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EFFICIENCY AND PRODUCTIVITY CHANGE ESTIMATION OF TRADITIONAL FISHERY SECTOR AT THE ARABIAN GULF: THE MALMQUIST PRODUCTIVITY INDEX APPROACH

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ABSTRACT

This paper explores the evolution of productivity of the traditional fishery fleet resources that operates in the Arabian Gulf. This fleet produced 65% of traditional total fishery production in 2006. The gap between total consumption (231,000 tons) and local fish production (81,000 tons) in 2006 pushed towards increasing fishing effort numbers, and resulted in over-fishing. Estimation of total factor productivity changes by evaluating both efficiency and technical changes became a necessary step for a sustainable traditional fishery. This study used Malmquist Productivity Index estimation (MPI) over the period 2001-2006, on both yearly and monthly bases. Results showed that the average yearly MPI ranged from -5.4% to +54.7%, which require improving the technology used by small fishing boats applying Trap fishing methods. Large fishing boats using Trap at South of the Gulf need to improve its technology to avoid the negative impact (-5.5%) on MPI. Fishermen skills need to be improved to increase their efficiency, especially for those using small boats and Manasb fishing methods. Both, pure-efficiency changes and scale-efficiency changes, are tools to direct programs of increasing efficiency of fishermen. Based on yearly and monthly total factor productivity changes and its components, this study will help policy makers in setting priorities regarding fishing technology and fishermen skills using small and large boats at different fishing grounds.

Keywords: Data Envelopment Analysis, Malmquist Index, Total Factor Productivity, Technological Changes, and Efficiency Changes.

INTRODUCTION

Total fish production in Saudi Arabia (KSA) was 81,000 tons in 2006. Marine fishery and aquaculture shares were 80% and 20%, respectively. In 2006, Red Sea and Arabian Gulf fish production were 23,435 and 42,037 tons, respectively. Local fish consumption increased from 147,000 in 2001 to 231,000 tons in 2006 (Ministry of Agriculture, 2009); which means that self sufficiency fell from 50% in 2001 to 35% in 2006. Availability of long coastlines (2520 km) on the Red Sea (1800 km) and the Arabian Gulf (720 Km), gave an indicator of marine fishery resources availability, which needs to be used efficiently.

Estimation of maximum sustainable yield (MSY) of traditional fishery sector at KSA was estimated at 53,000 tons per year based on supply side economic analysis (Elhendy *et al*., 1998). Technical inefficiency of Saudi traditional fishery sector were estimated using parametric approach by (Elhendy, 2000), which is based on the concept of limited dependent variable, Green (2002). Also, there are different techniques to measure efficiency of fishery sector, Herrero, (2005); which are applied for Spanish trawl fleet operating in Moroccan water.

The Saudi traditional fishery sector was evaluated from technical and efficiency economic point of view. Such evaluation can shed some light on the impacts of fishery policy changes and its role in sector improvement over a period of time under consideration. The Arabian Gulf traditional fishery production constitutes a large share of total production of fish, and thus has to be utilized efficiently to avoid over fishing. Based on fishing yield as output, and inputs such as fishing efforts, fishing days, and fishing equipments for different fishing methods at different fishing locations are essential data for studying the economics of resource use. Analyzing productivity changes in the Arabian Gulf production, efficiency, and technological changes, is a necessity to develop the traditional fishery sector.

Based on Fishery Statistics by the Ministry of Agriculture (2009), the relative importance of Red Sea production decreased from 49% to 35% between 1995 and 2006. At the same time, traditional fishing production in the Arabian Gulf increased from 42% to 64%. This increase in the Arabian Gulf share of fish production happened even though the number of fishing boats decreased from 28% to 18.1%, which reflects increasing technology improvements. This fact is reinforced by the falling share of Arabian Gulf fishermen in the total number of fishermen in Saudi Arabia from 45% to 37%, while increasing its relative importance of production from 42% to 64%. This explains the efficiency changes of using new technology by fishermen. Thus, increasing traditional fishing production in the Arabian Gulf did not require increasing the number of fishing boats and fishermen.

METHODOLOGY

Efficiency and technological changes in the fishery sector would explain improvements or deterioration in the input productivity of the traditional fishery sector. Based on fishing method, boats type, and fishing locations; the study use the Malmquist Productivity Index (MPI) to evaluate efficiency and technological changes of traditional fishery sector over the period 2001-2006, Malmquist (1953).

The study treated each fishing area as a production unit or Decision Making Unit (DMU), then related each area to its technology level (fishing method). This approach considers two fishing areas, four fishing methods, and two boats sizes, Grifell -Tatje, and Lovell (1995). Data were collected for six years on monthly basis. The production function in the general form is:

$Y_{isj} = f(x_{ijsk})$

Where Y_{isj} is production at area (i), boat size (s), and fishing method (j).

Also, x_{ijsk} is input (k) used at area (i) for boat size (s) which applying fishing method (j).

Note that:

i=1,2, indicates fishing areas of north and South of the Gulf.

j=1,2,3, indicates fishing method of Karaker (Trap), Manasb (Gill-net), and Hadak (Hook-line).

s=1,2, indicates fishing boats size:

Small (Length 9 meter or less), and large boats (greater than 9 meter length).

and k= 1,2,3 indicates fishing inputs which include number of fishing efforts, number of fishing days, and number of using fishing equipments based on fishing method (j).

A secondary data were collected using fishery statistics over the study period (2001-2006). Such data used to show the relative importance of different sources of fish production.

The Data Envelopment Analysis Approach (DEA) and Malmquist Productivity Index (MPI) was used to measure technical efficiency and productivity changes, applying the program (DEAP) prepared by Coelli (1996).

Measurements of Productivity Change: The Malmquist Index: The efficiency measured from the above procedure is static in nature. The shift of the frontier over time cannot be obtained from DEA. To account for dynamic shifts in the frontier, we use the Malmquist Productivity Index (MPI) developed by Fare *et al* (1994). This method is also capable of decomposing the productivity change into efficiency and technical changes, which are components of productivity change.

DEA based Malmquist indices are used to measure this concept of productivity. The Malmquist Productivity Index (MPI) with two inputs and one output by Fare, Grosskopf, and Roos (1998), is defined using Figure (1) as following:

$$MPI = \left[\frac{OE/OG}{OC/OB} \; x \; \frac{OF/OG}{OA/OB} \right]^{0.5}$$

The index is the geometric mean of two indices. The first takes the production frontier of **t** as given and measures the distance of the two production points G and B, representing fishing area in two different periods (see Figure 1). The second index is similar, except the reference frontier is that of (S). A score greater than unity indicates productivity progress as a fishing area delivers a unit of output in (S) using less inputs. In other words, the fishing area in (S) is more efficient relative to itself in (t). Similarly, a score less than unity implies productivity regress and constant productivity is signaled by a unit score. The index can be simplified as follows:

$$MPI = \frac{OE \; / OG}{OA \; / OB} \left[\frac{OA}{OC} \; x \; \frac{OF}{OE} \right]^{0.5}$$

The component outside the brackets is the ratio of technical efficiency in each period and measures efficiency change when a move from (t) to (S), in Figure (1). It indicates whether the unit gets closer to its production frontier, i.e., becomes more efficient with a score greater than unity, or moves further away from the frontier, i.e., becomes less efficient, or stay the same, with a unit score. The second component of the Malmquist Index in brackets captures the technological change evaluated from both time periods. That is, movements of the actual frontier itself, the technology with reference to which the sample operates. The frontier (technology) can progress with score greater than unity, regress with a score of less than unity, or stay in the same position with a unit score.

In general, for each time period t =1,2, …, T the Malmquist index is based on a distance function, which takes the form:

$$D^t\left(X^t, Y^t\right) = \min \{ \delta : (X^t , Y^t / \delta) \in S^t \}$$

Where δ determines the maximal feasible proportional expansion of output vector Y^t for a given input vector X^t under production technology S^t at time period t.

If and only if the input-output combination (X^t, Y^t) belongs to the technology set S^t, the distance function has a value less than or equal to one. That is: $D^t (X^t, Y^t) \le 1$. If $D^t (X^t, Y^t) = 1$, then the production is on the boundary of technology and the production is technically efficient.

Caves *et al*. (1982) defined the Malmquist Index of productivity change between time period ***s*** (base year) and time period ***t*** (final year), relative to the technology level at time period ***s*** as:

$$M^s = \frac{D^s(X^t, Y^t)}{D^s(X^s, Y^s)}$$

It provides a measurement of productivity change by comparing data (combination of input and output) of time period ***t*** with data of time period ***s*** using technology at time ***s*** as a reference. Similarly, the Malmquist Index of Productivity changes relative to technology at time ***t*** can be defined as:

$$M^t = \frac{D^t(X^t, Y^t)}{D^t(X^s, Y^s)}$$

Allowing for technical inefficiency, Fare et. al. (1994) extended the above models and proposed an output-oriented Malmquist index of productivity change form time period ***s*** to period ***t*** as a geometric mean of the last two Malmquist productivity indices. A CRS technology is assumed to measure the productivity change, and the Malmquist index (MALM) is expressed as:

$$MALM = \left[\frac{D^s_{CRS}(X^t, Y^t)}{D^s_{CRS}(X^s, Y^s)} \frac{D^t_{CRS}(X^t, Y^t)}{D^t_{CRS}(X^s, Y^s)}\right]^{\frac{1}{2}}$$

Note that if $X^s = X^t$ and $Y^s = Y^{t,}$, i.e., there has been no change in inputs and outputs between the periods, then the productivity index signals no change when revealing

MALM (.)=1. The last equation of productivity change can be rearranged into two components: the efficiency change (EFFCH), and the technical changes (TECHCH), which take the following forms:

Efficiency changes (EFFCH) = $\frac{D^t_{CRS}(X^t, Y^t)}{D^s_{CRS}(X^s, Y^s)}$.

Technical change (TECHCH) =

$$\left[\frac{D^s_{CRS}(X^t, Y^t)}{D^t_{CRS}(X^t, Y^t)} \frac{D^s_{CRS}(X^s, Y^s)}{D^t_{CRS}(X^s, Y^s)}\right]^{\frac{1}{2}}$$

MALM = EFFCH **x** TECHCH

The term EFFCH measures the changes in relative position of production unit to the production frontier between time period **s** and **t** under CRS technology. The term TECHCH measures the shift in the frontier observed from the production unit's input mix over the period. How much closer a region gets to the regions' frontier' is called "catching up", and is measured by EFFCH. How much the regions' frontier' shifts at each region's observed input mix is called 'innovation', shown by TECHCH. Improvement in productivity is associated with a Malmquist indices and any component in the Malmquist index greater than one. On the other hand, deterioration in performance over time is associated with a Malmquist index and any other component less than unity.

Data Envelopment Analysis technique (DEA) can be used to solve this problem by using DEAP computer program by Coelli, (1996).

RESULTS

Based on study objectives, the study results include the following:

1- Total Factor Productivity change estimation based on Fishing Method.
2- Average yearly and monthly productivity change estimation.
3- The impact of pure technical efficiency change and scale efficiency change on efficiency changes.

First: Total Factor Productivity changes based on Fishing Method: The Malmquist Productivity Index (MPI), or total factor productivity (TFP) have been calculated. A value of TFP greater than one indicates positive productivity growth, while a value less than one indicates decline on productivity changes over time period. Total factor productivity changes (TFPCH) is broken into: Technological Changes (TECH), which reflects improvement or deterioration in performance of best practice at study area, and Technical efficiency changes (EFCH), which reflects the convergence towards or divergence from the best practice, or catching up, on part of the study area. The value of the decomposition is that it provides information on the sources of the overall productivity change in fishing area.

Following up the productivity changes results based on fishing method and location (Table 1), the Malmquist Productivity Index and its components, efficiency and technological changes can be summarized as: Jin, Thunberg, Kite-Powell, and Blake (2002).

A- Trap fishing method: The mean TFP indices indicated that productivity fell over the study period (2001-2006) by -3%, but this decline can be attributed to the deterioration of fish catches with best practice (efficiency changes) at the rate of -2.57% every year. TFP changes ranged between -5.4% for large boats at the north of Arabian Gulf, and +1% for small boats at the north Gulf too. The most interesting result was the performance of best practice (technological change) was positive at +2.7% each year over the study period, for small Boats at the north of the Gulf, while it was -6.6% for small boats at the South of the Arabian Gulf. Thus, the study stresses on increasing efficiency of using new technology for small boats at North, and large boats at South of the Arabian Gulf. For the technological changes based on applying new technology and use of new equipment for supporting fishing such as fish finder, results confirms the need to improve fishing technology (Table 1). Negative impact of technological changes on the total factor productivity changes were -6.6%, -3.4%, and -5.5%, for small boats at South of the Arabian Gulf, large boats at north and South of the Gulf, respectively.

B- **Manasb Fishing method:** Total factor productivity reached its maximum increase of 54.7% for small boats in the whole fishing area at the Arabian Gulf (Table 1). Large fishing boats total factor productivity change increased by 1.6%, too. The efficiency changes had its maximum negative value (-137.9%) for small boats, even that its factor productivity change was the highest as its technological changes achieved the highest positive record (149.2%). Decreasing technological changes of large boats at the rate -0.7% each year. At the same time efficiency changes were increasing each year by 2.3%, which explain the main source of increasing total factor productivity.

Hadak fishing method: Total factor productivity changes were negative at -2.4% and 3.5% for small and large fishing Boats, respectively (Table 1). Efficiency changes were negative, too, for small and large fishing Boats. Decreasing technological changes for large boats by -3.2% each year, while it was increasing by 0.2% for the small boats.

Table (1) Mean efficiency, technological, and factor productivity changes of Trap, Manasb, and Hadak fishing methods over the period 2001-2006.

	Trap Small Boats South of the Gulf			**Trap Large Boats South of Gulf**		
	EFFCH	TECH	TFPCH	EFFCH	TECH	TFPCH
mean	1.04	0.934	0.972	0.966	0.966	0.969
%	4	-6.6	-**2**.8	-3.4	-3.4	-3.1
	Trap Small Boats North of the Gulf			**Trap Large Boats North of the Gulf**		
	EFFCH	TECH	TFPCH	EFFCH	TECH	TFPCH
mean	0.984	1.027	1.01	1.001	0.945	0.946
%	-1.6	2.7	1	0.1	-5.5	-5.4

	Manasb Small Boats			**Manasb Large Boats**		
	EFFCH	TECH	TFPCH	EFFCH	TECH	TFPCH
mean	0.621	2.492	1.547	1.023	0.993	1.016
%	-37.9	149.2	54.7	2.3	-0.7	1.6
	Hadak Small Boats			**Hadak Large Boats**		
	EFFCH	TECH	TFPCH	EFFCH	TECH	TFPCH
mean	0.974	1.002	0.976	0.997	0.968	0.965
%	-2.6	0.2	-2.4	-0.3	-3.2	-3.5

Efficiency Change (EFFCH), Technological Change (TECH), and total factor productivity change (TFPCH).
Source: Study data analysis

Second: Average Yearly and Monthly Productivity Changes.

A Yearly Productivity Changes

1-Based on Boat size: The yearly fluctuations in productivity changes can be explained by the relationship between Maximum Sustainable Yield (MSY) or fishing capacity, and actual production level. Over harvesting which exceeds MSY level would result in increasing productivity change at the same year but decreasing productivity next year, Pascoe, and Tingley (2005). Such result will explain total factor productivity changes (Table 2).

Large fishing Boats: Table (2) shows that total factor productivity change (TFPC) was negative for all fishing methods at all fishing areas, except of Manasb. Traps at north of the Gulf had the highest decreasing rate in productivity change (-5.4%), while Manasb got positive rate of productivity change at 1.6%. Over the study period (2001-2006), large fishing boats efficiency changes (EFFCH) were the main reason for increasing total factor productivity change especially for trap (Table 2), it was +67% and +55.2% at north and South of the Gulf in years 2005 and 2006, respectively. This result explains the reason of getting the highest TFPC in 2005 and 2006. Technology changes (TECH) support the TFPC by +68.4% to reach 43.2% for Hadak in 2003. But increasing TECH did not insure increasing TFPC, as the case of trap at north of the Gulf in 2005, when TECH increased by only 18%, but TFPC decreased by 23.9%, because of over harvesting.

Small fishing Boats: For small fishing Boats, using trap, at north and South of the Arabian Gulf over the period 2001-2006, total --factor productivity changes increased from -23.7% to +21.7% between 2004 and 2005, at South of the Gulf. The last result can be explained by efficiency changes which increased from -23.9% to +37.4% at the same years. The negative impact of technical changes (-18%) for Trap at north of the Arabian Gulf was the reason of having a negative factor productivity changes (-2.4%) in 2002.

For small boats, using Trap fishing method at South of the Arabian Gulf, TFPCH got its highest increasing value (+14.6%) in 2003. Such increase was due to increasing technology changes (18.1%) not efficiency change (-2.9%). The efficiency changes have negative impacts on total factor productivity changes for the study period (2001-2006). However, these results require more investigation to adopt new technology to improve trap fishing method used by small fishing boats at the north of the Gulf. For small fishing Boats using Manasb, TFPCH got its highest increasing mean (54.7%) because of technology changes reached 149.2% to overcome the negative efficiency changes (-37.9%). Therefore, applying new fishing policies at both fishing areas must take into account the differences between two fishing grounds of productivity changes.

2- Based on fishing method:

Trap fishing method: The mean TFP, of Small Boats at North of the Arabian Gulf**,** indices indicated that productivity did not change over the study period (2001-2006), as its mean value equals one, but this stability can be attributed to the performance of best practice (technological change) was positive at 2.7% each year over the study period. Even that, the deterioration of fish catches with best practice (efficiency changes) was at the rate of -1.6%. For Small Boats at the South of the Arabian Gulf, TFP index decreased by 2.8% each year. Even that efficiency changes as fish catches with best practice was positive (+4%), but the deterioration of the performance of best practice (technological changes) decreased at a yearly rate of 6.6%. Using trap fishing method by large Boats at north of the Arabian Gulf, the total factor productivity decreased by 5.4% each year, such results can be attributed to the decreasing technological changes at the rate of 5.5% each year. At the same time efficiency changes was increasing each year by only 0.1%. Both efficiency and technological changes for large boats at south of the Arabian Gulf were -3.4% each year, this will explain that the total productivity changes decreased by 3.1% each year.

Manasb Fishing Method: Efficiency changes of Small fishing Boats achieved the highest decreasing rate (-37.9%) at this fishing area each year, but the rate of increasing technological changes was the highest too (149.2%) each year. The result was increasing total factor productivity change (Malmquist Index) by 54.7% each year on average of the study period (Table 2).

Efficiency changes of Large Fishing Boats increased by 2.3%, while technological changes decreased by -0.7%, so the total factor productivity increased by 1.6% each year.

Hadak Fishing method: The TFPCH of Small fishing Boats decreased by 2.4% each year, even though the technological changes increased by 0.2%. Years 2004 and 2006 are distinguished by increasing TFPCH by about 5% and 4%, respectively, while year 2002 is being distinguishedby the decreasing TFPCH by -14.7%. Reasons of increasing TFPCH are based on positive impact of EFFCH, while decreasing TFPCH were regarding decreasing TECH. The highest increasing rate of EFFCH and TECH were 17.6% and 31.2% on years 2005, 2006, respectively (Table 2). The new technologies support Hadak fishing method, such as fish finder, are required as long as EFFCH are positive in 3 years of the study period.

Table (2) shows that TFPCH of large fishing Boats were +43.2 % and 43.1% in 2003 and 2006, respectively. The greatest increase of TECH (68.4%) was in 2003, while EFFCH got its highest value (25.8%) in 2006. TFPCH has a mean value of -3.5% for the study period because productivity of fishing efforts, fishing days, and fishing equipment used (Hadak), as factors of production, were decreased on years 2002, 2004, and 2005 (Table 2). It is important to use such economic resources in efficient way to insure increasing its productivity.

B- Monthly Productivity Changes at the Arabian Gulf: The monthly total factor productivity changes (TFPCH) explains the impact of different weather and natural stock of fish size based on fishing month over the study period (2001-2006). Such factors affect directions of factor productivity changes, following up each fishing method over 12 months at each fishing grounds, and based on fishing boats size (small or large). Total factor productivity changes will be calculated for each month over the study period (2001-2006) as mentioned in Table (3). The most important fishing months were February, May, and June because TFPCH increased for all fishing methods, except of Trap fishing method using small fishing boats at South of the Arabian Gulf, and Trap for large boats at north of the Gulf for May and June. In general, Manasb fishing method by small fishing boats got the highest increasing rate for TFPCH for 10 months of the year, not including January and November (Table 3). TFPCH decreased for all fishing methods on March, except for Manasb fishing method using small Boats. Also, fishing month of December had a decreasing TFPCH, except for Trap for small Boats at north, and Manasb used by small boats. The greatest decrease of TFFPCH was -36.6% on January, for Hadak fishing method using large fishing boats. The study results support the use of large fishing boats using Traps at north of the Arabian Gulf, because all fishing months have a decreasing TFPCH, except for January and February, such results can be explained by increasing EFCH by rate exceeding the decreasing rate of TECH (Table 3). So, large fishing Boats need more training on new technologies by fishermen to increase their efficiency.

Table (2) Yearly total factor productivity change estimation of trap fishing method at Arabian Gulf

	Trap Small Boats- South of the Gulf			Trap Large Boats South of Gulf		
Year/Change	EFFCH	TECH	TFPCH	EFFCH	TECH	TFPCH
2002	1.203	0.82	0.986	0.871	1.014	0.883
%	+20.3	-18	-2.4	-12.9	+1.4	-11.7
2003	0.974	1.076	1.048	1.16	0.894	1.037
2004	0.761	1.003	0.763	0.626	1.008	0.631
2005	1.374	0.886	1.217	1.552	1.001	1.553
2006	0.993	0.91	0.903	0.856	1.251	1.071
%	-0.07	-0.09	-0.97	-14.4	+25.1	+7.1
mean	1.04	0.934	0.972	0.966	0.966	0.969
%	4	-6.6	-2.8	-3.4	-3.4	-3.1
	Trap Small Boats- North of the Gulf			**Trap Large Boats- North of Gulf**		
year	EFFCH	TECH	TFPCH	EFFCH	TECH	TFPCH
2002	0.979	1.007	0.986	0.945	0.929	0.878
%	-2.1	0.7	-1.4	-5.5	-7.1	-12.2
2003	0.971	1.181	1.146	1.04	0.986	1.025
2004	1.072	0.873	0.936	0.945	0.874	0.826
2005	0.979	0.933	0.913	0.645	1.18	0.761
2006	0.923	1.18	1.089	1.673	0.799	1.337
%	-7.7	18	8.9	67.3	-20.1	33.7
mean	0.984	1.027	1.01	1.001	0.945	0.946
%	-1.6	2.7	1	0.1	-5.5	-5.4
	Manasb- Small Boats				**Manasb- Larg Boats**	
Year/Change	EFFCH	TECH	TFPCH	EFFCH	TECH	TFPCH
2002	0.867	1.594	1.381	1.196	0.823	0.984
%	-13.3	59.4	38.1	19.6	-17.7	-1.6
2003	1.915	0.357	0.684	0.874	1.157	1.011
2004	0.028	1.256	0.0352	0.963	0.813	0.783
2005	1.773	0.037	0.0656	1.025	1.061	1.088
2006	0.132	0.396	0.0487	1.087	1.175	1.277
%	-86.8	-60.4	-95.13	8.7	17.5	27.7
mean	*0.621*	*2.492*	*1.547*	*1.023*	*0.993*	*1.016*
%	-37.9	149.2	54.7	2.3	-0.7	1.6
	Hadak-Small Boats				**Hadak-Large Boats**	
Year/Change	EFFCH	TECH	TFPCH	EFFCH	TECH	TFPCH
2002	0.91	0.937	0.853	1.139	0.576	0.656
%	-9	-6.3	-14.7	13.9	-42.4	-34.4
2004	1.018	1.028	1.046	0.993	0.733	0.728
2005	1.176	0.835	0.981	0.816	1.049	0.855
2006	0.789	1.312	1.036	1.258	1.137	1.431
%	-21.1	31.2	3.6	25.8	13.7	43.1
mean	*0.974*	*1.002*	*0.976*	*0.997*	*0.968*	*0.965*
%	-2.6	0.2	-2.4	-0.3	-3.2	-3.5

Efficiency Change (EFFCH), Technological Change (TECH), and total factor productivity change (TFPCH).
Source: Study data analysis.

Such results, of monthly productivity changes, stress the importance of controlling the number of fishing efforts of small traditional fishing boats each month to avoid productivity decreases. Also, the number of boats at fishing area needs to be controlled by limiting the permission of new fishing boats to save the natural stock of fish from over fishing. The policy of shrimp fishing ban for six months each year need to be adjusted with other fish species based on monthly productivity changes.

Table (3) Total factor productivity estimation of different fishing methods and Boats sizes at the Arabian Gulf on a monthly bases.

Month	TSS	TSN	TLS	TLN	MS	ML	HS	HL
1	0.969	0.964	0.947	1.023	0.953	1.037	1.126	0.634
2	0.918	1.047	0.96	1.027	1.012	1.35	1.081	1.178
3	0.962	0.958	0.972	0.94	1.1	0.918	0.956	0.941
4	0.89	0.972	1.007	0.928	1.234	0.92	0.944	0.954
5	0.959	1.063	1.033	0.95	4.318	1.116	1.036	1.01
6	0.987	1.025	1.011	0.922	1.327	1.221	1.038	1.026
7	0.963	0.97	1.025	0.903	4.199	0.934	0.757	0.943
8	1.011	0.957	0.984	0.931	4.056	0.985	0.958	1.095
9	1.032	1.021	1.014	0.894	1.504	0.95	1.027	1.107
10	1.028	0.968	1.02	0.954	1.06	0.964	0.905	1.049
11	0.966	1.084	0.943	0.95	0.914	1.02	0.971	0.894
12	0.986	1.109	0.995	0.935	1.008	0.873	0.967	0.873
mean	0.972	1.01	0.992	0.946	1.547	1.016	0.976	0.965

Trap-Small Boats-South of Gulf (TSS), Trap-Small-North (TSN), Trap-Large Boats-north (TLN), Manasb-Small Boats (MS), Manasb-large Boats (ML), Hadak-Small Boats (HS), Hadak-Large Boats (HL). **Source:** Study data analysis.

Third: The impact of pure technical efficiency change (pech) and scale efficiency change (SECH) on efficiency changes (EFFCH): As mentioned that the value of total factor productivity change (TFPCH) has two components: overall efficiency change (EFFCH) and technological change (TECH), which can explain the cause of TFP changes. For the same concept, overall efficiency changes (EFFCH) are based on two sources of changes: the first one is the pure technical efficiency change (PECH), and the second is scale efficiency change (SECH). Following up different fishing methods, study results show that:

1-Trap Fishing Method: For small fishing boats at South, mean overall efficiency change was 4%, pure technical efficiency change contributed 2.3% to the change, compared with 1.7% scored by scale efficiency. Since both (PECH) and (SECH) are positive and greater than unity, depict improvements in efficiency of trap fishing for small boats at north Gulf. In 2004, small boats using trap fishing method at South of the Arabian Gulf has not shown improvement in efficiency change (-23.9%). However, pure efficiency change has improved (2.8%), while scale change depicts deterioration in improvements (-26%). This result suggests that, on average, the source of efficiency lies in the input-output configuration rather than in the size of operation. Small fishing boats using trap at north Gulf have negative efficiency change on average,-11.6%, same as large boats at South of the Arabia Gulf, which has deterioration in improvement equal -3.4% (Tables 4). Large boats using Traps at north Gulf got the highest improvement as its overall efficiency change reached 67.3%, both pure efficiency and scale efficiency changes show improvement by 33.1% and 25.7%, respectively in 2006 (Table 4).

2- Manasb Fishing Method: Table (4) shows that small and large fishing boats have -37.3% and +2.3% efficiency changes (EFFCH) on average, respectively, even though both pure efficiency changes were negative, but the difference between small and large efficiency related to scale efficiency change (SECH). The positive (EFFCH) of large fishing boats result from a positive (SECH), namely, 6.3%. Thus, large scale activity of large fishing boats will result in an increasing efficiency changes, which is not the case with small fishing boats applying Manasb fishing method.

3-Hadak Fishing Method: Large fishing boats have positive (EFFCH) in 2002 and 2006, while small fishing boats got it in 2003, 2004, and 2005. Pure efficiency changes (PECH) are the main source of positive (EFFCH) for small boats in 2003 and 2005, while in 2004, scale efficiency change (SECH) is the source. So, mean scale efficiency change is close to one, which means that the scale of small fishing boats activity is close to its best size of production, same as large fishing boats, at the mean of the study period (2001-2006). Table (4) shows the fluctuations of (EFFCH), and sources of such fluctuations based on values of (PECH) and (SECH).

Summary and Conclusions: Traditional fishery sector in Saudi Arabia produces 80% of total fish production from Red Sea and Arabian Gulf. The relative importance of Arabian Gulf fish production increased from 42% in 2001 to 64% in 2006. Thus, most of economic resources used by traditional fishery sector need to be redirected for efficient use. The study estimated the Total Factor Productivity (TFP) and its two components, Efficiency and Technical Changes. Total factor productivity (TFP) measures how much fish is caught by fishing boats relative to the amount of economic inputs used, such as fishing trips (efforts), fishing days, and fishing equipment used.

Table (4) The impacts of pure efficiency change (PECH) and scale efficiency change (SECH) on efficiency changes (EFFCH) for fishing methods (2001-2006).

year	Trap-small boat-south of Gulf			Trap-small boats-north of Gulf		
	EFFCH	PECH	SECH	EFFCH	PECH	SECH
2002	1.203	1.113	1.081	0.979	0.986	0.993
2003	0.974	0.934	1.042	0.971	1.017	0.955
2004	0.761	1.028	0.74	1.072	1.023	1.048
2005	1.374	1.048	1.312	0.979	0.999	0.979
2006	0.993	1	0.993	0.923	0.917	1.007
mean	1.04	1.023	1.017	0.984	0.988	0.996
year	**Trap-Larg Boats-South of Gulf**			**Trap-Larg Boats-North of Gulf**		
	EFFCH	PECH	SECH	EFFCH	PECH	SECH
2002	0.871	0.934	0.932	0.945	0.968	0.977
2003	1.16	1.076	1.078	1.04	1.06	0.981
2004	0.626	0.8	0.782	0.945	0.949	0.996
2005	1.552	1.259	1.233	0.645	0.828	0.779
2006	0.856	0.97	0.883	1.673	1.331	1.257
mean	0.966	0.996	0.969	1.001	1.014	0.987
year	**Manasb-small Boats**			**Manasb - Larg Boats**		
	EFFCH	PECH	SECH	EFFCH	PECH	SECH
2002	0.867	0.862	1.006	1.196	0.935	1.28
2003	1.915	1.678	1.141	0.874	0.816	1.07
2004	0.028	0.107	0.266	0.963	0.966	0.997
2005	14.773	5.232	2.824	1.025	1.02	1.005
2006	0.132	0.347	0.381	1.087	1.101	0.987
mean	0.621	0.776	0.8	1.023	0.963	1.063
year	**Hadak-Small Boats**			**Hadak-Large Boats**		
	EFFCH	PECH	SECH	EFFCH	PECH	SECH
2002	0.91	0.91	1.001	1.139	1.083	1.051
2003	1.019	1.078	0.945	0.85	1.123	0.757
2004	1.018	0.867	1.173	0.993	0.909	1.092
2005	1.176	1.114	1.056	0.816	1.109	0.736
2006	0.789	0.967	0.817	1.258	0.855	1.472
mean	0.974	0.982	0.991	0.997	1.009	0.988

Efficiency Change (effch) = Pure Efficiency Change (pech) x Scale Efficiency Changes (sech).
Source: Study data analysis using DEAP.

The study results concluded that total factor productivity mean, over the study period 2001-2006, were less than one, except for Manasb (Gill Net) fishing method, i.e. productivity changes were negative regardless of fishing boats size and fishing ground. Trap fishing method had the highest decreasing rate of total factor productivity changes (-5.4%) for large boats at north of the Arabian Gulf, and -2.8 for small boats at south of the Arabian Gulf. The highest total factor productivity was 54.7% for small boats using Manasb fishing method. Efficiency change (EFCH) had its positive impact with small boats using Trap at the south of the Arabian Gulf, and large boats using Manasb, while the other fishing methods have negative impact of efficiency change. Technological change values range from 149.2% to -6.6% for small boats using Manasb and Trap at the south of the Arabian Gulf, respectively.

For short run policy implications, the study results estimated the productivity changes on monthly bases over the study period. The relative importance for the month of fishing is related to fishing methods and fishing ground. These differences might be related to weather and fish reproduction seasons. Positive (TFPCH) were noted for May and June of the year with some exceptions, while other months had negative productivity changes

The study concluded that small and large fishing boats have a similar pattern of productivity changes, although the production technology of large boats seems to be more affected by regulatory policies than small boats. Also, gear improvements are more likely to be fully utilized by large boats due to the larger area allowed for fishery, and more fishing days per fishing trip.

TFP can grow when fishing boats adopt innovations such as electronics, improved gear design, or fishing aggregating devices (FADs), or more generally by technical changes. TFP can also grow when fishermen use fishing technology and economic inputs more efficiently, so that they catch more fish while using the same capital, labor, and harvesting technology, or more generally by increases in technical efficiency. TFP can also grow as fishing boats increase or decrease their scale of operations to a more efficient level, or more generally by improving their scale efficiency. That is, scale efficiency improves when fishing boats and all other economic inputs increase by a given percentage and fish catch increases by an even greater percentage. In sum, TFP change from one year to the next is comprised of technical change, changes in technical efficiency, and efficiency changes in the scale of operations, and accounts for changes in the quantities of economic inputs used, the size and availability of the fish stocks, and changes in environmental conditions. TFP growth accounts for changes in the fish catches when these changes in catches are due to technical changes or improvements in technical efficiency.

Policy implications of such results are based on the relation between efficiency and technical changes. In general, increases in productivity changes as a result of increases in efficiency changes were less than that of decreasing technical changes, which result in decreasing the mean productivity changed.

Thus, sustainable development policies for traditional fishery sector can specify programs of training to increase efficiency of fishermen and programs to develop fishing methods and fishing boats to increase technical changes of productivity changes based on the study results, which reflects that the actual level of production is close to Maximum Sustainable Yield (MSY) level. When yield exceeds MSY level, productivity change is positive as a result of over fishing, followed by less yield next year which results in decreasing productivity changes.

Therefore, fishing efforts must be controlled on a monthly bases to avoid fish reproduction season and over fishing which is followed by negative productivity changes for next month.

Despite the level of aggregation of data, it is believed that the approach taken here provides an important information compared to traditional approaches to measure productivity. It also provides a natural way to measure the phenomenon of catching up. The technical change component of productivity growth in this study captures shifts in the frontier of technology, providing a natural measure of innovation. This decomposition of total factor productivity growth into catching up and technical change is therefore useful in distinguishing diffusion of technology and innovation into traditional fishing sector, respectively

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