Thesis for the Degree of Master of Fisheries Science

Estimation of Productivity Growth, Technical Progress and Efficiency Changes of Fishing Vessels in Lake Kivu of Rwanda

by

Gatare Robert

KOICA-PKNU International Graduate Program of Fisheries Science

Graduate School of Global Fisheries

Pukyong National University

February 2019

Estimation of Productivity Growth, Technical Progress and Efficiency Changes of Fishing Vessels in Lake Kivu of Rwanda

르완다의 키부호수에 생선창고의 생산성장의 추정, 기술과정 그리고 효율성변화

Advisor: Prof. Yong-Min Shin

by

Gatare Robert

A thesis submitted in partial fulfillment of the requirement
for the degree of

Master of Fisheries Science

in KOICA-PKNU International Graduate Program of Fisheries Science,
Graduate School of Global Fisheries,
Pukyong National University

February 2019

Estimation of Productivity Growth, Technical Progress and Efficiency Changes of Fishing Vessels in Lake Kivu of Rwanda

A dissertation

by

Gatare Robert

Approved by:

(Chairman) Prof. PARK Cheol-Hyung

(Member) Prof. NAM Jongoh

(Member) Prof.SHIN Yong-Min

February 22, 2019

Table of Contents

List of Figures

Lists of Tables

Estimation of productivity growth, technical progress and efficiency changes of fishing vessels in Lake Kivu of Rwanda

Robert Gatare

KOICA-PKNU International Graduate Program of Fisheries Science

Graduate School of Global Fisheries

Pukyong National University

Abstract

This research evaluates the technical efficiency estimated for 6 fishing vessels from 2001 to 2016 by using Data Envelopment Analysis (DEA). Input orientated continues variable return to scale (VRS) was used. Based on the input- and output-oriented CCR model, productive units DMU (1) was found to have the objective function value equal to one. This means that DMU (1) and (2), were efficient, but the other vessels were inefficient since TE < 1.Fishing vessels of between (2001 and 2016) were estimated by using DEA – solver, the basic BCC-1 Model. The BCC-1 Model continues variable returns to scale (VRS). The efficiency rate was evaluated through examining input-oriented (BCC Model).Based on this analysis, the mean technological efficiency of entire fishing vessels in Lake Kivu were inefficient.

The movement of technological efficiency caused the raise in productivity of Lake Kivu fisheries. On top of all, technological progress and scale efficiency took part as a vital function in the changes in efficiency of each fishery. To sustain productivity, it is better to improve good fisheries management policies by the government and efforts by the fishing industries that help productivity boost.

Keywords: Technological Efficiency, BCC-1 Model, Data Envelopment Analysis, Variable Return to Scale, Lake Kivu.

Introduction

1.1. Background

Productivity is an average measure of the efficiency of production. It can be expressed as the ratio of output to inputs used in the production process, i.e. output per unit of input. When all outputs and inputs are included in the productivity measure, it is called total productivity. Outputs and inputs are defined in the total productivity measures their economic values. The value of outputs minus the value of inputs is a measure of the income generated in a production process. It is a measure of total efficiency of a production process and as such the objective to be maximized in production process (Kurosawa, 1975).

The productivity of fisheries must be developed and improved on optimal use and good management of fisheries resources. In general, productivity development occurs through improved technological progress and technical efficiency (Kalirajan et al., 1996).

With increasing worldwide demand, imports will be more difficult to source, and Rwanda's future needs will have to be met by domestic production. According Master plan for fisheries and fish farming in Rwanda (2008), the data shows that from July 2017 to March 2018, Rwanda's fish export volumes increased to seven million kgs, from 6.5 million kgs reported over the same period in 2016-2017.

This means that fisheries sector goal should improve to produce requirements from fishes, cut imports, and increase exports to enhance the national demand. The fishery sector remains extremely underdeveloped with minimal contribution to the national fish harvest in Rwanda, where fish consumption is one of the main sources of animal protein in terms of food security. Fish is the main source of cheap animal protein for a growing population (FAO, 2010).

The level of per capita fish consumption in Rwanda is estimated at 2.9 kg. The country will need 130,000 tons just to attain the average Sub Sahara per capita consumption of 6.7 kg/person/year and 28,200 metric tons to reach the global average of 16.6

The country has fairly well distributed ample water resources, good physical and communication infrastructure, and very good national macroeconomic policies which if exploited can provide a very firm basis for rehabilitation and development of the Aquaculture and Fisheries sector for increased fish production (MINAGRI, 2010).

Rwanda is a landlocked country, one of the East African countries located 1,200 km from Indian Ocean and 2,000 km from Atlantic Ocean with a total Area of 26,340 km^2. Fisheries contribute national's economy, making up less than 0.3%of as total GDP in 2002 (NISR, 2017). Fishery products are necessary as a source of affordable protein and as element of the traditional food. The fishing zones in which artisanal fishing units operate are located around three main fishing centers in Rwanda. These centers are Gisenyi, Kibuye and Cyangugu. This study focuses on Lake Kivu as it has about 294 fishing vessels (Gill Monofilament, Hook, Longline and Gill net, small seine, cast net)(FAO, 1991).

Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontier it is used for purpose of calculating efficiencies in production in decision-making units (or DMUs).

In condition of benchmarking, the efficient DMUs, as defined by DEA .May not necessarily form a “production frontier”, but fairly guide to a “best-practice frontier” (Cook et al., 2014).

In this research, input orientated DEA under assuming constant returns to scale (CRS) has been used to calculate and know which fishing vessels are efficient in each fishery (Fare et al., 1994).

The major reason for use of input-orientated DEA is to measure efficiency for each fishery so that we can minimize inputs at a given level of outputs or maximize inputs at given level of inputs. In order to review efficient units, super efficiency models. Unlike the CCR, BCC models we used to calculate the efficiency rate of each unit for fishery vessels are proportionally expanded without altering the input quantities used. The CRS hypothesis was suitable when all DMUs were operating at an optimal scale (Coelli, 1996).

In conclusion, input-oriented BCC Model were used for calculating efficiency change and scale efficiency change in each fishery.

As stated by Kirkley et al., (2001); Kim et al. (2007); Zheng et al. (2005); and Pascoe et al. (2006); technical efficiency was analyzed in short-term to calculate fishing capacity. It is vital to give attention to carry out a lot of study in this area since this can assist us to identify more in relation to fisheries productivity and decide the right choice for growth.

The research goal is to calculate technical efficiency by using (input orientated-DEA model with assuming CRS) for 6 fishing vessels and to estimate the total factor productivity from 2001 until 2016 of common fisheries in Lake Kivu by an input-oriented approach and to analyze the basis of the changes in productivity which segmented into technical efficiency and technological progress. Along this was to present policy implications for the improvement of future fisheries productivity.

1.2. Location and description of fisheries of Lake Kivu

1.2.1. Study area

Lake Kivu is located in western province of Rwanda, where fishing activity takes place with one of the most diverse fleet that accounts for fully half of the fishing vessels of Rwanda. It is known for the Tanganyika sardine, Limnothrissamiodon. Lake Kivu is famous, compared to other African great lakes for it is poor fauna, with 29 species comprising 15 endemic haplochromines and a few non-native species (Darchambeau *et al*., 2012). The lake is in a mountainous region between 1°34' and 2° 30' South latitude and between 28°50' and 29°23' East longitude. It is 112km (70miles) Western of Kibuye from Kigali. Lake Kivu is shoreline with its huge fishing diversity. In 5 districts of Rwanda its total area: 2700 km2 Rwandan side: 1.000sqm, Congolese side: 1370 km^2.

The artisanal fishery on Lake Kivu provides employment to a total of 6,563fishermen;

3,027 of them operate FEU's - trimaran and 3,536 are traditional fishermen. In addition, some 3,340 women market and distribute the fish. Lake Kivu is one of the main fishing grounds along Rwandan Lakes. The highest fishing effort was recorded in Lake Kivu with 6.8% of the total motorized vessels in Rwanda.

Figure 1. Map of Lake Kivu.

1.2.2. Production and main Fisheries

The total capture production from fisheries sector signify about 16,060 ton in 2014, regarding 11.4% of the total catch of the Lake Kivu fisheries in Rwanda. However, the total production from Lake Kivu fisheries was the highest in 2008, representing about 34,039 tons, with almost 13.6% of the total catch of Lake Kivu fisheries. This shows that there was a fall in production by 16% between 2010 to 2015.The production declined from 2010 to 2014. Following a number of problems observed in the fisheries production decreasing, insecurity, related crimes and the illegal movement of the population through Lake Kivu, the Western province restricted the security organs like Rwanda DEFENCE FORCE (RDF) and Rwanda National police (RNP) besides their primary roles they are mandated to enforce law and control illegal fishing**.** In order to control these activities and fish increase production, as shown in Fig. 2.

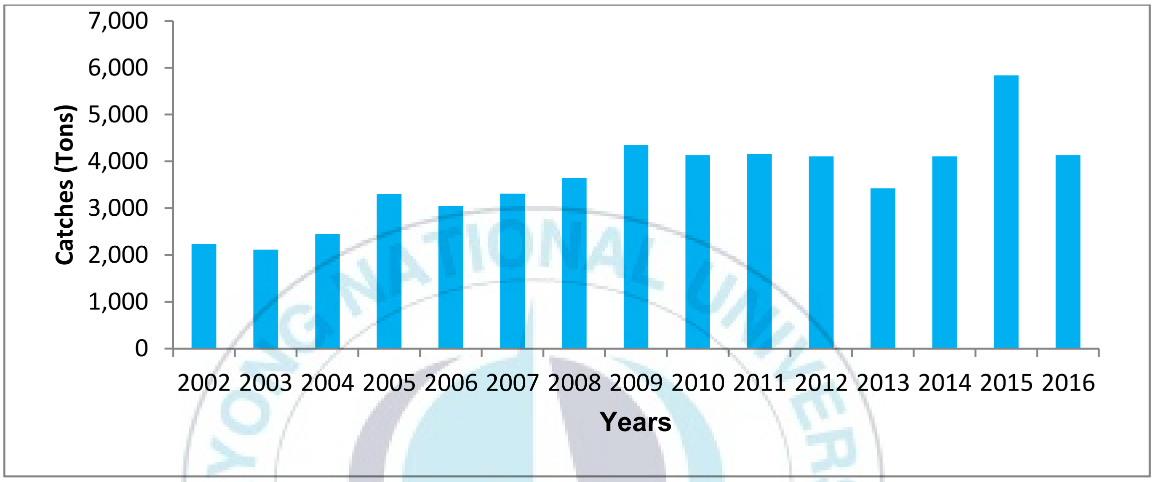

Figure 2.Total Production capture fisheries in Lake Kivu.

1.2.3. Gill Monofilament Fishery

Gill Monofilament fishery plays brilliant task in the business fishery. Noted that monofilament gill nets are 1.2 to 3.3 times more efficient than nets of other materials. Monofilament is made of a single thin and nearly transparent thread that presumably has low visibility in water. The Gill Monofilament fishery catch represents more than 35% of the total catch, and more than 65% of total Gill Monofilament fishery catch are

Limnothrissamiodon, Redfish, anglers, Common ling fish, Black spot tusk fish, haddock, blue ling, lump sucker dogfish (Tran-VanTri and Ha-Khac-Chu 1963).

1.2.4. Hooks fishery

Hooks plays vital position in Lake Kivu fisheries. Hand lines and hooks are used to catch Nile tilapia and haplochromines and hooks are rising since of their cheapness. However, hooks tend to reduce the size of the brood stock made up of big tilapia that carries millions of eggs (FAO, 2013).The targeted catch species are Nile Tilapia *Oreochromis niloticus*. Used 1/0 to 2/0 for shiners.

1.2.5. Long line fishery

Long line fishery exploit a long line, Baited hooks are attached to the longline by short lines called snoods that hang off the mainline. The longline can be many kilometers long and can carry thousands of hooks. Pelagic longline are not anchored and are set to drift near the surface of the ocean with a radio beacon attached so that the vessel can track them to haul in the catch (Gilman *et al*. 2006, Beverly *et al*. 2009).Limnothrissa Miodon are catch targeted species.

1.2.6. Gillnets fishery

The gillnetting and the lengths of the nets range between 5 and 14 km depending on their area of operation. Little is known about the effects of by catch in small scale gillnets fisheries on population. Estimated catch is 17-22 % of total catch every year according to the available data. By catch in the Rwanda could amount to 4,405tons every year certain targets and target sizes of fish, crabs etc.

1.2.7. Small seine fishery

Seine net fishing used to catch longfin Tilapia (*Oreochromis macrochir*) makes an important contribution to total fish landings. It is a major fishing method used in Lake Kivu, although the fishery remains poorly throughout most of the period. Seine fishing occurs in near shore (50 - 400 m from shoreline), shallow, coral rubble, patch reef, and sand habitats (approx. 1.5 - 15 m deep).

1.2.8. Cast net fishery

The cast net fishery continues to be an important component of the Lake Kivu fishery. Some of the economically important species such as Citharinus species, Tilapia. This is where a circular net is used and is put in water, spread and trap fish beneath. The catch per unit of effort (CPUE) has declined in the cast net fishery possibly due to the increase in effort by the major fishing gears over the years.

1.2.9. Fishing Permits

Fishing activities in Lake Kivu requires fishing permits or concession permits to be authorized. Fishing Permits are provided, based on the report of the District fisheries officer who is in charge. Fishing Permit for scientific research requirements as stipulated in Article 16 ofn°58/2008 of 10/09/2008 Determining the Organization and Management of Aquaculture and Fishing in Rwanda, this Law shall be fulfilled. The license granted contains all conditions as well as the boundaries in which the research can be conducted. Fishing concession contract is given for Aquaculture activity that is concluded between the applicant and the Minister in charge of water management and the concession contract shall not exceed a period of 40 years.

1.2.10. Stock assessment and management

Stocks depletion in Lake Kivu have been influenced by a variety of factors such as improper management and inappropriate fishing gears and techniques, which resulted an overexploitation in a desultory manner of narrow coastal. Adoption of management measures.

No activity is allowed in 50 m from the lake to protect shores, which are the major reproduction zones. For anyone who pollutes inland water masses by dumping, spilling, or depositing chemicals of any nature that may cause or increase water pollution faces a fine ranging from two million (2,000,000) to five million (5,000,000) Rwandan francs and an imprisonment from two months to two years. In 2011, the National hatchery started producing Tilapia Niloticus fingerlings for Lakes restocking in the period of 2 months where there is no fishing activities to increase productivity.

Material and methods

2.1. Data Envelopment Analysis (DEA)

DEA is a linear-programming approach, which uses data on the input and output measures of a group of DMU (or firms etc.) to build a piece-wise linear surface over the data points. DEA can be either input-orientated or output-orientated. In the input orientated case, the DEA method describes the frontier by looking for the maximum possible proportional reduction in input usage, with output levels held constant for each fishing vessel. While, in the output-orientated case, the DEA method seeks the maximum proportional increase in output production, with input levels held fixed. The two measures provide the same technical efficiency scores when a constant return to scale (CRS) technology applies but are unequal when variable returns to scale (VRS) is assumed. This study uses DEAP computer software (version 2.1) developed by Coelli (1996) to measure technical and scale efficiency in the Lake Kivu fisheries and fishing.

2.1.1. Input –Oriented DEA Model

This study focuses on minimizing the level of inputs with an assumption of fixed level of outputs. The purpose of input–oriented approach. An input-oriented model or an output-oriented model may be used to estimate the relative efficiencies in the DEA model. Input orientation refers to calculation of the possible and simultaneous reductions of percentages for each output at a given output level, while output orientation refers to calculation of the possible and simultaneous increased percentages for each output at a given input level is as follows:

$$\max h_0 - \frac{\sum_{r=1}^{s} u_r y_{r0} - \sum_{j=1}^{p} w_j z_{j0} + c_0}{\sum_{i=1}^{m} v_i x_{i0}} \quad (1)$$

Subject to

$$\frac{\sum_{r=1}^{s} u_r y_{r0} - \sum_{j=1}^{p} w_j z_{j0} + c_0}{\sum_{i=1}^{m} v_i x_{i0}} \leq 1, q = 1, \ldots, n,$$

$$\mathrm{u_r} \geq 0, \mathrm{r}{=}1, \ldots, \mathrm{s}, v_i \geq 0, i = 1, \ldots, m, w_j \geq 0, j = 1, \ldots, p.$$

Where

$Y_i$is a M´1 vector of output quantities for the i-th vessel;

$X_i$is a K´1 vector of input quantities for the i-th vessel;

Y is a N´M matrix of output quantities for all N vessels;

X is a N´K matrix of input quantities for all N vessels;

l is a N´1 vector of weights; and f is a scalar.

1≤f<∞, and f-1 is the proportional increase in output that could achieve by thei-th vessel, with input quantities held constant. 1/ f is a efficiency score which varies between zero and one (Coelli, 1996). This study used multi-stage DEA, where it conducts a sequence of radial LP is to identify the efficient projected point. The multi-stage DEA is more computationally.

2.1.2. Productivity change

Productivity growth decomposed into two mutually exclusive and exhaustive components: changes in technical efficiency over time and shifts in technology over time (Färe et al., 1997).

When consider (X^t, Y^t) is input and (X^{t+1}, Y^{t+1}) is, at times t and t +1 ,$(X^t, Y^t) \in F^t$, and $(X^{t+1}, Y^{t+1}) \in F^{t+1}(X^t, Y^t) \in F^t$ and $(X^{t+1}, Y^{t+1}) \in F^{t+1}$. Here, F is production technology that converts the input (X) into the output (Y), and the frontier of F is a production function. The input–output relationship changes from $(X^t, Y^t)$to (X^{t+1}, Y^{t+1}), with period, and these can be considered as changes in productivity. Production technology is commonly modeled by means of a production function, which in the scalar output case specifies the maximum output obtainable from an input vector. It may be defined using the output set, F, which represents the set of all output vectors, y, which can be produced using the input vector, x. That is $F^t = \{(X^t, Y^t) \in X^t$ can produce Y^t.

2.1.3. Technical efficiency

Technical efficiency is the degree to which the actual output of a production unit approaches its maximum (Färe et al., 1978). Both of technological progress and technical efficiency will be measured by estimating distance function that can be defined as in Eq.3. Hence, the ratio between the maximum possible output from the input at time t and the actual output called the output distance function at time t. This function is defined as the reciprocal of the "maximum" proportional expansion of the output vector Y^t, given inputs X^t (Farrell, 1957).

2.1.4. Constant Returns-to-scale.

Returns-to-scale describes how the output level changes as all input levels change, e.g. all input levels doubled. If, for any input bundle $(x_1 \ldots x_n)$, $f(tx_1, tx_2, \ldots tx_n) = t, f(x_1, x_2, \ldots x_n)$, then the technology described by the production function f exhibits constant returns-to-scale, e.g. doubling all input levels doubles the output level (t=2).When all input levels are increased proportionately, there need be no such "crowding out" as each input will always have the same amount of other inputs with which to work. Input productivities need not fall and so returns-to-scale can be constant or even increasing. Input oriented is very useful in describing the technology in a way that makes it possible to measure efficiency and productivity.

2.1.5. Variable returns to scale (VRS)

Is a type of frontier scale used in data envelopment analysis (DEA), it helps to estimate efficiencies whether an increase or decrease in input or output does not result in a proportional change in the outputs or inputs respectively (Copper, Seiford, & Zhu, 2011).

This method includes both increasing and decreasing returns to scale. Hence, VRS may exhibit increasing, constant and decreasing returns to scale when working in Data Envelopment Analysis program (DEAP).

2.1.6. Scale efficiency

Scale efficiency in each period is constructed as the ratio of the distance function satisfying constant returns to scale (CRS) to the distance function restricted to satisfy variable returns to scale (VRS). The production frontier that assumes variable returns to scale is more flexibly than the production frontier that assumes constant returns to scale.

$SE = TE_{CRS/}\, TE_{VRS}$ (2)

There is scale efficiency when SE=1 and if SE<1, there is scale inefficiency.

Thus, it can estimate TECRS (distance function for CRS) from Eq.4.Where; (TEVRS) is pure efficiency.

TECRS =SE /TEVRS (3)

Like,

Efficiency Change (EFFCH (t, t+1) = TE^{t+1}/TE^{t}_{CRS} (4)

Pure Efficiency Change; PECH (t, t+1) = $TE_{VRS}^{t+1}/TE^{t}_{VRS}$ (5)

Scale Efficiency Change; SECH (t, t+1) =SE^{t+1}/SE^{t} (6)

Therefore, it can calculate the technical efficiency change between two consecutive periods can be evaluated from Eq.7

$$EFFCH (t, t + 1) = PECH (t, t + 1) \cdot SECH (t, t+ 1) \quad (7)$$

2.2. Data

The data were collected from all Unions of fishers comprising Districts of Rubavu, Rutsiro, Karongi, Nyamasheke and Rusizi Respectively. From 2002 to 2016 and from effort of *L. miodon* logline fisheries, expressed in tons and number of vessels for each year respectively. According to the market importance the catch species are separated by groups on the board, *Limnothrissa mio*don(freshwater sardine), *Lamprichthystanganicanus*(haplochromines), fish and others are the main target of this fishery and the species with the highest economic value are the *Limnothrissamiodon*(the freshwater sardine) (Spliethoff, De Longh et al. 1983).The statistical data were recorded monthly in the groups mentioned by fishermen and collected, revised and processed by the fisheries officer. The yearly average catch and effort data were used to assess the economic performance of fishing gears to the fishermen. Different administrative officers from the year 2002 to 2016 by the fisheries and aquaculture specialists and fisheries cooperatives representatives collected the data. The catch per unit efforts (CPUEs) was used as the input variable and it was calculated from (Total production / fishermen) to make the analysis more accurate. Aim fisheries Gill Monofilament (Gf), Hooks (H), Longline (L) and Gillnets (G) (Table 2).

Table 1. Mean values of output and inputs variables of fishing vessels (period 2002-2016).

DMU	Output(Y)	Input(x)	
	Production (tons)	Horsepower(HP)	Fishermen(Persons)
A	16	31,002	140
B	17	1,693	25
C	21	5,600	59
D	18	5,095	51
E	22	6,835	72
F	19	6,066	24

Table 2. Mean values of output and inputs variables of Lake Kivu fisheries (2002-2016).

Fishing Vessels	**Output(Y)**	**Input(x)**		
	Production (tons)	Horsepower (HP)	Fishermen (Persons)	CPUE
Gillmonofillament	16	31,002	140	0.114
Hooks	17	1,693	25	250.680
Longline	21	5,600	59	590.356
Gillnet	18	5,095	51	510.333
Small seine	22	6,835	72	720.306
Cast net	19	6,066	24	240.750

BCC Model was selected, because it is simultaneously minimizing inputs and maximizing outputs, which are subjected to given input levels of efficient production frontier points of set satisfying the efficiency conditions.

Table 3. Comparison between DEA CCR Model and DEA BCC Model

DEA CCR Model	DEA BCC Model
The model assumes constant returns to scale; meaning any change in inputs should produce a proportional change in output.	The model, changes in the formulation of CCR in order to analyze the variable returns to scale in DEA.
The model uses the mathematical programming optimization method to determine the efficiency of a DMU (Decision Making Units	When the production frontier exhibits constant returns to scale, efficient DMUs have the same productivity.
The model can be instructed to output, and thus, maximize output, holding constant the level of inputs.	The model are introduced the variables v* (scale factor in the output orientation) and u*(scale factor in the input orientation)

Results and discussion

3.1. Efficiency rate

Technical efficiency has been calculated for each fishing vessel in different fisheries using DEA method as presented in Tables 3-6 by Eq.2. Input-oriented DEA method has been used. The technical efficiency assumes the most efficient fishing vessel equals 1. When the value is closer to 1, it means that the fishing vessel is working near to the production frontier.

3.1.1. Efficiency rate of Gill Monofilament fishing vessels

The efficiency rate was 1. This means that efficiency boundary exist frontier production as of its production value was the lowest one by 16 tons match compared to other fishing vessels. Based on tonnage, horsepower, numbers of fishermen were the lowest upon to other fishing vessels that are made, Gillmonofillamen (Gf) efficient. Since the production, horsepower, number of fishermen was the highest that is why Gillmonofillament (Gf). The Gillmonofillament (A) and Hook (B), were ranked as efficient productivity, respectively. Because of the production of Gill Monofilament (A) and (B) were less than Gill Monofilament (A) by 16 and 17 tons and also based on value, horsepower, number of fishermen were less too. That made both Gill Monofilament (A) and (B) efficient as shown in Table 4.

Table 4. Efficiency rate of Gill Monofilament vessels (A)

DMU	**Output(Y)**	**Input(x)**		Efficiency rate
	Production (tons)	Horsepower(HP)	Fishermen(Persons)	
A	16	31,002	140	1.0000
B	17	1,693	25	1.0000

3.1.2. Efficiency rate of Hooks fishing vessels

The rate efficiency was 1.The efficiency of Hook (H) was also efficient frontier, because of its production being the second lowest by 17 tons compared to other fishing vessels. All other units are inefficient, they fall short of the efficiency the number of fishermen for Hook (H) was the lowest weigh against with other fishing vessels 6 that makes more efficient whereas tonnage and horsepower were not the lowly. Since the production was the second lowest, two by 17 tons contrast among other fishing vessels. For, tonnage, horsepower, number of fishermen was not the highest that is why Hook (H) is the most efficient. The efficiency of Hook (H) and (C) were about 1 and 0.4824, respectively. The production of Hook (H) and (C) were less than Hook (H) by 17and 21 tons, however, of both horsepower and number of fishermen was higher than Hook (H). Thus, both Hook (H) and (C) working close to the production frontier as shown in Table 5.

Table.5.Efficiency rate of Hooks fishing vessels

DMU	**Output(Y)**	**Input(x)**		Efficiency rate
	Production (tons)	Horsepower(HP)	Fishermen(Persons)	
C	21	5,600	59	0.4824
B	18	5,095	51	1.0000

3.1.3 Efficiency rate of Longline fishing vessels

The efficiency rate was 0.3939. In addition, ranked as number 6, since its production was third by 18 tons compared with other fishing vessels. In addition, based on number of fishermen and Horsepower were the third as to Longline (L). This is for the inefficient points, which define the frontier. The production of Longline (L) was lower than (C) by 3 and 18 tons respectively. As shown in Table 6.

Table 6. Efficiency rate of Longline fishing vessels

DMU	Output(Y)	Input(x)		Efficiency rate
	Production (tons)	Horsepower(HP)	Fishermen(Persons)	
D	22	6,835	72	0.3965
C	19	6,066	24	0.4824

3.1.4 Efficiency rate of Gillnets fishing vessels

The efficiency rate was about 0.4235. Which makes it the most inefficient point of frontier, since of its production was the second highest by 19 tons contrast by means of other fishing vessels. Also based on horsepower, numbers of fishermen were the highest that is why gillnets (G) is the inefficient.

The efficiency rate of cast net (Cn) was 0.4235 because of its production was the highest one by 22 tons and horsepower, number of fishermen were the highest too. However, the production was highest; its efficiency rate was higher than small seine (C) as shown in Table 7.

Table 7 Efficiency rate of Gillnet fishing vessels

DMU	**Output(Y)**	**Input(x)**		Efficiency rate
	Production (tons)	Horsepower(HP)	Fishermen(Persons)	
E	22	6,835	72	0.3939
F	19	6,066	24	0.4235

3.1.5 Efficiency rate

Efficiency rate were estimated for each fishery with input-oriented DEA is shown in Table 7. The VRS/CRS options have no weight on the input-oriented DEA because both are used to calculate the efficiency rate (efficiencies). Six efficiency rates were calculated for each fishery in each year. These are relative to the previous periods CRS DEA frontier, the current periods CRS DEA frontier (t), the next periods CRS DEA frontier (t+1) and the current periods VRS frontier (t). Input oriented the most productive or efficient fishery measure up to 1 and demonstrates the relative efficiency between fisheries. When the value is nearer to 1, it implies that the fishery is working close the production frontier.

Table 8 Productive unit efficiency rate – input-oriented CCR model

DMU	Efficiency Rate	Ranking	λ1	λ2	X1	X2	X1	X2
A	1	1	0	0	0	0	2,238,227	1,376
B	1	1	0	75	92	174	7,162	4
C	0.5	3	0	163	111,576	439	871	54
D	0.4	6	0	14	181,815	448	81	5
E	0.3	5	0	165	123,257	548	66,475	41
F	0.4	4	0	12	186,902	416	7,834	5

Therefore, DMU (C, D, E, and F) would be efficient if they reduced inputs to (Table 7), with outputs left unchanged. The output-oriented CCR model says that in order to attain efficiency, productive units must increase their outputs. In case of DMU (C, D, E, F). On average, fisheries vessels have a very low efficiency level, equal to 0.03% and therefore, they could proportionally decrease their inputs by 33% and still produce the same amount of output. Moreover, the standard deviation and the range of CRS scores reveal that the results are characterized by low variation.

It also ranks the number of vessels that operate under constant, increasing and decreasing returns to scale. Table 3 provides the descriptive statistics of CRS and VRS scores for the Fishery vessels in Lake Kivu. The results also found out that there was an insignificance difference in the efficiency performance between the fishery areas.

Table 9 Difference between Constant Return to Scale (CRS) and Variable Return to Scale (VRS) in DEA.

VARIABLE RETURN TO SCALE (VRS)	CONSTANT RETURN TO SCALE (CRS)
There is no proportional change for input and output variables.	There is Proportional change for input and output variables.
This is based on increasing or decreasing returns to scale.	This is based on constant input or output variable.
These model BCC model or VRS frontier is based on Banker, Chames and Cooper.	CCR model or CRS frontier are based on Charnes, Cooper & Rhodes model of DEA.
In DEAP, VRS frontier model shows technical efficiency difference between VRS and CRS.	In DEAP, it shows only one technical efficiency (constant).
The Interpretations is very difficult.	It is better in making interpretations
It is used only when specifically, it is required to check for increasing or decreasing returns.	It is Mostly commonly used.

On the other hand, the average scale efficiency score is much lower (0.62) and hence, fishery vessels do not operate close to the optimal scale of production. According to Table 8, the decision-making units of 1, and 2, represented (1%) operate under constant returns to scale, while 0.04% operates under increasing returns to scale. Therefore, if the fishermen decrease their input usage to optimally operation then, the majority of vessels can be more productive,

Table 10.Descriptive statistics of CRS and VRS for fishery vessels

Variable	Mean	standard Deviation	Minimum	Maximum
CRS	0.6160	0.2991	0.3939	1.0000
VRS	0.3859	0.5527	1.0000	6.0000

Table 11.Descriptive statistics of CRS and VRS for fishery vessels

Scale of operation	DMU
CRS	2vessels 1%
IRS	3 vessels 0.04%
IRS	4 vessels 0.0004%
IRS	5 vessels 0.03%

3.1.6 Scale efficiency series

The scale efficiency of Lake Kivu fisheries throughout the period implied an increase a little by 0.01 % within fisheries time, the scale efficiency for Gillmonofillament fishery (Gf) and Hook fishery (H)a little improved annually by 1and 1%, respectively. However, all other units are inefficient i.e. they fall short of the efficiency.

In view of the scale efficiency (SE) Lake Kivu fisheries that consist by constant return to scale (CRS) and variable return to scale (VRS), they arrive to 2.3%, 3.6% respectively. The mean annual value of scale efficiency was improved by 3.4 % throughout the time series. Movement of inactive of increasing fishing effort can be the key cause of rising or declining of the efficiency. In the case of the efficiency of monofilament fishery (Gf) was evidenced increased by 1% and higher than the other fisheries in Lake Kivu. Besides, decline in technological efficiency can cause decline in fishery industry, this is very different in the other fisheries. When technological efficiency is improved, thus the technological efficiency shows the way to a raise as well.

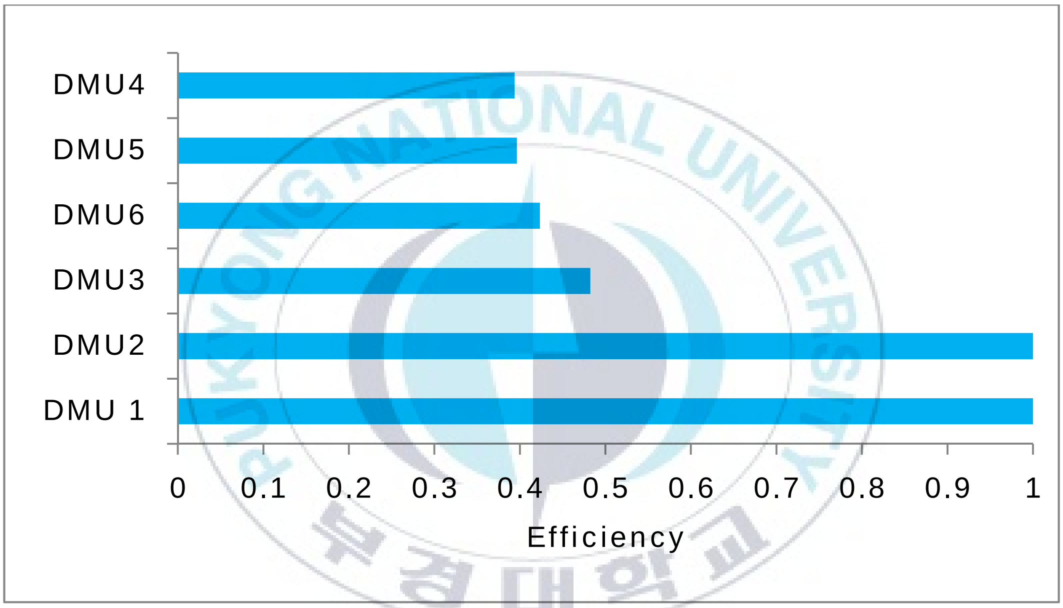

Figure 3.Scale Efficiency

Conclusion and Implications

This study is incomplete as the data was gathered from one lake (Lake Kivu) did not contain data for fishing vessels. Hence, the data from Lake Kivu are suitable to the analysis for the technological efficiency of the Lake Kivu fisheries, and correlation to scale efficiency. According to (PAIGELAC, 2011), the production of Lake Kivu fisheries declined in 2013 compared to 2012 by 10%. A new Fisheries and Aquaculture Policy in Rwanda is in practice from 1998 as Master plan for fisheries and fish farming and water resources management. However, the policy called for improvement in aquaculture production, coordination of fisheries and aquaculture activities with water resources management, development of fisheries and aquaculture management capacity, and review of the policies. Thus, enforcement of these policies is still weak and, as effect, fisheries are uncontrolled. This leads to the problem of overfishing. Effective management is as well poor not having sufficient evaluation of main viable fish biomass as well as difficulties intrinsic within the collective scenery lots of this biomass. Additionally, there is inadequate and a precise strategically goals within the Fisheries Act .However, there are no affirmed rule structure for aquaculture and fisheries by the Rwanda Agriculture Board (RAB) or in the Ministry of Agriculture and Animal Resources thus, fisheries policy needs to be conditional as of measures in used by new Fisheries and Aquaculture Policy. Even though, the authority lives within the Minister of Agriculture and Animal Resources to address fisheries management issues and this authority has not been used largely utilized. As an effect, the fisheries of Rwanda are uncontrolled.

There are policy objectives established for the management of fisheries in Rwanda but not well enacted and the Act is primarily an administrative tool (Higgins, 2005; Silvia et al., 2009).In addition, lack of coordination in support of supervising fishing vessels that could assist fishermen to apply a different fishing gear that leads to a drop in the productivity of the fisheries. One more difficulty is that many fishermen use fishnets with small slots that catch immature fish leading to a decrease in fish seize. Productivity is a very important aspect for economic growth, especially for fisheries where improved productivity leads to independence in fish yield. Every appropriate environment should be affordable to get better yield. Fisheries are diverse than industrialized manufacturing. Natural ecological factors can have a collision on production. Therefore, it is essential to preserve fishery resources and stable organization to improve fisheries productivity. In addition, stable organizations are needed if the fishery is exploited. An education scheme for monitoring fishing vessels is very vital to sustain the fish biomass. For the viability of sustainable fisheries development, much research should be conducted. According to Karagiannakos (1996), the Total Allowable Catch (TAC) and Individual Transferable Quotas (ITQs) are considered as the corner stone of resource management and conservation policy of the Common Fisheries Policy (CFP). Thus, both of TAC and ITQs ought to be applied.

Policies intended to promote fishery development needs with pleasure of duties of two forms of boundaries: 1) those continue to exist in the fishery sector: 2) and control among the fishery and other sectors of the economy. The previous dominates mainly consideration of how to supervise a fishery. Thus, fishery management is a vital element of fishery development. Combined achievement linking fishing category may execute a administration role, whether done alone, with foreign partners, or in collaboration with governments. Addressing the second place of boundaries: requires an understanding of how decisions in the fishery sector influence outcomes elsewhere and vice versa. These effects may be either “real”, in which output levels in one sector are influenced by decisions in another, or "financial", in which the primary effects are on the prices of outputs or inputs in the affected sector. A development policy that looks at the potential contribution of the fishery to the entire economy, considers development from that perspective minimizes frustration, and increases the chances of achieving development goals (Johnston, 1992).The key conclusion is that the fishery yield is relatively low.

It is necessary to continue the study to make up for differences in the size of decision-making unit compared to other decision-making units.

Acknowledgement

“In the name of Almighty God “Most important, I would like to express my deep gratitude and my heartfelt thanks to Almighty God. I write these expressions for my family, mostly my wife and my Children. I would like to thank KOICA for giving me this opportunity. Exceptional thanks goes to Professor Yong-Min Shin for his guidance, advice and support during my study. Countless thanks to my TAC members Prof. PARK Cheol- Hyung and Prof. NAM Jongoh and Ms. Gyeowoon Jeong, thank you very much for your unlimited help. I also want to thank the course program coordinator Professor Kang and her assistant Ms. Seulki for all their hold up during the course of the program.

References

Ahmad, N. (1954). Fishing gears of East Pakistan. Pak. J. Sci., 1(3): 195 – 203.

FAO. Code of Conduct for Responsable Fâcheries. Rome, FAO. 1995. 41 p. ISBN 92-5-103834-5.

Kang S, Jo S (2007). Change of total factor productivity and determinants in Korean manufactures.Int Area Stud 11:630–656.

Fulginiti L, Perrin R (1998). Agricultural productivity in developing countries. Agric Econ 19:45.

Caves K, Christensen L, Diewert W (1982). The economics theory of index numbers and the measurement of input, output, and productivity. Econometrica 51:1393–1414.

Kirkley J, Fare R, Grosskopf S, McConnell K, Squires D., Strand I. (2001). Assessing capacity and capacity utilization in fisheries when data are limited. North Am J Fish Managers 21:482–497.

Umaru G. Wali[a]Stefan Uhlenbrook[bc]Shreedhar Maskey[b]Mc Ard J.Mlotha[d1]OmarMunyaneza[ab]. Water level monitoring using radar remote sensing data: Application to Lake Kivu, central Africa.

Haneketal, (1988), on the exploit the stock of Limnothrissamiodon in lake Kivu

Kaningini, *et al*, (1996), revealed that Gill net was selected and developed, Banker, R.D., Charnes, A. and Cooper, W.W. (1984), “Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis”, Management Science, 30, 1078-1092.

Charnes, A., W.W. Cooper and E. Rhodes (1978), “Measuring the Efficiency of Decision Making Units”, *European Journal of Operations Research*, 2, 429- 444.

Coelli, T.J. (1997), *A Multi-Stage Methodology for the Solution of Orientated DEA Models*, mimeo, Centre for Efficiency and Productivity Analysis, University of New England, Armidale.

Fare, R. and C.A.K. Lovell (1978), “Measuring the Technical Efficiency of Production”, *Journal of Economic Theory*, 19, 150-162.

Norman, M. and B. Stoker (1991), Data Envelopment Analysis: An Assessment of Performance, Wiley.

Farrell, M.J. (1957), “The Measurement of Productive Efficiency”, *Journal of the Royal Statistical Society*, A CXX, Part 3, 253-290

Chang, K.P.; Guh, Y.Y. Linear Production Functions and the Data Envelopment Analysis. European Journal Of Operational Research, 1991; 52: 215-223

Panzar, J. C.; Willing, R.D. Economies of scale in multi-output Production. Quarterly Journal of Economics 1977 9: 481-494

De Young, C. (Ed.). (2006). Review of the state of world marine capture fisheries management: Indian Ocean (No. 488). Food & Agriculture Org.

FAO (2013) Fishing Gear types. Technology Fact Sheets. In: FAO Fisheries and

Aquaculture Department [online]. Rome. Updated 13 September 2001. [Cited 18August 2017]. http://www.fao.org/fishery/geartype/249/en.

(MINAGRI)Nº.58. 2008, Ministry of Agriculture and Animal Resources determining the Organization and Management of Aquaculture and Fishing in Rwanda

Tran-Van-Tri and Ha-Khac-Chu. 1963."Second World Fishing Gear Congress "Working papers; l: 49.

(Johnston, 1992).Development perspective minimizes frustration, and increases the chances of achieving development goals.

Appendices

Appendix 1. Initial data of fishing vessel Gill Monofilament

Year	production	Horse power	fishers	CPUE
2002	86,932	2,093	9	41.535
2003	90,526	2,005	9	45.150
2004	90,732	2,500	9	36.293
2005	268,188	2,000	9	134.094
2006	104,863	2,267	9	46.256
2007	108,226	2,868	9	37.736
2008	112,313	2,652	9	42.350
2009	325,402	2,319	9	140.320
2010	436,973	2,654	9	164.647
2011	308,722	2,399	9	128.688
2012	1,332,342	1,900	10	701.233
2013	2,096,195	1,400	10	1497.282
2014	3,017,645	1,329	10	2270.613
2015	4,669,735	1,240	10	3765.915
2016	3,125,075	1,376	10	2271.130
Total	**16,173,869**	**31,002**	**140**	**521.704**

Appendix 2 Initial data of fishing vessel Hooks

Year	production	Horse power	fishers	CPUE
2002	13,612	2,239	2	6.079
2003	12,578	2,114	2	5.950
2004	13,317	2,443	2	5.451
2005	9,873	3,309	2	2.984
2006	10,307	3,052	2	3.377
2007	10,961	3,311	2	3.310
2008	11,776	3,648	2	3.228
2009	12,024	4,353	2	2.762
2010	11,154	4,138	2	2.696
2011	12,934	4,162	2	3.108
2012	12,431	4,107	1	3.027
2013	14,558	3,425	1	4.251
2014	10,885	4,105	1	2.652
2015	11,255	5,839	1	1.928
2016	10,131	4,137	1	2.449
Total	**177,796**	**54,382**	**25**	**3.269**

Appendix 3 Initial data of fishing vessel Longline

Year	production	Horse power	fishers	CPUE
2002	163,338	392	5	416.679
2003	150,947	335	5	450.588
2004	159,793	339	5	471.366
2005	118,471	332	5	356.840
2006	123,687	329	5	375.948
2007	131,541	293	5	448.945
2008	141,311	289	4	488.965
2009	144,283	323	4	446.697
2010	133,852	342	3	391.380
2011	155,203	354	3	438.427
2012	149,169	437	3	341.348
2013	174,698	432	3	404.394
2014	130,615	438	3	298.208
2015	135,059	472	3	286.142
2016	121,576	493	3	246.605
Total	**2,133,543**	**5,600**	**59**	**380.990**

Appendix 4 Initial data of fishing vessel Gillnets

Year	production	Horse power	fishers	CPUE
2002	13,612	299	4	45.525
2003	12,579	307	4	40.974
2004	13,316	318	4	41.874
2005	9,873	308	4	32.055
2006	10,308	319	4	32.313
2007	10,962	213	4	51.465
2008	11,776	217	3	54.267
2009	12,024	393	3	30.595
2010	11,154	325	3	34.320
2011	11,154	312	3	35.750
2012	12,934	403	3	32.094
2013	12,431	416	3	29.882
2014	14,558	421	3	34.580
2015	10,885	415	3	26.229
2016	11,255	429	3	26.235
Total	**178,821**	**5,095**	**51**	**35.097**

Appendix 5. Initial data of fishing vessel Small seine

Year	production	Horse power	fishers	CPUE
2002	182,810	491	6	372.322
2003	175,368	445	6	394.085
2004	147,454	449	6	328.405
2005	180,855	442	6	409.174
2006	297,048	429	6	692.420
2007	326,456	243	6	1,343.440
2008	362,298	279	4	1,298.559
2009	352,745	413	4	854.104
2010	20,748	442	4	46.941
2011	18,668	454	4	41.119
2012	19,176	546	4	35.121
2013	19,049	522	4	36.492
2014	16,147	528	4	30.581
2015	46,119	563	4	81.917
2016	92,706	589	4	157.396
Total	**2,257,647**	**6,835**	**72**	**330.307**

Appendix 6. Initial data of fishing vessel cast net

Year	production	Horse power	fishers	CPUE
2002	10,519	429	2	24.520
2003	11,468	445	2	25.771
2004	12,219	449	2	27.214
2005	8,542	442	2	19.326
2006	9,042	429	2	21.077
2007	9,354	393	2	23.802
2008	10,629	389	2	27.324
2009	11,919	312	2	38.202
2010	10,925	332	2	32.907
2011	10,192	343	1	29.714
2012	12,653	432	1	29.289
2013	12,723	412	1	30.881
2014	14,624	426	1	34.329
2015	10,253	412	1	24.886
2016	10,946	421	1	26.000
Total	**166,008**	**6,066**	**24**	**27.367**