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TECHNICAL EFFICIENCY OF SMALL SCALE FISH FARMING IN KIAMBU COUNTY

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DECLARATION

This is my original work and has not been presented for a degree award in any other university.

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DEDICATION

To my wife Violah and son Ian. You are my encouragement.

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ABSTRACT

Fish production systems in Kenya are still under developed with the yields hardly exceeding 1.04kg/m^2/year. The farmers in the Country are reported to be producing between 0.05- 1.04kg/m^2/year as compared to 3 to 5kg/m^2/year that the Fisheries Research Institutions recommend. This necessitated analysis of the level and determinants of technical efficiency in small scale fish farming in Kiambu County. A structured questionnaire was administered to a total of 94 small scale fish farmers that were randomly selected from six sub-counties out of the 12 sub counties of Kiambu County. A Cobb-Douglas stochastic production function was used to estimate the level of technical efficiency using Maximum Likelihood Estimation method. The predicted farm specific technical efficiency ranged between 0.1847 and 0.9537 with a mean of 0.4115. The study revealed that fish feed, size of the pond and fertilizer application were statistically significant in the production of fish in the study area. Based on these findings the farmers needs to increase the size of the fish ponds, access quality fingerlings, fish feed and fertilizer in the right proportions. The age of the farmers, education level, farming experience and access to extension services affected technical efficiency negatively. On the other hand household size and access to credit services influenced technical efficiency positively. Male operated fish farms were found to be more technically efficient than female run farms. The government needs to improve extension coverage to many farmers to address simple farming anomalies such as excess utilization of feed and inaccessible yield improving technologies. Policy should be suggested to be directed to encourage the entrepreneurs in fish farming to access credit facilities to improve on their fish farming. The government should also encourage the most educated and young population to take up fish farming husbandry and not leave it to the old age farmers.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

FAO	Food Agricultural Organization
ERS	Economic Recovery Strategy
PRSP	Poverty Reduction Strategy Paper
GOK	Government of Kenya
ESP	Economic Stimulus Programme
MT	Metric Tonnes
HA	Hectares
NPV	Net Present Value
IRR	Internal Rate of Return
SFA	Stochastic Frontier Analysis
SPF	Stochastic Production Frontier
DFA	Deterministic Frontier Analysis
MOLFD	Ministry of Fisheries Development
MLE	Maximum Likelihood Estimate
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
ADP	Agricultural Development Programmes
LGAs	Local Government Areas
GOK	Government of Kenya

OPERATIONAL DEFINITION OF TERMS

Efficiency	measure of how well resources are used to produce a certain level of output
Inputs	resources required to produce output (kgs of fish)
Output	kilograms of fish harvested by the farmer
Pond	area for producing or rearing fish
Fingerlings	seed of fish or young ones of fish
Inefficiency	inability of the farmer to produce the output as it should be.
Aquaculture	the farming of fish, aquatic organism mollusks and crustaceans in controlled environment

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The growing human population and reports of large numbers of malnourished people especially in the developing countries have made the need for food production a major worldwide matter of concern. It is estimated that about 870 million people in the world do not have adequate access to food and 852million of these are in developing countries (FAO, 2012). Most of these countries are characterized by low economic growth, low agricultural production, recurring political upheavals, persistent drought, environmental degradation and severe poverty. Given this scenario, it's imperative to focus on new ways of providing the people with alternative means of getting food sufficiency. The three main groups of human activities that contribute to food production are: agriculture, aquaculture and fisheries.

In Kenya, fisheries sector plays a significant role in the social and economic development through the sector's positive contribution to employment creation, revenue generation and food security – all of which are crucial for the attainment of the Millennium Development Goals and achievement of Kenya vision 2030(Fisheries Department, 2010).The national fish production comes from three major sources namely; Inland lakes and rivers (capture fisheries), Marine and fish farming. The global capture fishery is in a disaster with most of the world's fisheries being fully exploited and about one third of them being either depleted or overexploited (FAO, 2003). According to FAO (2004), deterioration of global fisheries is raising significant concern, mainly because an estimated one billion people, mostly in low-income countries, depend on fish as their primary source of protein. Similarly, Kenya's Lake Victoria which has been supplying 90% of total national fish production has been recording declining fish stock. The production from the lake declined from 143,908 metric tonnes in the year 2006 to 124,643 metric tonnes in year 2013(Fisheries Department, 2011; Government of Kenya, 2014). This scenario calls for prudent management of the fish stocks in the natural sources by expanding fish production in the country through aquaculture.

Fish farming in Kenya started in 1900s when colonialists stocked trout in rivers between 1910 and 1912 for sport fishing (Vernon and Someren, 1960).The activity was seen as one of the ways of promoting protein food supply, creation of employment opportunities, and supplementing the capture fisheries in-terms of supply of fish, which currently is acutely threatened. Though aquaculture was introduced in Kenya at the beginning of the last century, the production has not picked up considerably considering the existence of great potential of fish farming in the country (Gitonga, Mbugua & Nyandat, 2004). The production of fish farming stood at 12,153 metric tonnes by the year 2010 having stagnated below 1000 metric tonnes for nearly ten years (Fisheries Department, 2012). The dismal performance was occasioned by the slow uptake of fish farming by many communities that were not traditional fish eaters as well as low-level extension services, lack of quality fingerlings, lack of information on fish farming technology and fish breeding practices and unknown investment return-rates (Manyala and Ngugi, 2004).

This situation was even made worse because the Kenyan fisheries sector had operated without a comprehensive policy and legal framework on fisheries since 1963. However fisheries production and management measures were from time to time mentioned in various policy documents. Fundamental among these include : The National Food Policy (1981 and 1994) in which the importance of fish as a nutritious food commodity was emphasized, the District Focus for Rural development Policy (1985) that required all districts to have fisheries presence irrespective of their fisheries potential, the Poverty Reduction Strategy Paper (PRSP) of 2001 that introduced a social responsibility and poverty reduction element into the fisheries agenda, the Economic Recovery Strategy (ERS) for wealth creation and employment (2003-2007)into which the PRSP evolved that recognizes the contribution made by fisheries to local incomes, subsistence and nutrition.

Other initiatives on fish farming in Kenya were geared towards using fish farming as a tool for poverty alleviation and food security, and were addressed through various project activities that included: pond construction and management, stocking rates trials, feed trials, integration of fish farming with other agricultural activities, brood stock management, seed quality and evaluation of growth performance of Nile tilapia and Catfish strains by the Fisheries Department. However these initiatives had limited impacts due to slow uptake of fish farming by farmers emanating from lack of information on fish farming technology and breeding practices of fish. This is exemplified by the fact that in the year 2010 there were only 4,742 fish farmers in Kenya with 7,471 ponds producing 12,153metric tonnes of farmed fish (Figure 1.1).

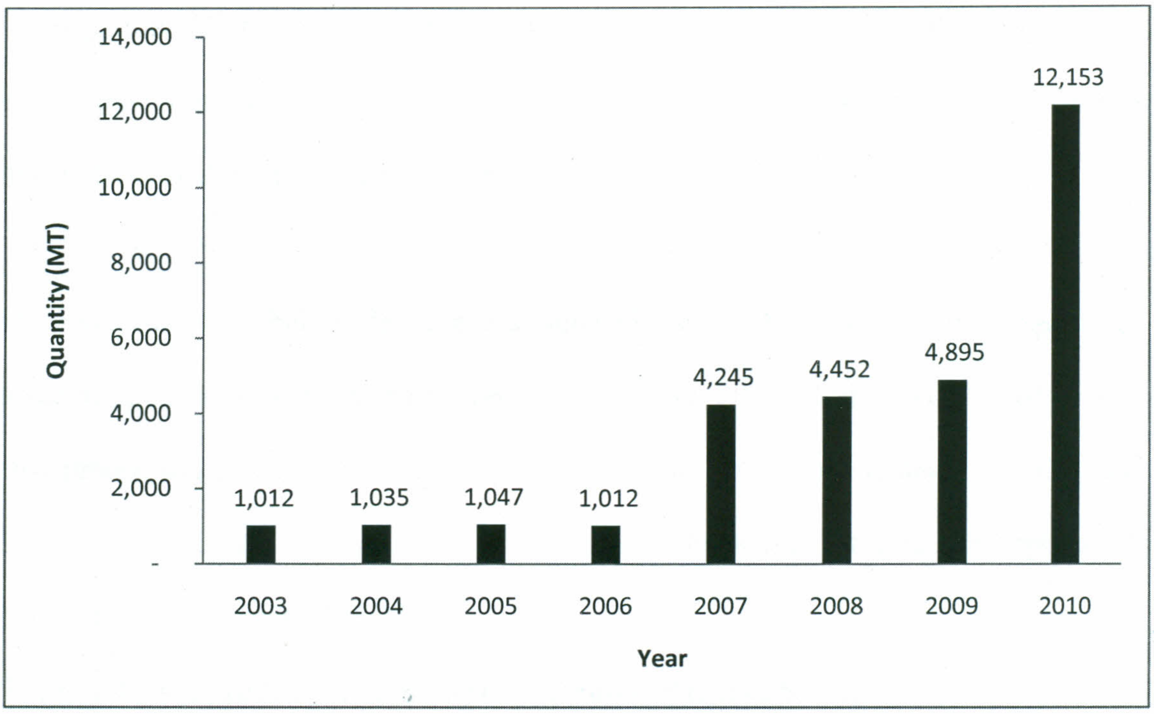

Figure 1.1: Aquaculture production in Kenya from the year 2003-2010

Source: Fisheries Statistical Bulletin, (2012)

The figure shows that production from aquaculture remained relatively low for the seven years (2003-2009). However with the introduction of Economic stimulus programme in 2009 the output from fish farming improved to above 12,000metric tonnes. According to Fisheries Department, the contribution of farmed fish at that time was just about 8% of the National Fish Production in Kenya.

Fish farming received a major boost in the year 2008 when the government identified it as one of the activities to be funded in the Medium Term Expenditure Framework (MTEF) budget of the year 2009 through the Economic Stimulus Programme (ESP). The implementation of this programme saw the increased hectares of land under fish farming from 722 hectares to 14,076 hectares (G.O.K, 2012). The output of fish farming during this period increased from 4,245 to 21,487 metric tonnes accounting between 3 and 16% of total domestic fish production in this period (G.O.K, 2012).

However on a global scale Kenya's aquaculture production is still insignificant accounting for 0.09% of the world production (FAO, 2012; Rothuis *et al.,* 2011). The fish production has not been able to meet the ever increasing demand for fish and fishery products in the country which has always been met through the importation from other countries (table 1.1).

Table 1:1 Fish production and import volumes of fish in Kenya

Year	**1961-1970**	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2010**
Yearly average Production (MT)	24,846	37,368	117,294	188,018	143,662
Annual average Import (MT)	2,230	3,878	6,080	8,441	16,244

Source: FAO Fisheries Statistics, (2011)

The table shows that the yearly average fish production in the country increased from 24,846 to 188,018 metric tonnes then declining to 143,662 metric tonnes. On the other hand annual average import of fish steadily increased from 2,230 to16, 244 metric tonnes .This shows an increasing supply gap in Kenya meaning consumption of fish is outpacing production. These calls for attention either through improved production techniques and attain self-sufficiency or continue meeting the deficits through importation. The second option is not attainable in the long run considering the fact that foreign exchange is limited in Kenya which is still relying on importing other essential commodities like drugs and capital goods. To address this issue of increasing demand the Kenya government stepped up efforts to increase production of fish by extensively promoting fish farming in high potential areas.

Kiambu County in central Kenya was identified as one of the fish farming potential areas because of its climatic conditions that are suitable for fish farming. The county is densely populated with majority of the inhabitants owning less than an acre piece of land (G.O.K, 2009)

Fish farming can easily be integrated with other agricultural activities since it requires a small area to construct the fish pond. Similarly there were reports that coffee and tea which had for a long time been the main source of income for the region were faced with international marketing challenges and farmers were contemplating uprooting the crops. Fish farming was seen to be one of the ways of diversifying the economic activities, employment creation, and protein food supply in the county. According to Fisheries County Statistical data of 2011 and 2012, Kiambu County produced 1217 and 1336 metric tonnes of fish respectively. There is indication of high aquaculture production in Kiambu region if only the challenges such as lack of prerequisite information on aquaculture, affordable credit facilities, inadequate supply of quality fish seed, extension support, lack of comprehensive policy on aquaculture, lack of capacity to explore market forces, as well as the presence of inefficiency are overcome(Mbugua, 2008). Predominantly, the level of inefficiency of utilization of available resources for fish farming has remained an unanswered question in the quest for increased fish production in Kiambu County. It is against this background that the present study was undertaken to examine the factors influencing technical efficiency of fish farming in Kiambu County.

1.2 Statement of the Problem

Kenya imports a lot of fish and fishery products, for instance a total of 16,244 metric tonnes of fish and fishery products were imported between 2003 and 2010 (FAO, 2011). The increasing demand is largely related to people shifting from animal protein to fish protein and increasing tourism activities in the country (FAO, 2010).

Fish farming in Kenya is carried out in earthen ponds measuring $300m^2$; the productions in these ponds hardly exceed $1.04kg/m^2/year$ which is inadequate to match the demand of fish in the country (Fisheries Department, 2012). To reduce the deficit, the government supported fish farming in all fish production potential areas of the country through the government funded Economic Stimulus Programme (ESP) and Economic Recovery, Poverty Alleviation and Regional Development programme (Fisheries

Department, 2010). In Kiambu County, this promotion was mainly done through demonstrations, farmer trainings, provision of fingerlings and credit to farmers.

Despite the extensive promotion of fish farming, the production has not changed significantly. In the year 2011 and 2012, Kiambu had a total of 4015and 4273 ponds producing 1217 and 1336 tonnes of fish worth Ksh 288million and Ksh 311million respectively (Fisheries Department, 2012). The County statistical data of 2013 shows that Kiambu County produced 2,820 MT which is 6 percent of the total fish produced in Kenya compared to potential of producing 10 to 15 percent of the total national production. The farmers in the County are reported to be producing between 0.05-1.04kg/m^2/year as compared to 3 to 5kg/m^2/year that the Fisheries Research Institutions recommend (Fisheries Statistical Bulletin, 2012).

This therefore means the increasing output of fish being witnessed in Kenya can be attributed to the increased number of hectares under fish farming but not improved fish pond productions. Studies have been done on efficiency in livestock and crops production in Kenya and many have dwelt on the efficiency on crops and none has dwelt on fish farming. (See for instance Kuria *et al.*, (2003), Wambui, 2005, Ngeno *et al.*, (2011), Njeru, 2010). This study therefore seeks to fill this gap by determining the level of technical efficiency among the fish farmers in the county and analyze the factors affecting the technical efficiency.

1.3 Objectives of the study

The general objective of this study is to analyze the level of technical efficiency among the small scale fish farmers in Kiambu County.

Specifically, the study seeks to:

(i) Estimate the level of technical efficiency among the fish farmers in Kiambu County.

(ii) Analyze the determinants of technical efficiency in the fish farming enterprise in Kiambu County.

1.4 Research Questions

(i) What is the level of the technical efficiency among the small scale fish farmers in Kiambu County?

(ii) What are the determinants of technical efficiency of small scale fish farming in Kiambu County?

1.5 Significance of the study

Understanding the factors that determine technical efficiency of the small scale fish farming can enable improvement in efficiency and consequently the profitability of fish farmers and achieving self-sufficiency in food protein supply. To achieve an economic optimum output and thus profitability, resources have to be optimally and efficiently utilized. An efficient fish farming industry will not only help to ease the pressure in the fishing on the inland lakes and rivers but also create employment opportunities to Kenyans and improve the revenues to the government. Examination of technical efficiency of the fish farming will make it possible for fishery managers to determine to what extent they can raise productivity of aquaculture by utilizing the existing resource base and available technology. Further, the findings of this study will add to the current body of knowledge on the technical efficiency of small scale fish farming.

1.6 Scope of the study

This study will focus on examining the level of technical efficiency, factors affecting the technical efficiency of small scale fish farmers in Kiambu County since its one of the greatest production potential areas due to its favorable geographical features. The study will use structured questionnaire to collect data from the fish farmers on the production information, market information and demographic information. The technical efficiency will be measured in the twelve sub counties of Kiambu over the period 2009- 2012. This is the period when the government supported the fish farming through the Economic Stimulus Programme.

1.7 Organization of the study

The remaining part of this proposal is structured as follows; Chapter two presents a literature review addressing the various aspects of efficiency in production and how they are inter-linked as well as the measurement of technical efficiency. It outlines past studies relating to efficiency of production. Chapter three presents a theoretical model and proceeds to outline an empirical model for technical efficiency and the factors that influence the technical efficiency. It concludes with a description of the data that will be used in the study, including the source and how they will be collected. Chapter four presents the data and discusses the empirical findings of the study while Chapter five gives the summary of the findings, conclusion and policy implications of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews relevant literature on efficiency. It presents a review of theoretical literature, the techniques of efficiency measurement and empirical literature. The final section presents determinants of technical efficiency and overview of literature.

2.2 Theoretical Literature

This section discusses theories of production, concept of production functions, technical efficiency and its measurement.

2.2.1 Scientific Management theory

According to the scientific management theory, the occupations involved in the design and fabrication of products were gradually split into more and more specialized professions (division of work). One of its first advocates was Scottish economist Adam Smith. In the book The Wealth of Nations (1776) Smith pointed out how specialization tends to develop skill, dexterity, and innovations. Moreover, it saves the time lost in changing from one kind of work to another. To this list of blessings English mathematician Charles Babbage (in the book On the Economy of Machinery and Manufacturers, 1832) added that dividing the task into short operations allows paying lower wages for the easier tasks. In 1913, Henry Ford put the work division theory in practice and introduced an assembly line in his car factory, thus reducing the time to assemble a car from 12 hours and 28 minutes to one hour and 33 minutes.

According to the theory of scientific management each supervisor and manager is expected to have a total view on the process of fabrication, define its objectives and steer daily work so that the targets are met. The limitation of the theory is the idea of looking at production only from labour point of view. From economics, production encompasses quite a number of variables hence this theory is not applicable for the current study.

2.2.2 Neoclassical Production Theory

Neoclassical theory argues that Profit is determined by the level of the marginal productivity of capital, and the wage of workers is determined in a similar way by the marginal productivity of labor. Therefore if a union succeeds in raising the workers' wage, the inevitable result will be unemployment. In tandem with this new theory of wages and profits Pareto first dismissed the theory of Utilitarianism which called for redistributing income, and then developed a new definition of economic efficiency to replace it. According to Pareto's definition, the higher union wage results in economic inefficiency. Although entirely different from Ricardo's theory of profits and wages, the neoclassical theory of profits and wages is an application of another of Ricardo's theories that of land rent, and this is how neoclassical economics got its name. According to Ricardo, parcels of land differ in their fertility. The most fertile land is put into production first, and as agricultural production expands less and less fertile parcels are added; the rent for less fertile parcels is lower than the rent for more fertile land.

Neoclassical economists argue that the process of adding labor and capital when industrial production is expanded is similar. As industrial production expands, additional workers are hired (while the quantity of capital is held constant) and, exactly as the fertility of additional units of land in agriculture falls, neoclassical economics assumes that the productivity of each additional worker, which is her marginal product, diminishes. Neoclassical economics assumes that the employer hires workers one by one. When she considers whether to hire an additional worker she compares the value of that worker's marginal product to the wage. As long as a worker's value of marginal product exceeds the wage, the worker is hired. But because the marginal product is diminishing, eventually so many workers will have been hired that the value of the marginal product of an additional worker would be less than the wage. At this point the hiring will stop. Of course, if at this point the wage rate were raised, some workers would get fired, because the value of the marginal product of at least some workers would be below the new wage. Thus, if unions push the wage higher, some workers would become unemployed, a situation that is not only painful to these workers but is also Pareto inefficient.

The process of hiring capital is exactly the same. A unit of capital is added when the value of the marginal product of capital exceeds the rental price of capital and the process stops when, because of the decreasing marginal productivity of capital, the value of the marginal product of capital becomes lower than the rental price. This theory looks at production broadly in terms of profit and cost which the current study in not concerned with and hence the theory is not applicable.

2.2.3 The Classical Production Theory

Classical economists postulated the identical production function, which can be written as $Y = f(K, L, N, S)$ which means that output depends on the stock of capital, labour force, land and the level of technology. In the generalized classical growth model

'Land' is taken as "the supply of known and economically useful resources" and this seems like the right thing to do as it is not the amount of cultivable land and its fertility that determines the national output but the total supply of known and usable natural resources.

Most of the other classical economists, except for Adam Smith, seem to believe that the production function is linear and homogeneous, which implies that it has constant returns to scale meaning that on doubling the quantities of all the factors of production output would double. Adam Smith, on the other hand, believed in increasing returns to scale on account of improved division of labour. In case the term land is restricted to cultivable land only, the supply of which is a fixed amount, then the question to be answered would be as to how the output would respond to an increased supply of labour with a fixed supply of land. This theory is relevant to the study and will be relied heavily on the study mainly the production function.

2.2.4 The Classical Production Function

A production function (also commonly referred to as the production frontier) is often used to illustrate the technical relationship between inputs and outputs in the production process. The production function represents the maximum level of output attainable from alternative input combinations (Coelli *et al.,* 2005). The classical production function (assuming only a single output is produced from various inputs) can be specified as:

$q = f(x)$ .... (2.1)

Where q represents output and $x=(x_1, x_2 \ldots x_N)'$ is an Nx1 vector of inputs used in the farm.

The function f (.) is the production frontier and equation 2.1 gives the upper boundary of T. Given the input x, the maximum production output q=f(x) can be achieved. In the form of maximization the production frontier is expressed as:

$f(x)=\max\{q : T(x, q\}\geq 0$..2.2.

The production frontier serves as the standard against which to measure technical efficiency. It should contain only the efficient observations. It's assumed in production theory that the production function has the following properties: No negativity: the value of f(x) is a finite non-negative, real number. Weak essentiality: the production of positive output is impossible without use of at least one input. Non decreasing in x (monotonicity): Additional units of an input will not decrease output.ie if $x^0 \geq x^1$ then $f(x^0) \geq f(x^1)$. If the production function is continuously differential monotonicity implies all marginal products are non-negative. Concave in x: any linear combinations of vectors x^0 and x^1 will produce an output that is no less than the same linear combinations of $f(x^0)$ and $f(x^1)$.

Nonetheless, in practice these properties are not exhaustive and may not be universally maintained. For instance, excess usage of inputs might result in input congestion, which relaxes the monotonicity assumption. Also, a stronger essentiality assumption often applies in cases where each and every input included proves to be essential in a production process (Coelli *et al.,* 2005). Furthermore, flexibility of a production function (i.e., no restrictions imposed except theoretical consistency) is another desirable feature in order to allow data to capture information on critical parameters.

2.3. Technical Efficiency

A producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if reduction in any input requires an increase in at least one other input or a reduction in at least one output Koopmans, (1951). Thus a technically inefficient producer could produce the same outputs with less of at least one input or could use the same inputs to produce more of at least one output.

Farrell (1957) introduced measure of technical efficiency. His measure of technical efficiency is defined as one minus the maximum equiproportionate reduction in all inputs that still allows continued production of given inputs. A score of unity indicates technical efficiency because no equiproportionate input reduction is feasible and a score less than unity indicate technical inefficiency. According to Farrell (1957), measure of technical efficiency can be obtained by using input and output without introducing prices of these inputs and outputs.

2.3.1Farrell's Measure of Efficiency

According to Farrell (1957), measure of technical efficiency can be obtained by using input and output quantity without introducing prices of these inputs and outputs. Technical efficiency can be categorized into three; scale efficiency, allocative efficiency and pure technical efficiency. However this study will be limited to focusing only on technical efficiency.

In the figure 2.2 below, observation A uses two input factors to produce a single output. SS' is the efficient isoquant estimated with an available technique. Point B on the isoquant represents the efficient reference of observation A. the technical efficiency of a production unit operating at A is most commonly measured by the ratio:

TE = OB/OA,

This is equal to one minus BA/OB. It will take a value between zero and one, and hence an indicator of the degree of technical inefficiency of the production unit. A value of one indicates the firm is fully technically efficient. For example the point B is technically efficient because it lies on the efficient isoquant. If the input price ratio, represented by the slope of the isocost line WW' in the figure 2.2 is also known, allocative efficiency may also be calculated.

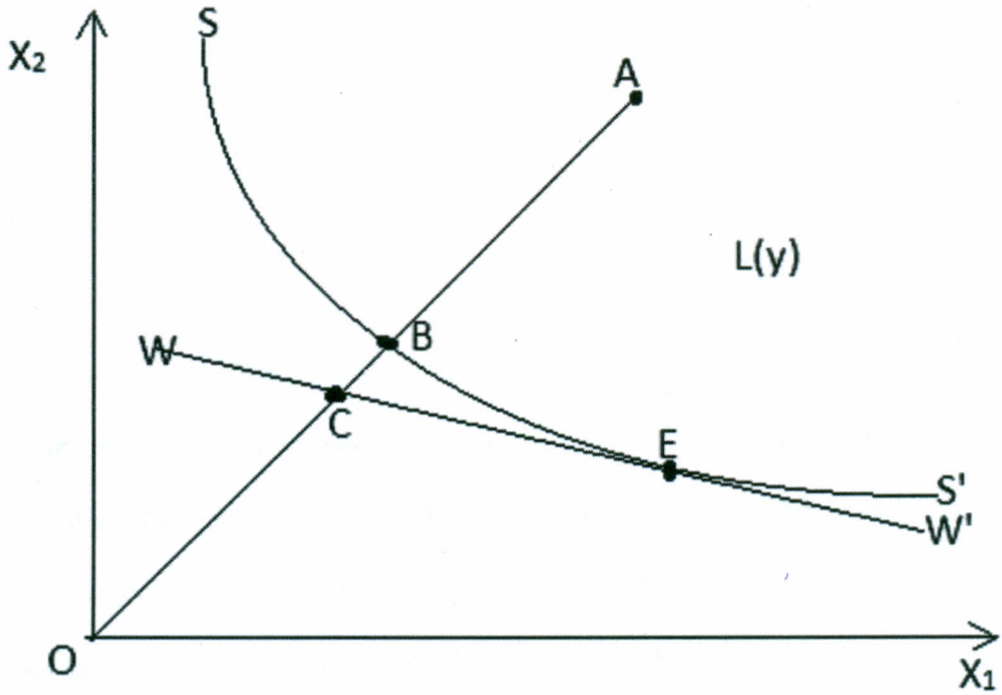

Figure 2.3 technical and allocative efficiencies

Source: Farrell, (1995)

The allocative efficiency (AE) of a PU operating at A is defined to be the ratio:

AE= OC/OB

Since the distance CB represents the reduction in production cost that would occur if production were to occur at the allocative and technically efficient point E, instead of the inefficient point B.

The total economic efficiency (EE) is defined to be the ratio:

EE=OC/OA

Where the distance CA can also be interpreted in terms of a cost reduction. The product of technical efficiency and allocative efficiency measures provide the measure of overall economic efficiency.

2.4 Empirical literature

Weir (1999) and Weir and Knight (2000) using the stochastic frontier analysis studied the impact of education externalities on production and technical efficiency of farmers in rural Ethiopia. They found evidence that the source of externalities to schooling is in the adoption and spread of innovations that shift out the production frontier. Mean technical efficiency of cereal crop farmers ware 0.55, for instance a unit increase in years of schooling increases technical efficiency by 2.1 percentage points. One limitation of the Weir (1999) and Weir and Knight (2000) is that they investigated the levels of schooling as the only source of technical efficiency. However the current study studied several variables which could be affecting technical efficiency.

Kuria *et al.,* (2003) examined the technical efficiency associated with rice production in Mwea Irrigation Scheme in Kenya using the stochastic frontier method of estimation. The study compared two groups of farmers, one group consisting of farmers growing a single crop of rice in a year and the other growing a double crop of rice in a year. Empirical results indicated that farmers growing a single crop of rice were more technically efficient than those growing a double crop of rice in a year. Farmer's education level and farming experience as well as availability of credit and extension facilities were found to be significant variables that influence technical efficiency. However the assumption that farmer's specific characteristics as well as institutional factors are the only one causing technical inefficiency effects may be misleading.

Okechi(2004) evaluated the profitability assessment of Catfish Fish farming in Lake Victoria Basin using the Net Present Value (NPV), Internal Rate of Return (IRR), payback period and Debt Service Coverage Ratio. A sensitivity analysis on stocking density, survival rates, cost of feed, cost of fingerlings and sales price was also conducted. The findings of the analysis indicate that catfish farming is financially feasible. The results obtained indicate a positive NPV and acceptable IRR and a payback period of five years. A debt service coverage ratio of more than 1.5 was obtained thus indicating that the cash flow is adequate. Sensitivity analysis on price, sales and investment obtained indicated that the enterprise was highly sensitive to stocking density, survival rates and sales price but less sensitive to costs of fingerlings and costs of feed used in the production. The study also indicated that it was also more economical to operate 12 ponds than one pond due to gains from economies of scale. The major limitation of this study is failure to use a proper method of analysis i.e. parametric (SFA) or non-parametric (DEA) hence the results may not have capture all the variables for the study.

Kareem *et al.*, (2008) applied stochastic frontier approach to estimate the technical, allocative and economic efficiency among the fish farmers using concrete and earthen pond systems in the Ogun State Nigeria. The results of economic efficiency revealed an average of 76% in concrete pond system while earthen pond system made as high as 84% economic efficiency level. The results of the analysis of the mean technical efficiency for both systems revealed that concrete pond system with 88% while earthen pond system was 89%. Similarly, the allocative efficiency results revealed that concrete pond system was 79 percent while earthen pond had 85%. The findings also revealed that pond area, quantity of lime used, and number of labour used were found to be the significant factors that contributed to the technical efficiency of concrete pond system while pond, quantity of feed and labour were the significant factors in earthen pond system.

Ng'anga *et al.,* (2010) using the stochastic profit frontier function analyzed the efficiency of sampled milk producing farmers in the Meru South District of Eastern Kenya. Using detailed survey data obtained from 27 milk producing farms, the study showed that profit inefficiency varied moderately among the sampled farmers. It ranged from 26 to 73% with a mean of 60%. The mean level of efficiency indicates that there exists some room to increase profit by improving the technical and allocative efficiency. The farm specific variable used to explain inefficiency indicates that those farmers who have a higher level of education, more experience and larger farm size tend to be more efficient while those who are aged tend to be less efficient. This study further observed that level of education, experience, and the size of the farm influenced profit efficiency positively while profit efficiency decreased with age. Failure to include the extension services was the major drawback of this study.

Njeru (2010) examined the factors influencing technical efficiency in wheat farming in Kenya using a stochastic frontier production function in which technical inefficiency effects were assumed to be functions of both socioeconomic characteristics of the farmer and farm-specific characteristics. The paper used random sampling to interview

160 farmers comprising 97 large-scale farmers and 63 small-scale farmers. The results revealed existence of significant levels of technical inefficiencies in wheat production, especially among the large-scale farmers. The study found that the magnitude of technical efficiency varied from one farmer to another and ranged from 48.9% to 95.1%, with a mean of 87.2%. This implied that farmers lost close to 13% of the potential output to technical inefficiencies. There was variation depending on the size of farm with small-scale farmers attaining higher technical efficiency than the large-scale farmers. The main factors that influenced the degree of inefficiency were education levels, access to credit, and ownership of the capital equipment.

Awoyemi, &Taiwo (2011) using descriptive statistics method Analyzed the Profitability of Fish Farming among Women in Osun State, Nigeria. The simple random sampling technique was employed in selecting 62 farmers drawn from the sampling frame obtained from the list of Agricultural Development Programme (ADP) contact farmers in the four Local Governments Areas (LGAs) of Egbedore, Olorunda, Ede South and Ife Central, which made up the study area. The study concluded that fish production in the study area is economically rewarding and profitable. The limitation of the study was failure to use the parametric method to analyze the profitability of fish farming. The parametric method is capable of capturing the factors which are beyond the of farmers control, however this study will use the stochastic frontier technique.

Ng'eno *et al.*, (2011) applied the Cobb-Douglas stochastic production function to determine the technical efficiency among the bulrush millet producers in Kenya South

Rift Valley. The study sampled smallholder farmers in Narok, Bomet and Kericho counties of Kenya .The bulrush millet production efficiency varied widely among farmers, with Bomet varying from 11 to 83%, Kericho, 16 to 89% and Narok, 17 to 88% and averages of 72% for Bomet and 44% for Kericho and Narok. Farmer's education, hectares of land, seasons of planting and farming experience as well as availability of credit facilities were the variables of the study. The study however did not include extension services and also failed to estimate the elasticities of the socioeconomic variables to ascertain their effects hence the results are inconclusive.

Theodora *et al.*, (2011) assessed the profitability analysis of small scale aquaculture enterprises in Central Uganda using descriptive statistics and ordinary linear regression method. The data were collected by use of a questionnaire administered to 200 small scale fish farmers in the three major fish farming districts of Mpigi, Mukono and Wakiso in central Uganda. The study showed that farming experience, fish price, record keeping, feed cost and volume of fish harvested were the most influential factors in explaining profitability. The key factors identified as hindrances to aquaculture development in the region included predators, unavailability of credit facilities, expensive feeds, shortage and poor quality of fingerlings. However the study did not use econometric method of analysis to show the extent of the relationship between output and inputs or even the degree of influence of factors that affect the profitability of aquaculture.

From so many other studies it's very clear that there are quite a number of factors that interact to influence technical efficiency of farming activities. It's also clear that the most preferred method of estimation by many researchers is the stochastic frontier approach which this study intends to use.

2.5 Determinants of Technical efficiency

Parikh *et al.*, (1995) suggested that several factors may impact agricultural farming; farmer's level of education, number of working animals, and credit per acre and number of extension visits. Coelli and Battese (1996) identified three factors; the number of years of schooling, land size and age of farmers being positively related to technical inefficiency. Wang *et al.*, (1996) concluded that a household's educational levels, family size and per capita net income are positively related to productive efficiency, but off-farm employment is negatively related to efficiency.

Tadesse and Krishnamoorthy (1997) reported significant differences in technical efficiency across farm size groups, with paddy farms on small- and medium-sized holdings operating at a higher level of efficiency than large farms. Seyoum *et al.,* (1998) found technical inefficiency to be a decreasing function of farmers' education and hours of extension visits to farmers participating in the modern technology project. He further suggested that Education does not significantly affect the efficiency of farmers using traditional farming methods.

Binam *et al.,* (2004) concluded that access to credit, social capital, and distance from the road and extension services are important factors explaining the variations in technical efficiencies. The current study will adopt the SFA technique and will determine the effects of the socio-economic factors on technical efficiency (i.e. number of years spent in schooling, extension visits, household size, farming experience, age of the farmer). On the technological point of view; number of fingerlings, labour, feeds, pond size and amount of fertilizer used will be examined.

2.6 Overview of Literature

The review of literature confirmed that technical efficiency can be estimated using either parametric (Stochastic Frontier Analysis) or non-parametric (Data Envelopment Analysis) techniques. DEA is used to measure the relative efficiency of decision making units by calculating the economic efficiency of a given organization relative to the performance of other organizations producing the same good or service, rather than against an idealized standard of performance. Some of the problems associated with using DEA technical efficiency include; difficulty in separating the independent variables as inputs or determinants of efficiency, the inputs and determinants may be correlated thus cause biased and inconsistent estimates, unobservable determinants of efficiency, such as management abilities. Stochastic frontier analysis technique was independently proposed by, Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977).

SFA is widely used in the measurement of technical efficiency. One of its strongest points is the ability to take into account the random error and its ability to estimate standard errors which makes is possible to test hypotheses and construct confidence intervals for the estimated efficiency levels. SFA is also ideal for production processes that are stochastic in nature such as fishery production. According to Coelli *et al.* (1998), the stochastic frontier is considered more appropriate than DEA in agricultural applications especially in developing countries where the data is likely to be influenced by measurement errors and the effects of weather conditions and diseases. This study will, therefore, use SFA in the analysis of technical efficiency of the fish farming in Kiambu County.

Empirical studies suggest that technical efficiency in fish farming depends on the farmer's level of education, access to credit and number of extension visits, labour, seeds, age of the farmer fertilizer and size of the land(Parikh *et al.* (1995); Coelli and Battese (1996);Wang *et al.* (1996).

Although the literature suggests a number of explanations to this phenomenon, there have not been any recent empirical evidence studies in Kenya which can validate these hypotheses.

There are many studies on technical efficiency especially in Asia, Europe and many African countries (see for instance (Kumbhakar, (1994), Tadesse and Krishnamoorthy (1997),Inoni (2007),Sharma and Leung (2000), Awoyemi, and Taiwo (2011), Pascoe et al., (2011). However in Kenya there are only few such studies on technical especially on crops and livestock and few on fish farming (see for instance Ng'anga *et al.*, (2010),Njeru (2010), Ng'eno *et al.*, (2011). Some of the studies used descriptive methods and did not use parametric or non-parametric methods of analysis (see Okechi (2004)). This shows a glaring gap which the study intends to fill.

The available studies in Kenya on efficiency have concentrated on crops and livestock (see for instance; Ng'anga *et al* (2010); Njeru (2010); Ng'eno *et al* (2011). Some of the studies used descriptive methods and did not use parametric or non-parametric methods of analysis (see for instance, Okechi, (2004)). This study intends to analyze the level and determinants of technical efficiency in Kiambu using the stochastic frontier method of analysis.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents theoretical framework, empirical model and describes the research design in the study, meaning of variables used are described. The data sources and methods of data analysis are explained.

3.2 Research design

This study adopted a descriptive research design. The reason for the descriptive research design was to collect the data at a particular point in time and use it to describe the existing conditions in the field without manipulation. A descriptive study attempts to describe a subject, often by creating a profile of a group of problems, people, or events, through the collection of data and tabulation of the frequencies on research variables or their interaction as indicated by Cooper and Schindler (2003). Descriptive research portrays an accurate profile of persons, events, or situations. Descriptive design allows the collection of large amount of data from a sizable population in a highly economical way.

3.3Theoretical Model

The classical production theory specifies how outputs are most likely to change in response to changes in quantity of inputs given the technology. The stochastic frontier production function proposed by Aigner, Lovel and Schmidt (1997) and Meeusen and Van den Broeck (1977) is specified as follows:

$$Yi = Xi\beta + (Vi - Ui) \quad (1)$$

Where Y_i represent a firms output of the i^t sample farm, X_i is the vector of inputs used in the farm, while β are the parameters to be estimated, V_i is a random error having zero mean N (0, δu2) which is associated with random factors such as measurement errors in production and weather which the farmer does not have control over.

3.4 Empirical Model

Following Battese (1992) and Battese and Coelli (1995) models the stochastic frontier model was specified as follows:

$$Y_i = f(X_i; \beta) \exp (V_i - U_i) \quad (2)$$

Where i =1, 2…….n

Where Y_i = is the output of the ith farm, X_i is the K x 1 vector of the input quantities, $f(X, \beta)$ is an appropriate production function like Cobb Douglas or Translog, β is the coefficient vector of X_i, V_i is the random error having zero mean (associated with random factors like measurement error, weather, animal destruction) not under the control of farmers. $U_i$is a one sided error term called the inefficiency.

The Cobb Douglas production function for the fish farmers in the study area will be specified as follows:

$$LnY = \ln \beta_o + \beta 1 \ln X_1 + \beta 2 \ln X2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + V - U \quad (3)$$

Where:

ln= the natural logarithm

Y= total Quantity of fish harvested (kg), X_1 = Number of fingerlings, X_2 = Labour (man hours) ,X_3 = Feed consumed (kg), X_4 = Pond size (m^2), $X_{5=}$ fertilizer (kgs), βs is parameters to be estimated

V= are random variables which are assumed to be independent of U identical and normally distributed with zero mean and constant V variance N $(0, \delta^2 2)$.

U= account for technical inefficiency in production and is specified as:

$$U = \gamma_0 + \gamma 1R1 + \gamma_2 R_2 + \gamma_3 R_3 + {}_{\gamma 4}R4 + {}_{\gamma 5}R_5 + {}_{\gamma 6}R \quad (4)$$

Where: U = the inefficiency term, R_1= number of years spent in schooling, R_2= number of extension contact per session, R_3= household size, R_4= farming experience, R_5=age of the farmer

R_6=credit services accessed by the farmer.γ_0-γ_6 = estimated inefficiency model coefficients.

Technical efficiency of a given farm is defined to be the ratio of observed output (Yi) to the corresponding frontier output (Yi*) using the available technology and so the technical efficiency of the farm is denoted by;

$$TE = Y_i/Y_i^*$$

$$=f(X_i; \beta) \exp (V- U) \; / \; f (Xi ; \beta) \exp V = E[\exp (-u)] \quad (5)$$

For technical efficiency to occur exp V= 1 and U = 0 since exp (0) = 1. Thus TE has values that range between 0 and 1, with 1 defining efficient farms and 0 inefficiency. It should be noted that the larger the U the less the technical efficient the farmer.

3.5 Definition and measurement of the variables

Table 3.1 Definition of Variables

Variables	**Meaning**
Output (Y)	Total Quantity of fish harvested in a year by the farmer (kg)
Inputs fingerlings (X_1)	Number of fingerlings stocked in the fish ponds by the farmer
X_2	Amount of labour used in (man hours),
X_3	Feed consumed (kg),
X_4	The size of the Pond (m^2)
X_5	Fertilizer used by the farmer (kgs)
Socio-economic variables	
U	Inefficiency term
R_1	Gender of the farmer (1 if male and 0 if female)
R_2	Age of the farmer in years
R_3	Household size(in numbers)
R_4	Level of education(1= primary, 2=secondary, 3= tertiary, 4= university)
R_5	Farming experience in years
R_6	Access to extension services(1- if accessed and 0 if not accessed
R_7	Access to credit services (1 if accessed and 0 if not accessed

3.6 Study area

The study was conducted in Kiambu County. Kiambu County is one of the 47 counties in the Republic of Kenya. It's located in the Central Kenya and covers a total area of 2543.5km^{2}with 476.3 under forest cover with the human population of 1,623,282 according to the 2009 Kenya Population and Housing Census. The county has twelve sub-counties which act as administrative units of the county.

3.7 Data and sampling technique

The study followed a two-stage sampling technique. The first stage involved purposive selection of the six sub-counties as the administrative unit's. Within each sub administrative unit fish farming producing wards were purposively selected basing on their production potential. The fish farming extension officers were consulted to generate sampling frame. In the six administrative units a total of ninety four farmers were randomly selected and supplied with questionnaires.

3.8 Data collection procedure

Primary data was collected through field survey and household interviews using a structured questionnaire. The questionnaire was structured in such a way that the first part covers the socio-economic variables such as the age of the household head, size of the household, gender etc. The second part dealt with the factors of production such as, land, labour, seed (fingerlings), fertilizer and the last part will look at the collection of marketing information regarding where they buy their inputs and where they sell their output.

A well thought out questionnaire (Appendices 1) was designed to obtain crucial information about fish farming to address the objectives of the study. The research instrument had both closed and open ended questions that provided necessary checks to ensure correct answers were returned. Six research assistants from the area were employed in data collection and the researcher supervised and collected data.

3.9 Instrument Validity and Reliability

Research instruments were pretested to establish the validity of the instrument. This was to enable the instruments to be adjusted to reflect the demands of the study. The research instrument was pre-tested in Thika Sub County to ensure its validity and reliability. Questions that appeared redundant and misplaced were removed and those that the researcher felt were left out due to oversight were included. The instrument had a number of probing questions to ensure consistency of the information received. After data collection, field editing was done to ensure errors were corrected before leaving a given location. Data were entered in the excel sheet for them to be latter transferred to Frontier 4.1 programme for analysis

CHAPTER FOUR

EMPERICAL FINDINGS

4.1 Introduction

This chapter presents the information analyzed from the data collected during the study on the determinants of fish farming in Kiambu County. It also describes the results for each objective, hypothesis testing and technical efficiency estimates. The final section presents results for factors influencing technical efficiency for small scale fish farmers.

4.2 Summary statistics of Small Scale Farmers in Kiambu County

A number of socio-economic factors were considered for this study. They include age, gender, education level, household size, access to extension services, farming experience and access to credit services (Table 4.1)

Table 4.1: Summary Statistics of Small Scale Farmers in Kiambu County

Variable	Frequency	Percentage
Age (years)		
21- 30	5	5
31-40	11	12
41-50	21	22
51-60	32	34
61-70	18	19
71-80	4	4
81-90	3	3
Mean	53	
Std dev	13	
Gender		
Male	70	74
Female	24	26
Household size		
1-3	15	16
4-6	60	64
7-9	22	23
10-12	6	6
≥13	2	2
Mean	6	
Std dev	2.2	
Education		
Primary	29	29
secondary	45	48
Tertiary	17	18
University	4	4
Farming experience(years)		
1-2	37	39
3-4	36	38
5-6	21	23
Mean	3	
Std dev	2	
Access to Credit		
Yes	19	20
No	75	80

Source: Authors own calculations

The summary statistics for variables for small scale fish farmers in Kiambu County is shown in the Table 4.1 above. The mean age of the farmers was 53 years with the youngest farmer being 25 years old while the oldest being 87 years old. This implies that fish farming in the county is practiced by relatively middle aged farmers .This age category according to Kenyan employment laws represents retirement age. Nonetheless there is no age restriction in carrying out fish farming in the study area as long as the farmer is willing and has the minimum land for pond construction. The majority(75%) of the fish farmers were males which implies that women are yet to take up fish farming perhaps due to the past land ownership regime that disadvantaged women.

Education of the farmer plays a critical part in decision making and accessing essential production information which is normally in English. It helps farmers in gaining skills and adapts new technologies. The table shows that most (48%) of the farmers had secondary level of education, while 31%, 18%, and 3% of the fish farmers had primary, tertiary and university level of education respectively. This implies that most of the fish farmers in the county were fairly educated and this will facilitate the rate of adoption of fish farming technologies which has the potential of increasing productivity of the activity. Education level of more than 4 years has been reported to improve efficiency of farmers (Sharma and Leung, 2000, Lockheed et al., 1980).

In the less developed countries agriculture rely heavily on manual labour for production.

Household size therefore determines the number of persons available to provide labour for fish farming. This may be crucial during fish pond construction when human labour is highly demanded. In the study area, the average household size was 6 persons. Output of labour however, does not depend on the size but rather on its ability to engage in production. For example a family of six may comprise of school going children and infants. In that case, only two people in the household are engaged in production. Therefore relative size of a household does not automatically guarantee labour availability especially for school going children, but rather an indicator for potential labour availability.

The longer one stays on a particular occupation, the better that person becomes in terms of skills to accomplish tasks. A farmer, therefore, learns how to adapt to risks and uncertainty with experience. Therefore, experience plays a significant role in improving production. In this study, the average number of year spent on fish farming was 3 years. It could then be inferred that most of them entered the sector during the inception of economic stimulus programme in 2009- 2012. This findings confirms the findings of Kareem *et al*., (2008) that farmers with more experience would be more efficient, have better knowledge of climate conditions and market situations and are thus expected to run a more efficient and profitable enterprise.

The findings also revealed that majority (96%) of the farmers were accessing extension services mainly from the government. However 80% were not accessing credit services which could be attributed to inadequate information on the profitability of the fish farming enterprises in the county.

4.3 Determining Technical Efficiency of Small Scale Fish Farmers

This objective formed the main idea of the study, however, before this objective was analyzed, the first step was to test whether the small scale fish farmers were producing along the frontier level. This required carrying out test statistic for the mentioned hypothesis to have useful inferences.

4.3.1 Test Statistic

The first test concerned selection of the functional form of the model, whether a Cobb-Douglas or translog function was appropriate for data analysis. Secondly, testing whether inefficiencies exist or not. Lastly whether production is along the frontier, which is the main objective of the study. Testing for these hypotheses requires imposition of restrictions on the model or the functional forms (Battese and Coelli, 1995) and using the log likelihood values to compare outcome values with those provided in Kodde and Palm (1986).

The log likelihood (LL) test statistic compares the log likelihood values from the restricted model (LR) (Null hypothesis) and the unrestricted log likelihood (LU) model (the alternative). The value obtained is compared with the critical values in Kodde and Palm (1986) with the degrees of freedom equal to the parameters excluded in the unrestricted model. The appropriateness of the functional model was tested by estimating both the Cobb Douglas and the translog production functions. The null hypothesis (LR) was the Cobb Douglas log likelihood values because it is the restricted form of the translog function.

Table 4.2: Log likelihood test for hypothesis and functional forms.

Null hypothesis	(λ*)	Degrees of freedom	Critical values	Inference
H_o : βj=o for i≤j=1….5 (Cob-Douglas frontier)	0.43	8	15.51	Not rejected
H_o: Rm R1=R2…=R7 Farmers are technically efficient	15.85	8	15.51	rejected

Source: Authors own calculation

Results presented in Table 4.2 revealed that the null hypothesis was not rejected thus Cobb Douglas production function was considered to be the best represent the data. Esmeali, (2006), while estimating technical efficiency in Iranian Persian fishery similarly rejected a translog production function, while Hyuha (2006) rejected the null hypothesis. The null hypothesis was that the functional form had no inefficiency factors and the alternative had the inefficiency factors that included age, gender, household size, and level of education, fish farming experience, access to extension services, and access to credit services. The null hypothesis suggesting that the farmers were technically efficient was rejected and the alternative hypothesis that the farmers were technically inefficient is accepted.

4.3.2 Technical Efficiency of Small Scale Fish Farmers in Kiambu County

This section analyses technical efficiency of small fish farmers and presents their efficiency levels in table 4.3 below.

Table 4.3: Maximum Likelihood Estimates of the Stochastic Frontier Production Function for Small Scale Farmers.

Variables	Coefficient	t-ratio
Production model		
Constant	1.5708	1.5821*
Fingerlings	0.3375	0.5947
Labour	-0.062466	-0.07012
Feed	-0.6589	-4.1913***
Pond Size	0.2744	1.4974*
Fertilizer	0.7793	5.42268***
Diagnostic statistics		
Sigma squared (δ^2)	0.607028	5.75824*
Gamma (γ_m)	0.26604	0.756622
Log likelihood function	-109.128	
Log ratio	11.5365	

*statistically significant at 10%**statistically significant at 5%***statistically significant at 1%

Source: Authors own calculations

Table 4.3 above shows the maximum likelihood estimates of the stochastic frontier production function for small scale fish farmers. As shown in the Table 4.3, the estimated sigma squared (δ^2) of 0.607 was significantly different from zero at 10% level of significance. This indicated a good fit of the model and the correctness of the specified distributed assumption of the composite error term. The gamma (γ_m) value was 0.26604 though not significant at any level confirmed that farmers in the study area were not producing along the frontier level. Gamma (γ_m) is bound between zero and one (Battese, 1992). Where it is zero, inefficiency effects do not exist in the model and if it is one, inefficiency is significant and is not random. This means that the observed inefficiencies are related to farmer practice.

The upper part of Table 4.3 shows the maximum likelihood estimates of the production model. It indicates that feed consumed, pond size and fertilizer were significant at 1%, 10% and 1% respectively. However fingerlings and labour were not significant at any level. Furthermore labour had negative coefficient. The implication of the results is that the optimum level of labour utilization under the current scale of fish production in the study area had been reached. This is true considering the fact that the fish ponds were small hence may not have required a lot of manual work.

The coefficient of feed was negative and statistically significant at 10% level. This implies that increasing the amount of feed by 10% will reduce the output of fish by the same percentage. This result may be due to the fact that the more the farmers feed the fish daily with low quality feed, the less their output efficiency. These findings contradict the findings of Inoni (2007) who suggested that for fish to reach maximum market size, quantity and quality of feed must increase, holding other inputs constant.

According to Inoni (2007), improving the yield requires fast growing fingerlings of economically viable fish species, if the farmer is to maximize profit. Thus the positive coefficient of fingerlings may be attributed to the farmer's goal to realize the highest output from the resources employed in production. The coefficient of pond size was positive implying it affected positively the output of farmed fish. The positive and the significance level of pond size implied direct relationship between the variable and fish output. As the pond size increases given other inputs, fish output will increase. This is because the pond is one important variable upon which production in fish farming depends. This finding is consistent with the findings of (Nwosu *et al.*, 2012) who noted that the more the size of the pond increases the farmer's output increase.

Inoni (2007) opined that if other inputs are available to expand, the farmer will have to expand the size of his ponds if existing ponds are stocked to the maximum capacity. Fertilizer application positively affected the output of fish in the study area. This was shown by the positive coefficient of fertilizer and its significance level of 1%, the implication of the result meant if fish output is to be increased fertilizer usage should be increased.

4.3.4 Level of Technical Efficiency among the Small Scale Fish Farmers in Kiambu County

Table 4.4: Frequency Distribution of Technical Efficiency (%) in Small scale Fish Farming.

Range	Frequency	Percentage
11-20	2	2
21-30	18	19
31-40	31	33
41-50	27	29
51-60	10	11
61-70	4	4
71-80	1	1
81-90	0	0
90-100	1	1
Total	94	100
Mean TE (%)	41.15	
Minimum TE (%)	18.47	
Maximum TE (%)	95.50	

Source: Authors own calculations

The efficiency distribution Table 4.4 above shows that, efficiency of small scale fish farming is distributed across a wide range of frequency and no farmer has attained the frontier level of a hundred percent. The result indicated that about 2% of fish farmers are operating at 70% or more technical efficiency levels. Furthermore, about 17% of fish farmers are operating at a technical efficiency level of 50% or more. The result also suggests that for the technical efficiency level of less than 50%, there were about 83% of the fish farmers operating at same.

The predicted farm specific technical efficiency ranged between 18.47% and 95.37%. The average mean of the study was 41.15% which is below the frontier level. About 54% of the farmers are operating below the mean technical efficiency of 41%. This means that in the short run, there is room for increasing fish production by about 59% by adopting the new technology and techniques used by the best practiced fish farms.

The low levels could be related to low input usage as well as farm specific factors such as lack of specialized extension services and education level. Capacity for improving the existing technical efficiency level to that of the best farm in the country or fairly different level is possible. This is by placing emphasis on farmer education and extending targeted or specialized extension education which are considered low cost methods for attaining increased technical efficiency (Ellis, 2003).

4.3.5 Technical Efficiency Distribution and Household Characteristics

Table 4.5: Summary of technical efficiency by household characteristics.

Household characteristics		Technical efficiency Mean	Standard Dev	p value
Education level	Primary	35.17	1.65	0.813
	Secondary	44.59	1.93	
	Tertiary	41.8	2.59	
	University	55.13	7.39	
Extension	0	42.23	4.17	0.002
	1	40.58	1.2	
House Hold Size	1-5	46.62	1.89	<0.001
	6+	35.92	1.34	
Farming Experience	0-3	42.57	40.93	
	4-6	39.15	37.13	
Age	< 30	55.64	10.63	0.29
	30 – 49	40.8	1.5	
	50 – 69	40.02	1.51	
	70 +	40.81	7.91	
Credit	No	41.22	1.42	1
	Yes	40.88	2.93	
Gender	Female	41.25	2.29	0.81
	Male	41.12	1.52	

Table 4.5 above shows summary statistics of efficiency score by household characteristics (age, gender, household size, and level of education, fish farming experience, access to extension services, and access to credit services). The results revealed that there was a statistically significance difference in technical efficiency between the farmers who accessed the extension services and those who did not access the service as shown by the p-value of 0.002 and standard deviation of 4.17 for those who did not and 1.2 for those who accessed. Similarly there was statistically

significance difference in technical efficiency between the farmers who had household size 1-5 to those which had household size beyond six family members as revealed by the p-value of 0.001 and standard deviation of 1.89 and 1.34 for 1-5 and 6+ household sizes respectively. The other household characteristics (education level, fish farming experience, access to credit and gender) were not statistically as revealed by their p-values.

4.4 Determinants of technical efficiency in the small scale fish farming in Kiambu County

This objective aims at analyzing the farm specific factors that result in variations in technical efficiency of fish farmers. It was analyzed by Frontier 4.1 programme together with the production model hence the results are contained in the Table 4.6. Factors that were considered included gender, age, education level, access to extension services, household size, farming experience, access to credit services.

4.4.1 Inefficiency model

The results of the inefficiency model are presented in the table4.5 below. These are the factors that are considered to influence efficiency of fish farming in the study area.

Table 4.6: Estimates of the Technical Inefficiency of Small Scale Fish Farmers.

Variables	Coefficient	t-ratio
Inefficiency model		
Constant	5.2633	1.22530
Gender	-0.04553	0.20170
Age	-0.006387	-0.65570
Household size	0.09134	1.74520*
Education level	-0.115682	-0.89884
Farming experience	-0.029635	-0.39073
Access to extension services	-4.20767	-1.11497*
Access to credit services	0.11893	0.508399

*statistically significant at 10%**statistically significant at 5%***statistically significant at 1%

Source: Authors own calculations

The estimates of the technical inefficiency of small scale fish farmers are shown in Table 4.6 above. The coefficients of, gender, age, education level, fish farming experience, and access to credit had negative sign. The negative sign in the inefficiency model indicates positive effect on the efficiency level of the farmers. The study revealed that education level was not statistically significant at any level. The negative coefficient of education level means that increasing the level of education of the farmer would reduce inefficiency. Education reduces inefficiency by helping farmers acquire skills and adopt required technologies for production. The same results have been reported on areas of maize and rice (Kibaara, 2005, Hyula, 2006). A review of efficiency studies revealed that education level of the farmers is positively related to technical inefficiency (Parikh *et al*., (1995). For this study the average level of education was found to be secondary level which is consistent with the previous findings.

Fish farming experience is the knowledge, skills and practices acquired over a given period of time by farmers in practice. The results showed that fish farming experience is negatively related to the technical efficiency of fish farming though not significant. This implies that the farmers with more experience tend to be more efficient in production because more skills are developed over time. This finding concurs with the findings of Ram (1980) that with increase years of experience farmers becomes more specialized. Furthermore the more the experience the farmer has the higher is his output and higher is the technical efficiency (Revilla-Molina et al., 2009). According to Kareem *et al.*, (2008) the inefficiencies of production of fish farmers tends to decline as they continue the operation of fish farming on yearly basis.

Another important determinant of technical efficiency was age of the farmer. The coefficient of age was negative and statistically insignificant. The implication of these findings was that increasing the farmer's age raises the level of technical efficiency. This is expected because the older the farmer, the higher the experience increases, the more the farmer gets used to farm production processes and techniques and hence increased technical efficiency. Farmer's age influences the farm practices directly or indirectly through labour management and knowledge (Singh, 2005). Young and middle- aged farmers are more willing to adopt new technology; on the other hand older farmers are conservative, risk averse and hence less likely to use new technology.

The estimated coefficient of household size was positive and statistically significant at 10% level of significance. This implied that increasing the number of household size will increase the level of technical inefficiency. This could be due to the fact that most household size is increased by the number of school going children who are not involved in actual production. With the free primary and secondary education provided by the government this is likely to happen .This finding conforms to that of Muhammad-Lawal *et al.* (2009). This occurs when the most of the farming household members are young and their effects in terms of labour provision have not been felt in fish production. Parikha and Shah (1994) and Karki (2004) reported a positive relationship between households' size and technical inefficiency in Pakistan and Nepal, respectively. Thus, an increase in household size means a reduction of labor force as a result of increased number of defendants.

The estimated coefficient of access to credit was positive and not statistically significant at any level of significance. This implies that access to credit by the farmers could increase technical efficiency. Provision of seed credit alleviates the problem of lack of capital especially for resource constrained household to acquire certified fingerlings, feed and hiring of labour.

Nevertheless, Ellis (2003) cautions that the relative costliness should be considered before such ventures are undertaken.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary, conclusion and recommendations of the main findings on the level and determinants of efficiency of small scale fish farming in *Kiambu County*.

5.2 Summary

Fish farming in Kenya has been identified as one of the ways of attaining food sufficiency, achieving Millennium development goal number one as well as achieving Kenya's vision 2030.

However, given the average output of 153kgs/year and technical efficiency (41%) being experienced in the county, preferred results will not be achieved unless efforts of improving technical efficiency of fish farming are up scaled. To achieve fish production sufficiency as a country, efficiency improving strategies need to be pursued.

This study examined the level and determinants of technical efficiency of small scale fish farming in the study area. The study used descriptive research design which was appropriate since the study wanted to ascertain the state of affairs in the fish farming sector without manipulating any variable. The population of the study comprised 94 farmers which were randomly selected from the six sub-counties of Kiambu. Data on inputs (fingerlings, labour, feed, pond size and fertilizer) and socio economic variables (gender, household size, education level, farming experience, access to extension services and access to credit services) were collected. The maximum likelihood method was used to estimate the stochastic frontier production function. It found out that the small scale farmers were technically inefficient having recorded a mean technical efficiency of 0.41.

From the regression model, the study established that there were factors influencing the efficiency of fish farming in Kiambu County which include gender, age, and education level, fish farming experience and access to credit services negatively affect fish farming. The household size was statistically significant at 10% while the access to credit services affect fish farming positively.

5.3 Conclusion

The study has discovered that there is potential for increasing fish production in Kiambu County by increasing the levels of pond size, fingerlings stocked, feed and fertilizer application. But, given the subsistence conditions, it may not be possible to exploit the economies of scale observed in the study area. The results of technical efficiency analysis have indicated the presence of technical inefficiency effects on fish production, as depicted by the estimated 'γ' (0.27) parameter of the model, and by the predicted technical efficiency amongst the farmers. The technical efficiency was found to range between 0.18 and 0.95, with mean value of 0.41.

The results revealed that about 2% of fish farmers were operating at 70% or more technical efficiency levels. Moreover, about 17% of fish farmers were operating at a technical efficiency level of 50% or more. The result also indicated that about 83% of the fish farmers were operating at less than 50%, level of technical efficiency.

The study discovered that the Cobb-Douglas form of stochastic frontier production function was more reliable than that of translog form under fish farming situation in Kiambu County. Fingerlings, feed, pond size and fertilizer were significantly different from zero and of importance in production of fish in the study area. Furthermore, analysis of technical inefficiency model revealed that household size and access to credit services were the main socioeconomic variables having significance. Gender, age, education level, fish farming experience and access to extension services had negative coefficients. These variables reduced technical inefficiencies of fish farming in the study area.

5.5 Recommendations

To improve on technical efficiency of small scale fish farming, the government should encourage the farmers to increase the size of their fish ponds, access quality fingerlings, feed and fertilizer in the right proportions. There is need to improve extension coverage to many farmers to address simple farming anomalies such as excess utilization of inputs. Government policy should be focused on adopting the best technology (fast fish growing species) to improve the level of efficiency. The government should devise ways of encouraging the credit institutions to offer credit services to fish farmers since access to credit has been seen to significantly improve on farmer's efficiency.

5.6 Areas for Further Research

Since the study focused on the determinants of efficiency of small scale fish farmers in Kiambu County, further studies should be done on the entire country and more variables not included in the current study should be considered to ascertain whether the study will yield the same results.

To effectively gain a wider picture of fish farming system in Kenya and how it may improve on fish sufficiency of the country, allocative and hence economic efficiency studies need to be undertaken. This would provide an insight into how prices are influencing economic decisions of the farmers. Secondly, resource use among the fish farmers was poor; therefore studies aimed at determining optimal resource use in this are necessary.

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APPENDICES 1

QUESTIONAIRE FORM

KENYATTA UNIVERSITY, SCHOOL OF ECONOMICS, DEPARTMENT OF APPLIED ECONOMICS

Questionnaire number……………………………………………………………

County……………………………………………………………………………

Sub-county………………………………………………………………………

A) BACKGROUND INFORMATION

1) Respondent's Names………………..……………………….. (2) Sex (a) Male (b) Female

3) Marital status (a) Married (b) single (c) Widowed

4) Age……….. (5) Education level ………….…….. ……………………………..

6) Household size …………… (7) Adults……………… (8) Children……………..

Age Group	Sex	
	Male	Female
0-10		
10-20		
20-30		
30-40		
50-60		
60+		
Total		

(8) Which of the following form part of your major occupational activity?

Activity	fish farming	Business	Formal Employment	Casual work
Years in activity				

(9) What species of fish do you farm/stock? (1)..

(.2).. (3)..

B) LAND UTILISATION

10) How much land do you allocate to fish farming?

a) 0-5 acres ( ) (b) 5-10 acres ( ) 10 and above ( ) tick where appropriate

(C) PRODUCTION INFORMATION ON FISH

INPUT UTILISATION

(11) Do you use the following inputs in your fish ponds?

A) Improved seeds Yes ( ) No ( )

(B) Fertilizer Yes ( ) No ( )

(12) Do you access inputs from government agencies Yes ( ) No ( )

(13) If yes, how much was received……….(Kg)

(14) Have you received any form of training on use of inputs in fish production?

a) Yes ( )

b) No ( )

(15) If yes who provided the training?

a) Extension officers (government)

b) NGO (name of NGO)

c) Farmers

d) Others specify………………

(D) LABOUR INPUTS IN FISH PRODUCTION

(15) What is the main source of labour for fish production?

(a) Family labour and how many hours

(b) Hired labour and how many hours

(c) Both and how many hours

(E) FISH OUTPUT

16) How much fish do you produce on you farm? Please fill in the table below.

Year	Harvested area(acres)	Quantity of fish harvested(Kg)

F) GENERAL INFORMATION

(17) Do you have access to credit Yes ( ) No ( )

If yes fill the following table:

Sources of credit	Amount received	interest rate	Total amount paid	Payback period	use of credit received

APPENDICES 2 -Results

Final maximum likelihood estimates for translog

	coefficient	**standard error**	**t-ratio**
constant	-228.738	4.9205	-46.4867
fingerlings	-7.3786	4.9393	-1.4938
labour	95.054	10.9528	8.6785
feed	-9.4222	8.4491	-1.1152
pond size	29.8067	2.2528	13.2311
fertilizer	-9.4285	5.8352	-1.6158
(fingerlings)2	3.0162	0.3677	8.2035
(labour)2	-7.4947	2.9248	-2.5625
(feed)2	0.1502	0.1659	0.9054
(pond size)2	-0.3107	0.3087	-1.0065
(fertilizer)2	-0.2826	0.2274	-1.2426
fingerlings * labour	-4.5378	1.7946	-2.5286
fingerlings*feed	0.1775	0.3689	0.4813
fingerlings*pond size	-3.0654	0.7021	-4.3661
fingerlings * fertilizer	1.2184	0.4863	2.5056
labour*feed	1.591	1.9304	0.8242
labour * pond size	-1.4445	0.0255	-56.5431
labour * fertilizer	0.4773	1.0746	0.4442
feed* pond size	-0.1301	0.2489	-0.5227

feed * fertilizer	0.0605	0.2966	0.2038
fertilizer	0.4059	0.3674	1.1048
constant	2.8484	10.8847	0.2617
gender	-0.1703	0.0894	-1.9043
age	-0.1547	0.1295	-1.1949
household size	0.084	0.0379	2.2183
education level	1.2643	0.089	0.142
farming experience	-0.001	0.0069	-1.4424
access to extension	-0.3314	0.1818	1.8224
access to credit	0.2047	0.157	1.3035

Log likelihood function = -87.835764

LR test of the one-sided error = 15.855709

With number of restrictions = 9

Final maximum likelihood estimates for Cob-Douglas

	Coefficient	standard-error	t-ratio
constant	1.5708	0.9929	1.5821
fingerlings	0.3375	0.5675	0.5947
labour	-0.06247	0.8909	-0.0701
feed	-0.6589	0.1572	-4.1913
pond size	0.2744	0.1832	1.4974
fertilizer	0.7793	0.1437	5.4227
constant	5.2633	4.296	1.2253
level of education	-0.1157	0.1287	-0.8988
access to extension	-4.2077	3.7738	-1.115
house hold size	0.0913	0.0523	1.7452

fish farming experience	-0.0296	0.0758	-0.3907
age	-0.0064	0.0097	-0.6559
access to credit	0.1189	0.2339	0.5084
gender	0.0455	0.2257	0.2017
sigma-squared	0.607	0.1054	5.7582
Gamma	0.266	0.3516	0.7566

Log likelihood function = -109.12871

LR test of the one-sided error = 11.536479

With number of restrictions = 9

(Maximum number of iterations set at: 100)

Number of cross-sections = 94

Number of time periods = 1

Total number of observations = 94