# PRODUCTION ANALYSIS AND MEASUREMENT OF TECHNICAL EFFICIENCY OF CHARTER FISHING INDUSTRY IN NORTH CAROLINA

by

KAZI EHSANUL BARI

(Under the Direction of Craig E. Landry)

## ABSTRACT

Despite the contribution of recreational and charter fishing in the economy, there has not been any efficiency analysis conducted on charter fishing industry. This study aims to conduct a production analysis and measure the technical efficiency of the charter fishing industry of North Carolina using a translog stochastic production function. Analysis suggests number of trips made by the captains is influenced by vessel length, fuel, bait and ice. Captains become more efficient with experience. Using larger boats will help to increase the number of trips made by charter boats.

INDEX WORDS: Recreational fishing, Stochastic production frontier, Technical efficiency

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A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2019

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August 2019

ACKNOWLEDGEMENTS

I would like to express my gratitude to my advisor Dr. Craig E. Landry for giving me the opportunity to work under his guidance. Without his mentoring and guidance, this work would not have been possible. Special thanks to my committee members, Dr. Travis Alan Smith and Dr. John Whitehead for their valuable suggestions and helping me to complete the research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page No.

# CHAPTER 1

# INTRODUCTION

Recreational fishing is defined as angling for primarily personal enjoyment with catch not being traded in commercial markets (FAO, 2017). Recreational fishing generates significant economic value for participants and contributes to the economy by promoting tourism, creating jobs, supporting related industries, and fostering infrastructure development (FAO, 2017). According to World Bank estimates, recreational fishing has contributed USD 70 billion in global GDP (FAO, 2017). It is one of the most popular outdoor activities in the United States with approximately 73 million adult participants in 2008 (White et al., 2014). At the same time, it has huge economic impact. According to USFWS (2016) recreational fishing has generated over $46 billion in the United States in retail sales in 2016; in addition, recreational fishing supports approximately 472,000 jobs (NOAA, 2018).

Focusing on North Carolina, recreational fishing has generated approximately $1.6 billion in retail sales and created over 16 thousand jobs (Harrison, Pickle, Vegh, & Virdin, 2017). According to Dumas et al. (2009) there are approximately 750 charter boat vessels and head boat vessels that operate in North Carolina. Their study shows that this industry serves more than four hundred thousand passengers annually who pay approximately $65 million in fishing fees and generates approximately $202 million consumer surplus every year. These results signify the importance of recreational fishing in the economy of North Carolina.

Most existing research on recreational fishing has focused on household decision-making and economic impacts (Dumas, Whitehead, Landry, & Herstine, 2009; Hadley, 2015; Savolainen, Caffey, & Kazmierczak, 2012). Some of this research includes analysis of fishing mode, a subset of which includes large head boat recreational fishing vessels, smaller for-hire charter fishing vessels, and private fishing boats.

While the overwhelming majority of studies has focused on recreation decision-making, there has been no systematic or in-depth analysis of production decision of charter and head-boat firms, nor any exploration or their technical efficiency. Analysis of production is important in understanding the underlying technology involved in creation and marketing of charter trips; the sector's factor demand for capital, labor, fuel, and other inputs; and the resulting profits and surpluses that are generated by the industry. Analysis of technical efficiency provides important insights into economic profitability as it measures a firm's is ability to produce maximum output with a given set of inputs (Kumbhakar & Lovell, 2000). Improved productivity results in increased production, and efficiency of the resources available play an important role in determining the level of productivity (Goyal, Suhag, & Pandey, 2006).

This research is focused on the analysis of technical efficiency of charter fishing in North Carolina. It uses a panel dataset collected from 160 charter boat captains.

Stochastic production frontier approach is used for the measurement of technical efficiency of the charter fishing industry. Stochastic frontier analysis a commonly used concept in the field of agriculture and fishery. Stochastic frontier analysis (SFA) is a method of economic modeling that estimates production or cost functions in economics, while accounting for the existence of firm inefficiency (Kumbhakar & Lovell, 2000). Ozkan, Ceylan, & Kizilay, (2009) offers a review of the literature on productive efficiency in agricultural production

**1.1 Objective**

The objective of this project is analysis of production and measurement of technical efficiency of the charter fishing industry of North Carolina.

**1.2 Motivation of the Study**

Production analysis helps to understand the relation between the factors of production and the output (Besanko & Braeutigam, 2010). Failure to achieve the maximum possible level of output with the available inputs results in inefficiency (Kumbhakar & Lovell, 2000).

Technical efficiency analysis is a common practice in agriculture, forestry and fishery. Ben-Belhassen & Womack (2000) measured the technical efficiency of hog production in Missouri. Their study adopts the stochastic frontier model developed by Aigner, Lovell, & Schmidt, (1977) and employs a two stage analytical procedure with the first stage being the estimation of frontier and the second stage being the measure ment of technical inefficiency. Their study finds labor to have positive coefficient in the production frontier. They also find the average efficiency of the hog production industry of Missouri to be approximately 82%.

Kirkley, Squires, & Strand (1995) assess the technical efficiency in commercial fisheries of the mid-Atlantic sea scallop fishery. Their study shows that technical efficiency is higher between March and August, which might be partially influenced by environmental factors such as temperature, rainfall etc. The study of Rabbani, Khan, Islam, & Lucky (2017) on the technical efficiency of the set bag net fishery in Bangladesh uses translog stochastic frontier. Their study finds age and engine horse power to influence technical inefficiency among other variables. Goyal et al. (2006) estimated technical efficiency of paddy farmers in Haryana state of India. They also used the translog stochastic production frontier in their analysis and find age to have positive coefficient in the inefficiency model. Due to the relevance between commercial fishery and charter fishing, results of these studies provide guideline for our research.

There have not been a lot of studies conducted on the production of charter fishing industry in North Carolina. Steinback & Brinson (2013) analyzed the economics of recreational for-hire fishing industry in the northeast United States. They used descriptive statistics to analyze vessel characteristics, trip characteristics, cost and earnings etc. Their study reveals approximately 1.6 million passengers used for-hire recreational fishing vessel in 2011. The results also show that the average charter boat produced approximately $5 thousand in net income in 2010 and average head boat generated over $95.1 thousand in net income in 2010. Dumas et al. (2009) focused on the economic impacts and recreational benefits of the for-hire charter industry in the coastal region of North Carolina. Their results show that the North Carolina for-hire fishery receives approximately $65 million annually in fishing fees paid by passengers, with about $55 million received by charter vessels and $10 million received by head boat vessels. Herstine, Dumas, & Whitehead (2007) analyzed the economic benefits of recreational boating in North Carolina. Results from their study reveal that boating industry generated approximately $500 million in sales of boats, motors and boating equipments per year.

Review of the previous literatures suggests the charter and recreational fishing industry not only make important contribution to the economy but also, they play an important role as a source of outdoor recreation of the people. However, there have not been any study conducted on the production and technical efficiency of the recreational charter fishing industry of North Carolina to the best knowledge of the researchers. Considering contribution of recreational fishing in the economy of North Carolina, an analysis of the technical efficiency of the recreational fishing industry would be an important addition to literature.

# CHAPTER 2

# LITERATURE REVIEW

A broad and critical review of existing literature on production analysis, technical efficiency analysis, recreational and commercial fishery and application of technical efficiency analysis in recreational and commercial fishery has been conducted for the purpose of this research. First part of this chapter consists of a review of literature on production analysis and development of stochastic frontier followed by application of stochastic frontier in agriculture and fishery and review of literature on charter and recreational fishing.

## Production Analysis and Development of Stochastic Frontier

The concept of a production function came into usage during the first decade of the last century, and it became firmly rooted in microeconomics by the 1930s (Chambers, 1988). The entire production process begins with the supply of factors of production or inputs used towards the production of a final good. Production of goods and services involves transforming the factors of production such as labor, capital, raw materials, and the services provided by facilities and machines into finished products (Besanko & Braeutigam, 2010). Analysis of production activities provides a connection to supply in production markets and demand in factor markets.

Multi-factor production function can be expressed as $q = f(z_1, z_2, \ldots, z_N)$, where q is a volume of production, and $z_1 \ldots z_N$ are a vector of production resources that serve as inputs to the production process (Besanko & Braeutigam, 2010). Different types of functional forms can be used for production analysis depending on assumptions about the production process and characteristics of the data. Griffin, Montgomery, & Rister (1987) provide a literature review on different functional forms used in production analysis and their specific characteristics. Although producers aim to maximize their output with the available set of inputs or minimize inputs to produce a given level of output, often they fail to meet their desired level of production, resulting in inefficiency (Kumbhakar & Lovell, 2000). Production frontier represents the maximum output that can be produced with the available inputs and given technology with technically efficient producers operating on the frontier (Kumbhakar & Lovell, 2000).

Farrell (1957) offers a pioneering study of technical efficiency, employing a deterministic approach to measure the productive efficiency of agricultural production in different states of the U. S. A. Technical inefficiency is defined by Farrell as the ratio of the least possible amount of inputs to be used to actual amount of inputs used for a given amount of output.

The interpretation of Farrell enables him to disaggregate technical and resource-allocation inefficiencies. By this disaggregation, it becomes possible to estimate technical efficiency of production, evaluate input choice, assess market outcomes, and to make projections for policy purposes.

Aigner, Lovell, & Schmidt (1977) devise a stochastic frontier model for measuring technical efficiency which utilizes a parameterized stochastic frontier function that embraces both technical inefficiencies of the production process and the probabilistic, random effects leading to random noise in production data. In this sense, the approach introduces a composite error term involving technical inefficiency and random statistical noise. Therefore, the stochastic frontier function enables the researcher to measure both the technical efficiency sources and impact of random unobserved aspects of production or factors that are not directly related with production process itself. The estimated function appears as a frontier or benchmark with the parameter estimates indicating whether the enterprise or production unit is producing at the production (or profit) frontier.

The method of decomposing the error term and obtaining technical inefficiency enables interpretation of factors that influence technical inefficiency. In this way, the demographic and socio-economic characteristics of the farms are considered as independent variables explaining the measured technical inefficiency. Battese & Coelli (1995) use the concept developed by Aigner et al. (1977) and assume the inefficiency effects are independently distributed and with means which are linear function of explanatory variables.

**Application of Stochastic Frontier analysis in Agriculture and Fishery**

Goyal et al. (2006) used the stochastic frontier production function approach for panel data to measure the technical efficiency in paddy production. They employed the model developed by Battese & Coelli (1995). They modeled the production process with a single-output production frontier and technical inefficiency effects are modeled in terms of some farmer-specific variables in the production process. Their study finds negative coefficient for family size and positive coefficient for age in inefficiency model meaning inefficiency decreases for larger family but increases for old farmers.

Kirkley et al. (1995) argue the parametric statistical approach to be the most suitable for assessing technical efficiency of firms exploiting renewable resources, as there is inherent stochasticity involved. They measure technical efficiency for a selected panel data set of ten Mid-Atlantic sea scallop fishing vessels using the stochastic production frontier. They use translog production frontier function, which is a generalization of the Cobb-Douglas function, as the empirical model of the study, and output was measured in terms of scallop meat weight. They use monthly dummy variables in the production function to measure the influence of stock size with the temporal pattern. Likelihood ratio tests reveal that only the monthly dummy variables for February through March and October through December are statistically significant. Their results show technical efficiency decreases as the trip length (number of days) increases.

Rabbani et al. (2017) use the stochastic frontier model in technical efficiency analysis of Setbag Net Fishery in Bangladesh. The results show that total cost for Setbag net fishing which is considered as an input in the production frontier, is positive and significant at 10 percent level. Which means output increases with total cost. The coefficient of captains' age is found negative and significant at 5 percent level in the technical inefficiency effect model, indicating that technical inefficiency decreases with the increase in captains' age. Analysis shows that both coefficients of captains' education and captains' experience were negative and insignificant in the technical inefficiency effect model for Setbag net fishing, meaning inefficiency decreases with the increase in captains' education and experience. The coefficient of engine horsepower is found to be negative and significant at 1 percent level in the technical inefficiency effect model, indicating that technical inefficiency decreases with the increase in engine horsepower.

Crentsil & Essilfie, (2014) measure the technical efficiency of smallholder fish production in Ghana using a stochastic frontier approach. They use a translog production function to determine the effects of predetermined variables on fish production. Their study reveals location, labor, and feed have positive influence on efficiency. Sharma & Leung, (1999) study the technical efficiency of the longline fishery in Hawaii. Their research uses a translog production frontier with revenue per trip as the output variable and input variables measured in average per trip basis. They also measure output elasticities and marginal products of trip days, crew size and other inputs which include the cost of fuel, bait, ice and other miscellaneous items. They find crew size to have highest elasticity followed by number of trips. Their results show that vessel and operator specific variables such as ownership and experience of fishermen influence efficiency.

### Literature on Recreational and Charter Fishing

Numerous studies have been conducted on the recreational and charter fishing industry in the United States, which primarily focuses on the economic impact of this industry and recreational decision-making characteristics. Poe et al., (2013) reviews the literature on the net benefits of recreational fishing in the great lakes basin. They conclude that the aggregate annual net value of recreational fishing in the great lakes lies between \$393 million to \$1.47 billion. Savolainen et al. (2012) studies the economic and attitudinal perspectives of the for-hire fishing industry in the U. S. Gulf of Mexico. They focus on a comprehensive study of the economic and policy status of the recreational for-hire fishery sector in the U. S. Gulf of Mexico and construct cost, earnings and attitudinal profiles by operational class and region.

Hadley, (2015) focuses on the economic analysis of recreational and commercial fisheries occurring in the middle and lower Cape Fear River, North Carolina. He estimates the net benefit from recreational fishing and the economic impact based on the trip expenditures for the recreational fisheries. His results show that total economic value of recreational fishing trips occurred on the Middle Cape Fear River was approximately 1.15 million in 2013. Lew & Larson, (2012) measure the economic value of sport fishing in Alaska through stated preference method. They study the characteristics of the fishing trips and estimated the willingness to pay for fishing trips. Their findings suggest that the mean trip value ranges from \$246 to \$444. Lucente et al. (2012) study the charter fishing industry of Ohio’s Lake Erie. Their study focuses on the characteristics of the charter industry such as trips characteristics, cost, and returns.

Dumas et al. (2009) measure the economic impacts and recreational benefits of the for-hire charter industry of North Carolina. Their study provides an insight about the magnitude of the for-hire charter fishing industry of North Carolina. For-hire fishing industry serves approximately 431,000 passengers annually and the spending made by the for-hire fishing passengers supports approximately $667 million in economic output and about 10, 200 jobs.

# CHAPTER 3

## Materials and Methods

### Data Collection

Data used for this research was collected in 2007 and 2008. Primarily the list of for-hire vessel operating from different ports along the North Carolina was acquired from The North Carolina Division of Marine Fisheries (NCDMF 2008). The database had 794 for-hire vessel permits listed for 2007-2008. Among them, North Carolina residents accounted for 750 permits. 27 of these 750, operated as headboats and the rest of the vessels operated as charters.

A questionnaire was sent by mail to all for-hire captains either (i) holding NOAA/NMFS Open-Access Permits for Dolphin/Wahoo, Pelagic Fish or Snapper/Grouper, (ii) identified by field surveyors interviewing passengers at marinas, (iii) listed on regional charter/ headboat fishing web site (e.g. www.time4fishing.com), or (iv) identified by a web site search for individual NC charter and headboat web sites. 158 usable captain surveys, consisting of 150 charter boat surveys and 8 head boat surveys were obtained.

**Description of data**

Analysis of the demographic data shows that the respondents were predominantly male (99.38%) and White (98.16%). Average age of the respondents was approximately 49, though captains as young as 21 years and as old as 75 years of age were surveyed. 38.61% of the respondents had 75%-100% of their family oncome from charter fishing. Majority of the respondents (53.09%) were experienced between 0 to 10 years.

Table 3.1: Summary of the demographics of the charter boat captains

| Category | Frequency/Value | Percent | Category | Frequency/ Value | Percent |
|---|---|---|---|---|---|
| **Gender** | | | **Experience (years)** | | |
| Male | 161 | 99.38 | | | |
| Female | 1 | 0.62 | 0-10 | 86 | 53.09 |
| **Ethnicity** | | | 11-20 | 39 | 24.07 |
| White | 160 | 98.16 | 21-30 | 26 | 16.05 |
| Hispanic | 1 | 0.61 | 31-40 | 8 | 4.94 |
| Dutch | 1 | 0.61 | 41-50 | 2 | 1.23 |
| African-American | 1 | 0.61 | 51-60 | 1 | 0.62 |
| Native American | | | **Percentage of Household Income** | | |
| **Age** | | | | | |
| Average | 48.72 | | 0-.25 | 36 | 22.78 |
| Maximum | 75 | | 0.25-0.5 | 37 | 23.42 |
| Minimum | 21 | | 0.5-0.75 | 24 | 15.19 |
| | | | 0.75-1 | 61 | 38.61 |

**Vessel Related information**

Table 3.2: Summary of the vessel related information

| | Average | Minimum | Maximum | Standard Deviation |
|---|---|---|---|---|
| Vessel Length (feet)_ | 40.78 | 18 | 85 | 13.39 |
| Vessel Power (hp) | 729.02 | 90 | 3300 | 510.65 |
| Market Value (usd) | 236459.32 | 450 | 1250000 | 241262.34 |

According to the data provided by the respondents, average vessel length was 40.78 feet, with 729 hp. Average market value of vessel is $236,459 approximately with the lowest market value being $450 and the highest being $1,250,000. On an average 50.31% of the respondents had one full time crew and 63.13% of the respondents had no part time crew. 21% of the boat captains had no full time or part time crew.

Table 3.3: Summary of crew related information

| Full time crew | | Part time crew | |
|---|---|---|---|
| Number of Crew | Percent | Number of Crew | Percent |
| 0 | 43.56 | 0 | 63.13 |
| 1 | 50.31 | 1 | 28.75 |
| 2 | 4.29 | 2 | 5.00 |
| 3 | 1.23 | 3 | 1.25 |
| 4 | 0.61 | 4 | 1.25 |
| | | 5 | 0.63 |

**Trip Related Information**

Table 3.4: Summary of the trip related information

| Month | Full day | | Half day | | Overnight | |
|---|---|---|---|---|---|---|
| | Average No. of Trips | Average Distance Covered (miles) | Average No. of Trips | Average Distance Covered (miles) | Average No. of Trips | Average Distance Covered (miles) |
| January | 2.31 | 24.63 | 0.46 | 3.67 | 0.02 | 50.00 |
| February | 1.34 | 24.27 | 0.36 | 3.47 | 0.03 | 50.00 |
| March | 2.21 | 30.83 | 0.31 | 5.53 | 0.03 | 50.00 |
| April | 4.97 | 33.55 | 1.02 | 5.65 | 0.03 | 50.00 |
| May | 8.52 | 31.40 | 2.30 | 5.42 | 0.03 | 50.00 |
| June | 11.69 | 30.23 | 5.71 | 5.92 | 0.04 | 52.67 |
| July | 10.98 | 29.64 | 6.09 | 6.34 | 0.08 | 43.25 |
| August | 9.09 | 29.59 | 6.01 | 6.39 | 0.08 | 43.25 |
| September | 5.71 | 30.15 | 3.11 | 5.89 | 0.07 | 45.00 |
| October | 5.61 | 28.62 | 2.01 | 7.19 | 0.04 | 50.00 |
| November | 3.70 | 29.67 | 0.79 | 6.89 | 0.03 | 50.00 |
| December | 2.15 | 27.79 | 0.42 | 5.69 | 0.02 | 60.00 |

The survey findings show that both full day and half-day trips were higher during May, June, July and August. Average number of trips and average distance covered both were lower for full day and half day trips during November, December, January and February.

**Cost Related Information**

Costs are divided into two categories, fixed costs and variable costs. Fixed costs are further categorized as monthly fixed costs and yearly fixed costs. Monthly fixed costs include Dock/Slip fees per month, vessel loan payment per month, vessel insurance payment per month, telephone costs per month etc. On average respondents pay approximately $2009.53 per month as monthly fixed costs. Yearly fixed costs consist of NC Recreational Fishing Permit/License Fees per Year, other state recreational fishing permit/license fee per year, federal recreational fishing permit/license fee per year, fishing supplies per year, electronics costs per year, engine repair costs per year, boat yard expenses per year, other vessel maintenance expenses per year etc. These costs add up to approximately $20,026.02 per year on average.

Table 3.5: Summary of the fixed costs

| Category | Category | Average cost($) |
|---|---|---|
| Monthly Fixed costs | Dock/Slip Fees per Month | 299.04 |
| | Vessel Loan Payment per Month | 879.18 |
| | Vessel Insurance per Month | 496.47 |
| | Telephone Costs per Month | 99.63 |
| | Other Monthly Fixed Costs--Value | 235.21 |
| | Total | 2009.53 |
| Yearly Fixed Costs | NC Recreational Fishing Permit/License Fees per Year | 399.52 |
| | Other State Recreational Fishing Permit/License Fee per Year | 81.71 |
| | Federal Recreational Fishing Permit/License Fee per Year | 193.27 |
| | Fishing Supplies per Year | 3382.46 |
| | Electronics Costs per Year | 912.76 |
| | Engine Repair Costs per Year | 4829.78 |
| | Boat Yard Expenses per Year | 2135.69 |
| | Other Vessel Maintenance Expenses per Year | 2485.09 |
| | Fishing Assoc/Professional Fees per Year | 229.38 |
| | Accounting/Book Keeping Fees per Year | 1014.38 |
| | Legal Expenses per Year | 359.26 |
| | Advertising and Promotion per Year | 3066.11 |
| | Other Yearly Fixed Costs--Value | 936.60 |
| | Total | 20026.02 |

Variable costs include cost of fuel and oil per trip, wage paid to captain per trip (if captain not the owner of the boat), total paid to mate/crew per trip, bait costs per trip, ice costs per trip, food/drink costs per trip. Analysis of the data shows that these costs are higher for overnight trips than those of full day and half day trips. In case of overnight trips total variable cost is $2475.93, for full day and half day trips total of the variable costs are $881.53 and $245.99 respectively.

Table 3.6: Summary of the variable costs

| Category | Average Cost | | |
|---|---|---|---|
| | Full day | Half day | Over night |
| Cost of Fuel and Oil per Trip | 487.02 | 121.16 | 1018.82 |
| Wage Paid to Captain per Trip (if captain not the owner of the boat) | 168.97 | 54.67 | 687.50 |
| Total Paid to Mate/Crew per Trip | 142.06 | 38.93 | 472.35 |
| Bait Costs per Trip | 47.57 | 13.44 | 211.47 |
| Ice Costs per Trip | 19.68 | 8.04 | 49.12 |
| Food/Drink Costs per Trip | 16.23 | 9.74 | 36.67 |
| Total | 881.53 | 245.99 | 2475.93 |

**Model Selection**

Three different production functions, Cobb-Douglas, Translog and Generalized Leontief were tried for the study.

**Cobb-Douglas production function**

Cobb-Douglas function employs a relationship between inputs and output which is linear in log. Elasticities in a log-linear Cobb-Douglas finction is same as the coefficients of the explanatory variables. Following expression can be used to estimate the output as a function of n inputs using:

$$ln(Y_i)=\beta_0+\sum_{i=1}^{n}\beta_i lnX_i$$

**Translog production function**

The translog production function represents a flexible functional form for the production analysis. Translog production function considers the non-linear relationship between output and allows interaction between the production factor. It takes the following form:

$ln(Y_i)=\beta_0+\sum_{i=1}^{n} \beta_i lnX_i + ½\beta_{ij} \sum_{i=1}^{n} \sum_{j=1}^{n} lnX_i lnX_j$

Elasticities can be calculated from a translog production function using the following equation:

$\varepsilon = \frac{d(lnY_i)}{d(lnX_i)} = \beta_i + \sum_{j=1}^{n} b_i lnX_j$

Marginal product represents how a unit change in a factor of production effects the output.

Marginal product $\frac{d(Y)}{d(X_i)} = \varepsilon \frac{Y}{X_i}$

**Generalized Leontief production function**

Genralized Leontief production function is flexible functional form that allows an input to have zero value. It can be expressed as the following equation:

$ln(Y_i)=\beta_0+\sum_{i=1}^{n} \sum_{j=1}^{n} \left(lnX_i lnX_j\right)^{1/2}$

**Model Selection Criteria**

Both Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) estimate the relative quality of statistical models using the log likelihood estimates.

AIC = -2ln(L) + 2K

BIC = -2ln(L) + ln(n)K

Here,

L = log likelihood estimate,

K = number of parameters

n = sample size

AIC and BIC are closely related, with the difference being BIC considers the sample size. Both the criterion penalizes for adding more parameters in the model. The model with lower AIC and BIC score is considered better than the ones with higher AIC and BIC scores. Based on the AIC and BIC scores translog production function in selected for the analysis of this research

**Model Specification**

Translog stochastic frontier production function used for the analysis can be expressed as:

*ln(Y)=f(lnX, beta)+V-U*

We measured output in terms of number of trips made per month. We considered five explanatory variables in our production function. They are vessel length, labor, fuel, bait and ice. We included dummy variables for months in the production function to catch the monthly variation in trips.

**Technical inefficiency**

Error term of stochastic production function has two components, $V_{it}$ and $U_{it}$. The first term represents the statistical noise ($V_{it} \sim N(0, \sigma_u^2)$) and the second term represents a non-negative technical inefficiency ($U_{it} \geq 0$) (Jondrow, Knox, Materov, & Schmidt, 1982).

We estimated the model assuming the technical inefficiency follows a exponential distribution. The variance of technical inefficiency is considered to be a function of covariates Zi that are hypothesized to influence inefficiency:

$\sigma_u^2 = \exp(\delta_0 + \sum_{i=1}^{n} \delta_i Z_i)$

CAHPTER 4

RESULTS AND DISCUSSION

## Analysis of the production function

Table 4.1: parameter estimates from production frontier

| | Translog | | Cobb_Douglas | | Generalized Leontief | |
|---|---|---|---|---|---|---|
| | Coef. | Std. error | Coef. | Std. error | Coef. | Std. error |
| Vessel Length | 0.812 | 1.353 | 0.251 | 0.076 | 0.086 | 0.071 |
| Labor | -0.200 | 0.184 | 0.016 | 0.012 | -0.075 | 0.090 |
| Fuel | 0.024 | 0.260 | 0.198 | 0.018 | -0.278 | 0.074 |
| Bait | -1.039 | 0.449 | 0.177 | 0.032 | 0.530 | 0.083 |
| Ice | 1.621 | 0.472 | 0.103 | 0.029 | -0.005 | 0.093 |
| Vessel Length^2 | -0.156 | 0.167 | | | | |
| Labor^2 | -0.036 | 0.011 | | | | |
| Fuel^2 | -0.036 | 0.007 | | | | |
| Bait^2 | 0.089 | 0.015 | | | | |
| Ice^2 | -0.003 | 0.014 | | | | |
| Vessel Length*Labor | 0.099 | 0.050 | | | 0.092 | 0.096 |
| Vessel Length*Fuel | 0.108 | 0.065 | | | 0.629 | 0.096 |
| Vessel length*Bait | 0.385 | 0.119 | | | 0.189 | 0.156 |
| Vessel length* Ice | -0.422 | 0.131 | | | 0.151 | 0.162 |
| Labor*Fuel | 0.013 | 0.011 | | | 0.096 | 0.041 |
| Labor*Bait | -0.073 | 0.025 | | | -0.075 | 0.052 |
| Labor*Ice | 0.074 | 0.026 | | | 0.011 | 0.051 |
| Fuel*Bait | -0.113 | 0.019 | | | -0.471 | 0.125 |
| Fuel*Ice | 0.039 | 0.024 | | | 0.057 | 0.142 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Bait*Ice | -0.053 | 0.023 | | | -0.215 | 0.062 |
| January | 0.045 | 0.061 | 0.059 | 0.074 | -0.051 | 0.390 |
| February | -0.037 | 0.058 | -0.079 | 0.074 | -0.015 | 0.390 |
| March | -0.067 | 0.053 | -0.071 | 0.068 | -0.091 | 0.062 |
| April | 0.255 | 0.063 | 0.274 | 0.076 | 0.229 | 0.064 |
| May | 0.655 | 0.081 | 0.698 | 0.088 | 0.641 | 0.067 |
| June | 1.091 | 0.085 | 1.096 | 0.094 | 1.060 | 0.068 |
| July | 1.049 | 0.088 | 1.032 | 0.098 | 1.023 | 0.068 |
| August | 0.910 | 0.087 | 0.911 | 0.095 | 0.883 | 0.068 |
| September | 0.451 | 0.080 | 0.512 | 0.086 | 0.436 | 0.065 |
| October | 0.384 | 0.074 | 0.444 | 0.083 | 0.373 | 0.065 |
| November | 0.095 | 0.060 | 0.137 | 0.074 | 0.083 | 0.063 |
| Constant | -0.552 | 2.783 | -0.907 | 0.357 | -0.098 | 0.285 |
| AIC | 4015.653 | | 4388.672 | | 4063.029 | |
| BIC | 4215.815 | | 4505.433 | | 4224.271 | |

The table above shows the parameter estimates from Cobb-Douglas, Generalized Leontief and Translog production function and AIC and BIC scores for the respective functions as well. Based on the AIC and BIC score we preferred translog production frontier for the analysis. Parameter estimates of the translog production function are not directly interpretable given the extensive array of interaction terms. Marginal effects of the explanatory variables are calculated separately. Some of the variables are found to have negative coefficients (Table 4.1) but positive marginal effects.

Analysis of elasticities (Table 4.2) shows vessel length, fuel, bait and ice have positive elasticity and marginal products. One unit increase of vessel length results in increase of number of trips by 0.183. One unit increase of fuel increases number of trips by 0.058. One unit increase of bait increases number of trips by 0.199. Labor has a negative elasticity and negative coefficient in the stochastic production frontier, which is similar to the findings of Rabbani et al., (2017). Negative elasticity and marginal product for labor might indicate that there is more than required amount of labor in the industry.

Parameter estimates of the dummy variable for months show that May, June, July, august have higher coefficients than other months of the year, meaning greater numbers of trips during summer.

Table 4.2: Elasticities and Marginal products of the explanatory variables

| | Elasticity | Marginal Product |
|---|---|---|
| Vessel Length | 0.339* | 0.139* |
| Labor | -0.019* | -0.009* |
| Fuel | 0.076* | 0.036* |
| Bait | 0.268* | 0.207* |
| Ice | 0.063* | 0.062* |

**Efficiency Estimates**

Table 4.3: Efficiency estimate

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| efficiency | 1,920 | 0.702787 | 0.148178 | 0.076502 | 0.927634 |

Average efficiency of the captains is found to be approximately 70% which means they are almost 30% below the frontier.

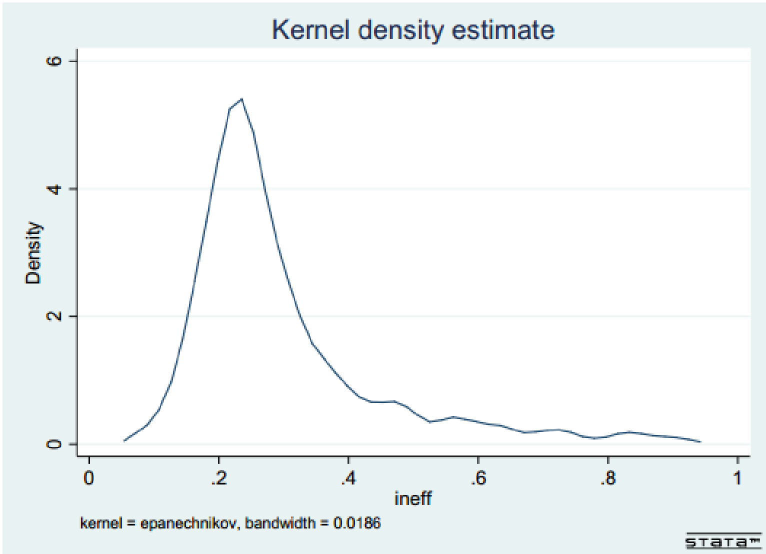

Figure 4.1: Distribution of inefficiency

Distribution of inefficiency reveals that most of the captains are around 20% inefficient with very few being more than 50% inefficient. Marginal effect analysis of the inefficiency model reveals that year increase of age increase inefficiency by 40% and one year increase in experience decreases inefficiency by 10%.

Table 4.4: Marginal effects from the inefficiency model

| | Coef. | Std. Err. | z | P>\|z\| | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| Age | 0.40193 | 0.062225 | 6.46 | 0 | 0.279972 | 0.523888 |
| Experience | -0.10116 | 0.019458 | -5.2 | 0 | -0.1393 | -0.06303 |

# CHAPTER 5

# CONCLUSIONS

Charter fishing service is important as it serves the recreational need of a large number of people who do not own boats. Dumas et al., (2009) suggests for-hire fishing passengers spend about $380.0 million per year in both on and off vessel spending in North Carolina. With economic multiplier effects, this spending supports about $667.4 million in economic output (sales) along the coast. Estimates of consumer surplus in their study shows that average consumer surplus for charter boat trip is $624 per fisher per trip and for head boat trip $102 per fisher per trip. In aggregate consumer surplus for charter boat is $189 million and for head boat $13 million. This research examined the production technology and technical efficiency with a sample of charter boat captains from North Carolina, using a translog stochastic frontier model. Results obtained from the study show that vessel length, fuel, bait and ice have statistically significant positive elasticities and marginal products. Vessel length has the highest elasticity among the explanatory variables. Investment in larger boats is expected to increase the number of trips made by the captains. Labor has negative elasticity and marginal product meaning the industry has more labor than required. Experience is found to be negatively correlated with inefficiency, meaning more experience captains are more technically efficient than less experienced captains. Number of trips increases during the summer, meaning there might be an impact of weather on the trips made. Further studies can be focused on the impact of weather on charter and head boat trips and welfare analysis to determine the optimum allocation of resources.

## References

Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). FORMULATION AND ESTIMATION OF STOCHASTIC FRONTIER PRODUCTION FUNCTION MODELS. *Journal of Econometrics 6*, *6*, 21–37.

Battese, G. E., & Coelli, T. J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics*, *20*, 325–332.

Ben-Belhassen, B., & Womack, A. W. (2000). MEASUREMENT AND EXPLANATION OF TECHNICAL EFFICIENCY IN MISSOURI HOG PRODUCTION. *American Agricultural Economics Association*, (573).

Besanko, D., & Braeutigam, R. R. (2010). *MICROECONOMICS*.

Crentsil, C., & Essilfie, F. L. (2014). Measurement of technical efficiency of smallholder fish production in Ghana : A stochastic frontier approach. *Journal of Development and Agricultural Economics*, *6*(5), 203–211. https://doi.org/10.5897/JDAE12.146

Dumas, C. F., Whitehead, J. C., Landry, C. E., & Herstine, J. H. (2009). *Economic Impacts and Recreation Value of the North Carolina For - Hire Fishing Fleet*.

FAO. (2017). *GLOBEFISH Highlights - A Quarterly Update on World Fish Market*.

Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, *120*(3), 253–290. Retrieved from https://www.jstor.org/stable/2343100

Goyal, S. K., Suhag, K. S., & Pandey, U. K. (2006). An Estimation of Technical Efficiency of Paddy Farmers in Haryana State of India. *Ind. Jn. of Agri. Econ.*, *61*(1).

Griffin, R. C., Montgomery, J. M., & Rister, M. E. (1987). Selecting Functional Form in Production Function Analysis, *12*(2), 216–227.

Hadley, J. (2015). *An Economic Analysis of Recreational and Commercial Fisheries Occurring in the Middle and Lower Cape Fear River , North Carolina*.

Harrison, J., Pickle, A., Vegh, T., & Virdin, J. (2017). *NORTH CAROLINA'S OCEAN*

*ECONOMY*.

Herstine, J., Dumas, C., & Whitehead, J. (2007). *Report to the North Carolina Sea Grant Program , the North Carolina Department of Environment and Natural Resources ( NCDENR ) and the North Carolina Beach , Inlet and Waterway Association ( NCBIWA ) on the Economic Impacts and Economic Benefits of Recrea*.

Jondrow, J., Knox, C. A., Materov, I. S., & Schmidt, P. (1982). ON THE ESTIMATION OF TECHNICAL INEFFICIENCY IN THE STOCHASTIC FRONTIER PRODUCTION FUNCTION MODEL. *Journal of Econometrics*, *19*, 233–238.

Kirkley, J. E., Squires, D., & Strand, I. E. (1995). Assessing Technical Efficiency in Commercial Fisheries : The Mid-Atlantic Sea Scallop Fishery. *Amer. J. Agr. Econ.*, *77*(August).

Kumbhakar, S. C., & Lovell, C. A. K. (2000). *Stochastic Frontier Analysis*. CAMBRIDGE UNIVERSITY PRESS.

Lew, D. K., & Larson, D. M. (2012). Economic Values for Saltwater Sport Fishing in Alaska : A Stated Preference Analysis Economic Values for Saltwater Sport Fishing in Alaska : A Stated Preference Analysis. *North American Journal OfFisheries Management*, *32*, 745–759. https://doi.org/10.1080/02755947.2012.681012

Lucente, J. E., Gabriel, T., Davis, G., Wellington, C., Lucente, J. E., Gabriel, T., … Lichtkoppler, F. (2012). Ohio's 2010 Lake Erie Charter Fishing Industry. *Fisheries*, *37*(July), 532–541. https://doi.org/10.1080/03632415.2012.742805

NOAA. (2018). Fisheries Economics of the United States 2016, (December).

Ozkan, B., Ceylan, R. F., & Kizilay, H. (2009). A Review of Literature on Productive Efficiency in Agricultural Production. *Journal of Applied Scienes Research*, (January).

Poe, G. L., Lauber, T. B., Connelly, N. A., Creamer, S., Ready, R. C., & Stedman, R. C. (2013). Net Benefits of Recreational Fishing in the Great Lakes Basin : A Review of the Literature. *HDRU*, (13).

Rabbani, G., Khan, A., Islam, M. S., & Lucky, R. Y. (2017). Technical Efficiency of the Setbag Net Fishery in Bangladesh: An Application of a Stochastic Production Frontier Model. *The Agriculturists: A Scientific Journal of Krishi Foundation*, *15*(2), 59–65.

Savolainen, M. A., Caffey, R. H., & Kazmierczak, R. F. (2012). *ECONOMIC AND ATTITUDINAL PERSPECTIVES OF THE RECREATIONAL FOR-HIRE FISHING INDUSTRY IN THE U.S. GULF OF MEXICO*.

Sharma, K. R., & Leung, P. (1999). Technical Efficiency of the Longline Fishery in Hawaii : An Application of a Stochastic Production Frontier. *Marine Resource Economics*, *13*, 259–274.

Steinback, S., & Brinson, A. (2013). *The Economics of the Recreational For-hire Fishing Industry in the Northeast United States The Economics of the Recreational For-hire Fishing Industry in the Northeast United States*.

White, E. M., Bowker, J. M., Askew, A. E., Langner, L. L., Arnold, J. R., & English, B. K. (2014). *Federal Outdoor Recreation Trends : Effects on Economic Opportunities October 2014*.