TECHNICAL EFFECIENCY OF SMALL SCALE BANANA FARMING IN MERU COUNTY, KENYA

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF ECONOMIC THEORY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ECONOMICS (POLICY & MANAGEMENT) OF KENYATTA UNIVERSITY.

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DECLARATION

This research project is my original work and has not been presented for any award in any University.

Signature…………………………...   Date………………….

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I confirm that this research project is the work of the candidate and was done under my supervision.

Signature: ……………………………………... Date: …………………………………...

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DEDICATIONS

To Very Rev.Fr. Dr. Douglas Mwija, my mother Lydia John, my Sponsor Signora Pessolato Elide, my uncle Silas Mutua, our entire family and my Friends.

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LIST OF ABBREVIATIONS

AFA- Agriculture and Food Authority (Kenya)

ANOVA- Analysis of Variance

CRS- Constant Returns to Scale

DEA- Data Envelopment Analysis

FAO- Food and Agriculture Organization (United Nations)

GDP – Gross Domestic Product

GOK- Government of Kenya

HA- Hectare (10,000M^2)

KAPP- Kenya Agricultural Productivity Project

KES- Kenya Shillings

KNBS- Kenya National Bureau of Statistics

MLE- Maximum Likelihood Estimates

MOLS - Modified Ordinary Least Squares

MT- Metric ton

OLS- Ordinary Least Squares

SFA- Stochastic Frontier Analysis

TE - Technical Efficiency

TFP- Total Factor Productivity

USAID- The United States Agency for International Development

VIF- Vector Inflation Factor

OPERATIONAL DEFINATIONS OF TERMS

Allocative Efficiency- Is a measure of the ability of a firm to utilize inputs in optimal ratios given their prices.

Efficiency – It is measure of how well resources are employed to produce a certain output level. It is a ratio of real output to the highest possible level of output that can be obtained using a set level of inputs.

Inefficiency- It is the magnitude by which the real output falls short of maximum possible output.

Production technology- Refers to how well a firm combines a level of inputs to produce an output.

Productivity- It is the ratio of volume of output produced by a firm to a volume of inputs used in production by the firm.

Stochastic Frontier- it is formed by a regression line that passes on top of the observations.

Technical Efficiency- refers to how well inputs are combined to produce an output. It measures how best the firm combines the given inputs to obtain the maximum possible level of output.

Small Scale Farmer – is a farmer with less than two acres of land area under banana production.

ABSTRACT

Banana production is important due to the role it plays in the economy of Kenya. It provides income to the farmers; generate job opportunities and boost food security in the country. Banana is ranked as the fourth most valuable crop in the world after maize, wheat and paddy. In some Eastern and central parts of Kenya banana plantations have replaced coffee plantation which was formerly the main source of income to the farmers in the region. Nevertheless, despite the important roles the banana production plays in the economy of Kenya, the overall banana output has been falling in the last two decades notwithstanding the increase in area under banana production. Moreover the full potential of fruits production in Kenya, among them banana production remains unexploited despite the prospects for growth in demand owing to rise in demand for fresh fruits and fruit products. In Kenya the area under banana production has been increasing, however there has been no correspondence increase in banana output. Moreover, the banana output per acre is lower compared to the probable output per acre. In the existence of scarce production resources (especially land), the achievement of maximum technical efficiency at farmer level would be key to achieving sufficiency in banana production and enhancing food security which is among the Kenyan government's big four agenda. The study addressed two objective; the estimation of technical efficiency and the establishment of the determinants of the technical efficiency of banana farming in Imenti South, Meru Kenya. The non-experimental research design was used, utilizing cross-section data which was collected by use of questionnaires which were filled by sample farmers. The stratified random sampling design was used to pick a random sample of farmers to participate in the study. The quantitative data on inputs and output for every sampled farmers was collected. The study used the maximum likelihood to determine the stochastic frontier production function and a multiple regression analysis to determine the determinants of technical efficiency. The technical efficiency was measured in the five wards of Imenti South Sub-County which are the main cultivators of bananas for commercial purposes. To realize the objectives of this study, data from 91 valid questionnaires filled by small scale banana famers in the study area was used. Raw data was systematically organized and stochastic frontier analysis was utilized to estimate the efficiency levels. The Stochastic Frontier Analysis (SFA) results indicated that the average technical efficiency for small scale banana farmers was approximately 69 percent, this means the farmers on average were 31 percent technically inefficient. The regression results for efficiency model showed the age of the farmer, the highest education level achieved by the farmer, access to water for irrigation, access to credit had direct or positive effect on technical efficiency whereas access to extension services, the farmer's household size, gender of the farmer, land ownership by the farmer and the farmer's experience in banana farming had inverse or negative influence on technical efficiency. The study concluded that the small-scale banana production falls short the frontier output and therefore recommends availing of credit facilities at affordable rates to the farmers, formation of farmers' cooperatives and other self-help groups to enhance the disbursement of credit and other services, the government should ensure cheaper fertilizer is readily available to the farmers and offering frequent extension services to the farmers. These would result to an improvement in efficient production of bananas

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Banana is ranked fourth as the most valuable crop in the globe after maize, wheat and paddy (Nelson, Ploetz & Kepler, 2006). Globally India is leading in banana production with an average banana output of 39 million metric tons which represents 18 percent of total global banana output (FAO, 2014). The East Africa region's banana output accounts for half of Africa's total banana output annually providing staple food and contributing to the household income for more than 20 million individuals in the region (Karamura, Frison, Karamura, & Sharrock, 2000). The crop contributes significantly to the income levels for the rural poor who sells the banana output in the local markets. The rural poor uses bananas in several ways which include medicinal, cultural and industrial uses (Karamura, Frison, Karamura, & Sharrock, 2000). The rural poor are defined as people with inadequate productive means they include the family farmers, subsistence producers or landless agricultural workers in the rural areas (FAO, 2019)

In East African region banana production is almost half of Africa's banana production. It composes the biggest banana producing and consuming region in Central, Eastern and Southern African (Kasyoka, Mwangi, Kori, Mbaka, & Gitonga, 2011). The annual production is estimated at 20 Million tonnes, accounting for 25.6 percent of total world output (Nzioka,2009). Furthermore, the much production in global banana output is by small scale farmers (Nzioka,2009). The banana output provides staple food and income for the farmers and other stakeholders of banana production (Kasyoka, Mwangi, Kori, Mbaka, & Gitonga, 2011). Increased efficiency in banana production would therefore mean, increased food for households and higher revenues for the farmers. The increased income would moreover mean increased aggregate demand in the economy at large, contributing to economic growth.

The situation in Eastern and East Africa is replicated in Kenya. Approximately 80 per cent of population in Kenya live in rural areas (Kimenyi, 2008). The livelihood of these rural dwellers comes from agriculture (Runo, 2009). Agriculture being the mainstay of Kenya's economy contributes approximately 26 percent of Kenya's GDP (KNBS, 2018). Therefore, more focus in improving production of all crops grown in the country should be emphasized to ensure economic growth. According to Kimenyi (2008), there are approximately 4.5 million farmers engaging in small scale farming and whose production accounts for around 75 percent of total agricultural output in Kenya. These small-scale farmers are more often faced by production constraints which makes their production to fall short the potential production per acre. To ensure improvement in food production in order to ensure the country is food secure, it is important to evaluate the technical production efficiencies for different crops and sources for such efficiencies be established to ensure improvement in the production levels of each crop and agriculture as whole.

In the recent years Kenya has been described as food insecure country (KIPPRA 2017). This is due to low agricultural production coupled with low value addition to agricultural output and enormous after-harvest losses. The low agricultural production is associated with improper farming system and high cost of farm inputs such as fertilizers, planting seeds, insecticides and pesticides. Notwithstanding, food insecurity in various parts of East Africa among them Kenya, there is great potential of producing enough food, achieving regional food security (KIPPRA

2017). Therefore, policy focus should be directed towards improving efficiency in production in all agricultural sub-sectors, in order to ensure the country is food secure.

Banana cultivation in Kenya is mainly on small scale. These small scale farmers 'produce contribute to food requirement in the country. However, despite the distinct and fundamental role, the small-scale farmers are among the poorest group in the society hence cannot spend much in their farms (Adama, 2014). The land under banana production accounts for about 2 percent of Kenya's cultivatable land. According to Mbogoh et al., (2002) and USAID, (2014) the crop is cultivated to provide income to millions of rural Kenyans in several Eastern parts of the country, following the downfall of what previously used to be considered as main cash crops which included coffee and tea. Therefore, the estimation of technical efficiency levels of banana producing farmers is imperative, with an aim of improving the productivity per acre in order to mitigate the challenge of food insecurity and enhance income for the farmers.

Banana farming is significantly essential due to the role it plays in the Kenyan economy. It is a source of income, provides employment opportunities and also contributes to food security (Republic of Kenya, 2004). The banana production in Kenya is nearly 1.4 million tons providing food to the residents. This is because the banana output is consumed locally (USAID, 2017). Banana marketing in Kenya is by use of intermediaries who acquire bananas directly from farmers, transport them to a collection center and thereafter transport them to other different markets by use of trucks. According to Mbaka, Mwangi & Mwangi, (2008) majority of the banana brokers are women who buys bunches of bananas directly from farmers.

1.1.1 Banana Production in Kenya

In Kenya Banana is an essential fruit accounting for 31.61 percent of the total value of fruits (Agriculture and Food Authority (AFA), 2016). Banana is a main source of pay and food security for the small scale and large holder farmers (AFA, 2016). Despite the important roles played by bananas, the overall output of banana has been falling in the country over the last twenty years (Kasyoka et al., 2011). Improved production efficiency, would therefore mean more income for the farmers and increased food in the country. The increased banana proceeds in turn would lead to improved living standards for the farmers. Improvement in banana production would lead to provision of more job opportunities, increased revenue generation and improvement of food security. This is important in attainment of Kenya vision 2030 and achieving of the government's big four Agenda, since food Security is among the big four Agenda.

In Kenya, banana is the best known fruit, it is regularly taken as desert while the banana cooking variety serves as a basic food. It is mostly cultivated mixed with other crops and is considered as a security crop that offers constant income for the household at a low input regime (Mbaka, Mwangi & Mwangi, 2008). Therefore, if more attention is emphasized on banana productivity efficiency the banana farming enterprise would be more profitable to the farmer. Given that the demand for banana fruits is high especially in urban areas. The table below represents a summary of banana production in Kenya between 2012 and 2016.

Table 1.1: Banana production in Kenya

Period	2012	2013	2014	2015	2016
Area (Ha)	48,022	50,719	52,102	60,718	63,299
Volume (MT)	1,331,959	1,437,566	1,430,217	1,290,150	1,288,588
Value (Million KES)	12,934.55	17,751.00	18,164.00	16,703.03	16,977.13

Source of Data: Horticulture Validated reports

The area under banana farming in 2016 was approximately 63,299 Ha, while the total banana output amounted to 1,288,588 tons which had monetary value of KES 16.98 billion. The Area under banana coverage rises from 60,718 Ha to 63,299 Ha and value increased by Ksh774 Million which represents 4.25 percent and 4.78 percent respectively but output dropped by 0.12 percent. It is expected that, when the area under the production is increased production should also increase.

In 2014, the land area under banana farming was 52,102 Ha up from 50,719 Ha in 2013 with a production of 1.43 million tons whose value was estimated to be KES 18.16 billion, in the same year the value of banana increased by KES413 million representing about 3percent from 2013. Though the area covered by bananas increased from 50,719 to 52,102 in 2014 total output of banana reduced from 1,437,566 metric tons (MT) in 2013 to 1,430,217 in 2014. The area under banana farming increased by 2,581 Ha from 2015 to 2016 however banana production declined by 1562 Metric ton during the same period. It is clear that in spite of the growth in the size of land under banana, the productivity has not been increasing, this can be ascribed to inefficiency in banana production. The Production of bananas and the area under banana production in Kenya as per major banana producing counties is presented respectively in figure 1.1 and figure 1.2 below.

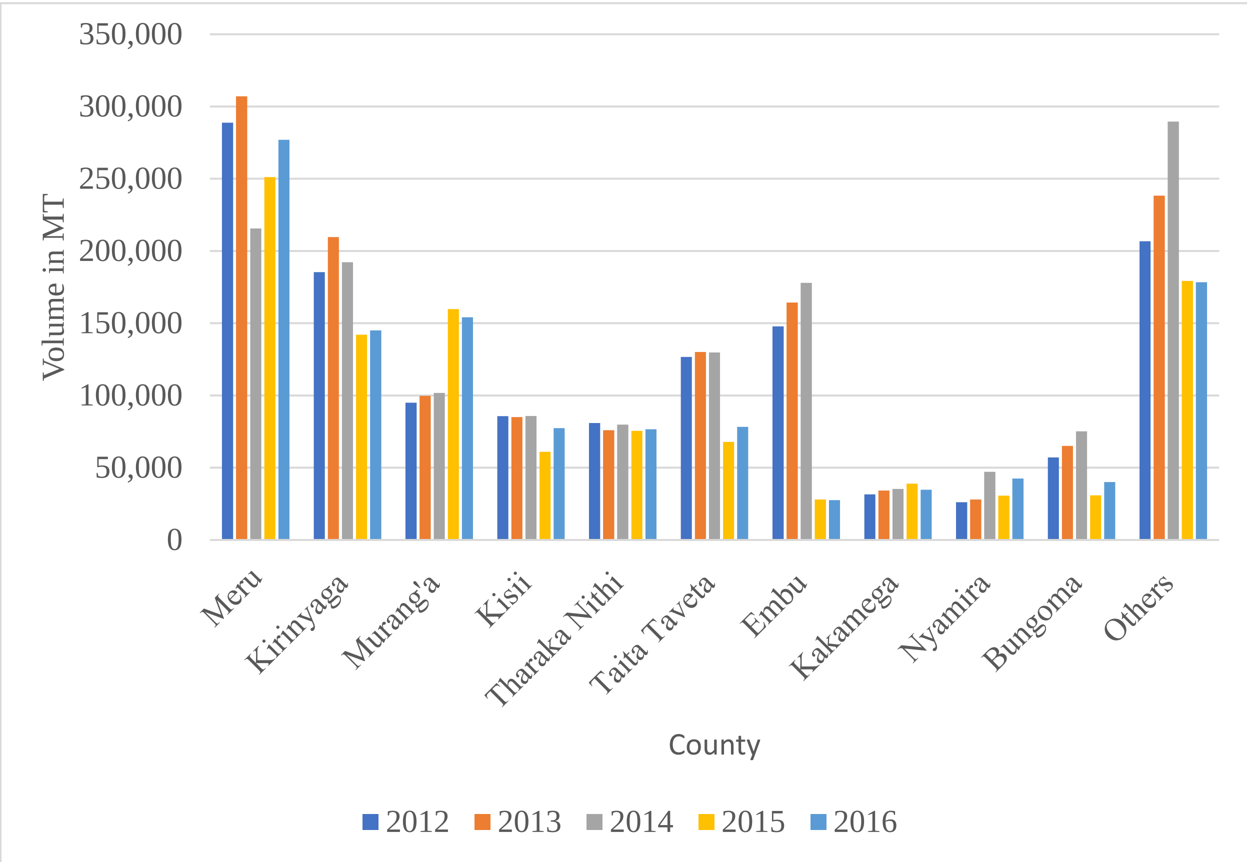

Figure 1.1: Production of Banana by selected Counties (2012-2014)

Source of data: (USAID, 2016).

Meru County is the largest banana producer, among the banana producing counties in Kenya. The banana output increased to 307,013 Metric tons in 2013 from 288,803 MT in 2012 but declined to 215,580 MT in 2014. Therefore, the production should be efficient so as to meet the consumer's demand and contribute to food sufficiency in the entire country.

The decline in output of banana production was linked to low productivities in places that do not have access to water for irrigation, particularly Embu and Bungoma counties. Counties of Meru, Kirinyaga, and Taita Taveta posted relatively higher yields due to factors such accessibility to water for irrigation, use of superior varieties, availability of clean materials for planting from Tissue Culture technology, and exposure of farmers to modern agronomic practices (USAID, 2014).

The top banana producing counties were: Meru 17 percent, Kirinyaga 11 percent, Muranga 9 percent, Kisii 8 percent, Tharaka Nithi 6 percent, Kiambu 5 percent and Taita Taveta 5 percent (AFA, 2016). The area under banana production has been increasing in different years as shown in the figure 1.2 below.

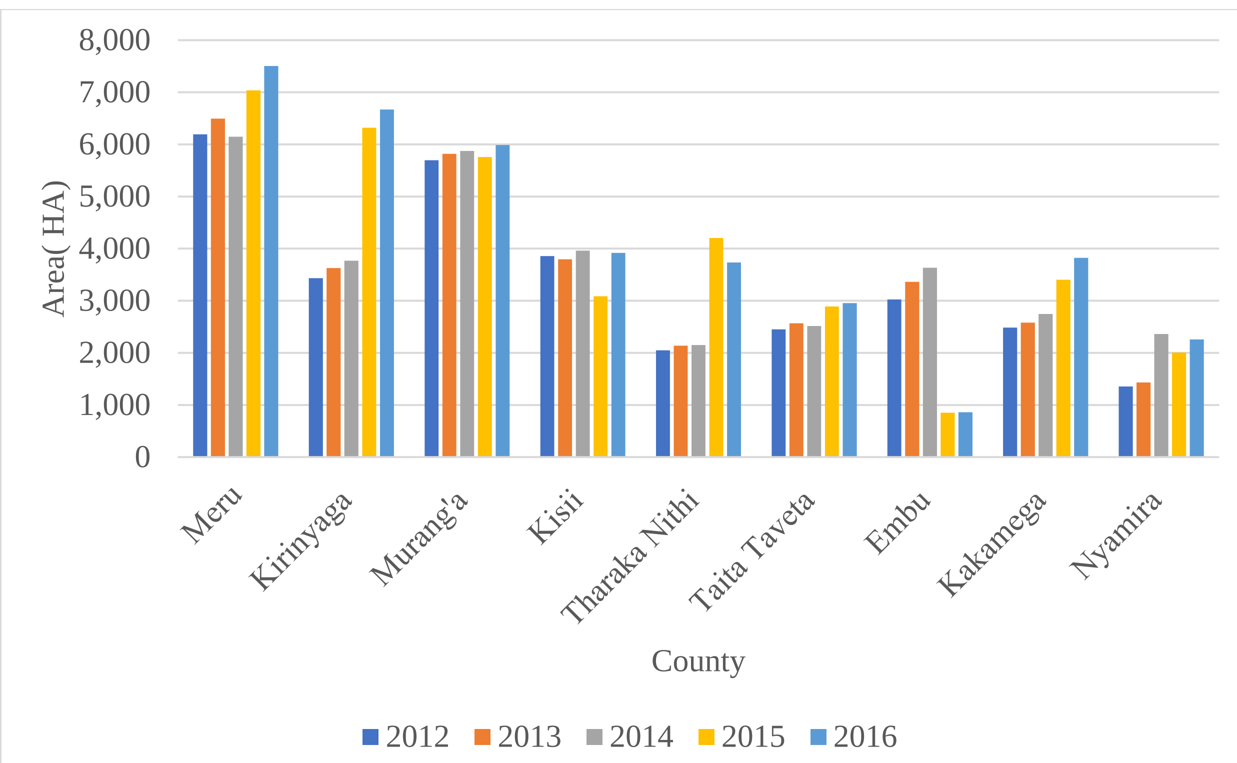

Figure 1.2: Area under banana Production in selected Counties (2012-2016)

Source of data: (USAID, 2016).

The area of land covered by banana plantation followed same trend as the output as shown in the figure 1.2 above. The area covered by bananas increased from 50,719 to 52,102 in 2014. Moreover, it increased by 2,581 Ha from 2015 to 2016.

Table 1.2 shows recorded retail market prices for bananas from 2012 to 2016 for the months of March and September.

Table 1.2: Retail Market Prices for Bananas, 2012 – 2016 (KSh per Kg)

	2012	**2013**	**2014**	**2015**	**2016**
MAR	40.13	39.01	42.46	37.46	37.36
SEPT	38.7	34.98	42.50	37.26	41.82

Source of Data: Kenya National Bureau of Statistic

Banana prices registered slight variations in each year, between the month of March and September. Bananas recorded highest price in the month of September 2014 and the lowest in month of September 2015. Table 1.2 shows variations in banana retail prices without a specific trend. Therefore, it can be noted that the banana prices are determined by market forces, hence a specific farmer cannot predict or influence the market prices for bananas.

1.1.2 Banana Production in Meru County

They are 47 counties in Kenya, Meru County being among them, lies on the eastern slopes of Mt. Kenya. It covers an aggregate land area of 693,620 ha, however 177,610 ha out of that land area is gazzeted forest. Meru County engages in crop cultivation and livestock rearing as the main economic activity (Republic of Kenya, 2015). Therefore, putting more focus on measures and policies that will improve agricultural production in all agricultural sub-sectors of the county, would enhance the county's economic growth and Kenya at large.

The County is highly agricultural productive due to favorable climatic conditions and fertile lands. Irrigation complements the rainfall-fed agriculture which forms an important source of income to household in the County, contributing up to approximately 80 percent of the usual household income (World Bank Group and Republic of Kenya, 2013). The determination of the magnitude of technical efficiency and further identifying the factors that determine such efficiency, by the current study, provides the measures which can be put in place to increase banana productivity. The increased productivity will in turn ensure increased banana income for the farmers and improved livelihood of the households. The improved productivity would further enhance the food security in the country, helping the government to achieving one of its big four agenda of ensuring Kenya is food secure.

In Meru County Bananas are produced for both subsistence and commercial purposes. The production is mainly by small-scale farmers. The banana production averages 200,000 to 300,000 tonnes (Meru County Government, 2014). However, according to USAID (2014), the full potential of fruits among them bananas remains unexploited. Nevertheless, there is prospective for growth in demand of bananas, owing to increased demand for products from fruits for example juices and concentrates and fresh fruits themselves in both local and international markets. In 2015 a total of 382,390 tonnes produced earning approximately equal to KES3.7 billion (Republic of Kenya, World Bank, 2013). This indicates that bananas form an essential source of income in the country. Therefore, improving technical efficiency in banana production in light of limited acreage of land would increase banana output, which would result to improved income enhancing the economic growth of the country.

Among the banana producing regions in Meru the Imenti South Sub-County region is the largest banana producer. It's one of the greatest production potential areas and it is the region where bananas are mostly grown in Meru due to its favourable climatic conditions, this justified its selection for this study.

In Imenti South Sub-County of Meru County, Banana farming is a prominent commercial activity. However, with lower yields compared to the potential per acre, the farmers are reported to produce 4.5-10 tons per acre as compared to potential of 30-40 tons per acre (Muchui et al., 2013). In presence of scarce production resources more particularly land, the attainment of maximum technical efficiency at farmer's level is crucial to achievement of maximum productivity of banana production. Additionally, Meru County being the top most banana producer in Kenya among the banana producing counties, the production should be efficient so as to meet the consumer's demand and increase food security in the entire nation.

1.2 Statement of the problem

Banana production contributes greatly to the economy of Meru County and the country as a whole. It provides income to the farmers, generates employment opportunities for the residents and revenue to the county government. In addition, it promotes food security of the residents and Kenya at large (Republic of Kenya 2004). In some areas of Eastern and Central regions of Kenya banana plantations have replaced coffee plantations (Muchui *et al*., 2013). Despite the important roles the banana plays the overall banana output has been falling in the country over the last two decades (Kasyoka et al., 2011). In Kenya between 2012 and 2016, the area under banana cultivation increased, in 2016 increased from 48,022 Ha in 2012 to 63,299 Ha in 2016. Though the area under banana production increased over the period from 2012 to 2016 the production has been declining from 2013 to 2016. In 2016 Bananas accounted for 31.61 percent of total fruits in Kenya which is a decline from 35.6 percent in 2014. Besides that, the bananas production compared to total fruits production fell from 47 percent in 2012 to 43 percent 2014.

The full potential of fruits among them banana remains unexploited, despite the prospects for growth in demand for bananas owing to rising demand for fresh fruits and fruits products. In Meru full potential of bananas of banana production has not been exploited, moreover in Imenti South Sub-County, the banana yields lower output than the potential output per acre. Therefore, in the pervasiveness of scare resources the attainment of maximum Technical efficiency is crucial in realizing maximum output banana production.

There is limited literature on technical efficiency of banana farming in Kenya, Nzioka (2009) concentrated more on economic and marketing efficiency of banana production in Kiambu East District. Though the study touched little about technical efficiency by only estimating the average technical score for banana farming in Kiambu, there is distinct difference between banana production between Meru County and Kiambu. Banana production in Meru is highly commercialized which accounts for around 17 percent of entire banana production in the country and leading among the banana producing counties. Other studies dwelt on technical efficiency of other crops leaving bananas. Kuria, Ommeha, Kabuage, Mbogo and Mutero (2003) concentrated on technical efficiency of rice irrigation in Mwea, Wambui, (2005) dwelt with technical efficiency of maize while Ngeno *et al.,* (2011) and Njeru, (2010) dwelt with analyses of technical efficiency of bulrush millet and wheat respectively.

Meru County being the top banana producer in Kenya among the banana producing counties, the production should be efficient to ensure its meets the consumer's demand and further enhancing increase food security in the whole country. Furthermore, the actual efficiency levels of banana production have not been estimated in Meru, thus the need to estimate the banana production technical efficiency. This study therefore bridged the knowledge gap by finding out the technical efficiency levels of banana production in Imenti South Sub-County of Meru County Kenya.

1.3 Research questions

The study sought to answer the following questions:

i) What is the level of the technical efficiency in banana production in Imenti South Sub-County?

ii) What are the determinants of technical efficiency in banana production in Imenti South Sub-County County?

1.4 Objectives of the study

The general objective of the study was evaluating the levels of technical efficiency in banana production among the small-scale banana farmers in Imenti South Sub-County. The following were the specific objectives of the study.

i) To estimate the level of technical efficiency in banana production in Imenti South Sub-County.

ii) To establish the determinants of technical efficiency in banana production in Imenti South Sub-County.

1.5 The scope and limitations of the study

This study focused on estimating the level of technical efficiency and establishing the determinants of technical efficiency of small-scale banana farming in Imenti South Sub-County. The study region was purposively selected since it is among the greatest production potential areas and it is the region where bananas are mostly grown in Meru due to its favorable climatic conditions. The study made use of questionnaires to obtain data from the banana farmers on the production information, and demographic information. The technical efficiency was measured in the five wards out six (since the five are the main cultivators of bananas for commercial purposes) of Imenti South Sub-County. This research project utilized primary data which was acquired from questionnaires filled out by the sampled banana farmers. The main limitations encountered during data collection were that, some farmers were not welcoming and friendly. The challenge was however overcame by using respected village elder to introduce the researcher to the farmers. Another limitation was time wasting during questionnaire filling. Some farmers shared their frustrations, challenges and bad experiences in farming of what was previously considered as major cash crop (coffee) in the region, instead of concentrating on the questions in the questionnaires, thus consuming a lot of time. To overcome this limitation, the research first introduced the purpose of the research before commencement of filling the questionnaire.

1.6 Significance of the study

The findings of the current study is of importance to the banana farmers, the county government of Meru and the national government. The understanding of the factors determining the technical efficiency of the small scale banana farming, enable the banana farmers to adopt best practices that will improve their efficiencies and consequently the total output will increse leading to increase in profit levels. The outcomes of the current study will further provide knowledge to the county government of Meru that will inform policy on measures to adopt in order to support productive capacity of banana farming,hence increasing food produce,creating job opportunities and increasing revenues. The information will also help the government in set up policies aimed at promoting effeciency in banana production.

1.7 Organization of the study

This study is structured in five different chapters. Chapter one deals with the background to the study in which the contextual and conceptual issues are discussed, the chapter brings out the study variables and highlights conceptual analysis to give the direction for this study. The chapter further presents the problem that the study wished to address, the research objectives and questions the study sought to answer. The scope, limitations, and organization of this study are also presented. In the second chapter, the empirical and theoretical literature on the study variables is presented. The review provides additional explanation on the context of the study. The chapter sums up studies that are considered to provide the basis upon which the findings were discussed. The chapter further provide the theory upon which the study was anchored. The relevant gaps in empirical studies were also identified. Chapter three presents the research methodology applied in this study. Its covers, the research design used, sampling procedure applied, description of research instruments, methods of collecting data and the techniques for analyzing data. While the analysis and the results of the study are presented in chapter four. Chapter five presents a brief summary of the findings of the study, the conclusions made by the study, policy implications of the study and the suggestions of the areas for further research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter present a review of theoretical and empirical literature on technical efficiency and its determinants. The study starts by reviewing the theoretical literature, followed by empirical literature on estimation and determinants of technical efficiency. The last section presents the summary of entire literature reviewed.

2.2 Theoretical Literature

This part discusses theories on the estimation of technical efficiency and its determinants.

2.2.1 The Classical Production Function

The production frontier (also known as production function) is mostly utilized to represent the technical association that exists between inputs and outputs. The production frontier represents the highest level of output that can be realized from different combinations of inputs (Coelli et al, 2005). It thus mirrors the state of technology in the industry. Assuming a single output, the classical production frontier is represented as follows:

$$y = f(x) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2.2$$

Where Y represents the output while x ($x = x_1, x_2 \ldots\ldots, x_N$) represents a vector of inputs used in the production. The production frontier is used as a standard against which the technical efficiency can be measured. The firms that produce along the frontier are deemed technically efficient. Whereas the ones that produce below the frontier are deemed technically inefficient (Coelli et al 2005). The production function was being relied on in estimation of technical efficiency.

1.2.2 Input Oriented Approach

These approaches explain the degree to which a firm can proportionately minimize inputs to yield a certain level of output Farell (1957). The illustration of the measurement of efficiency is shown in figure 2.1 using two inputs X_1 and X_2 and a single output Y.

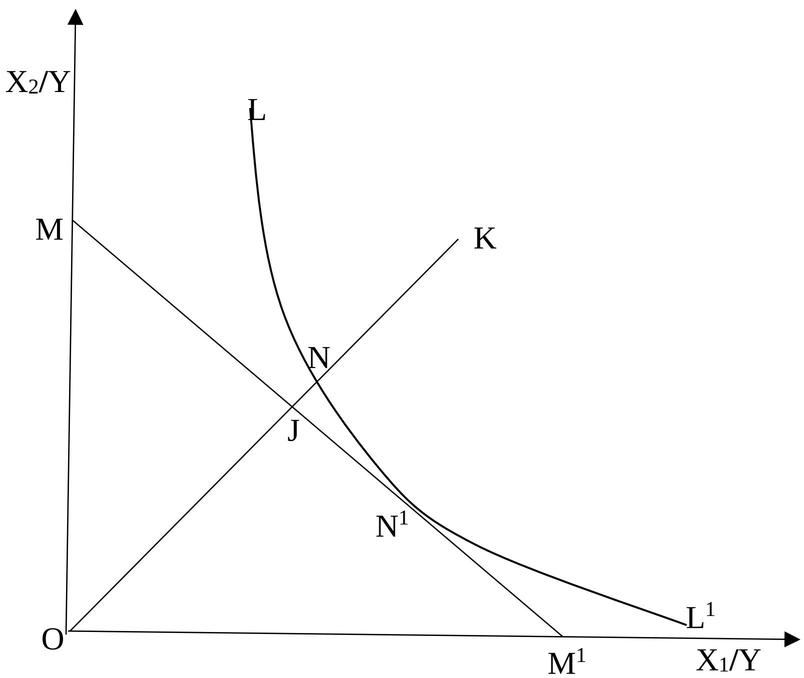

Figure 2.1: input –oriented approach to measuring efficiency

Source: Coelli, Battesse, Rao & O'Donnell, (2005)

The production function in the input-oriented measure is presented as:

$$Y = f(X_1, X_2) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 2.3$$

Assuming a CRS, a production function is given as $1 = f\left({X_1}/{Y}, {X_2}/{Y}\right)$, the efficient frontier could be illustrated as the isoquant LL^1 which indicates the most efficient combination of the two inputs X_1 and X_2 that are utilized in producing a particular output level. Any deviation from the frontier MM^1 causes inefficiency in the utilization of factors of production. The locus MM^1 is known as the isocost. If a certain producer uses inputs level defined by point K, in production of a single unit of output the technical inefficiency, therefore of that firm or producer is presented by the distance NK (Coelli*et al.*, 2005).

In general, the technical inefficiency is expressed as percent of the ratio NK/OK whereas the technical efficiency of a firm or a producer is measured by the proportion ON/OK which is equal to 1-(NK/OK). It ranges between zero and unity, thus providing an indicator for the magnitude of technical efficiency the producer. Where, one indicates the producer is fully technically efficient and zero indicates a producer is fully technically inefficient, for example in figure 2.1, point N is technically efficient since it corresponds on the efficient isoquant LL^1.

2.2.3 Output Oriented Approach

This approach determines how output could be improved given the level of inputs (Farell 1957), this is explained by use of a single input (X_1) and two outputs (Y_1,Y_2) as shown by figure 2.2. WW^1 represents the production possibility frontier where the locus LL^1 represents the isocost price line. If production of the firm takes place at point K, technical efficiency is expressed as OK/ON and technical inefficiency is represented by distance JN which can be expressed as 1-(OK/ON). The total efficiency is given by Technical efficiency * Allocative efficiency TE*AE= (OK/ON) *(ON/OJ) =OK/OJ (Coelli*et al.*, 2005).

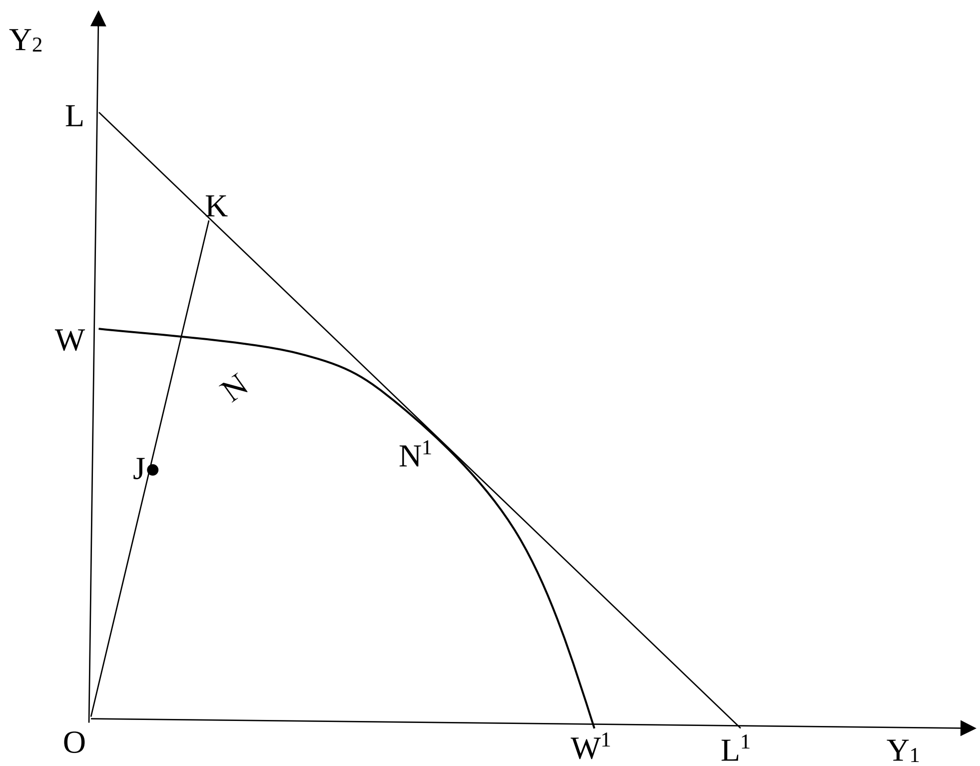

Figure: 2.2 Output-oriented efficiency measure.

Source: Coelli*et al* (2005)

The closer the ratio is to one, the greater the productive efficiency. At N on the graph, the productive efficiency is at the maximum. The determination of technical efficiency using the input and output oriented approaches assumes that the production function is well-known. However, it is not easy to exactly know the underlying production function. This shortcoming necessitates deriving of an efficient isoquant from the sample data in measuring technical efficiency. To overcome this challenge, Farrell (1957), proposed the use two different approaches to the estimation, the first approach is, use of a "non-parametric piece-wise-linear convex isoquant", which is fitted in a way that, there is no observed point that lies above or below it. The second approach, is by the use of a parametric function, for example of "Cobb-

Douglas form", which is constructed in a way that, the observed points does not lie either below or to the left side of the frontier (Coelli*et al.*, 2005). The first method resulted into the introduction of data envelopment analysis (DEA), subsequently the second method, resulted to development of parametric approaches, for example the deterministic frontier approaches and probabilistic frontier methods.

2.2.4 The Stochastic Production Frontier

Aigener and Schmidt (1977) and Meeusen and van den Broeck (1977) proposed the stochastic frontier production function model independently in the form below.

$$ln\ q_i = x_i'\beta + v_i - u_i \qquad (2.2)$$

Where

q_i Is the output,

x_i is a vector comprising of logarithms of inputs.

β is a vector of unknown parameters to be estimated.

v_i stands for the random error term

ui is a non-negative technical inefficiency part of the error term.

The model 2.2 above accounts for technical inefficiency moreover, it acknowledges the existence of random shocks which are not under the control of the producer. These shocks may include drought and in essence they can affect the output level of the firm. The superiority of the stochastic frontier models is that they make it possible to separate the impact of shocks owing to disparity in performance of both labor and machinery, unpredictable weather on output and bare windfall from influence of variation in technical efficiency on output. The model presented by equation 2.2 above denotes the stochastic form of production function in which the values of output are restricted from above by a random or stochastic variable given as $exp(xi'\beta)$. In this circumstance the Cob-Douglas form of the stochastic production frontier can be represented as follows:

$$ln\, q_i = \beta_0 + \beta_1 ln\, x_i + v_i - u_i \quad \text{……2.3}$$

or

$$q_i = \exp(\beta_0 + \beta_1 ln\, x_i + v_i - u_i) \quad \text{……2.4}$$

Considering the outputs and inputs levels of two producers, let say producer A and producer B which are fitted with the deterministic part of the model reflecting the presence of diminishing returns to scale. Producer A utilizes the inputs represented by XA in producing QA amount of output, whereas producer B uses the inputs represented by XB to yield QB amount of output. In instances where inefficiency effects are absent (U_A=0 then U_B =0, whereas U_A and U_B represents the inefficiency effects of producer A and producer B in that order), the frontier yield is represented as:

$$q_A = \exp(\beta_0 + \beta_1 \ln x_A + v_A) \quad \text{……2.5}$$

And

$q_B = \exp(\beta_0 + \beta_1 ln\, x_B + v_B)$………………………………………………………...2.6

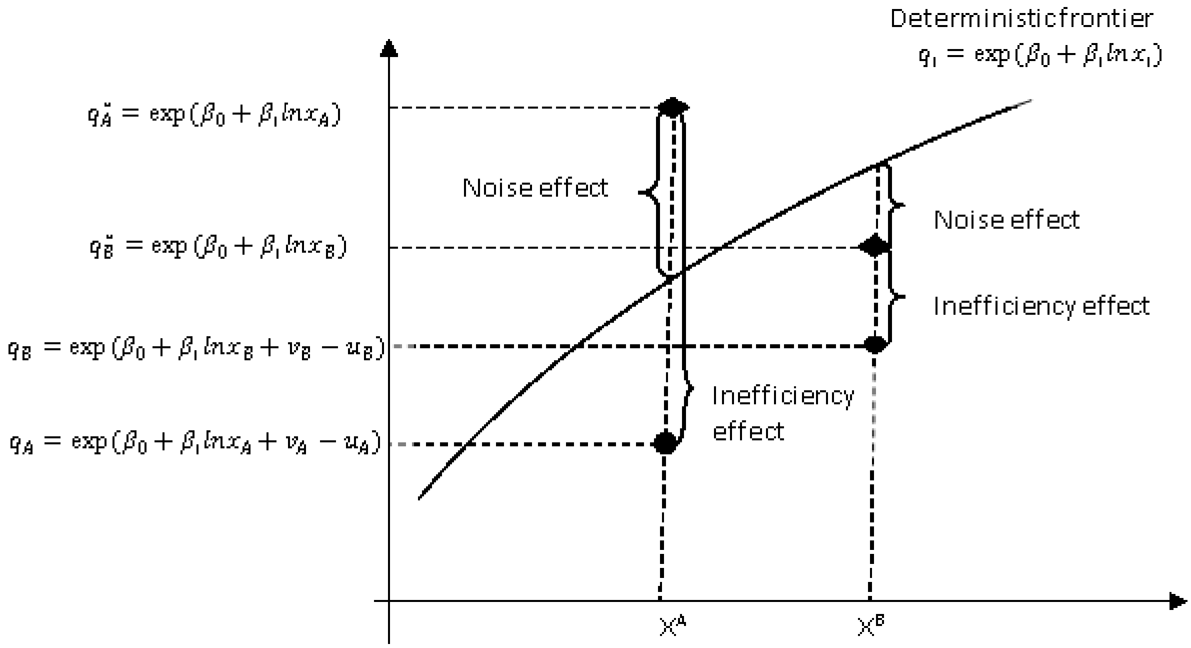

Figure 2.3: The stochastic production frontier
Source: Coelli et al (1998)

The output of the frontier for producer A in the figure 2.3 above, lie above the deterministic component of the production frontier, exclusively due to the fact that the effect of the statistical noise is greater than zero (positive) i.e. (v^A>0). In contrast, the output of the frontier for producer B lie below deterministic component since the effect of the statistical noise is less than zero (negative) i.e. (v^B>0). Further the observed or the actual output for producer A lie below the deterministic component of the frontier. This can be explained by the fact that the sum of the noise effect and inefficiency effect is less than zero (negative) i.e. $v^A - u^A < 0$. When the effect of the statistical noise is greater than zero i.e. positive and it is greater than the inefficiency effects the actual or the observed output would lie above the deterministic part of the frontier. Using the output-oriented method of technical efficiency is commonly expressed as a ratio of actual output to the output level which corresponds to stochastic frontier as presented below;

$$TE_i = \frac{qi}{\exp[x_i'\beta + v_i]} = \frac{\exp[x_i'\beta + v_i - u_i]}{\exp[x_i'\beta + v_i]} = \exp(-u_i) \text{ ………………………………………………2.7}$$

The technical efficiency values ranges between zero and unity, measuring the amount of yield of the i^{th} producer comparative to the amount that would be gotten from a completely efficient producer using the same level inputs.

Stochastic frontier production function can be predicted by use of either of the following approaches. The first is the modified ordinary least squares (MOLS) approach that was suggested by Richmond (1974). The second is by the use of the maximum likelihood (ML) approach. Lastly by use of either linear or quadratic programming. The former method involves optimizing the summation of absolute residuals, subjected to the constraint that the summation of these residuals is higher or else equivalent to zero. While the latter entails minimizing the total squared residuals which is also subjected to the constraint, that the total of the squared residuals is higher or equivalent to zero.

On the other hand, according to Coelli *et al.*, (2005) the OLS or ML can similarly be used in estimating the model. The main shortcoming of the deterministic parametric method is that it only considers the effect of measurement error or any other error on the frontier. Any deviation from the frontier is credited to technical inefficiency. The stochastic production frontier analysis was the anchorage of this study since it acknowledges the random shocks which are not within the control of the producer such as drought, diseases and pest which affects output that are common in agricultural production.

2.2.5 Non- Parametric Approach

The non-parametric approach includes DEA. DEA is a linear programming technique which was advanced by Farell (1957), Färe (1958) and Charnes (1978). It connects the observed or the actual combinations of best practice resulting to a convex production possibility frontier. The aim of DEA is to quantify every firm’s performance comparative to the best practice among the sample of the firms. The main objective of DEA is to find out which among a group of firms, as illustrated by empirical data, forming an envelopment surface or empirical production function. The firms that lies on the empirical production frontier are believed to be efficient, if not they are deemed not efficient (Meeusen and Broeck, 1977).

It involves determination of the set of producers forming the empirical production frontier. The producer lying on the empirical production frontier is considered efficient otherwise inefficient. DEA models can either be constant returns to scale form or the variable returns to scale form. The decision on which form to adopt is based on the economic assumptions as well as other assumptions about the data to be analyzed (Meeusen and Broeck, 1977).

DEA is characterized by the assumptions that it does not impose a functional form restrictions of the production frontier, it has no assumptions about the error term, and it terms the frontier as the most efficient (Boame, 2004). DEA assumes all unexplained variations in production represent the inefficiency in that the random error is zero, which might not be the case especially in agricultural production which is faced by several regular shocks such weather changes, destruction by animals, not forgetting omissions and measurement errors. Therefore, this invalidated DEA to be used in this study.

2.3 Empirical literature

Weir and Knight (2000) studied the impact the education externalities had on the technical efficiency of rural farming in Ethiopia. The study made use of the SFA to determine the technical efficiency scores of the farmers. The study utilized cross-sectional data the analysis, while the specific farmer was taken as the unit of analysis. The study concluded that, the sources of externalities among the famers were in spread and adoption of innovative practices. The average technical efficiency of cereal crop farming was reported to be 0.55. The major weakness of this study is that it considered the schooling levels as the lone source of technical efficiency. However, the current study studied several variables which could have been affecting technical efficiency of small-scale banana farming.

Kuria *et al.* (2003) examined the technical efficiency attributed rice farming in Mwea Irrigation Scheme. The motivation of this study was the fact that the rice production in Kenya did not meet consumer's demand and the shortage is normally met by importation rice. The farmers were grouped into two different categories. One category consisted of farmers who grew a single crop of rice yearly while the second was made up of farmers who grew a double crop of rice annually. The findings indicated that farmers who grew a single crop annually had higher technical efficiency scores than those who grew a double crop of rice annually. Education level of the farmer, farming experience, accessibility to credit facilities and accessibility to extension facilities were found to be statistically significant and positively influencing TE. The short coming of this study was that it assumed that the technical efficiency of a farmer was only influenced by farmer's specific characteristics only. However, the current study examined the influence of the farmer's specific characteristics together with production characteristics on technical efficiency in production by a farmer.

Wambui (2005), examined the technical efficiency of maize farming in Kenya. The study aimed at establishing the technical efficiency and further determining the socio-economic characteristics and management related practices that affect the technical efficiency of maize farmers in Kenya. To estimate the technical efficiency of maize farming, the study utilized cross-sectional primary data collected for 2003/2004 main maize harvest season using SFA. The findings of this study indicated that there existed technical inefficiency in maize production in Kenya, with an average technical efficiency of maize farmers of 49 percent. Further, the technical efficiency of maize farmers ranged between 8 to 98 percent. The study further found that use of tractors, time spent in school in years, the household's head age, gender and health had influence on technical efficiency. The current study borrowed some methodology from this study. It used cross-sectional data and SFA in determining the Technical efficiency of banana. However the current study focuses on a different type and class of a crop.

Gachanja, Etyang and Wawire, (2008) analyzed the change in total factor productivity in manufacturing sector of Kenya. The quantitative objectives that this study sought to address were; to measure total productivity changes in manufacturing sector and to establish sources of changes in total productivity. The study used Malmquist index analysis to measure total factor productivity growth in the manufacturing sector while Data Envelopment Analysis (DEA) technique was used to create a piece-wise linear production frontier for every sampled year. The study utilized the data collected in the 2002/03survey of 282 formal manufacturing firms. The Malmquist index indicated that mean TFP change was 0.917 which implied that there was a decline in total factor productivity of about 8.3 percent over the period 2000 to 2002. However, the technical progress was recorded of about 11.5 percent whose benefits were all eroded by a reduction in efficiency by about 17.8 percent over the period.The findings indicated that the manufacturing sector efficiency declined by 32.1 percent and by 0.5 percent between 2000 and 2001 and between 2001 and 2002 respectively. The results further indicated a technical progress was about 71.9 percent between 2000 and 2001 however a technical regress of about 27.6 percent was recorded between 2001 and 2002. Between 2000 and 2001, the technical progress offset the effect of decline in efficiency to record a TFP growth of about 16.8 percent which were however reversed by a technical regress between 2001 and 2002 this saw a fall in TFP of about 28 percent in the entire sector. The study under review utilized Malmquist Index Analysis to determine technical change, while the current study, determined the actual technical efficiency or in efficiency levels of small-scale banana farming using SFA approach.

Nzioka (2009) analyzed marketing and technical efficiency of smallholder banana farming in Kiambu East District, using linear programming technique to develop a production function frontier and analyze production and technical efficiencies. The study mainly aimed to evaluate banana production and marketing efficiency of banana farming in Kiambu. The study found out on average, 40 percent Kiambu were technically inefficient in production. The study further found some of the factors influencing banana production efficiency were a gender, educational level, age and land size were found to positively influence banana production. However, the study concentrated more on marketing efficiency of bananas. Further, there is distinct difference between banana production between Kiambu and Meru County which this study sought to address. Banana production in Meru is highly commercialized which accounts for around 17 percent of total banana output in the country and leading among the banana producing counties.

Korir, Mburu & Mwabu, (2010) analyzed DEA and SFA methods in estimation of hospital efficiency in Kenya using data which covered the period between the years 1995 to 2000. The study had three objectives which included, the first one was determining the efficiency scores in the operations of the public hospitals, the second one was determining whether the efficiency levels of hospitals had been varying during the period that was under consideration and finally to establish if there existed any statistically significance difference in efficiency levels among three classes of hospitals namely sub-district, district and provincial hospitals. The study under review utilized non-experimental design with the use of panel data where both DEA and SFA approaches were utilized to analyse data.The findings of the study showed that all the hospitals recorded gradual decline in inefficiency scores from the year 1995/96 to 1999/2000. The findings of the study further indicated that mean level of efficiency for the whole sample increased from 1.9384 in 1995/96, to 1.8146 in 1999/2000. Further the analysis of variance established, that there was no statistically significant difference in the average efficiency scores in the period under review. The mean cost efficiency of the hospitals was found to be 134.31 percent, suggesting that the hospitals functioned way above the minimum cost of operation by 34.31 percent. Conversely, the DEA model outcome, showed that the average cost of the hospitals was 27.40 percent above the frontier level, when the variable returns to scale form of DEA model was considered and 34.695 percent above full efficient level, when the constant returns to scale form was considered. However, this study did not explain factors that caused inefficiency in hospitals, further this study analysed efficiency in general the current study singled out the technical efficiency and therefore determined of small-scale banana farming using SFA approach, which was one of the main analytical tools in the study under review.

Ng'anga *et al.,* (2010) used the stochastic profit frontier function to investigate the efficiency of dairy farmers in the Meru South District (currently the Tharaka Nithi County) of Eastern Kenya. The study used a detailed survey information, acquired from 27 dairy farms, the results of the study shown that the profit efficiency moderately varied among the dairy farmers. The average profit efficiency was found to be 60 percent and it ranged between 26 and 73 percent. The results indicated that the level of education, the farming experience and size of the farm positively influenced the profit efficiency whereas the age of the farmer negatively influenced efficiency. Therefore, the results revealed that the farmers who had spent more years in school, the farmers who had more experience in dairy farming and those who had larger farm sizes were more efficient. However, the aged farmers were less efficient this is because the profit efficiency reduced with age. The study failed to include the extension services, this formed the major limitation of the study.

Njeru (2010) used the stochastic frontier technique in examining the factors that influenced technical efficiency in wheat farming in Kenya. The study assumed that technical inefficiency effects depend on the socio-economic and farm-specific characteristics. The study utilized a sample of 160 farmers who comprised 97 and 63 large scale farmers and smallholder farmers, picked through random sampling. The study found that among the large-scale farmers there existed statistically significant levels of technical inefficiencies in wheat production. The results further showed that, the average technical efficiency of wheat production was 87.2 percent ranging from 48.9 percent to 95.1 percent while varying from one farmer to another. This implied approximately to 13 percent of the prospective production of the farmers was lost to technical inefficiencies. The technical efficiency varied with the size of the farm where smallholder farmers recorded greater technical efficiency than the large-scale farmers. Levels of education, accessibility of credit, and the capital equipment ownership the main determinants that influenced the levels of technical efficiency.

Ngeno et al. (2011) examined the technical efficiency among the bulrush millet producers in Kenya. The study made use of Cobb-Douglas stochastic production frontier to measure the technical efficiency of farmers. The finding of this study indicated that there existed variations of technical efficiency of bulrush millet production among farmers in different geographical locations. The study found that using the prevailing technology and an improved utilization of available resources the production could be improved by 28 to 86 percent. The current study used a similar methodology as it used the Cobb-Douglas stochastic frontier in estimating the technical efficiency of banana farmers.

The study by Ogada (2013) on adoption farm technology, technical efficiency and productivity in small scale food crop cultivation in Kenya, sought to analyze factors that influenced adoption of improved farm technologies, measure technical efficiency and establish factors that influenced its variation across households on crop yields among the smallholders. The study used DEA to compute the technical efficiency scores and Tobit model was used to establish the factors that influence inter-household disparity in technical efficiency. The Results showed that adoption decisions on related technologies were inter-dependent. Such decisions were also influenced by specific characteristics of a farmer, plot-level factors and market imperfections. The smallholders were found to be technically inefficient, producing only 60 per cent of the possible output. Wide inter-household disparity in technical efficiency existed, influenced by farmer specific characteristics, production environment and production risks. Inorganic fertilizers and improved seed varieties were found to increase yields especially if adopted as a package and if farmers were more efficient. This study dealt with agricultural technical efficiency in the sector as whole, however different crop production has different efficiency levels, therefore it is important evaluate specific crops production efficiency levels. The current study determined technical efficiency of small-scale banana farming using SFA approach which takes into account shocks which are not under producer’s control and are mostly prevalent in agricultural production which this study sought to address.

Ingabire (2014) analyzed the TE among small-scale rice farming in two provinces of Rwanda (the eastern and southern provinces), with an aim of assessing the rice producers' technical efficiency as well as its determinants in Ntende scheme located in the Eastern province and Cyili scheme located in the Southern provinces of Rwanda. In the analyses the study used SFA with the Cobb-Douglas in estimation of the TE scores of farmers. The study made use of a randomly drawn sample of 185 rice farmers. The findings indicated that in Rwanda, the size of land, quantity of pesticides used and involvement of family labor in rice farming activities were the significant determinants in production of paddy. The results also showed that the average yield in the sample was 4.81tons per hectare and the average TE was 72 percent suggesting that the rice production by farmers fallen short of the frontier output. Regarding the determinants of TE, the age of rice farmers was found positively affecting technical inefficiency which indicated that as farmers become older, the inefficiency effects increase and TE decreases. On the other hand, trainings on rice farming practices and visits of extension agents were found to decrease inefficiency and significantly increase TE. The current study borrowed the methodology of this study in that it used Stochastic Frontier Analysis (SFA) with the use of Cobb-Douglas production function in determining technical efficiency of small-scale banana farming using SFA approach. Though the study under review and the current study are both based on agricultural production, they differed in terms of the crops under review and physical location of the study.

2.4 Overview of Literature

The literature reviewed on technical efficiency measurement provides understanding into the different variables that have effect on technical efficiency in agricultural production. The studies reviewed made use of variables which are in line with economic theory, consequently, they were beneficial in determining the variables that were included in this study. The studies reviewed suggested that technical efficiency in agricultural production depends on the gender, farmer's level of education, age of the farmer, fertilizer and size of the land these studies includes Ingabire (2014), Ogada (2013) and Kuria *et al.* (2003). The literature reviewed also revealed that there was potential of improving agricultural production meaningfully, basically by increasing the level of firm's or producers' technical efficiency with no further increase in inputs. Some of the studies did not investigate sources of technical efficiency which the present study investigated.

Majority of the literature reviewed on agricultural production used Stochastic Frontier Analysis this included Ingabire (2014), Ogada (2013), Weir and Knight (2000), Kuria *et al.* (2003, Nzioka (2009), Ng'anga*et al.,* (2010) and Njeru (2010). The current study borrowed the methodology of these studies in that it used Stochastic Frontier Analysis (SFA) with the Cobb-Douglas function in determining technical efficiency of small-scale banana farming in the area of the study using SFA approach. However majority of these studies dwelt on technical efficiency of other crops leaving bananas. Kuria, Ommeha, Kabuage, Mbogo and Mutero (2003) concentrated on technical efficiency of rice irrigation in Mwea, Wambui, (2005) dwelt with technical efficiency of maize while Ngeno *et al.,* (2011) and Njeru, (2010) dwelt with analyses of technical efficiency of bulrush millet and wheat respectively.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The chapter covers the study methodology, the research design, the theoretical framework, the model specification, definition and measurement of variables, study area and target population, sample design and sample size, the sources and types of data, the data analysis techniques and finally the diagnostic tests that were carried.

3.1 Research Design

This research assumed a non-experimental design. Further, the study adopted the cross-sectional design, which involved collecting production data in one period. In the design, quantitative research approach was utilized. The quantitative data on inputs and outputs for small scale banana farmers was collected for every farmer sampled. The study used the SFA to estimate the technical efficiency scores for the farmers and the determinants of such efficiency levels.

3.3 Theoretical Framework

This study was anchored on the classical production function theory. The 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 suggested by Aigner, Lovel and Schmidt (1997) and Meeusen and Van den Broeck (1977) is:

$$Y_i = X_i\beta + (V_i - U_i) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .3.1$$

Where Y_i, represent a firms output of the i[th] 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 and a constant variance, N(0, δ_v^2) which is linked to the random factors for example production measurement errors and variations in weather all of which are not within farmer's control (a random error term which takes care of unexplained variability in the data sample) and ui represents technical inefficiency component of the error term which .is a non-negative.

3.4 Model Specification

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

$$Y_i = f(X_i; \beta_i) \exp(v_i - u_i) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .3.2$$

Where $i = 1,2, \dots, n$, Y_i is an output of i[th] farmer, X_i is a vector of the input quantities, $f(X_i; \beta_i)$ is an appropriate production function like Cobb Douglas or Translog, Assuming that $(xi; \beta)$ takes the log linear Cobb-Douglas form equation 3.2 can be written as:

$$ln\, Y_i = \beta_0 + \beta_1 ln\, x_i + v_i - u_i \dots\dots\dots\dots\dots\dots\dots\dots 3.3$$

β's are parameters, V_i is the random error with a mean of zero and it is associated with random factors like measurement error, weather, animal destruction which are not under the control of farmers. U_i is a one-sided error term called the inefficiency.

The Cobb Douglas production function for the banana farmers in the study area was specified as follows:

$Ln\ Y = \text{Ln}\,\beta_0 + \text{Ln}\,\beta_1\, X_1 + \text{Ln}\,\beta_2\, X_2 + \text{Ln}\,\beta_3\, X_3 + V - U$……………………………......3.4

Where:

Ln= the natural logarithm

Y= total Quantity of banana (kg)

X_1, = Labor (man hours)

X_2 = total fertilizer used (kg),

X_3 = Total area under banana (acres)

β_i -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 variance N (0, δ_v^2)

U= account for technical inefficiency in production.

Technical efficiency of a given farmer is defined to be the ratio of actual or observed output (Y_i) to the corresponding frontier output (Y_i *) using the existing technology and so the technical efficiency of the farm is denoted by;

TE=Y_i/Y_i *

$TE_i = \frac{f(X_i;\beta_i)\exp(v_i - u_i)}{f[x_i'\beta + v_i]} = \exp\,(-u_i)$……………………………………………………3.5

For technical efficiency to occur exp V= 1 and U = 0 since exp (V) = 1. Thus, TE has values that range between 0 and 1, with 1 defining efficient farms and 0 totally inefficient farms. Therefore, it important to note that the higher the U the lower the technical efficient the farmer is. The first objective which was to Estimate the level of technical efficiency was determined using SFA by use of the equation 3.4

The knowledge that the farms are technically inefficient or efficient is only useful if the causes of the inefficiency or efficiency are also established (Admassie & Matambalya, 2002). Thus, the second phase of inquiry was to investigate determinants of technical efficiencies for the sampled farmers. U account for technical inefficiency, 1-U accounts for technical efficiency in production and is specified as follows:

$$1 - U = \rho_0 + \rho_1 Z_1 + \rho_2 Z_2 + \rho_3 Z_3 + \rho_4 Z_4 + \rho_5 Z_5 + \rho_6 Z_6 + \rho_7 Z_7 + \rho_8 Z_8 + \rho_9 Z_9 \ldots\ldots\ldots\ldots 3.6$$

Where: 1-U = the efficiency term,

Z_1= Gender of the farmer

Z_2= Age of the farmer

Z_3= Level of education of the farmer

Z_4= Household Size

Z_5= Farming experience

Z_6= Land ownership

Z_7= Access to water for irrigation

Z_8= Access to extension services

Z_9= Access to credit services by the farmer

ρ_0 -$\rho_9$estimated inefficiency model coefficients.

The second objective which is to analyze the determinants of technical efficiency of small-scale banana farmers in Imenti South Sub-County was determined together with objective one by simultaneous estimation of equation 3.4 and equation 3.6 using SFA.

3.5 Definition and Measurement of Variables

Variables	Meaning	Variable Measurement
Banana Output Y	Total volume of banana harvested in a year by the famer	Measured in tonnes
Inputs –X_1	Labor- amount of man hours	Measured in hours
X_2	Quantity of fertilizer used in the farm	Measured in Kgs
X_3	Total area under banana	Measured in acres covered by banana only
X_4	Irrigation	Dummy variable 1 if banana farming is under irrigation and 0 if not.
Socio-economic variables		
Z_1	Gender of the farmer	A dummy variable1 if male and 0 if otherwise
Z_2	Age of the farmer	Measured in years
Z_3	Level of education of the farmer	1=no formal education 2=pnmary,3=secondary, 4=tertiary colleges, 5= university
Z_4	Household size	Number of household members both children and adults
Z_5	Farming experience	Measured in years
Z_6	Land ownership	A dummy variable1 if owned

		and 0 if leased
Z_7	Access to water for irrigation	A dummy variable 1- if accessed and 0 if not accessed
Z_8	Access to extension services	A dummy variable 1- if accessed and 0 if not accessed
Z_9	Access to credit services	A dummy variable 1- if accessed and 0 -not accessed

3.6 Study area and Target population

The targeted area of the study was Imenti South Sub-County of Meru County. Imenti South Sub-County was selected since is the main banana producing area in Meru County. Meru County is found in the Eastern part of Kenya and covers a total area of 693,620 hectares out of which 177,610 ha is gazeted forest (Republic of Kenya, 2015). The total acreage under food and cash crops is 161,907 ha and 15,773 ha respectively which represents 23 percent and 2.3 percent of the total land area of Meru County (Republic of Kenya, 2015)

Table 3.1: Target population

Ward	Number of banana farmers
Mitunguu	8200
Abogeta East	5000
Igoji East	2000
Nkuene	500
Abogeta West	250

Igoji West	50
Total	16000

Source: Imenti South Sub-County Agriculture Office

3.7 Sample design and sample size

This study followed a multi-stage sampling method where the first stage involved the purposive selection of the five out of six wards which are main cultivators of bananas for commercial purposes of Imenti South Sub-County. Within each ward farmers were randomly picked. The stratified random sampling method was also utilized, which involved dividing population into strata and then picking random samples from every cluster to participate in the study. To make sure picked sample of farmers was representation of the total population Mugenda and Mugenda (2011) sampling technique was used.

$\boldsymbol{n} = \frac{\boldsymbol{NCv^2}}{\boldsymbol{Cv^2} + (\boldsymbol{N-1})\boldsymbol{e^2}}$ *Whereas n =represents size of the sample, N= the total study population, CV= is the coefficient of variation given as (0.5), e = significance level given as 0.05.*

$n = \frac{1600*(0.5)^2}{(0.5)^2+(1600-1)0.05^2}$*=99.385 approximately 100 people*

The formula below was used to make sure the allocation of the sample picked was random.

$$\frac{\boldsymbol{N1}}{\boldsymbol{N}} \boldsymbol{X\, n}$$

3.8 Data type and sources of data

The study employed primary sources of data collection. The data was obtained through administration and filling of the questionnaires in the field. The first part of the questionnaire covered the socio-economic variables which included the farmer’s age, the household size and the farmer’s gender. While the subsequent sections dealt with the factors of production.

A well-structured questionnaire was used to obtain crucial information regarding banana farming so as to address the study's objectives. The questionnaire comprised closed-ended questions.

3.9 Data Analysis

The data collected from the farmers was first tabulated. The analysis was carried in accordance with the objectives of the study, the first objective which was to Estimate the level of technical efficiency of small-scale banana farmers was determined using SFA. The second objective was to analyze the determinants of technical efficiency of small-scale banana farmers in Imenti South Sub-County was determined using SFA.

3.10 Diagnostic Tests

3.10.1 Heteroscedasticity

Heteroscedasticity have no influence on the unbiasedness and linearity of the regression model coefficients. However, it affects the best property of the estimator, making the inference made during hypothesis testing void. The study utilized the Breusch-Pagan test to test the presence of heteroscedasticity (Gujarati, 2004).

3.10.2 Multicollinearity

Multicollinearity causes uncertainty in the regression coefficients, moreover it causes the standard errors of the estimates to be non-finite. According to Gujarati, (2004) multicollinearity might be common amongst variables but what matters is the degree. To investigate the incidence of serious multicollinearity in this study used the variance inflation factors (VIF) test was used (Nachtscheim, 2004).

3.10.3 Normality Assumption of the Random Variable

The classical linear regression model assumes that the error term (statistical noise) follows a normal distributed, that is it has zero mean and a constant variance which is represented as $\mu (0,\sigma^2)$. The error term captures the effects of all other variables which influence dependent variable but are excluded from the model. Nevertheless, it is assumed that the factors omitted have a minor impact and at best random. To confirm normality of the error term, this study employed the Shapiro- Wilsk test.

CHAPTER FOUR

EMPIRICAL FINDINGS

4.1 Introduction

This chapter presents descriptive statistics and the findings of the analysis on Technical efficiency and determinants of technical efficiency of small scale banana farmers in Imenti South Sub-County of Meru County. This chapter also describes the results for every objective and technical efficiency estimate.

4.2 Descriptive statistics of Small-Scale banana farming

Tables 4.1- 4.8 below present descriptive statistics for study variables for technical efficiency of small-scale banana farming in the study area. The socio-economic factors which were considered in this study are, farmer's gender, farmer's age, land ownership by the farmer, highest education level attained by the farmer, household size of the farmer, farming experience of the farmer, access to extension services, credit services and water for irrigation by the farmer.

Table 4.1 Summary statistics for Gender among small scale banana farmers

Gender	**Frequency**	**Percentage**
Male	40	43.96
Female	51	56.04

Source: **Calculations by the Author**

In this study majority of the banana farmers were males at 56 percent, while 44 percent were female. This implies that both men and women are involved in commercial production of bananas. According to Yegon, Ngui and Mbuthia (2015), in the past women had little control over economic resources, limiting their participation in commercial agricultural production perhaps due to the past land ownership regime that disadvantaged women. However, with fight for equality in access to resources and opportunities women participation in economic production has been on the rise.

Table 4.2: Summary statistics for Age of small scale banana farmers

Age	Frequency	Percentage
Below 20	1	1.1
20-30	17	18.68
31-40	28	30.77
41-50	26	28.57
51-60	11	12.09
Above 60	8	8.79

Source: **Calculations by the Author**

Table 4.2 above shows that approximately 9 percent of the farmers were above 60 years of age. Nevertheless, majority of farmers were aged between 31-40 years, accounting for about 31 percent of the farmers, while the second majority at 29 percent fell under the age bracket of 41-50. Moreover, 12 percent of the farmers were aged between 51-60 years. However, there was just one farmer whose age was below 20 years. The age statistics from this study indicates that banana farming in the county is practiced by middle-aged farmers. Moreover, there is no age restriction in banana production. Age being one of the important social economic characteristics that affect decision making process of a farmer in production process. There is no standard average age of farmer, however the studies carried out on technical efficiency in agriculture shows that farming is practiced mostly by middle aged farmers. According to Runo (2009) the average age of small-scale coffee farmer in Kenya was found to be 45 years. While Njeru (2010) found out that the average age of wheat farmer is 42 years of age.

Table 4.3: Summary statistics for Education among small scale banana farmers

Education	**Frequency**	**Percentage**
No formal Education	17	18.68
Primary	24	26.37
Secondary	38	41.76
Tertiary College	10	10.99
University	2	2.2

Source: **Calculations by the Author**

Table 4.3 shows that most farmers had secondary level of education at 42 percent, while 26 percent had primary education, 19 percent had not acquired any formal education, 11 percent had tertiary education and 2% had university level of education. This implies that most of the banana farmers had the basic education, which therefore facilitates efficient adoption of new farming technologies. The efficient adoption of new and advanced farming technologies has the potential of increasing agricultural productivity of a given farmer. The highest education level attained by a farmer influences their decision making in the production process. This is because the education level influences, the ability of a farmer to access and utilize the production information which is mostly provided in English. Moreover, the level of education influences the ability of the farmer to adopt new and advanced technologies. According Sharma and Leung (2000) education level of more than 4 years has been reported to improve efficiency of farmers.

Table 4.4 Summary statistics Land Ownership among small scale banana farmers

Land Ownership	Frequency	Percentage
Rented	11	12.09
Owned	80	87.91

Source: **Calculations by the Author**

Table 4.4 shows that 88 percent of the farmers owned the land in which they produced bananas while 12 percent rented the pieces of land which they used in banana production. According to Ateka, Onono and Etyang (2018), Land is a key input in agricultural production; however, it is a scarce resource due to its fixed supply. Furthermore, land is unevenly distributed among the population in the country. Therefore, it's common for those who do not own land but wish to engage in agricultural production to rent land from land owners. Therefore, land ownership is an important factor in agricultural production.

Table 4.5: Summary statistics Access to Credit by small scale banana farmers

Access to Credit	Frequency	Percentage
No Access	73	80.22
Have Access	18	19.78

Source: **Calculations from the Author**

Credit plays an important role in financing various farm activities. 80 percent of the farmers had not accessed credit services with only 20 percent accessing mainly from the SACCOs, yet credit enables farmers to purchase farm inputs like manure, fertilizer and hire labour (Njeru, 2010).

Table 4.6 Summary statistics Access to Extension Services by small scale banana farmers

Access to Extension Services	**Frequency**	**Percentage**
No Access	63	69.23
Have Access	28	30.77

Source: **Calculations from the Author**

Table 4.6 shows 69 percent of banana farmers had not accessed extension services, while 31 percent of the farmers had accessed extension services mostly from government agricultural extension officers. Access to extension services by farmers influences the embracing and spread of improved farming methods among the farmers, more specifically in regard to the use of the proper amounts of fertilizers, manure, insecticides and pesticides (Njeru, 2010).

Table 4.7 Summary statistics Access to Water for irrigation by small scale banana farmers

Irrigation	**Frequency**	**Percentage**
No Access	6	6.59
Have Access	85	93.41

Source: **Calculations from the Author**

Availability and access of water for irrigation especially during the dry seasons by farmers is an important factor that influences agricultural production. Table 4.7 above shows that 93 percent of the farmers irrigated their banana during dry seasons due to availability of water for irrigation. While 7 percent of the farmers had no access to water for irrigation during dry season and depended only on rainfall. Shanmugam and Venkataramani (2006) found that farmers employing irrigation technology achieve greater efficiency.

Table 4.8 Summary statistics for continuous variables for Small-Scale banana farming

Variable	Mean	Std. Deviation
Household Size	4.04	1.69
Experience	10.36	5.26
Banana Output	10406.70	7858.0
Labor	108.80	81.96
Fertilizer	8.17	8.11

Source: **Calculations from the Author**

This study established that the mean household size was 5 people. The size of the household determines, the workforce available to provide labour for banana farming. This may be important especially during banana planting and when distributing manure into the farm. The output of labour depends on its ability to engage in production as opposed to the labour size. A household with fewer school going children may have more productive labour than a household with more school going children. Therefore, the average household size indicates the potential labour availability rather than guaranteed labour availability (Yegon, Ngui and Mbuthia 2015)

On average the farmers had experience of 10 years in banana farming. Experience plays a significant role in improving production, it is expected that the longer one works on a certain occupation, the better they become in regard of skills to accomplish tasks. According to Kareem *et al.*, (2008) farmers with more experience would be more efficient this is because they have better knowledge on climate conditions, market situations, best plant and pest diseases control measures; therefore, they are expected to run more efficient production entities

Labour and fertilizer are among the key inputs in banana production, the average fertilizer applied in a year was 8.2 bags of 25- kilogram (Kgs) per acre, while the standard deviation was 8.11 bags. In a year the mean labour used per farm was 108.8 man-days in the overall sample, with standard deviation of 81.96 man-days. The mean output of banana production per farm annually was 10406.7kgs with a standard deviation of 7858 Kgs. The banana output in a year ranged between 1800 Kgs to 54000kgs.

4.3 Diagnostic test

4.3.1 Test for Heteroscedasticity

The study utilized the Breusch-Pagan test to test the presence of heteroscedasticity (Gujarati, 2004). The hypothesis for the test was, null hypothesis Ho, variance is constant (homoscedastic) and alternative hypothesis Ha, variance not constant, (heteroscedastic. The results for heteroskedasticity are shown in the table 4.2 below.

Table 4.9 Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

Ho: Constant variance (homoscedastic)

chi2(1) = 121.42

Prob > chi2 = 0.0000

From table 4.2 p-value is below 0.05 at 5 percent level of significance therefore the null hypothesis was rejected and therefore concluding that there is presence of heteroscedasticity. In order to solve this problem, the heteroscedasticity robust standard errors were used in estimation.

4.3.2 Test for Multicollinearity

In order to investigate the incidence of serious multicollinearity amongst the variables, the variance inflation factors (VIF) was utilized and results are shown in the table 4.10 below.

Table 4.10 Multicollinearity results

Variable	VIF	1/VIF
Gender	1.14	0.876666
Age	1.33	0.753275
Education	1.20	0.834245
Household Size	1.34	0.743827
Experience	1.50	0.666028
Land Ownership	1.13	0.885751
Access to Irrigation	1.32	0.759540
Access to Extension	1.21	0.827216
Access to Credit	1.33	0.753943

Source: **Author's calculations**

The VIF results indicates that the VIF for all variables used was below 10 and tolerance defined 1/VIF was more than 0.1 therefore there was no serious multicollinearity between the regressors.

4.3.3 Normality test

The normality test for residuals was carried out based on Shapiro-Wilk statistic whose p-value was 0.01431. Considering the result for normality if the P-value is greater the level of significance we do not reject the null hypothesis that the residuals are normally distributed otherwise, the null hypothesis is rejected and we conclude non-normality. At 1 percent level of significance 0.01431> 0.01 thus we do not reject the null hypothesis, concluding that the residuals follow a normal distribution at 1 percent level of significant. However, at 5 percent level of significant 0.01431< 0.05 rejecting the null hypothesis at 5 percent level. The statistical assumption of normality in the distribution of error term or residuals allows the carrying out the significance tests for the estimates. Nevertheless, according to Koutsoyannis (1977), in the situation where the size of the sample involved is large, the normality in distribution of error term is guaranteed, this according to the Central Limit Theorem. A total of 91 observations from the valid questionnaires was used which is a large sample. In statistics a sample of more than 30 observations is considered to be a large sample and therefore this validates the carrying out of tests for significance of the estimates in this study.

4.4 Technical Efficiency of Small-scale Banana farming.

Determination of Technical Efficiency of small-scale banana farmers was the main objective of the study. It was important to first test whether the small-scale banana farmers were producing along the frontier. Moreover, determine the production function's best functional form to use given the Trans log and the Cobb-Douglas forms of production function. This required carrying out statistical tests for hypothesis and inference as appropriate.

4.4.1 Hypothesis Testing

According to Battese and Coelli (1995), testing for hypotheses in determination of the best functional form of production function, requires imposition of restrictions on the model and using the log likelihood values to compare test statistic values with critical values provided in Kodde and Palm (1986) tables.

The choice of the appropriate form of production function to be used in the study, depended on the log likelihood ratio test. The null hypothesis was the Cobb Douglas log likelihood values because it is the restricted form of the Trans log function. The test statistic of the log likelihood test was matched to Kodde and Palm critical values. The test statistic summaries were presented in the table 4.11 below.

Table 4.11 Test Statistic

Null hypothesis	Test statistic	Degrees of freedom	Critical value	Decision
H_0:β_1=β_2=…=β_9=0 Cobb-Douglas (restricted model) $H_1: \beta_1 \neq \beta_2 \neq \ldots \neq \beta_9 \neq 0$ Trans log (unrestricted model)	LR=0.19095102	8	14.853	H_0 not rejected
$H_0: \rho_i = 0$ No inefficiency effects $H_1: \rho_i \neq 0$ Presence of inefficiency effects	$\lambda^{\sim} = 2.2814719$	8	1.645	H_0 rejected

Source: **Author's calculations**

Considering the findings presented in the Table 4.11 above, the first null hypothesis was accepted and therefore the Cobb Douglas functional form of the production function was considered to be the best representation of the data. Ndicu, Muchai and Gachanja, (2015), and Yegon, Ngui and Mbuthia (2015) also did not accept the Trans log production function in favor of Cobb-Douglas production function. However, Lundvall and Battese (2000) rejected Cobb-Douglas form of production function in favor of the Trans log production function.

The second null hypothesis which suggested that the farmers were technically efficient was not accepted favoring the alternative hypothesis of the presence of inefficiency effects, thus concluding that farmers were technically inefficient. This necessitated the finding out of the determinants of technical efficiency in order to establish the sources of inefficiencies in production.

4.4.2 The Empirical results from the stochastic frontier analysis

This segment presents and discusses the findings of econometric analysis of the stochastic production frontier of the Cobb-Douglas functional form. The table 4.12 below, presents the results from estimation of the function, the diagnostic tests carried on the model and distribution assumption of the data.

Table 4.12: Maximum Likelihood Estimates of the stochastic frontier for production function

Variable	**Coefficient**	**t-ratio**
Constant	0.47216907*	8.0010841
Labor	-0.25411509	-0.41711168
Fertilizer	0.1857779*	3.2831896
Area	0.3868711*	5.4178735
Diagnostic Statistic		
Sigma squared (δ^2)	0.16503672*	5.9466976
Gamma (γ_m)	0.4852595*	2.2814719
Log likelihood function	-56.406067	
Log ratio	19.095101	

*Statistically significant at 5%

Source: C**alculations by the author**

Table 4.12 above presents the maximum likelihood estimates of the stochastic frontier production function for small banana farmers. The estimated sigma squared (δ^2) was reported to be 0.165 and was significantly different from zero at 5% level of significance. This is an indication of a good fitness of the model and the correctness of the specified distributed assumption of the composite error term$(v_i - u_i)$.The gamma (γ_m) value was 0.485 and was significant at 5percent level of confidence. The results show that banana farmers in the study area were not producing efficiently, this meant that they are not producing along the frontier level, indicating that the disparities between the observed (actual) and frontier (potential) output are as result of inefficiencies and not chance alone. According to Battese (1992) Gamma (γ_m) ranges between zero and one, when it is zero, inefficiency effects do not exist in the model and if it is one, inefficiency is significant and is not random.

The ML estimates of the production model show that the constant, the coefficient of fertilizer, and the area under banana production were significant at 5% level of significance. However, labor had a negative coefficient and was not significant at any level of significance. This contradicts the findings of Njeru (2010) who found out that labour had significant positive influence on wheat production. However, Yegon, Ngui and Mbuthia (2015), found out that labour had a negative coefficient and was not statistically significant on fish production.

The coefficients for area under banana production was also significant and positive implying that there is direct relationship between the variable and banana yield. This means as the area under banana production is increased given other inputs, banana output will also increase. It is expected that as land increases the output also increases. These results were consistent with findings of Njeru (2010) and Nzioka (2009).

Fertilizer application positively and significantly (at 5% level of significant) affected the banana yield in the study area, implying that increasing the total fertilizer usage would increase banana output. These findings agree to those by Evenson and Mwabu (1997), Njeru (2010), Nzioka (2009), Kuria et al (2003) that demonstrated positive and significant relationship between fertilizer use and productivity.

4.4.3 Technical Efficiency for small-scale banana farming.

This section analyses technical efficiency of small-scale banana farmers and presents the distribution of their efficiency levels in table 4.6 below

Table 4.13: Frequency Distribution of Technical Efficiency in Small scale banana farming

Range (in %)	**Frequency**	**Percentage**	**Cumulative downwards**	**Cumulative upwards**
91-100	14	15.37	15.37	100
81-90	10	11.00	26.37	84.63
71-80	4	4.40	30.77	73.63
61-70	33	36.26	67.03	69.23
51-60	26	28.57	95.60	32.97
41-50	3	3.30	98.90	4.40
31-40	1	1.10	100.00	1.10
Total	91	100		
Minimum	34.89%			
Maximum	98.96%			
Mean	68.52%			

Source: Authors own construction

Table 4.13 above, indicates that the technical efficiency levels of small-scale banana farming are distributed over a wide range. The predicted farm's specific technical efficiency ranged from

34.89 percent to 98.96 percent with an average mean technical score of 68.52 percent. In addition, there is no farmer who attained a frontier level of one hundred percent. The results further, showed that the minimum technical efficiency obtained by the farmers was 34.89 percent while the maximum technical efficiency achieved by the farmers was found to be 98.96 percent. Approximately 31 percent of banana farmers are producing at above 70 percent technical efficiency levels. Moreover, about 96 percent of the banana farmers are producing at a technical efficiency level of above 50 percent, leaving around 4 percent of farmers operating on technical efficiency level of 50 percent and below.

The average technical efficiency score of 68.52 is below the frontier, inferring that there is room for improving banana productivity by approximately 31.48. In the short run the farmers whose technical efficiency scores are below the average technical efficiency score of 68.52, can increase their technical efficiency by adopting practices of the best banana farmers which may include access to specialized extension services and training. The lower levels of technical efficiency can be attributed to either poor utilization of input or /and farmer’s specific factors which may include lack or inadequate access to training, extension services, access to irrigation water and land ownership.

4.4.4 Technical Efficiency Distribution and Farmer Characteristics

In providing more information on the technical efficiency of banana production it was important to analyse the technical efficiency scores by farmer’s characteristics which includes age, gender, size of the household, education level, the experience in banana farming, access to water for irrigation, land ownership, access to extension services, and access to credit services. Table 4.7 below presents the statistics of efficiency scores by farmer’s characteristics.

Table 4.14: Summary of technical efficiency by household characteristic

The tables below represents the summary of technical of small scale banana farmers by the household characteristics

Education	Categories	Mean	Std.Dev	Frequency	P-value
	No Formal education	65.142172	16.14898	17	0.4607
	Primary	68.220311	15.49789	24	
	Secondary	71.766375	15.132787	38	
	Tertiary College	63.744632	16.908677	10	
	University	63.249311	2.030711	2	
Access to extension services	No Access	68.023888	14.690722	63	0.6463
	Have Access	69.652379	17.422099	28	
Access to water for irrigation	No Access	53.227771	20.554473	6	0.0116
	Have Access	69.604764	14.643305	85	
Access to Credit Services	No Access	63.462017	12.563881	73	0.000
	Have Access				
Gender	Female	67.408286	13.82023	40	0.5458
	Male	69.400787	16.786559	51	
Land Ownership	Leased	97.376536	1.60279	11	0.000
	Owned	64.557871	11.89943	80	
Age	Below 20	59.348167	0	1	0.5719
	20-30	69.283913	15.589648	17	
	31-40	67.081372	16.626819	28	
	41-50	67.430416	14.541882	26	
	51-60	67.43446	15.566625	11	
	Above 60	78.168574	15.232338	8	
Household Size	0-4	68.584628	14.697167	52	0.9665
	5-8	68.445409	6.710069	39	
Experience	0-10	68.656128	16.700565	56	0.9665
	11-20	68.315098	13.595941	35	

Source: C**alculations by the author**

The results from table 4.14 above, revealed that there was a statistically significance difference in technical efficiency between the farmers who had access to credit services and those who did not have to access credit services, as shown by a p-value of 0.000 and standard deviation of 12.56 for those who did not have access to credit and 6.86 for those who had access to credit. Similarly, there was statistically significance difference in technical efficiency between the farmers who had access to water for irrigation and those had no access as shown by the p-value of 0.0116 and standard deviation of 20.55 for those who had no access and 14.64 for those who had access.

Further, the results showed that, there was a statistical difference in technical efficiency between the farmers who had leased land for banana production and those who owned the land under banana production as revealed by a p-value of 0.000 and a standard deviation of 1.6029 for those had leased the land and 11.90 for those owned the land under banana production.

Conversely, there was no significant difference in technical efficiency between farmers who had different levels of education, different age group, different levels of banana farming experience, different household sizes, those who had access to extension services and those had no access and between male and females as revealed by their p-values. This finding concurs to Ateka, Onono, Etyang (2018) who found that the Technical Efficiency of farming households which had a female head had no statistical difference from the Technical Efficiency of the farming households which had a male head. Even though the finding is dissimilar to Hong and Yabe (2015) whose findings indicated that the TE of the farming households which had a male head was significantly higher than the farming households that had a female head, it’s not uncommon.

The findings of Quisumbing (1995), indicated that six out of seven empirical studies showed statistical insignificant differences in Technical efficiency between the male farmers and the female farmers in agricultural production.

4.5 Determinants of technical efficiency in the small-scale banana farming

The second objective of the study was to analyse the determinants of technical efficiency of banana farmers in small scale banana farming, the factors that were considered include the farmer's gender, age, education level, ownership of land, access to water for irrigation, access to extension services, size of the household, farming experience, access to credit services. The efficiency model was used to measure the determinants of technical efficiency in the small-scale banana farming. The results of the efficiency model are shown in the table 4.8 below.

Table 4.15: Estimates of the Technical Efficiency of Small-Scale Banana Farmers.

Variable	Coefficient	t-ratio
Constant	0.7898764**	17.02
Gender	-0.358297**	-3.88
Age	0.0140416**	2.51
Education	0.0005649	0.16
Household size	-0.0209132**	-8.59
Experience	-0.0002063	-0.21
Land ownership	-0.3010688**	-9.04
Irrigation	0.1870791**	6.90
Access to extension services	-0.159625	-1.22
Access to credit	0.2289297**	10.56

**statistically significant at 5%

Source: Author's own calculations

The coefficients of the technical efficiencies of small-scale banana farming are presented in the Table 4.15 above. The coefficients of age, education level, access to water for irrigation and access to credit were positive. In the efficiency model (1-U) the positive sign associated with coefficients of the specific variables indicates positive influence on the efficiency level, while the negative sign of the variable's coefficient indicates a negative influence on the efficiency levels of a farmer. However, in the inefficiency model (U), the positive sign associated with coefficients of the specific variables indicates negative influence on the efficiency level, while the negative sign of the variable's coefficient indicates a positive influence on the efficiency levels.

This study found out that education level was statistically insignificant at all levels, however the positive sign of the coefficient of education level means that improving the level of education of the farmer would reduce inefficiency. The findings correspond to the results reported on studies on maize and rice by Kibaara, (2005), and Hyula, (2006) respectively.

The results showed that banana farming experience is negatively associated to the technical efficiency, however statistically insignificant at any level of significant. This was contrary to expectation; it was expected that as the experience increase, inefficiencies of production tends to decline as operation continues on yearly basis. This finding contradicts with the findings of Ram (1982) and Revilla-Molina et al., (2009) that found out that with increase in years of experience farmers become more specialized, resulting to higher output and higher technical efficiency.

At 5 percent level of significance the coefficient for the farmer's age is statistically significant. Moreover, it was positively related to technical efficiency. This, implied that increasing the farmer's age raises the level of technical efficiency. It is expected for the older farmers, to have more experience, since they are used to the production processes and techniques and hence increased technical efficiency. According to Singh, (2005) the farming practices of a farmer are influenced by their age either directly or indirectly in terms of knowledge and management of labour. The youthful and middle- aged farmers are more likely to adopt the emerging technology in farming compared to the older farmers who are unadventurous and fears risks hence less willing to adopt the advanced technology.

The estimated coefficient of household size was negatively related to technical efficiency and statistically significant at 5% level of significance, meaning when the size of the household increases the level of technical efficiency declines. This happens if the farming household is majorly composed of young whose efforts of providing labour have not influenced production. This could be ascribed to the fact that increases in household size is due to high number of school-going children who are not involved in actual production. Further, in Kenya it is unlawful for any child to be out of school, given that tuition fees for primary and day secondary schools is paid by the government. This finding conforms to that of Muharnmad-Lawal *et al.* (2013).

The coefficient of access to credit was positive and statistically significant at 5 percent level of significance, indicating that access to credit by farmers could increase technical efficiency. Provision of credit solves the problems of lacking capital more so for farmers who are faced resources constrains to buy fertilizers, and hire labour. Nevertheless, Aghion et al (2005) warns that the relative costliness ought to be looked at when making decision to take up a credit. Runo (2009), found out that the accessibility of credit to a farmer positively influences efficiency in coffee production, since the credit facility eases the financial difficulties experienced by the farmers, enabling them to acquire inputs for the farm.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a brief summary, conclusion and recommendations of the main findings on the technical efficiency levels and determinants of technical efficiency. Additionally, the chapter presents the suggestions for further research.

5.2 Summary

Banana is fourth most valuable crop in the globe behind maize, wheat and paddy (World Africa Harvest, 2007). India is the largest banana producer in the globe with an average banana output of 39 million metric tons which represents 18 percent of total global banana output (FAO, 2012). East Africa region accounts for approximately half of Africa's total banana output annually ,hence leading to provision of staple food and income for more than 20 million individuals in the region (Karamura et al, 2000). In Kenya Bananas are mainly grown by small scale farmers whose produce contribute to food requirement in the country (Nzioka, 2009). The land under banana production accounts for about 2 percent of Kenya's cultivatable land. The crop is cultivated to provide household income to millions of rural Kenyan's residents in several Eastern parts of the country, following the downfall of what was used to be considered as the main cash crop (that included coffee and tea), banana production has been a main source of income (Mbogoh et al., 2002, USAID, 2014). In Imenti South Sub-County despite the increased acreage increase in area under banana production the Banana production yields lower output compared to the potential per acre, the farmers are reported to produce 4.5-10 tons per acre as compared to potential of 30-40 tons per acre (Muchui et al., 2013). The efforts of the Kenyan government in putting in place measures to make sure that the country is food secure inspired the carrying out of this study. The objective of the government of ensuring the country is food secure could be achieved by ensuring that there is efficiency in production of food crops among them is banana. In Kenya the area under banana cultivation has been increasing, but production yields are lower than the potential per acre. The study investigated technical efficiency and the determinants of such technical efficiency among banana farmers in Imenti South Sub-County, Meru County. This research adopted cross-sectional design which involved collecting production data in one period. Further, it made use of a sample of 100 small scale banana farmers who were randomly picked from the five wards of Imenti Sub-County, Meru County, while in the analysis 91 valid questionnaires were utilized. The study utilized data on variables which included labour, size of land and fertilizer as well as socioeconomic variables which included gender, size of the household, education level, experience in banana farming, access to extension services, access to water for irrigation, ownership of land under banana and access to credit services. The study used MLE to estimate the stochastic frontier production function and the determinants of such efficiency levels. The results indicated that the average technical efficiency for small scale banana farming was 68.52, this means the farmers on average were 31.48 percent technically inefficient. The regression results for efficiency model showed that the farmer's age, level of education, access to water for irrigation, access to credit had positive influence on technical efficiency while the size of the household, gender of the farmer, access to extension services, land ownership and the experience of the farmer had negative influence on efficiency.

5.3 Conclusion

The conclusion of this study is that, the banana farmers' production falls short the frontier output. This study revealed that the average technical efficiency of banana farming was above average however, there is prospective for improving banana production by putting more cultivatable land under banana production and increasing fertilizer application. The results of technical efficiency analysis indicated that there existed technical inefficiency effects on banana production, as depicted by efficiency model. The study found out that the Cobb-Douglas specification of stochastic frontier production function was more suitable than Trans log form specification under banana farming situation in Imenti South Sub-County. Area under banana production and fertilizer were statistically significant and of significance in banana production in the area of study. Moreover, the analysis of efficiency model further revealed that gender, age, household size, experience, the land ownership, accessibility to water for irrigation and accessibility to credit services were statistically significant variables influencing farmer's scores of technical efficiency in Imenti South. Additionally, from the ML estimates of the production model show that the fertilizer and the area under banana production had significant influence on banana production whilst, labor had a statistically insignificant negative influence on banana production.

5.4 Policy Implications

This study recommends that; to ensure improvement of technical efficiency, there is need to put more emphasis on enhancement of the production and socioeconomic characteristics of farmers. Since the findings of this study revealed that the access to credit facilities by the farmers have a positive or direct effect on technical efficiency, the government through the agricultural finance institutions should ensure that credit is available to the banana farmers at an affordable interest rate at all times. The farmers should form banana cooperatives and self-help groups to help them seek micro-credit from financial institutions as well as government and non-governmental organizations. The county government can also ensure that banana farmers are in cooperatives and other self-help groups so as to ease the disbursement of the credit from the government and other stakeholders.

Both the National government and the County government of Meru, should ensure that fertilizer is readily and cheaply available at the appropriate time to banana farmers. Furthermore, they can set distribution depots within the locality of farmers in order to save on time and cost of searching. The Majority of the farmers did not access extension services therefore it is essential to ensure proper extension coverage to many farmers, the county government should also ensure that extension officers are trained regularly on new farming methods and techniques this will boost farmers' productivity.

5.5 Areas for Further Study

The current study established the technical efficiency and its determinants in small-scale banana farming in Imenti South Sub-County, Meru. However, further studies should be carried out on commercial banana farming in the entire country and especially the banana growing regions. In addition, more variables which were not considered in this study due to the limitations of the study, should be considered to establish whether the study will yield the same or different results. Finally, studies on allocative, market and economic efficiency of banana farming should be carried out to enrich the research on commercial banana farming in Kenya.

REFERENCES

Admassie, A., & Matambalya, F. (2002). Technical Efficiency of Small-and Medium-Scale Enterprises: Evidence from a Survey of Enterprises in Tanzania. *Eastern Africa Social Science Research Review*, *18*(2), 1-29.

Aghion, P., Angeletos, G. M., Banerjee, A., & Manova, K. (2005). *Volatility and growth: Credit constraints and productivity-enhancing investment* (No. w11349). National Bureau of Economic Research.

Agriculture and Food Authority (AFA). (2016). *Horticultural Validated Report 2015-2016*.

Africa Harvest. (2008). A Decade of Dedication: How Tissue Culture bananas has improved Rural Livelihoods in Kenya. Africa Harvest Biotech Foundation International. Nairobi. Kenya.

Aigner, D. J., Lovell, C. A. K., and Schmidt, P. (1977). “Formulation and Estimation of Stochastic Production Functions Models”. *Journal of Econometrics*, 6, 21-37.

Ateka JM, Onono P, Etyang M (2018). Productivity and Its Determinants in Smallholder Tea Production in Kenya: Evidence from Bomet and Nyamira Counties of Kenya. Journal of Agricultural Economics and Rural Development, 4, 416-422.

Battese G. E and Coelli, T. J. (1992). "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India." *Journal of Productivity Analysis*, 3, 153-169.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, *2*, 429–444.

Coelli, T. J. (1995). "Estimators and Hypothesis Tests for a Stochastic: A Monte Carlo Analysis." *Journal of Productivity Analysis*, 6, 247-268.

Coelli, T., Rao D. S. P. and Battese G. E. (1998). *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers.

Coelli, T.J., Battesse, G.E., Rao, D., & O'Donnell, C. (2005). *An Introduction to Efficiency and Productivity Analysis* (2nd ed.). New York: Springer Science+ Business Media Inc.

FAO. (2014). *Banana Market Review and Banana Statistics 2012-2013* (pp. 1-8). ROME.

Farrell, M. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society* 120, 253-281.

Forsund, F., K. Lovell, and P. Schmidt, (1980), A Survey of Frontier Production Functions and Their Relationship to Efficiency Measurement, *Journal of Econometrics*, 13, 5-25.

Gachanja, P., Etyang, M., & Wawire, N. (2008). *Total Factor Productivity Change in the Kenyan Manufacturing Sector: A Malmquist Index Analysis* (Ph.D.). Kenyatta University.

Gujarati, D.N (2004) "*Basic Econometrics*" 4th edition. McGraw-Hill, Book companies, New York.

Hong, N. B., & Yabe, M. (2015). Resource use efficiency of tea production in Vietnam: Using translog SFA model. *International Journal of Biology*, *7*, 160.

Karamura, E., Frison, E., Karamura, D. a, & Sharrock, S. (2000). Banana production systems in eastern and southern Africa, 401–412.

Kareem, A. (2008). Numerical simulation of wind effects: a probabilistic perspective. *Journal of*

Wind Engineering and Industrial Aerodynamics, *96*, 1472-1497.

Kasyoka, M. R., Mwangi, M., Kori, N., Mbaka, J., & Gitonga, N. (2011). Banana distribution and their seed systems in central and eastern Kenya. *African Crop Science Conference Proceedings*, *10*, 457–459.

Kibaara, W. B. (2005), Technical Efficiency in Kenyan's Maize Production: An Application of the Stochastic Frontier Approach, Department of Agricultural and Resource Economics, Colorado State University, USA. Unpublished Master's Thesis

Kimenyi, E., (2008). Kenyan Extension Services. *A paper presented at the JICA training program on Rural Development by Songa Mbele Community Development Initiative approach*. Nairobi.

KIPPRA (2017), Kenya Economic Report 2017, *Sustaining Kenya's Economic Development by Deepening and Expanding Economic Integration in the Region.* Kenya Institute for Public Policy Research and Analysis (KIPPA). Nairobi, Kenya

Kenya National Bureau of Statistics (KNBS), (2017). *Economic Survey 2017*. KNBS, Nairobi, Kenya. http://www.knbs.or.ke

Kenya National Bureau of Statistics (KNBS), (2018). *Economic Survey 2018*. KNBS, Nairobi, Kenya. http://www.knbs.or.ke

Kodde. D. A and Palm F. C, (1986). Wald criteria for jointly testing equality and inequality restrictions. Econometrics, (Sept, 1986) 1243- 1248.

Korir, J., Mburu, T., & Mwabu, G. (2010). *The Data Envelopment Analysis and Stochastic Frontier Approaches to the Measurement of Hospital Efficiency in Kenya* (Ph.D). Kenyatta University.

Koutsoyannis, S. P. (1977). Features of sound propagation through and stability of a finite shear layer.

Kuria J., Ommeha H., Kabuage L.,Mbogo L & Mutero, C. (2003). Technical Efficiency of rice producers in Mwea Irrigation Scheme.

Lundvall, K., & Battese, G. E. (2000). Firm size, age and efficiency: evidence from Kenyan manufacturing firms. *The journal of development studies*, *36*(3), 146-163.

Mbaka, J. N., Mwangi, M. and Mwangi, M. N. (2008). Banana Farming as a Business: The Role of Tissue Cultured Planting Materials in Kenya. *Journal of Applied Biosciences, 9(1): 354 – 361*

Mbogoh, S.G, Wambugu, F.M, Sam, W (2002). Socio-economic Impact of Biotechnology Applications: Some Lessons from the Pilot Tissue- Culture (tc) Banana Production Promotion Project in Kenya, 1997- 2002. Durban, South Africa: Paper presented during the XXV IAAE Conference, August 2003

Mechri, A., Lys, P., Cachia, F., & FAO. (2017). Productivity and Efficiency Measurement in Agriculture, A Literature Review and Gaps Analysis. *Global Strategy to Improve Agricultural and Rural Statistics*, (GO-19-2017 February).

Meeusen, W. and van den Broeck, J., (1977). Efficiency Estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, 18: 435-444.

Meru County Government. (2014). The Report: Meru County 2014 Kenya. Retrieved from http://meru.go.ke/image/Oxford report.pdf

Muchui, M. N., Gatambia, E. K., Kamau, M. W., Thuranira, D. M., Miruka, M., Wasilwa, L., Gitau, C. (2013). Enhancing small scale banana production through the farmer field school in Eastern Kenya.

Mugenda.O,.and Mugenda A,. (2011). Research Methods. Acts Press Publishers. Nairobi

Mwabu, G., and Everson, R., (1997): "A model of occupational choice applied to rural Kenya. "African Development Review, 9 :(1-14)

Nachtscheim, C.J. Neter, J. (2004). *Applied Linear Regression Models*, 4th edition.

Boston: McGraw-Hill Irwin.

Ng'ang'a S.K, J. Kungu, N. De Ridder and M. Herrero (2010). Profit efficiency among Kenyan smallholders' milk producers: A case study of Meru-South district, Kenya

Ng'eno. V, Rop. W, Langat. B., Ngeno E. K. and Kipsat M. J, (2011). Technical efficiency among the bulrush millet producers III Kenya. African Journal of Business Management, 5(16), pp. 6774-6777.

Njeru.J. (2010). Factors Influencing Technical Efficiencies among Selected Wheat Farmers in Uasin Gishu District, Kenya.

Nzioka, S. M. (2009). Economic Efficiency Analysis of Banana Farmers in Kiambu East District of Kenya: Technical Inefficiency and Marketing Efficiency. Journal *of Developments in Sustainable Agriculture*, 4:118-127.

Ogada MJ., (2013), Production risk and farm technology adoption in rain-fed semi-arid lands of Kenya. *AfJARE* 2010, 4(2).

Quisumbing, A.R (1995). Gender Differences in Agricultural Productivity; A survey of Empirical Evidence, Discussion Paper No.5.Washington D.C: World Bank.

Ram, R. (1982). International inequality in the basic needs indicators. *Journal of Development Economics*, *10*(1), 113-117.

Republic of Kenya (2004). Kenya Economic Survey 2017. Nairobi. Government Printers.

Republic of Kenya. (2015). *County Statistical Abstract, Meru County*. Nairobi: Government printers.

Republic of Kenya, (2017). "Economic Survey." Kenya National Bureau of Statistics. Nairobi: Government Printers.

Revilla-Molina, I. M., Bastiaans, L., van Keulen, H., Mew, T. W., & Zhu, Y. Y. (2009). Improvement of technical efficiency in rice farming through inter planting: A stochastic frontier analysis in Yunnan.

Richmond, J. (1974). Estimating the efficiency of production. *International economic review*, 515-521.

Runo, B., Nyangena, W., & Githiaka, K. (2009). *Technical Efficiency Amongst Coffee Farmers in Kenya: A Case Study of Githunguri Division, Kiambu District* (Masters). University of Nairobi.

Shanmugam, K., & Venkataramani, A. (2006). Technical Efficiency in Agricultural Production and Its Determinants: An Exploratory Study at the District Level. *Indian Journal of Agricultural Economics*, *61*(2).

Sharma, K. R., & Leung, P. (2000). Technical efficiency of carp pond culture in South Asia: An application of a stochastic meta-production frontier model. *Aquaculture Economics & Management*, *4*(3-4), 169-189.

Singh, J. (2005). Collaborative networks as determinants of knowledge diffusion patterns. *Management science*, *51*(5), 756-770.

USAID. (2014). *Horticulture Validated Report 2014*.

USAID. (2017). *Horticulture Validated Report 2016*.

Wambui, B. K, (2005). Technical efficiency in Kenyan's maize production: An application of the Stochastic Frontier Approach.

Weir, S, (1999). The effects of education on farmer productivity in rural Ethiopia. Working paper CSAE WPS99-7. Centre for the Study of African Economies, Oxford University.

Weir, S. and J. Knight. (2000). Education externalities in rural Ethiopia: Evidence from average and stochastic frontier production functions. *Working paper CSAE WPS/2000-4.* Centre for the Study of African economies. Oxford University.

World Bank Group & Republic of Kenya (2013). Kenya County climate Series, Climate Risk Profile Meru County, Washighton DC: World Bank.

Yegon, B., Ngui, D., & Mbuthia, A. (2015). *Technical Efficiency of Small Scale Fish Farming in*

Kiambu County (Masters). Kenyatta University.

Nelson, S. C., Ploetz, R. C., & Kepler, A. K. (2006). Musa species (banana and plantain). *Species profiles for Pacific Island agroforestry*, *15*(2), 251-259.

Appendix I:

QUESTIONNAIRE

Introduction

I am Eutycus Kinyua Mbae a student at Kenyatta University pursuing a Master degree in Economics (Policy & Management. I am conducting a research on Technical efficiency of small scale banana farming in Imenti South sub-County, Meru County. I hereby request for your assistance in terms of providing me with relevant information. (Kindly mark/tick appropriately, fill in the spaces/bracket provided to all the questions. The responses will be treated as confidential).

Questionnaire number…………………………………. Ward…………………………………….

Location……………………………………………Farm no………………………………………

A) Background information

1) **Gender**

i) Male [ ] ii) Female [ ]

2) Age

i) Below 20 [ ] ii) 20-30 [ ] iii) 31-40 [ ]

iv) 41-50 [ ] v) 51-60 [ ] vi) Above 60 [ ]

3) **Highest education level**

i) Post graduate [ ] ii) Bachelors [ ] iii) Diploma/certificate [ ]

iv) Secondary certificate [ ] v) Primary certificate [ ]

vi) No formal education [ ]

4) Household size……………….Number of adults………...Number of children……

5) For how long have you been into banana production (in years)……………………

B) Land utilization

Land ownership

6) Is the land Rented [ ] or owned [ ] or Both [ ]

7) How much land have you allocated for banana farming? (Tick where appropriate)

i) 0-0.5 acres [ ] ii) 0.5-1acres [ ] iii) 1-1.5 acres [ ] iv) 1.5-2 acres [ ]

v) Above 2 acres [ ]

C) Production information

i) Input utilization

8) Have you ever used the following inputs

1) Improved suckers No [ ] Yes [ ]

2) Organic manure No [ ] Yes [ ] if yes, how many Kgs in 2017……….

3) Inorganic fertilizer No [ ] Yes [ ] if yes, how many Kgs in 2017………..

ii) Labour inputs

11) What is the main source of labour?

i) Family [ ] how many hours …………….

ii) Hired [ ] how many hours ……………

iii) Both [ ] family, how many hours………….. Hired how many hours ………

9) Is your farming

i) Rain fed [ ] ii) Irrigated [ ] iii) Both [ ]

D) Extension and credit facilities

10) Have you ever received any training on banana farming? No [ ] Yes [ ] if yes, who provided the training i) extension officers (government) [ ] ii) NGOs [ ] (name)………………………………… ii) farmers organized [ ]

11) Do you have access to credit? No [ ] Yes [ ] if yes, fill in the table below

Sources	Amount received	Interest rate	Total paid	Payback period	Use of credit received

12) Do you belong to a banana farmers' cooperative No [ ] Yes [ ] if yes name the cooperative………………………………..

E) Banana output

13) How much bunches of bananas have you produced in the last one year (2017)

……………………………………………………………………………………..