quantitative analysis of raw data using DEAP Version 2.1.

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