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TECHNICAL AND ECONOMIC EFFICIENCY ESTIMATION OF TRADITIONAL FISHERY BOATS, AT HODEIDA PROVINCE, REPUBLIC OF YEMEN

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ABSTRACT

Estimating technical and economic efficiency, of traditional fishery sector, are considered as study objectives. Study results support fishing policy makers to adopt policies, which optimize the fishing resource use. In addition to save natural stock of fish, and determine the number fishing efforts, which satisfy the Maximum Sustainable Yield (MSY) of fish. Primary data collected by personal interviews with traditional fishermen at Republic Of Yemen, Hodeida Province, at fishing seasons in 2012 and 2013, are the main source of study data, in addition to the secondary data .The Data Envelopment Analysis (DEA) approach used for estimating technical and economic efficiency, based on fishing methods (Hocks and Gill Nets), engine horsepower, and fishing boat sizes. Small boats, using Hocks fishing method and 60 horsepower engines, were technically less efficient than that for small boats using 40 horsepower engine. The first one can increase its yield by 14%, while the second one by only 9% using the same fishing resources. Large boats using 60 horsepower engine, and Gill Net fishing method, were more technically efficient than that for large boats using 40 horsepower engine. Small boats, using Hock fishing method, would increase its economic efficiency from 73% to 95% by increasing its engine horsepower from 60 to 70. While, large boats using Hocks get the highest economic efficiency, 84%, using 60 horsepower engine. Large boats using Gill Net fishing method can reduce costs by 7% of fishing costs and achieve the same level of production.

Key words: Traditional fishery, Efficiency, constant return to scale, Data Envelopment Analysis.

INTRODUCTION

The Republic of Yemen had the fourth ranking place, in producing fish, among the Arab countries, Arab Organization for Agricultural Development (2011). The amount of fish produced in 2012 was 230.552 thousand tons, and the province of Hodeida produced 14% of total production. The traditional fishing sector is the main source of fish in the Republic of Yemen, with production of 228.655 thousand tons in 2012, valued at 115.365 million Yemeni Riyals. While traditional fishing sector production in the province of Hodeida was 31.583 thousand tons, representing 93.33% of the total fish production at the province, Ministry of Planning (2012). Republic of Yemen has 150 islands, and these islands are providing natural environment for marine life, which makes fishing areas more productive. Traditional fishery sector importance is based on its contribution to GDP in Yemen, 1% to 2%, also it contributes to food security and self-sufficiency of the fish consumption in Yemen. It also provides more than 70 thousand jobs in the field of fishing sector, and 30 thousand jobs in fish processing sector. In addition to, supporting activities such as transport, storage, and marketing of fish, Faqih (2004). Fishery sector is one of the most promising productive sectors in Yemen. The need to improve fishery sector will contribute significantly to poverty reduction, and help in solving food crises and unemployment problem. However, developing fishery resources, in the Hodeida Province, faces many obstacles such as non-efficient use of fishing resources. Also, the lack of infrastructure, using fishing equipments that lead to inefficient use of economic resources which result in high costs of fishing operation. Lack of cooperation between government agencies and fishermen cause an in-efficient use of resources available in fishery sector. The population increase will increase demand for fish, and increase the number of fishing efforts and result in over fishing problem.

To achieve the main study objectives, estimating technical and economic efficiency of traditional fishing boats, by maximize possible production using the same economic resources, and/or lowest costs for the current production level. Study results will guide the decision-makers for policies which increase resource use efficiency at the traditional fishing sector.

Data collected using questionnaire filed out through an interview with a random sample of traditional fishermen at the province of Hodeida. Data analyzed

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according to the concept of production function, using the non-parametric analysis approach of Data Envelopment Analysis (DEA) (Elhendy, and Alkahtani, 2013).

The Technical Efficiency estimates, including both Constant Return to Scale (TE_{crs}), and Variable Return to Scale (TE_{vrs}), are estimated. Economic Efficiency (EE), require the use of fishing input prices, thus it can calculate the cost savings, when achieve the same level of fish production, but at a lower cost.

METHODOLOGY

There is no doubt that the production of fish (Y) affected by a variety of Economic factors, Elhendy, and Alkahtani (2012), most notably, labor (X_1), fishing tools used (X_2), fuel (X_3), and Number of fishing efforts (X_4). Thus, the relation among study economic variables have the form of production function as following:

$$Y_I = f(X_1, X_2, X_3, X_4)$$

where: ***Y*** Total production of fish per boat for fishing method in the study areas.

X_1: Total employment for boat.

X_2: Number of fishing tools used with fishing effort.

X_3: The amount of fuel used for the fishing effort in liters.

X_4: The number of fishing efforts.

DEA model is a linear programming (non-parametric) approach, used to estimate relative technical and economic efficiencies. It has an objective function and constraints, as a linear programming problem. Theoretical development of this approach is discussed in detail in Charnes, *et al*, (1978); and Coelli, *et al*, (1998).

Objective Function

$$\text{Maximize } \theta = \frac{u_1 y_{1o} + u_2 y_{2o} + \dots + u_r y_{ro}}{v_1 x_{1o} + v_2 x_{2o} + \dots + v_m x_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

Maximize the efficiency rating θ for fishing boat o, this is subject to the constraint that, when the same set of *u* and v coefficients is applied to all other fishing units being compared, no fishing unit (SU) will be more than 100% efficient as follows:

$$\text{SU1} \quad \frac{u_1 y_{11} + u_2 y_{21} + \dots + u_r y_{r1}}{v_1 x_{11} + v_2 x_{21} + \dots + v_m x_{m1}} = \frac{\sum_{r=1}^{s} u_r y_{r1}}{\sum_{i=1}^{m} v_i x_{i1}} \le 1$$

$$\text{SU2} \quad \frac{u_1 y_{12} + u_2 y_{22} + \dots + u_r y_{r2}}{v_1 x_{12} + v_2 x_{22} + \dots + v_m x_{m2}} = \frac{\sum_{r=1}^{s} u_r y_{r2}}{\sum_{i=1}^{m} v_i x_{i2}} \le 1$$

$$\text{SUo} \quad \frac{u_1 y_{1o} + u_2 y_{2o} + \dots + u_r y_{ro}}{v_1 x_{1o} + v_2 x_{2o} + \dots + v_m x_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \le 1$$

$$\text{SUj} \quad \frac{u_1 y_{1j} + u_2 y_{2j} + \dots + u_r y_{rj}}{v_1 x_{1j} + v_2 x_{2j} + \dots + v_m x_{mj}} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1$$

$$u_1, \dots, u_s > 0 \text{ and } v_1, \dots, v_m \ge 0$$

Where:

m = number of fishing units (SU) being compared in analysis

SU_j = fishing unit number j

θ = efficiency rating of the fishing unit being evaluated.

y_j = amount of output *r* produced by fish unit j

x_J = amount of input (x) used by fishing unit j

j = number of inputs used by the fishing units SUs

r = number of outputs (fishes) produced by the fishing units SUs

u = coefficient or weight assigned to output r

v = coefficient or weight assigned to input x

RESULTS AND DISCUSSION

The technical and economic efficiencies of traditional fishing boats are estimated using DEA computer program, see Coelli (1996), according to fishing method, boat size, and boat engine power. Also, efficiency estimations are based on two assumptions, one for constant return to scale which assume that the fishing boat worked at its maximum capacity. The second assumption of variable returns to scale, which assumes that the fishing boat worked at levels less than its maximum capacity. Second assumption would represent the real fishing boats activities, as long as environment and technology of traditional fishing are not in optimal case. Study results can be presented as following:

First: The Technical efficiency of traditional fishing boats according to fishing boat size, and fishing methods:

1- Technical efficiency of small fishing boat using Hocks (Jalb) fishing method: Small fishing boats have the highest TEcrs, 0.97, using engine power of 70 horse power, see table (1). So, boats are able to increase its production by 3%, without any increase in resources used. The lowest value of technical efficiency was 0.78, with engine power of 60 horsepower, this means that boats are able to increase production by 22%, without an increase of resources used. While the with assumption of Variable Return of Scale (VRS), the highest TEvrs was 1 , with engine power of 70 horsepower. This means that these boats operate at full technical efficiency. The lowest value of TEvrs was 0. 86, when boats are using engine of 60 horsepower; so boats are able to increase production by 14%, using the same amount of resources, by developing its traditional fishing technology.

It is important to show that 73% of boats were using engine of 60 horsepower with TEvrs of 0.86, while boats with 40 horsepower engine, only 18% of boats, were more technical efficient, 0.91, which will direct fishing policy to support using less engine power to save fuel costs and increase fishing boat technical efficiency.

2- Technical efficiency of large fishing boats, using Hock (Jalb) fishing method: For large boats using Hock fishing method, the highest value of TEcrs was 0.91, using engine power of 40 horsepower. Even that, boats can increase production by 9%, without resources used increase. The lowest value of TEcrs was 0.84, with engine power of 75 horsepower, so boats are able to increase production by 16%, using the same amount of resources. For large boat using Hock fishing method, the highest value of TE_{crs} was 0.98 using engine of 40 horsepower, while its minimum value of TE_{crs} was 0.96, using boat engine of 230 horse power. Table (1), show that large fishing boats using Hocks using enginr of 40 horsepower were 53% of total boats, have the highest technical efficiency of 0.98.

3- Technical efficiency of small fishing boat using Gill Net fishing method: Data in the table (1) show that TE_{crs} ranged between 0.96 and 0.68. That result show that the most technical efficient boat can increase its production by 4% using the same resources, while the least efficient one can increase its production by 32% to reach its full technical efficiency. With the concept of technical efficiency assuming variable return to scale (TEvrs), that the boat worked with capacity less that its maximum capacity, the highest value was 1 , with engine of 40 horsepower. The lowest value of TEvrs was 0. 98, using engine of 75 horsepower.

Small boats using engine of 40 horsepower, 10% of small boats, were full technically efficient, 1.00. Even that, 46% of small boats were using engine of 60 horsepower with technical efficiency of 0.94. Last results prove that 40 horsepower engine in small boats using Gill Net were more technically efficient than that of small boats using 60 horsepower engine.

4- Technical efficiency of large fishing boat using Gill Net Fishing method: The average technical efficiency assuming Constant Return of Scale (TEcrs) was 1, with engines of 40, 60, 70 horsepower, This means that these boats were operate at full technical efficiency. The lowest value of technical efficiency assuming Constant Return of Scale was 0.98, using engine of 230 horsepower, this result means that these boats are able to increase production by 2%, without an increase in resources used. While the technical efficiency with assumption of Variable Return of Scale were close to full efficiency, which means the fishermen experience in traditional fishing are high and insure the most technical efficient use of fishing methods. The technical efficiency with assumption of Constant Return of Scale was 1.00, for boats engine using 40, 60, 70 horsepower engines , i.e., these boats operate at full efficient technology. The lowest value of technical efficiency with the assumption of Constant Return of Scale was 0. 98, using engine of 230 horsepower. These boats were able to increase production by 2%, without an increase in resources used.

Table (1) shows that large boats, using Gill Nets fishing method, are full technically efficient with the assumption of variable return to scale, when they use engine of 40, 60, and 70 horsepower, while its TEvrs will decrease when using more power engines, see table (1). Last result show that using more powerful engine for fishing boats will not insure increasing its technical efficiency, both TEvrs and TEcrs. Less power engines are more technically efficient, in addition to saving in fuel costs.

Second: The economic efficiency of traditional fishing boats according to boat size and fishing method.

1- Economic Efficiency to traditional small fishing boat to using Hock Fishing (Jalb) method: The highest value of economic efficiency, assuming constant return to scale (EEcrs), was 0.92 using engine of 70 horsepower, see table (2). This result means that boats are able to reduce costs by 8%, and achieve the same level of production. The lowest value of EEcrs was 0.40, using engine of 40 horsepower, so these boats are able to reduce costs by 60%, and having the same level of production.

The variable return to scale economic efficiency, EEvrs, has its highest value of 0.95, with engine of 70 horsepower. So, these boats are able to reduce costs by 8% and get the same level of production. While, the lowest value of EEvrs was 0.40, using engine of 40 horsepower, then the boats can reduce costs by 60%, and produce the same level of production.

2- Economic Efficiency of large fishing boats using Hock (Jelb) fishing method: Table (2), shows that EEcrs was 0.78, when using engine power of 230 horsepower, it was the highest value EEcrs. So, boats are able to reduce their costs by 22% and getting the same yield. The lowest value of EEcrs was 0.50, when engine power has 40 horsepower. So, these boats can get the full economic efficiency and reduce its costs by 50%, and get the same level of production. The EEcrs get it maximum value, 0.89, when it used engine power of 230 horsepower. Then, these boats can reduce their costs by 11% without decreasing level of production. The lowest value of EEcrs was 0.79, using boats engine of 40

Table (1) Technical efficiency of traditional fishing boats using different engine horsepower, under constant and variable returns to scale.

Fishing And Boat Types	Engine Horsepower	Percentage %	Technical Efficiency Constant Return of Scale (TE_{crs})	Technical Efficiency Variable Return of Scale (TE_{vrs})
Hocks	40	18.37	0.87	0.91
Small	60	73.47	0.78	0.86
Boats	70	8.16	0.97	1
Average Overall			**0.87**	0.92
Hocks Large Boats	40	53.19	0.91	0.98
	60	23.40	0.88	0.98
	75	19.15	0.84	0.97
	230	4.26	0.91	0.96
Average Overall			0.89	0.97
Gill Nets	40	10	0.68	1
Small	60	46.67	0.94	0.99
Boats	70	10	0.96	0.99
	75	33.33	0.91	0.98
Average Overall			0.87	0.99
	40	25	1	1
Gill Nets	60	22.5	1	1
Large	70	12.5	1	1
Boats	75	20	0.99	0.99
	230	20	0.98	0.98
Average Overall			0..99	0.99

Source: study data analysis using Data Envelopment Analysis program (DEAP).

Table (2) Economic efficiency of traditional fishing boats under assumptions of constant and, variable returns to scale, and boat engine power.

Method of Fishing	Engine Power	Percentage	Economical Efficiency Constant Return of Scale	Economical Efficiency Variable Return of Scale
Hocks	**40**	**18.37**	**0.40**	**0.40**
Small	**60**	**73.47**	**0.67**	**0.73**
Boats	**70**	**8.16**	**0.92**	**0.95**
Average Overall			**0.66**	**0.69**
Hocks Large Boats	**40**	**53.19**	**0.50**	**0.79**
	60	**23.40**	**0.53**	**0.84**
	75	**19.15**	**0.51**	**0.84**
	230	**4.26**	**0.78**	**0.89**
Average Overall			**0.58**	**0.84**
Gill Nets	**40**	**10**	**0.58**	**0.90**
Small	**60**	**46.67**	**0.44**	**0.50**
Boats	**70**	**10**	**0.76**	**0.81**
	75	**33.33**	**0.70**	**0.75**
Average Overall			**0.62**	**0.74**
Gill Nets Large Boats	**40**	**25**	**0.80**	**0.83**
	60	**22.5**	**0.87**	**0.93**
	70	**12.5**	**0.69**	**0.78**
	75	**20**	**0.68**	**0.77**
	230	**20**	**0.92**	**0.96**
Average Overall			**0.79**	**0.85**

Source: study data analysis using Data Envelopment Analysis program (DEAP).

horsepower, these boats are able to reduce their costs by 21%, and achieve the same level of production to get the full economic efficiency.

3- Economic efficiency of small fishing boat using Gill Net fishing method: Table (2), shows that the EEcrs ranged between 0.76 and 0.44, so with the highest value of EEcrs, using engine of 70 horsepower, boats can reduce costs by 24%, and having the same level of production. The lowest value of EEcrs, 0.44, with engine of 60 horsepower, boats are able to reduce costs by 56%, and get the same yield of fish. With the assumption of variable return of scale, the highest value of economic efficiency, EEvrs, was 0.90, using boat engine of 40 horsepower. Results show that boats are able to reduce their costs by 10%, and get the same level of production. The lowest EEvrs was 0.50, with engine of 60 horsepower. Then, boats are able to reduce costs by 50% of costs, and get the same level of production.

4- Economic efficiency of large fishing boat using Gill Net fishing method: The highest economic efficiency with assumption of constant return to scale, EEcrs, was 0.92, using engine of 230 horsepower, Then boats can reduce costs by 8%, and get the same production level, when it get its full economic efficiency. The lowest value of EEcrs was 0.68, using engine of 75 horsepower. The full economic efficiency of these boats require reducing costs by 32% and achieve the same fishing yield. While the EEvrs has its highest value of 0.96, with boat engine of 230 horsepower, so boats can reduce costs by 4%, with no change of production. The lowest value of EEvrs was 0.77, using engine of 75 horsepower, These less efficient boats can reduce costs by 50% with the same fishing yield.

Conclusions: Traditional fishery sector considered as the main source of fresh fish, in addition to be the main source of jobs for fishermen at Hodeida Provence, Republic of Yemen. The importance of traditional fishing resource use efficiency may be considered as a goal of decreasing fishing cost, Elhendy and Alzoom (2000). Technical and economic efficiency of using fishing resources are based on fishing method, boat size, and engine horse power.

The study results showed the impact of horse power engine on technical efficiency. That 73% of small boats, using Hocks fishing method, had 60 horse power engine and their technical efficiency (TE_{crs}) was 78%, while boats with 40 horse power engine, 18% of all small boats, have higher TE_{crs} of 87%. So, small boats using Hocks fishing method are more technical efficient with 40 than 60 horse power engine. Same results are applied with large fishing boats using Hocks fishing method, where 53% of large boats are using 40 horse power engine with 91% TE_{crs}. Technical efficiency of large boats using Hocks will decrease to 88% with boats using 60 horse power engines. Policy maker shall consider replacing 60 by 40 horse power engine in fishing boats applying Hock fishing method to increase its technical efficiency. Cooperative fishery communities would help in applying study recommendations.

For Gill Net fishing method and small fishing boats, 46% of boats are using 60 horse power engine and having higher technical efficiency (TE_{crs}) of 94%, which are greater than boats using 40 horse power, TE_{crs} of 68%. Large fishing boats using Gill Net fishing method are full technical efficient with both 40 and 60 horse power engine, so study recommend using 40 horse power engine to decrease fuel costs. Without information about fishing resource prices policy makers have to direct fishery development plan based on improving its technical efficiency, while improving economic efficiency require the use of fishing input prices.

Economic efficiency of boats using Hocks and Gill net fishing methods, 73% of small boats using Hocks were using 60 horse power engine need to increase engine horse power to 70, because economic efficiency will increase from 67% to 92%. For large boats, using Hocks fishing method, 53% of large boats using 40 horse power engines, need to increase engine horse power to 230 to increase economic efficiency from 50% to 78%. The fuel cost increase as engine horse power increase from 40 to 230 need more studies in future to compare between cost and returns. Gill net fishing method used by small fishing boats, and 60 horse power engine, were 46.6% of total small boats have 44% economic efficiency, which can be increased to 76% by increase engine horse power from 60 to 70. The large fishing boats using Gill net need to use the most powerful engine, 230 horse power, to reach the highest economic efficiency of 90%, because boats can reach new fishing grounds and stay for more than one day fishing trip.

Policy makers can apply study results to decrease fishing effort costs, which mean higher return to fishermen. Decrease number of fishing efforts will help in avoiding problem of overfishing, Elhendy and Eldwais (1998). Also, developing traditional fishing methods, which can get the same production yield by less fishing efforts, and help in saving natural stock of fish by getting its maximum sustainable yield (MSY)? Sustainable development of traditional fishery sector is the main objective of all fishing policies.

The future studies need to explain the relationship among fishing method, fish species, engine horse power, number of fishing efforts, and natural stock of fish species with its maximum sustainable yield. Supporting policy maker by such information would help in applying the most effective policies for developing traditional fishery sector at Yemen.

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