TECHNICAL EFFICIENCY AMONG SMALLHOLDERS DAIRY CATTLE FARMERS IN NYANDARUA COUNTY, KENYA.

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF ECONOMIC THEORY IN THE SCHOOL OF ECONOMICS BUSINESS AND TOURISM 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 thesis is my original work and has not been presented for a degree in any other University or any other award.

Signature……………… ……... Date………..…………….

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I confirm that the work reported in this project has been carried out by the candidate under my supervision.

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DEDICATIONS

I dedicate this research to my beloved wife, Jayne, whose unwavering support and encouragement have been my anchor throughout this journey. To my precious babies Joy and Levy, your presence brings boundless joy and inspiration to my life, motivating me to strive for excellence in all endeavors. In addition, to my dear parents, Mr. and Mrs. Bishop Joshua M. Kimani, your love, guidance, and sacrifices have shaped me into the person I am today. This research is a testament to the profound impact of your love and support on my academic and personal growth.

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I extend my heartfelt gratitude to the Almighty, acknowledging that my progress thus far is solely attributable to His benevolence. His grace has been the cornerstone of my achievements, and I offer Him profound praise and worship.

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ABBREVIATIONS

AI Artificial Insemination

CAIS Central Artificial Insemination Station

DEA Data envelopment analysis

ECDPM European Centre for Development Policy Management

FAO Food and Agriculture Organization of the United Nations

GDP Gross domestics product

ILRI International Livestock Research Institute

JKUAT Jomo Kenyatta University of Agriculture and Technology

KARI Kenya Agricultural Research Institute

KALRO Kenya agricultural livestock research organization

KIPPRA Kenya Institute of Public Policy Research and Analysis

KDPA Kenya Dairy Processor Association

KNBS Kenya National Bureau of Statistics

MoALFC Ministry of Agriculture, Livestock, Fisheries and Cooperatives-State Department of Livestock.

MOLD Ministry of Livestock Development

OECD Organization for Economic Co-operation and Development

SFA Stochastic frontier analysis

TE Technical Efficiency

OPERATIONAL DEFINITION OF TERMS

ALLOCATIVE EFFICIENCY- The farm's competence to utilize inputs adequately given their costs and existing technology.

TECHNICAL EFFICIENCY- the farm's propensity to optimize output from a particular combination of inputs.

EFFICIENCY is the ratio of real output of a farm to highest attainable output given a set of inputs.

PRODUCTIVITY- it's a measure of the final product compared to input in the dairy sector.

PRODUCTION FRONTIER-it is the maximum possible attainable output (milk) by a farm given a set of inputs

PRODUCTION TECHNOLOGY- It describes how a farm combines inputs to generate an output.

SMALLHOLDER FARMERS-farmers who own less than ten cows and produce less than one hundred litres of milk daily.

ABSTRACT

Dairy farming is crucial due to its significant role in Kenya's economy. It enhances the nation's food security, provides farmers with a source of revenue, and creates jobs. The majority of milk consumed worldwide originates from dairy cattle. The rearing of dairy cattle has supplanted tea and coffee plantations as the primary source of livelihood across Kenya's Rift Valley and central regions. Despite the sector remaining an integral part of Kenya's economy, overall dairy production has decreased over the past 20 years, even with an increase in cattle herds. Furthermore, despite the likelihood of increased demand for dairy products and milk due to urban population growth, Kenya's dairy farming industry has not yet reached its full potential. While dairy production has been rising in Nyandarua, studies demonstrate that there has not been a proportionate increase in productivity per cow when compared to neighboring counties.The attainment of maximal technical efficiency at the farm level is essential due to the scarcity of production resources (particularly land) for dairy farming and to boost food availability, which is among the Kenyan government's key targets. This assessment had two main objectives: to estimate the technical efficiency of smallholder dairy cattle farmers in the Kinangop sub-county of Nyandarua County, Kenya, and to identify the factors that influence their technical efficiency.A non-experimental research approach was adopted, and cross-sectional data were gathered using questionnaires completed by a sample of farmers. Since a complete population list was unavailable, a stratified sample from the ward was used to conveniently select participants for the study. Quantitative input and output data were collected from each sampled farmer. Multiple regression analysis was employed to identify elements that alter technical efficiency, and a maximum-likelihood estimation approach was used to establish the stochastic frontier production function.From the results, it was concluded that farmers were 71.1% technically efficient, with 95% of the dairy farmers performing above average and only 5% below average. The maximum likelihood estimates indicated that labor, acres allocated to fodder production, and concentrate and fodder fed to animals per day had positive coefficients, although these were statistically insignificant. However, expenditure on animal health had a negative, but statistically insignificant, impact on technical efficiency. The study also established that the level of education is a key determinant of efficiency in Kinangop.This study recommends that smallholder dairy farmers in Kinangop sub-county should strive to enhance their technical efficiency. This includes judiciously hiring labor to aid in farm operations, joining various societies that can provide critical services like credit, consistently using concentrates and fodder in dairy farming, and actively practicing hay and silage preservation. The study further recommends that the county government of Nyandarua should develop and implement policies that assist citizens in accessing higher education and extension services.

CHAPTER ONE: INTRODUCTION

1.0 Background of the study

Food production has continued to be center of man's farming objectives. It is one of the oldest arts in the world. It dates back to the civilization of mankind (Clark, 2001). There are approximately a billion heads of cattle in the world from 996 million in 2021. Dairy cattle are mainly reared for the production of milk though some other breeds a reared for beef and milk as well. Around 150 million people depend on milk and dairy products as vital food sources and sources of income in the global supply and value-adding chains. 81% of the world's milk comes from cattle, 15% from buffalo, 4% from goats, and the remainder comes from sheep and camels (*OECD-FAO Agricultural Outlook 2022 – 2031*, n.d.). Pakistan, China, Brazil, German, Russia, and France remain the leading producer each accounting for 3-6% and collectively contributing 39% of the total output. In the preceding years, there has been a notable surge in the global production of cow milk. The volume of cow milk produced worldwide witnessed a substantial increase, rising from 497 (four hundred and ninety-seven) million metric tons in 2015 to approximately 544 million (Five hundred and forty-four) metric tons by 2022. Notably, liquid milk emerged as the dominant segment within the global dairy market, holding the greatest share in relation to market value. This upward trend in cow milk production underscores the growing significance of this commodity in meeting global demand for dairy products.

In comparison to other major agricultural commodities, milk output is expected to expand at a quicker rate over the next ten years, reaching 1060 Mt by 2031, according to the FAO. Especially in Sub-Saharan Africa and principal (large) milk-producing countries like India and Pakistan - where output is low - the predicted growth in the quantity of dairy-producing animals is likely to be substantial at 1.2% p.a. While global yields are anticipated to expand gradually over the following ten years, there is significant regional diversity in growth rate ('World Food Agric. – Stat. Yearb. 2021', 2021). While yields in high-income countries is predicted to improve by only 0.5% per year, the highest growth is anticipated in Southeast Asia and North Africa, where yield growth average is around 1% per year. It has been anticipated that yield growth would enhance production more than herd growth in practically every part of the planet.

Dairy cattle's farming in Africa has is characterized by low output per cow due to frequent drought and poor breeds. The Maasai, Borana, Fulani, and Tuareg are some African groups with enduring dairy traditions (Ndambi et al., 2015). These communities among others practiced dairy farming mainly for subsistence consumption. Due to population growth demand for milk has increased and resulted in the adoption of commercial farming by these communities. A decrease in trucks of land has well contributed to the adoption of modern farming methods. The abandonment of open-field grazing has contributed to the development of intensive and semi-intensive forms of dairy farming across Africa. This is highly attributed to the increased output in Africa. However, Africa only contributes 5% of milk produced globally('World Food Agric. – Stat. Yearb. 2021', 2021).

More than a third of the global GDP is accounted for by the livestock sector in developing countries. East African dairy sector output is highly unpredictable. This is attributed to the high dependence on rainfall for fodder production. In Ethiopia, Rwanda, and Kenya dairy farming are most common in highlands and some Rift Valley regions that are characterized by cool and humid conditions unlike the rest of the region (Bingi & Tondel, 2015). Forage production and decline in the quality of pasture are highly correlated to the amount of precipitation received in the area. The high temperatures experienced in the region affect dairy output by exotics breeds. Despite this challenge exotics breed continues to produce the highest output per lactation period compared to indigenous breeds like zebu. In addition to low and poor forage; poor animal husbandry and poor genetic base affect dairy output in the block.

1.1.1 Dairy Cattle Farming in Kenya

A notable aspect of Kenya's economic success has been its adoption of agribusiness in the rearing of dairy cattle. Recent years have seen a rise in the smallholder crop-livestock system, particularly in the densely populated central parts of the nation. Introducing exotic animals by European immigrants to the central highlands marked the beginning of commercial dairy cattle production in Kenya a century ago. White settlers created organizations to help farmers and dairy traders in order to support the dairy industry. These included the Central Artificial Insemination Station (1946), Kenya Dairy Board (1958), Kenya Co-operative Creameries (1925), Naivasha Animal Husbandry Research Station (1935), Veterinary Research Laboratories (1910), and Central Artificial Insemination Station (1935). (Thorpe et al., 2000). Until 1990 KCC enjoyed a monopoly in the industry and by 1996 the monopoly slowly decreased. The liberation of the sector opened up the entry of private processors. All social strata drink the most processed milk in the pasteurized form (Olok-Asobasi & Sserunjogi, 2001). The dairy sector has continued to do research and development over time. According (*Kenya Livestock Breeds Catalogue*, 2022) from the year 2022, there are roughly 20.6 million cow heads in the nation. Kenya produces more than 60% of its milk from improved breeds, only 25% from indigenous cows, and the remaining from goats and camels. Kenya ranks 5th as countries with the most cattle herd in Africa and the 2nd highest milk-producing country after Ethiopia which produces 3 billion litres a day. Dairy farming is a major economic activity in Kenya, incorporating 1.8 million smallholder farmers. Dairy output accounts for 14% of Kenya’s agricultural GDP, in addition to creating employment. Milk is mainly produced by smallholders who account for 80% of the total output whereas 20%

is produced by large-scale farms (Aweer Duot Ajak et al., 2020). Despite concerted efforts by both national and county governments to increase milk output; individual cow productivity has remained low across the country. In Kenya the sector is faced with some challenges which include seasonality, low output per cow, poor dairy infrastructure (feeder roads, correction points, and electricity), poor breeding programs, and high cost of minerals, concentrate, and supplements. However, the amount of milk produced in Kenya has increased significantly from 591.4 million litres to 801.9 million litres in 2021. This has been attributed to the increase in herd size across the country contrary to individual cow productivity (*KENYA ECONOMIC SURVEY 2022*, n.d.)

Table 1.1: Milk Production in Kenya.

Kenya milk production 2017-2021						
year	**unit**	**2017**	**2018**	**2019**	**2020**	**2021**
production	million litres	591.4	652.3	685.9	684.8	801.9
milk processed into						
milk & cream	million litres	410.6	468.4	491.8	457.9	510.5
butter & ghee	tones	1127.3	1249.4	1013.4	957.6	1025.8
cheese	tones	338.3	384.3	305.4	158	176.4

Source of Data: Kenya National Bureau of Statistics, 2022

1.1.2 Dairy Cattle Farming in Nyandarua

Nyandarua County is one among other six counties in the Central Kenya region, located in the north-western part of the region and west of the Aberdare (Nyandarua) Ranges. The county boasts of an overall land size of 3,304 km2. "According to (*KENYA ECONOMIC SURVEY 2022*, n.d.), Nyandarua is the eighth biggest contributor to Kenya's agricultural GDP. In the dairy sector, Nyandarua is the second highest producer after Kiambu County nationwide. The county is constituted of five sub-counties which are Kinangop, Kipipiri, Ol Kalou, Ol Joro Orok, and Ndaragwa sub-counties which are further subdivided into twenty-five wards.

According to County Government Nyandarua (2018) dairy farming employs 80% of Nyandarua households. The County has a total dairy herd of 349,300 cows, with the majority of farms raring two to three dairy cows. The county produce roughly 296 million litres of milk. With an average price of Ksh. 32 per litre in 2019, the sector generated around Ksh. 13 billion to Nyandarua's domestic product. 60% of milk produced is traded in informal markets, with 40% sold in legal markets. Home consumption accounts for 20% of total milk production. The annual per capita milk intake is 114 litres, compared to the national average of 125 litres in nyandarua and the World Health Organization's optimum amount is 209 litres. Kinangop sub-county contributes to 40%, Kipipiri for 25%, and Ol Kalou, Ol Joro Orok, and Ndaragwa sub-counties contribute for the remainder.

Despite the scarcity of literature on the technical efficiency of dairy cattle producers in Kinangop, various studies conducted in the area (Nyandarua) in general demonstrate that the farmers are technically inefficient. (Mbugua, J. N., et al., 2012), for example, focused on the strategic and value chain research on the smallholder dairy business in Central Kenya. Although research on technical effectiveness in other agricultural sub-sectors in the area, none have established the degree of technical effectiveness in the dairy sector and its causes. (Waithaka, M.M. et al, 2003 examined the cost of milk production in Kenya, based on calculations from the Kiambu, Nakuru, and Nyandarua regions smallholders (R&D) project. (Ongwech, W. L., Obel-Gor, C., & Otiende, M. A., 2020) investigated the elements of credit availability amid smallholder dairy producers in the Kinangop sub-county of Kenya.

According to (Government of Kenya, 2007) the county government has implemented a number of strategic initiatives in order to achieve an average production of 20 litres per cow per day, up from the current five litres. Dairy genetic improvement is one of them, thanks to a County-subsidized artificial insemination programme run by a Public-Private Partnership in which farmers pay Ksh. 700 for local sperm and Ksh. 1,000 for foreign sperm. In addition to livestock registration with Kenya Stud Book/KLBO, a total of 8,560 cattle were inseminated in 2020. Fodder production, diversification, and conservation technologies should be promoted. Creating feed centres to promote Total Mixed Ration (TMR). Establishment of dairy demonstration and promotion farms. Promotion of competitive marketing and value addition by providing milk vending machines, coolers (weighing scales, milk analyzers, milk carrying cans/churns, and pasteurizers) to cooperatives. Research and distribution of innovative technology. Supporting animal health by building illness testing facilities, conducting vaccination campaigns, and rehabilitating cattle dips. Nyandarua Cooperative Union, other partners, and the Nyandarua County Government are working together to build a milk processing factory (cooling plant, pasteurizers, packaging unit, and product retail outlet). Improvement of extension advisory services, among other things, according to (County Government Nyandarua, 2018). Notwithstanding coordinated efforts over the last two decades, output still remains poor in the county, and particularly in Kinangop. The dairy sector output in Kinangop is 5 litres per day, while large scale farms in Kenya average 8 litres daily which if farm below European average as per (J. M. K. Muia et al., 2011) and (J. M. K. Muia et al., 2011). All of these approaches aim to close the output gap between Nyandarua and neighboring counties such as Kiambu, where a cow produces an average of 7.9 litres per day (Staal et al., 2003).

1.1.3 Dairy Cattle Farming in the Kinangop Sub-County.

The Kinangop sub-county runs along the slopes of the Aberdare ranges, about 100 kilometers northwest of Nairobi. It originated in time for the general elections in 1988. There were about 219, 576 persons living in its eight electoral wards by 2022. The primary economic activity in the 822 km2 region, which has a 20.3 percent natural forest cover, is dairy and crop cultivation. The region uses free grazing, semi-zero grazing together with zero grazing dairy cattle grazing techniques. Holstein Friesians are the most reared breeds followed by Ayrshire while Jersey is the least reared. Milk is marketed through brokers, dairy cooperatives, and processing firms for large-scale farms (County Government Nyandarua, 2018).

According to research by (J. Muia et al., 2011), smallholder dairy farmers encounter a number of difficulties, including inadequate road infrastructure, subpar marketing, expensive and scarce inputs and support services, insufficient use of relevant technology, and little value addition.. Despite the numerous obstacles, there is room for expansion for farmers because there is a substantial need for milk and dairy items in metropolitan areas due to the rapid growth of urban dwellers.

The high demand for milk in urban centers could only be met by a high output from the area. However, the continued subdivision of land for settlement poses a challenge to cheap free grazing and mechanization of farm operations. This calls for farmers to economically and technical efficiently produce the highest possible output per cow for increased economic prosperity. This is only conceivable if farmers can produce at the lowest possible cost, suggesting the necessity to point out the elements of technical efficiency in neighborhoods.

1.2 Statement of the problem

Dairy farming is significant because of its impact on the world economy. Dairy cattle milk is the most consumed in the world. Milk and dairy products are vital sources of nutrients and income for nearly 150 million individuals involved in the global production and value-addition chain. Milk output has been predicted to raise globally due to an increase in the number of cattle herds. In Africa, the biggest producers are Ethiopia, Kenya, Sudan, and South Africa, where the majority of cattle are crossbred, exotic breeds that produce only 5 to 11 litres per cow per day on average. The output per cow per day in Africa is far less in comparison to other continents. For example Europe with, 20 litres per day per cow.

Despite evident variances, Kenyan smallholder dairies follow many of the same practices as other African countries. Rain-fed fodder production is critical for dairy farmers. Cows are fed grass and agricultural leftovers, with the majority of forages being cut and given to the animals rather than grazing. Despite receiving greater government support than contemporary dairy farms in other countries, smallholder farms in Kenya face issues such as overgrazing, insufficient infrastructure, and low productivity per cow. The amount of milk produced in Kenya increased significantly from 591.4 million litres to 801.9 million litres in 2021 see *Table 1*. This was attributed to the increase in herd size across the country contrary to individual cow productivity and not improvement of technical efficiency levels.

Notwithstanding the promise of increased demand for milk and dairy products, dairy farming in Nyandarua County remains insufficiently utilized. Dairy output has been increasing, but there has been no growth in output per cow over time. According to studies within two decades, output per cow per day has declined from 8.9-5.68 liter. The studies however have not shown whether the level of technical efficiency has worsened over time.

Regardless of the paucity of literature on the technical efficiency of dairy cattle producers in Kinangop, various studies conducted in the region (Nyandarua) in general reveal that the farmers are technically inefficient. Presence of animal feeds through action directed towards programs including the use of AI, enriched fodder, and seed ranching are identified as some solutions to address the low productivity problem. Despite the concerted effort for the past two decades, output has remained low across the county and Kinangop in particular. The full potential of the dairy sector in Kinangop is far off the mark at 5 litres a day while large scales farms in Kenya are on an average of 8 litres a day.

The real levels of efficiency in smallholder dairy farms in the Kinangop sub-county have not been measured, necessitating an estimate of technical efficiency in the area. This study thus filled a knowledge vacuum by determining the technical efficiency and factors of technical efficiency in smallholder dairy cattle farmers in the Kinangop sub-county in general.

1.3 Research Questions

The assessment sought to answer the following questions.

i. What is the degree of technical efficiency in dairy cattle production Kinangop sub-county?

ii. What are the elements of technical efficiency in dairy cattle production in the Kinangop sub-county?

1.4 Objectives of the Study

The general objectives of this study is:

i To estimate the levels of technical efficiency in Nyandarua county and its determinants..

Specific objectives of this study are.

i. To evaluate the extent of technical efficiency amid smallholder dairy cattle farmers in the Kinangop sub-county.
ii. To identify the factors that influence technical effectiveness in dairy cattle production in the Kinangop sub-county.

1.5 The Scope and Limitations of the Study

The aim of this investigation is to assess the degree of technical efficiency and ascertain the elements altering technical efficiency amid small-scale dairy cattle farmers in the Kinangop sub-county. The selection of the research area was deliberate, as it boasts the highest output potential and stands out as the county with the largest dairy cattle farming community, thanks to its favorable weather conditions. The research employed surveys to collect information on production from farmers involved in dairy cattle farming. The technical efficiency was tested in the kinangop sub-county's eight wards. This study effort relied on primary data collected through questionnaires completed by the sampled dairy farmers. However, the use of cross-sectional data limited the scope of this study. As a result, the rate of change in technical efficiency for Kinangop sub-county smallholder dairy farmers is not investigated in this study.

1.6 Significance of the Study

The evaluation's conclusions would be important to dairy producers, the Nyandarua county government, and the national government. Understanding the factors influencing smallholder dairy farmers' technical efficiency would help them to implement best practices that would improve their efficiencies, resulting in a rise in overall output and profit levels per cow. The current study's findings would also be useful to the Nyandarua county administration in informing policy actions to improve dairy farmers' productive capability, consequently improving food output, job opportunities, and revenue. The data would also aid the authorities devise strategies to improve dairy production efficiency.

1.7 Organization of the Study

This investigation was structured into five key subsections, each serving a specific purpose.The initial part established the foundational context of the evaluation, addressing both practical and theoretical challenges. It meticulously defined the variables to be examined, conducted a guiding conceptual analysis, and clearly articulated the problem the study aimed to solve, its research objectives, and the questions it sought to answer. This section also outlined the scope, limitations, and overall organizational framework of the assessment.

Chapter two then provided a comprehensive review of existing literature, both empirical and theoretical, related to the research variables. It offered a detailed description of the study's setting, synthesized crucial studies that informed the findings, introduced the theoretical framework, and identified significant gaps in prior empirical investigations.

Moving to chapter three, the document elucidated the entire research approach. This included details on the chosen research design, sampling strategy, description of research instruments, and the specific methods used for data gathering and analysis. Chapter four was dedicated to presenting and examining the results of the study.

Ultimately, chapter five offered a succinct overview of the research outcomes, presented the conclusions drawn, discussed relevant policy implications, and provided recommendations for subsequent studies.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This section aims to provide an overview of technological efficiency in dairy cattle farming and its influencing factors, based on both theoretical and empirical research. It begins by reviewing the theoretical literature, and then analyzing empirical studies on technical efficiency. The section concludes with a summary of all the evaluated material.

2.2 Theoretical literature

This section discussed theories of production, technical efficiency estimation approaches, determinants, and input factor demand.

2.2.1 The classical theory of production

This theory demonstrates that there is a connection between inputs and outputs. The production function (frontier) of a farm can be used to illustrate this relationship. Given a set of inputs, the production boundary shows the highest possible output that a farm can achieve. According to Coelli et al., (2005), technological possibilities of a farm that uses several inputs in its production can be represented in the following production function

$$Q=f(x) \qquad \text{……………………………………………………….2.0}$$

In this case, Q is the output and X is a N x 1 vector of farm inputs such that $Q= f (X1, X2,.., Xn)$. Other inputs that are beyond the decision maker's (farmer's) control, such as rainfall, are equally essential, but for this study, it would be easier to incorporate them into the overall framework of the function f (.). It shall be assumed that the production function is an ideal representation of technological efficiency. Where farms that lie along the production frontier are deed efficient whereas those below are deemed inefficient (T. J. Coelli et al., 2005). Production can be estimated using various approaches.

2.2.2 Efficiency

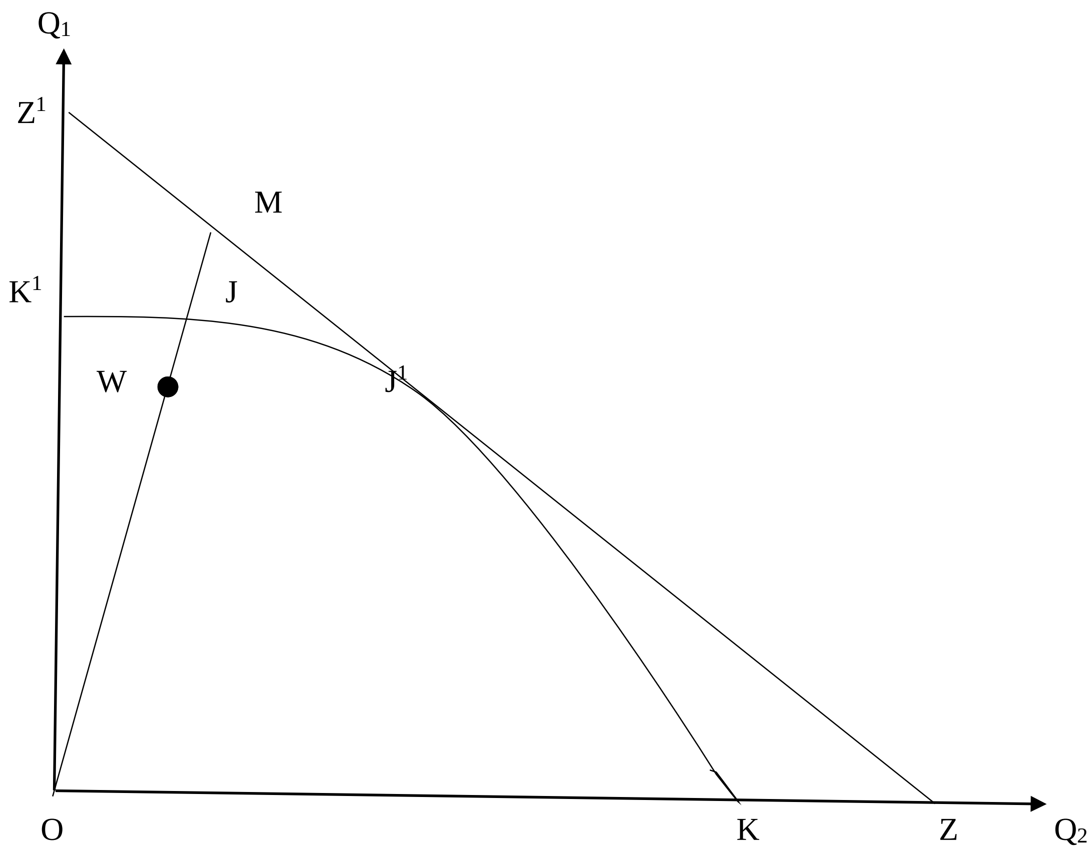
It involves juxtaposing the optimal and anticipated values of a process. In the comparison, the ratio of observed to highest potential of output that can be generated from considering a direction of inputs, or the ratio of lowest potential to observed inputs needed to achieve a specific output, are employed (Ndicu et al., 2016). The first analysis of agricultural productivity was by (Farrell, 1957). The scarcity of resources is the major reason for the need for economic agents to operate efficiently. Two forms of efficiencies define production at the individual farm level i.e., allocative and technical efficiency. Technical efficiency evaluates a farm's capacity to get the most out of a specific combination of inputs. (Etich, 2013). The term "allocative efficiency" refers to the relationship between the estimated lowest possible production cost and the real production expense. Both allocative and technical efficiency compose the economic efficiency of the farm. For a farm to be profitable it has to operate efficiently to minimize cost. Different literature has proposed different approaches to estimating technical efficiency (T. J. Coelli et al., 2005; Farrell, 1957; Lovell & Kumbhakar, 2000) both parametric and non-parametric approaches.

2.2.3 Output-oriented Approach

(T. J. Coelli et al., 2005) tries to respond to the query ' To what extent can the amount of output be proportionally expanded without affecting amounts of inputs'. As illustrated in Figure 2.1, this is ellaborated by the usage of one input (X1) and two outputs (Q1, Q2). The locus K1K symbolises the production potential frontier, whereas the isocost price line is represented by the locus Z1Z. If the firm's output occurs at point M, technical efficiency is demonstrated as OM/OJ, while technical inefficiency is indicated by extent JW, that can be defined as 1- (OM/OJ). Technical efficiency * Allocative efficiency equals total efficiency.

(TE*AE) = (OM/OJ *(OJ/OW)

Figure 2. 1: Output Oriented Efficiency Measure.



Source: ***(T. J. Coelli et al., 2005)***

2.2.4 Input-oriented approach

This approach; unlike the output-oriented emphasizes the proportionate reduction of inputs subject to a particular level of output (T. J. Coelli et al., 2005). As a consequence, figure 2.2

illustrates the measurement of efficiency using this approach with two inputs and only one output.

Figure 2.2 Input Oriented Efficiency Measure

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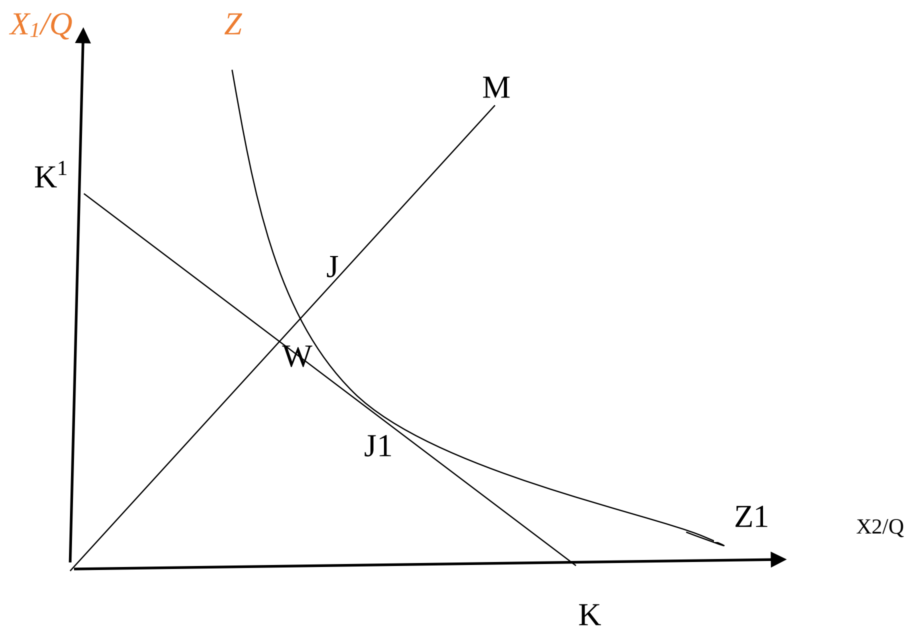


Source: (T. J. Coelli et al., 2005)

In input-oriented measure, the production function is shown as:

$Q = f(X_1, X_2)$……………………………………………………………………………2.3

Grounded on assumption that CRS, a production function with the formula 1=f(X1Q,X2Q) can be used to describe the efficient frontier. This isoquant, ZZ1, indicates the best possible combination of the two inputs, X1 and X2 that can be utilized to produce a specific output level. Any variation from the KK1 frontier leads to an ineffective use of the production factors. The isocost locus is designated as KK1. If a particular producer employs the level of inputs specified by point M during the creation of only one unit of output, distance JM represents the firm's or producer's technical inefficiency (T. J. Coelli et al., 2005)

Technical inefficiency in general, is defined as percentage of the proportion JM/OM, conversely a firm's or producer's technical efficiency is as determined by the ratio OJ/OM, which is equivalent to 1-(JM/OM). It has a value from 0 to 1, expressing the degree of the producer's technological efficiency. Where 1 elucidates that the producer is fully technically efficient as a consequence 0 indicates that the producer is entirely technically inefficient, point J in Figure 2.2 is technically efficient because it conforms to the efficient isoquant ZZ1.

2.3 The Stochastic Production Frontier

Unlike previous approaches, stochastic frontier models have an advantage of separating the impact of shocks due to differences in labor and machinery performance, erratic conditions regarding output, and a pure windfall from an effect of differences in technical efficiency on output. It additionally makes it possible for traditional test of hypotheses and the assessment of inefficiency impacts in a single phase (Lovell & Kumbhakar, 2000). SFA enables more accurate estimation of the causes of inefficiency in dairy farms (Kumbhakar et al., 1991). Using a collection of Decision-Making Units (DMUs), this method uses data to econometrically estimate the parameters of a hypothesized function. The stochastic frontier approach was separately put forward by (Aigner et al., 1977) and (Meeusen & van den Broeck, 1977) in the following form

$ln\ q_i = x_i,\beta + v_i - u_i$……………………………………………..... (2.1)

Where q_i = output,

x_i = vector made up of the input logarithms.

β = set of unknown parameters that must be calculated.

v_i = random error term

u_i = non-zero technical inefficiency element within the error term.

Model 2.1 above accounts for technical inefficiency; additionally, it recognizes occurrence of haphazard shocks outside producer's control, such as rainfall, crises, and so on, that alter the farm's output level. Equation 2.1 illustrates the stochastic form of a production function, wherein a random or stochastic variable, represented by exp(xi′), constrains the output values from above. This is how the stochastic production frontier appears in its Cob-Douglas version in this instance:

$ln\ q_i = \beta_0 + \beta_1 ln\ x_i + vi - u_i$ ……………………………………………………………….2.2

or

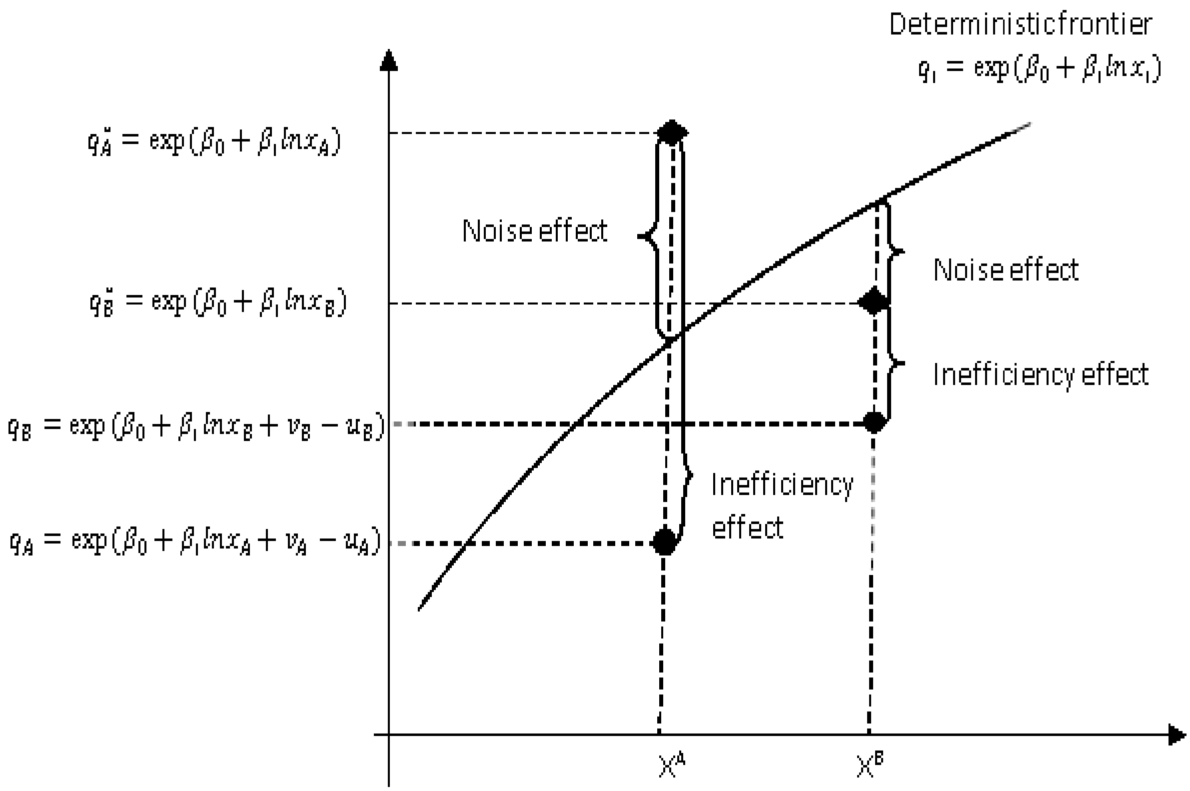
$q_i = \exp(\beta_0 + \beta_1 ln\ x_i + v_i - u_i)$……………………………………………………………….2.3

Assuming the amounts of input and output for two producers, let's call A and B, who fit the deterministic part of the model, which shows that there are diminishing returns to scaling. Producer A produces QA amount of output from the inputs represented by XA, whereas Producer B produces the QB amount of output from the inputs represented by XB. In the absence of inefficiency effects (UA=0, then UB=0, where UA and UB represent the ineffective consequences of producer A and producer B, respectively), the representation of the frontier yield is:

$qA = \exp(\beta 0 + \beta 1 \ln xA + vA)$ ……………………………………………………………….2.4

And

Figure 2. 3 Stochastic Production Frontier



Source: (Coelli et al., 1997)

As pinpointed in Figure 2.3 above, the output of producer A's frontier is positive, or more than zero (V_A>0). Producer B's frontier output, on the other hand, is smaller than the deterministic element since statistical noise has a negative (less than zero) impact, or V_B>0. Moreover, producer A's measured or real production is lower than the deterministic element of the frontier.

This is because V_A-U_A<0, or the sum of the impacts of inefficiency and noise, is less than zero (negative). Actual or observed output is above the predictable portion of the frontier when the influence of statistical noise is greater than the effect of inefficiency and more than zero, or positive. Technical efficiency, which is an output-oriented technique, is ordinarily expressed as the proportion of real output to the production degree that aligns with the stochastic frontier depicted below.

$$\mathrm{TEi} = \mathrm{qiexp}[\mathrm{xi}, \beta + \mathrm{vi}] = \frac{\mathrm{exp}[\mathrm{xi}, \beta + \mathrm{vi} - \mathrm{ui}]}{\mathrm{exp}[\mathrm{xi}, \beta + \mathrm{vi}} = exp\,(-ui) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.6$$

The technical efficiency values vary from 0 to 1, measuring the amount of produce generated by the i^{th} producer in comparison to the amount generated by a perfectly efficient producer utilizing a comparable level of inputs.

Either of the following approaches can be used to predict the stochastic frontier production function. As a consequence, the ML is the first. The second method is to employ the MOLS methodology proposed by (Richmond, 1974). Finally, either linear or quadratic programming can be used. Earlier method entails maximizing the sum of absolute residuals, with the condition that the total residuals are ≥0. Whereas the latter implies reducing the aggregate squared residuals, which are likewise constrained, the total squared residuals are ≥ 0.

Conversely, (Coelli, T. J. et al., 2005) contend that the model may be estimated in the same manner using either OLS or ML. The chief drawback of the predictable parametric approach is that it just assesses the impact of measuring error as well as any other kind of mistake on the frontier. Any departure from the frontier is ascribed to technological inefficiencies. Since it acknowledges random shocks that are outside of the farmer's control, like drought, diseases, pests, and parasites that affect output, the stochastic production frontier analysis would act as the study's foundation.

2.4 Non- Parametric Approach

DEA is among the linear programming techniques commonly used, it was advanced by (Farrell, 1957). It creates a convex production frontier by connecting combinations of observed or real best practices. Measuring each firm's performance in relation to the sample of firms' best practices is the aim of DEA. Finding the enterprises that, as evidenced by empirical data, make up either envelopment surface or empirical production function is the main goal of DEA. Businesses are stated as efficient if they are located on the empirical production frontier; consequently, if not, they are not as demonstrated by Meeusen and van den Broeck (1977).

It includes identifying the producers that make up the empirical production frontier. It is believed that a producer who is situated on the empirical production frontier is efficient, whereas a producer who is not is considered inefficient. There exist two categories of DEA models: variable returns to scale models and constant returns to scale models. Economic generalizations and presumptions regarding the data to be evaluated inform the structure choice (Meeusen & van den Broeck, 1977)

The core tenets of DEA are that it refers to the production frontier as the most efficient, does not enforce functional form limitation on it, and cannot generalize about the error term (T. Coelli et al., 1997). DEA assumes that all unexplained deviations in production symbolizes inefficiency because the random error is zero, which may not be the actual case, particularly in agricultural production, which is subject to a number of regular volatility such as weather changes and animal destruction, not to mention omissions and measurement errors. According to (T. Coelli, 2016) Malmquist DEA provides for the assessment of the rate of change in time in efficiency; however, due to the utilization of cross-sectional data, estimating the rate of change would be difficult in this study. As a result, the utilization of Malmquist DEA in this research is rendered invalid.

2.5 Empirical literature

Several investigations have delved into this subject matter, Technical efficiency in resource usage was the main topic of (Nyagaka et al., 2009): Evidence from small-scale Irish potato growers in Nyandarua. While (Kamau et al., 2016) Smallholder coffee farmers in Murang'a, Kenya were assessed for their technical efficiency. Two steps comprised the data analysis process. The technical efficiency measures were computed in the first step using the non-parametric DEA model. Technical efficiency ratings that were calculated were subsequently regressed against a range of descriptive variables, including characteristics of households, farm size, and additional indicators related to institutional structures and usage of technology.

A mean technical efficiency of 54% was found in the results. The outcome shows that key factors influencing technical efficiency in coffee production include household size, farmers' age, loan availability, and coffee variety. It was discovered that improved access to financing services that help farmers buy market supplies for coffee operations and the adoption of superior varieties, especially by younger farmers, would increase technical efficiency and, as a result, coffee output. While this study used a Cobb-Douglas technology and stochastic frontier analysis, the prior research used DEA to evaluate technological efficiency.

The study (Mukami, 2018) concentrated on the welfare advantages and technical effectiveness of smallholder farmers' snow pea production in Kenya's Nyandarua County. While the paper focused on distinct subsectors, the present analysis concentrated on smallholder dairy farmers.This paper only served to inform the charistic of farmers in the study area.

In a study conducted by Kinyua (2019), technical efficiency of small-scale banana farming in Meru County, Kenya, was investigated. In consequence, primary aims of the research were to compute technical efficiency and identify factors contributing to technical efficiency in banana farming in Imenti South, Meru, Kenya. This study employed a non-experimental research methodology, with participant farmers providing cross-sectional data through completed questionnaires. A stratified random sampling strategy was utilized to highlight a representative through sampling of farmers for participation in the research.

Research conducted by Kinyua (2019) employed multi-regression scrutiny to identify the factors influencing technical efficiency, and the maximum likelihood approach was utilized to determine stochastic production function. Accordingly, outcomes of the Stochastic Frontier Analysis (SFA) portrayed that small-scale banana growers exhibited an average technical efficiency of approximately 69%. This implies that the farmers were, on average, 31% technically inefficient in their banana farming practices.

The regression analysis of the efficiency model indicated that factors such as access to extension services, size of the farmer's household, gender, land ownership, and prior experience in growing bananas had a negative impact on technical efficiency. Conversely, the farmer's age, highest access of education, access to water for irrigation, and access to credit had positive effects on technical efficiency. Consequently, study suggests that farmers could benefit from increased access to loans with reduced interest rates. The insights from this reviewed study had a substantial impact on the methodology employed in the upcoming investigation.

Maina et al., (2020) undertook an examination on the economic efficiency of milk production. The researchers concentrated on small-scale dairy farmers in Mukurwe-ini Sub-County, Nyeri County, Kenya. Dairy industry plays a pivotal role, generating and translating 17% to the agricultural GDP annually, making it the most robust sector within agriculture. Small-scale farmers, primarily located in the Central and Rift Valley provinces, contribute significantly to the nation's milk production. Despite similarities in ecological conditions and animal breeds, there are variations in milk production, with some farms achieving 20 litres per cow per day, in constrast others produce only about 5 litres per cow per day. Mukurwe-ini sub-county in Nyeri County, situated in the Central part of Kenya, was chosen for the research due to its substantial number of dairy farms, coupled with a relatively low milk production per cow. In 2017, the study involved sampling 91 small-scale dairy farmers utilizing semi-structured questionnaires. In addition, cross-sectional data on socioeconomic factors and milk production in the preceding month were generated as part of the research methodology.

The study utilized the Tobit model to examine elements altering economic efficiency, while the Stochastic Frontier model was optimized to assess the technical, distributive, and economic effectiveness of milk production. The average technical efficiency, allocative efficiency, and economic efficiency among farmers were determined to be 68.7%, 91.3%, and 62.6%, respectively. Notably, farmers exhibited high levels of allocative efficiency, suggesting that insufficient technical efficiency was the primary contributor to economic inefficiency. The findings of the study highlight significant inefficiencies in milk production, emphasizing opportunities for enhanced productivity through better resource utilization and cost reduction measures. The results underscore the potential for improvements in the efficiency of production processes, which could lead to increased overall economic performance in the dairy farming sector.

A higher yield of milk can be accomplished via more efficient use of the resources already available, as farmers with increasing returns to scale (IRS) showed. Low milk yield among small-scale producers was shown to be caused by increasing herd sizes, giving animals enough concentrates, and increased spending on animals' medical care. Simultaneously, it was found that the technological inefficiencies in milk production were the fault of older farmers. A significant portion of the overall expenditures associated with dairy production was found to be the cost of concentrates and other feeds. The study area's farmers were effective at minimizing costs despite having low resources, as evidenced by their comparatively high allocative efficiency.

Among Mukurwe-ini small-scale dairy farmers, age, household size, the use of dairy farming as the chief source of income, the use of rented labour, and the monthly cost of concentrates were shown to be substantive factors correlated with economic efficiency. The study under consideration looked at broad characteristics that affected technical efficiency but did not look at the cattle breeds that this study would look at. The evaluated study, on the other hand, would enlighten some of the variables to addressed in this investigation.

(Aweer, D. A., et al., 2020) assessed the performance of dairy cattle on smallholder farms in Kenya's Nyeri County, focusing on three main areas: managing young and growing stock, reproductive and productive performance, and feed availability and feeding practices. An aggregate of 200 farmers were randomly selected from each of the study sites, namely Mathira East and Othaya Sub Counties. Information related to feed resources, feeding systems, calf feeding, age at first service, age at first calving, calving interval, milk yield, and lactation duration was assembled using a semi-structured questionnaire. Additionally, samples of both concentrates and forages were collected for quality analysis.

The data was computed using SPSS version 21.0 to reach a conclusive outcome. The most popular feeding technique was stall feeding (74.2%). The concentrates feeds were fed most frequently than soya meal, maize germ, handmade dairy concentrate, and commercial dairy meal. It was shown that food deficiencies were the root cause of low reproductive and productive efficiency. The efficiency levels of the farms' performance were not examined in the study that is currently being reviewed. The study focused on feeds and did not measure the efficiency with which feeds were distributed among farms' cows or converted into production. Although the study under evaluation examined animal feeding, the approach used was not applied since this study is not experimental.

Another investigation by Ngeno and Chumo (2021) conducted to assess the technical efficiency of small-scale dairy farmers in Kenya across different agroecological zones. Employing stochastic meta-frontier analysis and region-specific frontiers based on the "true" random effect paradigm, the researchers examined the technical efficiencies, technological gaps, and meta-frontier technical efficiency of small-scale dairy producers in various zones of Kenya. On that account, empirical study utilized three waves of panel data collected at the household level from different zones.

TE of small-scale dairy producers in Kenya operating in different agroecological zones was examined by (Ngeno & Chumo, 2021). maximizing stochastic meta-frontier and region-particular frontiers based on the "true" random effect paradigm, they investigated the technical efficiencies, technological gaps, and meta-frontier technical efficiency of Kenyan small-scale dairy farmers in various zones. Three waves of panel data at the home level from different zones served as the basis for the empirical study.

The results showed differences in efficiency indices and that small-scale farmers' milk production is defined by growing returns to scale. Based on the available technology and the climate in each zone, the results show that smallholder dairy farmer' milk yields in all zones fall short of their potential. Additionally, they found that dairy production in Kenya's three agro-ecological zones differed significantly in terms of technology. The study under examination highlights the technological differences between the zones and focused on comparing them. However, the goal of this examination is to assess the degree of technological efficiency among farmers in the same agro-ecological zone.

(Ayuko et al., 2023) The investigation focused on the degree and components of technological efficiency in the production of fodder in Homa Bay County. This study found that fodder cultivation increases income through feed, milk, and livestock sales. They learned that it was anticipated that the bordering countries' need for hay would increase to nearly 500 billion bales annually. Kenya's demand for fodder surged, but supply could not keep up with demand. In response, the ILRI helped create a number of projects to encourage the cultivation of fodder to increase milk yield. In this study, first-hand data was gathered collected from approximately 300 farmers in the Rachuonyo East and South sub-counties through structured questionnaires. The Tobit model and the stochastic Frontier model was employed for analysis. The outcome from the SFA revealed that the level of TE was affected by factors such as land area, seed quality, planting labor, and weeding labor.

According to Tobit's findings, herd size, group participation, loan availability, household size, and having access to training all have an impact on farmers' TE. To boost fodder production, the study advised that farmers increase fodder reservation, planting supplies, and the amount of person-days spent sowing and weeding. This study borrowed and examined some variables from the study under review. However, the methodology of this study differed from the study under review in that it did not use the Tobit model but SFA and Cobb-Douglas function.

2.6 Overview of Literature

The evaluation of technical efficiency literature review gives a comprehension of the various elements affecting technical efficiency in agricultural production, notably dairy farming. The studies examined used variables that are consistent with economic theory. As a result, they were useful in defining the variables that would be analysed in this research. Preceding examinations evaluated revealed that the farmer's gender, educational level, age, breeds, land size affect TE in agricultural production, and general farm features. (Aweer, D.A et al., 2020; Etich, 2013; Maina et al., 2020). The studied literature also demonstrated the possibility of significantly enhancing dairy production, namely by raising farm or producer technical efficiency with no additional increment in inputs. Some investigations did not look into the sources and drivers of technological efficiency, which is what the current study did.

The vast majority of the agricultural production literature analysed employed Stochastic Frontier Analysis, including (Ayuko et al., 2023; Etich, 2013; Kinyua, 2019; Maina et al., 2020). The present investigation applied the methodology of these previous studies, namely SFA using the Cobb-Douglas function, to determine the technical efficiency of small-scale dairy cattle farming in the study area. In addition, vast majority of these research, however, focused on the technical efficiency of other agricultural goods, leaving dairy cattle out. (Etich, 2013)concentrated on the technical efficiency of sorghum farming in Machakos County, (Aweer, D.A et al., 2020) concentrated on animal feeding and husbandry practices, (Kinyua, 2019)concentrated on banana farming in Imenti South, Meru County. (Kamau et al., 2016) concentrated on technical efficiency among coffee farmers in Murang'a and (Ayuko et al., 2023) examined the extent and determinants of technical efficiency in fodder production in Homa Bay County. Most of this studies analyzed farmer characteristics and paid no concentration on dairy while most farmer were mixed farmers. This emphasizes a need for specific dairy-focused analysis.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

The section discusses this research's methodology, design of the study, theoretical framework, model specifications, variable description and evaluation, study population and area, sampling strategy and size of the sample, sources of information and types, methods for analyzing data, and ultimately the diagnostic tests, which were performed.

3.1 Research Design

A non-experimental design underpinned this assessment. The study specifically utilized a cross-sectional methodology, necessitating the collection and subsequent analysis of production data at a singular temporal point. Adhering to a quantitative research technique, the design facilitated the systematic acquisition of numerical input and output information from each sampled farmer. Stochastic Frontier Analysis (SFA) was employed to evaluate farmers' technical efficiency scores and to ascertain the causal factors contributing to observed efficiency levels.

3.2 Theoretical Framework

The classical production function theory served as the foundation for this research. Given the technology threshold, the theory defines how outputs vary as a result to variations of inputs. The proposed stochastic frontier production function by (Meeusen & van den Broeck, 1977) is: $Yi=Xi\beta+(Vi-Ui)$……………………………………………………………….3.1

Where Xi is a vector of inputs, Yi is the ith sample farm's output, and β is the parameters that need to be estimated. On the grounds of this, Vi is a random error with a constant variance and zero mean, or N(0, $\delta v2$). It is related to random factors, like weather fluctuations and inaccuracies in production measurement, which are all beyond the farmer's control (a randomised error term that accounts for unwarranted volatility in the data sample); additionally, the error term's non-negative technical inefficiency component is called ui.

3.3 Model Specification

The specification of the stochastic frontier model is as follows, based on models by (T. J. Coelli et al., 2005)

$Yi = (Xi;\beta i)\exp(vi - ui)$……………………………………………………………….3.2

Where Xi is a vector of the input values, Yi is the farmer's output, and (;) is a pertinent production function, like a Cobb Douglas or Trans log. If $(xi;\ \beta)$ adopts the log-linear Cobb-Douglas form, equation 3.2 as consequence it can be written as follows:

$ln\ Yi = \beta 0 + \beta 1 ln\ xi + vi - ui$…........................3.3

Parameters are represented by β, and the random error with an average of zero, Vi, is related to random factors that farmers cannot control, like measurement error, weather, and diseases. Ui, or inefficiency, is a term for a one-sided error.

Cobb Douglas production function for dairy cattle farmer in the research vicinity is as outlined below:

$LnY = \beta_0 + \beta_1 \text{Ln}L + \beta_2 \text{Ln}ACRES + \beta_3 \text{Ln}QC + \beta_4 \text{Ln}FODD + \beta_5 \text{Ln}EXP + V - U$…………………….....3.4

Where:

Ln= natural logarithm

Y= total output (litres)

L = Labor (man-hours)

QC = Average amount of concentrates used per cow per (kg),

ACRES = Total area under fodder (acres)

FODD= Average amount of fodder per cow per day(kg)

EXP=Monthly expenditure on animal health (Kenya shillings)

βi -To be estimated parameters.

V= are identical, normally distributed, having random variables with zero mean and constant variance N (0, $\delta v2$) that are thought to be independent of U.

U= is the technical inefficiency in production.

A farmer's technical efficiency is characterized by the ratio of actual output (Yi) to the corresponding frontier output (Yi*) achievable with the current technology. Therefore, the technical efficiency of the farm is mathematically expressed as;

TE=Yi/Yi *

$$TEi = \frac{f(Xi;\beta i)\,\exp(vi-ui)}{f[xi,\beta+vi]} = exp\,(-ui) \quad \text{...3.5}$$

Technical efficiency arises when exp V = 1 and U = 0 because exp (V) = 1. TE, then, having values between 0 and 1, where 0 represents wholly technically inefficient farms and 1 represents efficient farms. It is crucial to keep in mind that a farmer's technical efficiency decreases with increasing U. Using SFA and equation 3.4, the first goal—estimating the degree of technical efficiency—would be achieved.

It is only helpful to ascertain if a farm is technically efficient or inefficient if the underlying causes of the efficiency or inefficiency are also found (Admassie & Matambalya, 2002). As a result, the investigation's second phase concentrated on ascertaining the reasons for the sampled farmers' technical efficiencies. U represents technical inefficiency, while technical production efficiency is represented by 1-U, as explained below:

$$\mu_i = \theta_0 + \theta_1 X_1 + \theta_2 X_2 + \theta_3 X_3 + \theta_4 X_4 + \theta_5 X_5 + \theta_6 X_6 + \theta_7 X_7 + \theta_8 X_8 + \theta_9 X_9 + \theta_{10} X_{10} + \theta_{11} X_{11} + \theta_{12} X_{12} + \theta_{13} X_{13} \ldots\ldots\ldots 3.6$$

Where: μ_i= 1-U = the efficiency score for the i^{th} farmer,

X1= the farmer's gender

X2= the farmer's age

X3= the farmer's educational attainment

X4: Size of the household

X5: Farming experience

X6: Land ownership

X7: Grazing technique

X8: Access to extension services

X9= the farmer's access to credit

X10= the farmer's access to irrigation water

X11= the breeds of cattle

X12= the primary source of income is dairy farming

X13=membership to cooperative society

$\theta_0 - \theta_{13}$ calculated inefficiency model coefficients.

The second goal is to investigate the technical efficiency elements of small-scale dairy farmers in Kinangop sub-county, which was determined in conjunction with the first goal by concurrently estimating equations 3.4 and 3.6 using SFA.

Table 3. 1: Expected Signs, Definition and Measurement of Variables Estimating Efficiency of the Farmer

Variables	**Meaning**	**Variable Measurement**	**Expected sign**
Milk Output y	The total volume of milk in a month.	Measured in litres	NA
Inputs –L	Labor- the number of man hours	Measurable in hours	+
QC	Quantity of concentrates used in the farm	Measurable in Kgs	+
ACRES	The total area under fodder	Measurable in acres covered by fodder only	+
FODD	The average amount of fodder per cow per day(kg)	Measured in kg	+
EXP	Monthly expenditure on animal health	Measured in Kenya shillings	-

Socio-economic variables

Variable	Meaning	Variable Measurement	Expected sign
X_1	Farmer's Gender	A dummy variable 1 if male and 0 if otherwise	+
X_2	Farmer's Age	Measurable by years	+
X_3	Level of education of the farmer	1=without formal education 2=pnmary,3=secondary, 4=tertiary colleges, 5= university	+
X_4	Household size	No. of household members both children and adults	+/-
X_5	Farming experience	Measured in years	+
X_6	Land ownership	A dummy variable 1 if owned 0 otherwise	+
X_7	Grazing method	A dummy variable 1 if zero-grazing 0 otherwise	+
X_8	Accessibility to credit services by the farmer	A dummy variable 1 if accessible 0 otherwise	+
X_9	Accessibility to extension services	A dummy variable 1 if accessible 0 otherwise	+
X_{10}	Access to irrigation water	A dummy variable 1 if yes, 0 otherwise	+
X_{11}	Cattle breeds	A dummy variable if mixed=0,ayrshire=1,holst ein/freshian=2, jersey=3	+
X_{12}	Dairy farming as the sole source of income	A dummy variable is 1 if yes 0 otherwise	+
X13	Membership in cooperative societies.	A dummy variable is 1 if yes,0 otherwise	

3.4 Study Area and Target Population

The Kinangop sub-county, one of Nyandarua County's five sub-counties, was the subject of the research. It is approximately 100 kilometers north-west of Nairobi, on the slopes of the Aberdare ranges. It formed in time for the 1988 general elections. It is divided into eight electoral wards. The primary economic activity in the 822 km2 geographical area with a natural forest covering about 20.3 kha is dairy and crop farming. In the area, dairy cattle grazing regimes such as zero grazing, semi-zero grazing, and free grazing are used. Kinangop sub-county was purposefully chosen since it accounts for 40%, Kipipiri 25%, and the remaining three sub-counties account for the remainder. The most reared breeds are Holstein Friesians, followed by Ayrshire, while Jersey is the least reared.

Table 2.2: Target population

Ward	Number of smallholder dairy cattle farmers
ENGINEER	4,659
GATHARA	4,309
NJABINI KIBURU	3,942
NYAKIO	5,376
NORTH KINANGOP	5,010
MAGUMU	2,150
MURUNGARU	6,093
GITHABAI	4,301
TOTAL	35,840

Source: (Ongwech et al., 2020)

3.5 Sample Design and sample size

This investigation used a stratified sampling approach, with the first phase including the purposeful selection of all eight wards that comprise the Kinangop sub-county to stratum. The convenience sampling approach was also used, which entails selecting random samples from each stratum at the researchers' discretion to participate in the study due to the unavailability of the farmers' list to build a sampling frame. To ensure that the selected sample of farmers is representative of the overall population the following sampling technique used by (Ongwech et al., 2020) was employed.

$$n = \frac{NC^2}{C^2 + (N-1)e^2} \quad \text{.......} 3.7$$

Whereas n_0 *=represents the sample size,*

N=the total population of the study,

C=*is the coefficient of variation given as (0.5),*

e = level significance given as 0.05.

In general *100 people*

The sample selected was chosen at random from among the wards using the formula below..

$$n_o = \frac{Ni}{N} \times n \quad \text{.......} 3.8$$

Where,

N_i = total population of dairy farmers in the ith ward.

N_o = number of farmers sampled from the ith ward.

N = target population.

n = size of the sample.

3.6 Data Type and Sources of Data

The assessment collected data from primary sources. In consequence, data was collected in the field by administering and filling out questionnaires. The first section of the questionnaire addressed socioeconomic factors such as the farmer's age, household size, and gender. While the second parts included production related questions.

To achieve the study's objectives, a well-structured questionnaire was provided to acquire critical information on dairy cattle farmers. The survey included both closed and open-ended questions.

3.7 Data Analysis

First, dataset collected from the farmers were tallied. This is because the initial objective of the study is to determine the technical efficiency level of small-scale dairy cattle farmers using SFA, and the analysis was conducted in compliance with those goals. The second objective is to investigate the variables that affect the small-scale dairy producers' technical efficiency in the Kinangop sub-county, which was calculated using SFA.

3.8 Diagnostic Tests

3.8.1 Heteroscedasticity

The presence of heteroscedasticity does not impact the unbiasedness and linearity of the regression model coefficients. Nevertheless, it has an effect on the estimator's best property, rendering the inference drawn during hypothesis testing worthless. In addition, Breusch-Pagan test was used in the study to test for heteroscedasticity (Gujarati et al., 2009).

3.8.2 Multicollinearity

Multicollinearity causes ambiguity in the regression coefficients, as well as non-finite standard errors in the estimates. According to (Gujarati et al., 2009) (Gujarati et al., 2009), multicollinearity is ubiquitous among variables, but the degree is what matters. The variance inflation factors (VIF) test, as described in (Kinyua, 2019), was employed in this study to assess the incidence of significant multicollinearity.

3.8.3 Normality Assumption of the Random Variable

The error term, or statistical noise, is represented by the symbol μ (0, σ^2) in the conventional linear regression model, which assumes that it has a normal distribution. The impacts of every additional variable that influences the dependent variable under consideration but is not part of the model are incorporated into the error term. However, the omitted elements are believed to be, at most, random and to have a minor effect. The normalcy of the error term in this study was confirmed using the Shapiro-Wilks test, as utilized by (Kinyua, 2019).

CHAPTER FOUR: EMPIRICAL FINDINGS

4.1 Introduction

The chapter presents the findings and discussion of the study, focusing on descriptive statistics and the results of the analysis regarding technical efficiency and technical effectiveness in dairy cattle production in Kinangop sub-county. It offers a comprehensive overview of the data collected, highlighting key metrics and trends observed among the smallholder dairy farmers. The analysis delves into various factors influencing technical efficiency, such as resource utilization, management practices, and environmental conditions. Additionally, the chapter assesses the effectiveness of different production techniques and their impact on overall productivity. Consequently, providing a detailed description of the study's objectives and the corresponding results, the chapter offers valuable insights into the current state of dairy farming efficiency in the region, identifying areas for potential improvement and recommending strategies to enhance productivity and sustainability.

4.2 Descriptive Statistics for Small Holder Dairy Cattle Farmers

The subsequent sections outline the descriptive statistics of the variables of study for technical efficiency among smallholder dairy cattle farmers in Kinangop Sub County Kenya. The demographic characteristics identified in the study included farmer’s gender, years of experience, the level of education, size of their households as well as their primary source of income. The study further sought to determine the farming experience, land ownership, grazing techniques, access to extension services, financial services, irrigation, land acreage, employment status, number of hours of hired labour as well as access to credit facilities and the type of dairy cattle reared.

Table 4.1 Summary statistics for Gender

	Frequency	Percent
Female	40	40
Male	60	60
Total	**100**	**100**

Source: Calculations by Author

From the results it can be noted that 60 percent of the total respondents were male whereas 40 percent were female. Males are perceived to be engaged largely in the dairy farming activities compared to their female counterparts.

Table 4.2: Age of Small Holder Dairy Cattle Framers

	Frequency	Percent
20 - 40 Years	40	40
41 - 60 Years	44	44
61 - 80 Years	14	14
Over 80 Years	2	2
Total	**100**	**100**

Source: Calculations by Author

It can be observed that 40 percent of the total respondents in the study were aged between 20 and 40 years, whereas 44 percent were aged between 41 and 60 years, 14 percent were aged between 61 and 80 years, and finally, 2 percent were over 80 years. The age distribution of smallholder farmers informs adaptability and openness to new technologies and methods by farmers, which can contribute to higher efficiency levels. Middle-aged farmers typically have accumulated experience and resources.

Table 4.3: Level of Education of Small Holder Dairy Cattle Farmers

	Frequency	Percent
Formal Education	2	2
Primary	37	37
Secondary	30	30
Certificate/Diploma	25	25
Bachelors Degree	5	5
Post Graduate	1	1
Total	**100**	**100**

Source: Calculations by Author

From the outcomes, the majority (37 percent) of the participants possessed primary education as their highest level of education, 30% posted secondary education, 25 percent possessed a certificate or diploma, 5 percent held a bachelor's degree, 2 percent had some form of formal education, and finally, 1 percent possessed a postgraduate degree. The educational attainment of the dairy farmers is crucial in determining their technical efficiency. Education influences the skills acquired by the farmers in relation to dairy farming.

Table 4.4: Land Ownership of Small Holder Dairy Cattle Framers

	Frequency	Percent
Rent	9	9
Both	32	32
Own	59	59
Total	**100**	**100**

Source: Calculations by Author

From the results, it can be noted that 59 percent of the respondents owned land, 32 percent both rented and owned land for dairy farming while 9 percent rented the land for dairy farming. Land ownership is critical in enhancing the technical efficiency of the dairy farmers. This because, the farmers who own land are likely to cut on costs associated with renting land for carrying out the dairy farming activities including space for zero grazing, grazing lands as well as lands where fodder can be grown.

Table 4.5: Results for Irrigation Farming by Small Holder Dairy Cattle Framers

	Frequency	Percent
No	87	87
Yes	13	13
Total	**100**	**100**

Source: Calculations by Author

It can be noted that 87 percent of the respondents contacted did not practice irrigation in their farms while 13 percent indicated that they were practicing irrigation in their farms. Access to irrigation services enhancing the productivity of the farmers by ensuring continuous productivity of fodder even during dry seasons.

Table 4.6: Dairy Farming as the Only Source of Income

	Frequency	Percent
No	54	54
Yes	46	46
Total	**100**	**100**

Source: Calculations by Author

The results indicate that 46 percent of the respondents had dairy farming as their only source of income whereas 54 percent indicated that, other than dairy farming, they had other sources of income. Having other sources of income enhances the technical efficiency of the farmers by enhancing the availability of inputs including concentrates, money for hiring labour, money for ensuring good animal health which ultimately have a positive effect on the technical efficiency of the farmers. However, it would reduce attention and time that is required in enhancing the productivity of the dairy cattle.

Table 4.7: Employment Status of Small Holder Dairy Cattle Framers

	Frequency	**Percent**
Farming Only	39	39
Business	30	30
Employed	30	30
Business and Employed	1	1
Total	**100**	**100**

Source: Calculations by Author

In terms of employment status of the respondents, 39 percent indicated that they were only practicing dairy farming, 30 percent indicated that other than dairy farming, they were engaged in other businesses. In addition, 30 percent also indicated that other than dairy farming, they were employed and finally 1 percent indicated that other than dairy farming, they were engaged in other businesses and were also employed. Having other sources of income enhances the technical efficiency of the farmers by enhancing the availability of inputs including concentrates, money for hiring labour, money for ensuring good animal health which ultimately have a positive effect on the technical efficiency of the farmers. However, it would reduce attention and time that is required in enhancing the productivity of the dairy cattle.

Table 4.8: Hiring Labour of Small Holder Dairy Cattle Framers

	Frequency	**Percent**
No	**25**	**25**
Yes	**75**	**75**
Total	**100**	**100**

Source: Calculations by Author

On whether the respondents were hiring labour in their dairy farming, 75 percent pointed out that they were hiring labour while the remaining 25 percent were of the contrary opinion. Hiring labour to assist in the activities of dairy farming.

Table 4.9: Level of Mechanization in Dairy Farming

	Frequency	Percent
Low	57	57
Intermediate	39	39
Intensive	4	4
Total	**100**	**100**

Source: Calculations by Author

In terms of the level of mechanization of the smallholder cattle farmers in the Kinangop sub-county, 57 percent indicated that the level of mechanization was low, 39 percent indicating that the level of mechanization was intermediate whereas the remaining 4 percent were of the opinion that their level of mechanization in dairy farming was intensive.

Table 4.10: Level of Hiring Machinery in Dairy Farming

	Frequency	Percent
Low	58	58
Intermediate	39	39
Intensive	3	3
Total	**100**	**100**

Source: Calculations by Author

On whether the respondents were hiring machinery in their dairy farming, 58 percent indicated low levels of hiring machinery, 39 percent indicating intermediate level whereas 3 percent were at intensive levels of hiring machinery for their dairy farming.

Table 4.11: Society Membership by Small Holder Dairy Cattle Framers

	Frequency	Percent
No	42	42
Yes	58	58
Total	**100**	**100**

Source: Calculations by Author

On whether the respondents were subscribed to any society membership, the results indicated that 58 percent were members of particular societies while 42 percent had joined any of the existing societies.

Table 4.12: Access to Extension Services by Small Holder Dairy Cattle Framers

	Frequency	**Percent**
No	14	14
Yes	86	86
Total	**100**	**100**

Source: Calculations by Author

It is worth noting that 86 percent of the participants showcased access to extension services while 14 percent did not have access to any extension services in their dairy farming. Extension services are critical in enhancing the productivity of the dairy cattle and hence the technical efficiency of the smallholder farmers in Kinangop county

Table 4.13: Provider of Extension Services

	Frequency	**Percent**
No Access	11	11
Government	9	9
Cooperative Society	22	22
Private Hired Officers	55	55
Farmers	3	3
Total	**100**	**100**

Source: Calculations by Author

From the results, participants indicated that 55 percent of the extension services at their disposal were provided by private hired officers, 22 percent of the extension services they could access were provided by cooperative societies. In addition, 11 percent did not access any of the extension services provided by different groups, 9 percent indicated that the extension services at their disposal were provided by the government while the remaining 3 percent portrayed access to extension services provided by their fellow farmers.

Table 4.14: Access to Credit

	Frequency	Percent
No	46	46
Yes	54	54
Total	**100**	**100**

Source: Calculations by Author

It can be observed that 54 percent of the respondents had access to credit while 46 percent did no have access to any credit facilities in their dairy farming. Credit services are critical in enhancing the productivity of the dairy cattle and hence the technical efficiency of the smallholder farmers in Kinangop county. The results are in tandem with the findings of Kinyua (2019) which indicated that factors including access to credit services had a negative impact on technical efficiency. Dairy farming as a primary occupation, financial education, association membership and number of dairy cattle as the significant determinants of credit access(Ongwech et al., 2020). The study therefore concluded that there were significant determinants of credit access in the study area and recommended that formulating policies geared towards enhancing educational attainment of farmers would be vital in enhancing credit accessibility to farmers in the study area hereby by concurring to the finding of this research.

Table 4.15: Provider of Credit

	Frequency	Percent
No Access	43	43
Others	7	7
Cooperative Society	44	44
Commercial Banks	6	6
Total	**100**	**100**

Source: Calculations by Author

From the results, the respondents indicated that 44 percent of the credit facilities at their disposal were provided by cooperative societies, 43 percent had no access to credit provided by the different groups. In addition, 7 percent pointed out that they could access credit facilities through other sources while the remaining 6 percent pointed out access to credit facilities through commercial banks.

Table 4.16: Credit Repayment from Dairy Proceeds

	Frequency	Percent
No Access	44	44
No	23	23
Yes	33	33
Total	**100**	**100**

Source: Calculations by Author

It is clear that 44 percent of the respondents contacted in the study had no access to credit, 33 percent were able to service their loans from dairy proceeds only while the remaining 23 percent were not able to service their loans from dairy proceeds only. The findings of Kamau et al. (2016) which indicated loan availability and improved access to financing services that help farmers buy market supplies for coffee operations. In addition, Ayuko et al. (2023) further indicated that loan availability has an impact on farmers' technical efficiency.

Table 4.17: Zero Grazing as Main Grazing Method

	Frequency	Percent
No	54	54
Yes	46	46
Total	**100**	**100**

Source: Calculations by Author

On whether the respondents were practicing zero grazing as the main method of grazing, 46 percent agreed while 54 percent had other methods of grazing other than zero grazing.

Table 4.18: Use of Concentrates by Small Holder Dairy Cattle Framers

	Frequency	Percent
No	10	10
Yes	90	90
Total	**100**	**100**

Source: Calculations by Author

On whether the respondents used concentrates in their dairy farming, 90 percent agreed that they were using concentrates in their dairy farming while 10 percent pointed out that they were not using concentrates in their dairy farming. Maina et al. (2020) indicated that indicated that giving animals enough concentrates enhanced the productivity of the dairy cattle. The monthly cost of concentrates were shown to be substantive factors correlated with economic efficiency. Furthermore, the findings of Aweer et al. (2020) indicated that concentrates feeds were fed most frequently than soya meal, maize germ, handmade dairy concentrate, and commercial dairy meal. It was shown that food deficiencies were the root cause of low reproductive and productive efficiency.

Table 4.19: Cattle Breeds Reared

	Frequency	Percent
Mixed	27	27
Ayrshire	6	6
Holstein/Freshian	66	66
Jersey	1	1
Total	**100**	**100**

Source: Calculations by Author

In terms of the dairy cattle breeds reared by the respondents, majority (66 percent) were rearing Holstein/Freshian, 27 percent were rearing mixed breeds, 6 percent were rearing Ayrshire while

1 percent were rearing Jersey. This is an indication that Holstein/Freshian was a common breed reared by smallholder farmers in Kinangop Sub County.

Table 4.20: Silage Preservation by Small Holder Dairy Cattle Framers

	Frequency	Percent
No	42	42
Yes	58	58
Total	**100**	**100**

Source: Calculations by Author

When asked about silage preservation, 58 percent agreed that they were preserving silage while 42 percent were not preserving silage in their dairy farming.

Table 4.21: Hay Preservation by Small Holder Dairy Cattle Framers

	Frequency	Percent
No	40	40
Yes	60	60
Total	**100**	**100**

Source: Calculations by Author

When asked about hay preservation, 60 percent agreed that they were preserving hay while 40 percent were not preserving hay in their dairy farms. The results of Ayuko et al. (2023) found that fodder cultivation increases income through feed, milk, and livestock sales. Kenya's demand for fodder surged, but supply could not keep up with demand. In response, the ILRI helped create a number of projects to encourage the cultivation of fodder to increase milk yield. The study advised that farmers increase fodder reservation, planting supplies, and the amount of man days spent sowing and weeding.

Table 4.22: Purchase of Fodder by Small Holder Dairy Cattle Framers

	Frequency	Percent
No	49	49
Yes	51	51
Total	**100**	**100**

Source: Calculations by Author

On whether the respondents were purchasing fodder, 51 percent agreed that they were purchasing fodder in their dairy farming while 49 percent pointed out that they were not purchasing fodder in their dairy farming.

Table 4.23: Results for Feeding Farm Residuals

	Frequency	Percent
No	5	5
Yes	95	95
Total	**100**	**100**

Source: Calculations by Author

On whether the respondents were feeding their dairy cattle on farm residuals, 95 percent agreed that they were feeding their dairy cattle on farm residuals while 5 percent pointed out that they were not feeding their dairy cattle on farm residuals.

Table 4.24: Use of Artificial Insemination

	Frequency	Percent
Yes	100	100

Source: Calculations by Author

On whether the respondents were artificial insemination, 100 percent agreed that they were using artificial insemination services in cattle breeding. The use of artificial insemination services enhances the productivity as it improves the breeds of the dairy.

Table 4.25: Summary Statistics for Continuous Variables

	Mean	Std. Deviation
Household size	4.73	2.187
Experience in farming	13.46	12.38
Acres of land owned	2.908	3.65925
Acres of land rented	0.9775	1.4342
Acres allocated to animal grazing	1.0005	1.79693
Acres allocated to fodder production	1.46	1.40682
How many hours of labour do you hire in a day?	4.67	3.269
How much do you spend on hired labour per day?	477	580.553
Concentrates Cost Per 70kg Bag	2617	987.554
Kgs of concentrate per cow per day on average	3.17	2.3173
Kgs of fodder per day per animal	41.83	26.928
Expenditure on purchase of fodder (P.A)	8069.8	13878.5
Expenditure on animal health (P.M)	2622	4840.35
Dairy animals in the farm	3.72	2.675
Animals milked	2.31	1.916
Litres of milk produced daily	20.975	20.9834
Litres of milk sold daily	18.84	19.591
Milk selling price	42.655	5.6344

Source: Calculations by Author

The mean household size for the study was 5 people. Household size is significant in the provision of labour as well as skills necessary in dairy farming. The results of Maina et al., (2020) indicated that household size was shown to be substantive factors correlated with economic efficiency. In addition, the results of Ngeno and Chumo (2021) pointed out that household size is a key factor influencing technical efficiency in coffee production. The findings of Kinyua (2019) indicated that factors including the farmer's household size had a negative impact on technical efficiency.

On average, the respondents had experience of about 14 years with a standard deviation of 12.38 years. Prior experience in dairy farming is essential in enhancing the technical efficiency of the dairy farmers. It is critical in identifying the challenges that the farmers may encounter as well as the possible solutions that be adopted by the farmers. In addition, with prior experience, the farmers can use their prior knowledge on the optimal amounts of inputs that the farmers can give the dairy cattle for maximum production and become technically efficient. However, the results of Kinyua (2019) indicated that prior experience in growing bananas had a negative impact on technical efficiency.

On average, the dairy farmers who were the respondents in the study owned 3 acres of land with a standard deviation of 3.66 acres. The size of land determines the number dairy cattle that the farmer can rear. It also determines the size of fodder production that is sufficient for the dairy cattle. Thus, land acreage is a significant determinant of the technical efficiency of the dairy farmers. The results of Kamau et al. (2016) indicated that farm size enhances technical efficiency.

On average, the respondents in the study rented at least 1 acre of land with a standard deviation of 1.43 acres. The dairy farmers who were the respondents in the study allocated about 1 acre of land for animal grazing with a standard deviation of 1.8 acres. Renting land for dairy farming is significant as it increases the productivity of the dairy farmers especially the farmers with small parcels of land. It also determines the size of fodder production that is sufficiently enough for the dairy cattle.

On average, the dairy farmers who were the respondents in the study allocated about 1.5 acres of land for fodder production with a standard deviation of 1.41 acres. The dairy farmers spent about 42 kilograms of fodder per cow per day with a standard deviation of 26.93 Kgs. The dairy farmers spent about Ksh.8000 per annum to purchase fodder with a standard deviation of Ksh. 13878.5. Fodder production supplements grazing by the dairy cattle. The results of Ayuko et al. (2023) found that fodder cultivation increases income through feed, milk, and livestock sales. Kenya's demand for fodder surged, but supply could not keep up with demand.

On average, the dairy farmers hired about 5 hours of labour per day with a standard deviation of 3.27 hours. The dairy farmers spent about Ksh.500 on hired labour per day with a standard deviation of Ksh.580.55. Hiring labour to assist in the activities of dairy farming has a positive effect on the technical efficiency and productivity of the dairy farmers. The results are in tandem with the findings of Maina et al., (2020) which indicated that the use of rented labour was shown to be substantive factors correlated with economic efficiency.

On average, the cost of concentrates cost per 70kg bag was Ksh.2600 with a standard deviation of Ksh.987.55. The dairy farmers spent about 3 kilograms of concentrate per cow per day with a standard deviation of 2.32 Kgs. The results of this study indicate that Maina et al. (2020) indicated that indicated that giving animals enough concentrates enhanced the productivity of the dairy cattle. The monthly cost of concentrates were shown to be substantive factors correlated with economic efficiency. Furthermore, the findings of Aweer et al. (2020) indicated that concentrates feeds were fed most frequently than soya meal, maize germ, handmade dairy concentrate, and commercial dairy meal. It was shown that food deficiencies were the root cause of low reproductive and productive efficiency.

On average, the dairy farmers spent about Ksh.2600 per month on animal health with a standard deviation of Ksh.4840.35. Having other sources of income enhances the technical efficiency of the farmers by enhancing the availability of inputs including concentrates, money for hiring labour, and money for ensuring good animal health, which ultimately have a positive effect on the technical efficiency of the farmers.

On average, the dairy farmers had about 4 dairy animals in the farm. The dairy farmers milked about 2 dairy animals. The results of Maina et al., (2020) pointed out that increasing herd sizes is a remedy for low milk yield among small-scale producers. Ayuko et al. (2023) further indicated that herd size, group participation, loan availability, household size, and having access to training all have an impact on farmers' technical efficiency.

On average, the dairy farmers produced about 21 litres of milk daily with a standard deviation of 20.98 litres. The dairy farmers sold about 19 litres of milk daily with a standard deviation of 19.59 litres. The selling price of milk was about Ksh.43 per litre with a standard deviation of Ksh.5.63. The results of Maina et al., (2020) indicated that a higher yield of milk can be accomplished via more efficient use of the resources already available, as farmers with increasing returns to scale (IRS) showed. Low milk yield among small-scale producers was shown to be caused by increasing herd sizes, giving animals enough concentrates, and increased spending on animals' medical care. Simultaneously, the technological inefficiencies in milk production were the fault of older farmers. A significant portion of the overall expenditures associated with dairy production was found to be the cost of concentrates and other feeds.

4.3 Diagnostic Tests

4.3.1 Test for Heteroscedasticity

The existence of heteroscedasticity does not influence the impartiality and linearity of the regression model coefficients. Nonetheless, it does affect the prime characteristic of the estimator, making the conclusions drawn during hypothesis testing invalid. Breusch-Pagan test was used in the study to test for heteroscedasticity (Gujarati et al., 2009).

Table 4.26: Heteroscedasticity Test Results

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance (homoscedastic)
chi2(1) = 0.132
Prob > chi2 = 0.0714

From the results presented, with a p value 0.0714>0.05, then the results imply that heteroscedasticity is not present.

4.3.2 Multicollinearity

It is worth noting that multicollinearity causes ambiguity in the regression coefficients, as well as non-finite standard errors in the estimates. According to (Gujarati et al., 2009) (Gujarati et al., 2009), multicollinearity is ubiquitous among variables, but the degree is what matters. The variance inflation factors (VIF) test, as described in (Kinyua, 2019), was employed in this study to assess the incidence of significant multicollinearity.

Table 4.27: Mutlicollinearity Test Results

	Collinearity Statistics Tolerance	VIF
(Constant)		
Age	0.659	1.517
Level of education	0.666	1.501
Land ownership	0.738	1.356
Irrigation farming	0.854	1.171
Dairy farming as the only source of income	0.582	1.717
Employed or in business	0.506	1.977
Hiring labour	0.636	1.572
Level of mechanization	0.291	3.434
Level of hiring machineries	0.261	3.826
Society membership	0.581	1.72
Access of extension services	0.474	2.109
Provider of extension services	0.544	1.84
Accessed to credit	0.119	8.419
Credit provider	0.13	7.683
Credit repayment	0.182	5.503
Zero grazing as the main method of grazing	0.762	1.312
Use concentrates	0.808	1.237
Cattle breeds reared	0.862	1.16
Silage preservation	0.653	1.531
Hay preservation	0.873	1.146
Purchase of fodder	0.728	1.373
Feeding farm residuals	0.797	1.254

Source: Calculations by Author

From the results, it can be noted that all the VIF values for the variables identified in the study are <10 implying that there is no multicollinearity among the variables in the study.

4.3.3 Normality Assumption of the Random Variable

The error term, or statistical noise, is represented by the symbol μ (0, σ^2) in the conventional linear regression model, which assumes that it has a normal distribution. The impacts of every additional variable that influences the dependent variable under consideration but is not part of the model are incorporated into the error term. However, the omitted elements are believed to be, at most, random and to have a minor effect. The normality of the error term in this study was validated using the Shapiro-Wilks test, as employed by (Kinyua, 2019). The p-value obtained from the test was 0.0625, which is greater than the significance level of 0.05. This suggests that the study does not reject the null hypothesis, indicating that the data follows a normal distribution at a 95 percent significance level.

4.4 The Empirical results from the stochastic frontier analysis

This section showcases and demonstrates the outcomes of econometric analysis of the stochastic frontier of Cobb-Douglas functional form. The empirical results from the estimation of the function are presented in Table 4.28.

Table 4.28: Maximum likelihood estimates of the stochastic frontier for production function

	Coefficient	Standard error	t Ratio
(Constant)	0.295	0.0381	0.772
labour	0.426	0.872	0.488
concentrate	0.595	0.933	0.638
Acres-fodder	0.209	0.106	0.198
fodder	0.538	0.839	0.641
Expenditure -health	-0.472	0.342	-0.138
R-Squared	0.145		0.27
log likelihood function	-0.101		
Gamma (γm)	0.782		-0.153

Source: Calculations by Author

From the estimates, the estimated R Squared for the stochastic production function for the small holder dairy farmers was 0.145 and was statistical significance at the 5% threshold indicates that the estimated stochastic production function was indeed notable at the same level of significance. The findings suggest that smallholder dairy cattle in Kinangop sub-county were not operating efficiently, implying they were not performing at the frontier level. This indicates that the disparities between observed (actual values) and the frontier (potential output) are attributable to inefficiencies rather than mere chance. The Gamma (γm) parameter varies between zero and one. A value of zero denotes the absence of inefficiency effects in the model, while a value of one denotes significant and non-random inefficiency. From the estimates, all variables were insignificant at 5%. However, only expenditure on animal health had a negative coefficient. Labour hired in Kinangop had no impact on TE due to the non-intensive nature of the sector unlike in Mukurue-ini where(Maina et al., 2020) found labour to be negatively influencing TE. Availability of vast tracts of land and the frequent rains in the area explain why the acres under fodder production was insignificant unlike in (Ngeno & Chumo, 2021) who found that increasing returns to scale of milk production in the three agro-ecological zones implying that SDFs operate in their first stage of the classical production function and they are still likely to attain their optimal capacity. In Kinangop the scale of fodder proction didn't matters,

Table 4.29: Frequency Distribution of Technical Efficiency in Dairy Farming

Range (%)	Frequency	Percentage	Cumulative downwards	Cumulative upwards
0-10	0	0	0	100
11.-20	0	0	0	100
21-30	2	2	2	100
31-40	0	0	2	98
41-50	3	3	5	98
51-60	7	7	12	95
61-70	26	26	38	88
71-80	45	45	83	62
81-90	17	17	100	17
91-100	0	0	100	0

Minimum 22.82%
Maximum 88.80%
Mean 71.10%

Source: Calculations by Author

According to the findings presented in Table 4.29, the technical efficiency of smallholder dairy cattle farmers exhibits a broad distribution. The observed out among these farmers ranged from 0 litres to 120 litres, with an average mean technical score of 71.1%percent. Notably, no farmer achieved a frontier level of 100%. Only approximately 5% of the smallholder dairy farmers operated at below 50% technical efficiency levels, while the vast majority, 95%, operated above this threshold, with 83% operating above 70% technical efficiency levels. The average technical efficiency score falling at 71.10% below the frontier underscores the urgent need to enhance the technical efficiency of smallholder dairy farmers in Kinangop sub-county by approximately 28.9%. This improvement could be achieved by optimizing input utilization and leveraging available extension services and increased society membership to enhance productivity through improved input access. The lower levels of technical efficiency may be attributed to factors such as underutilization of inputs like concentrates and fodder, limited access to extension services, land constraints, low level of education, and the high cost of inputs, including labor and other resources.

4.5 Technical Efficiency Distribution and Farmer Characteristics

The study further sought to analyze the technical efficiency scores by the farmer's characteristics including level of education, land ownership, employment status, level of mechanization, level of hiring machineries, provider of extension services, provider of credit services as well as the cattle breeds reared. Table 4.30 presents the results.

Table 4.30: Summary of Technical Efficiency by Household Characteristic

characteristic	category	mean	std.dev	frequency	p-value
Level of Education	No Formal education	0.673	0.1150	2	0.0027***
	Primary	0.681	0.1180	37	
	Secondary	0.687	0.1180	30	
	Certificate/diploma	0.773	0.0740	25	
	Bachelors degree	0.759	0.4960	5	
	Post graduate	0.837	0.0000	1	
Land Ownership	Rent	0.686	0.0900	9	0.8868
	Both	0.725	0.0950	32	
	Own	0.707	0.1230	59	
Employed or in Business	Farming only	0.691	0.1378	39	0.3664
	Business	0.706	0.0904	30	
	Employed	0.741	0.0896	30	
	Business and Employed	0.756	0.0000	1	
Level of Mechanization	Low	0.710	0.1025	57	0.6757
	Intermediate	0.720	0.1214	39	
	Intensive	0.638	0.1448	4	
Level of Hiring Machineries	Low	0.714	0.1038	58	0.7830
	Intermediate	0.720	0.1214	39	
	Intensive	0.696	0.1060	3	
Provider of Extension Services	No access	0.681	0.1197	11	0.2725
	Government	0.639	0.1638	9	
	Cooperative society	0.770	0.0527	22	
	Private hired officers	0.705	0.1114	55	
	Farmers	0.711	0.0833	3	
Credit Provider	No access	0.682	0.1110	43	0.0127**
	Others	0.610	0.1968	7	
	Cooperative society	0.746	0.0779	44	
	Commercial banks	0.783	0.0805	6	
Cattle Breeds Reared	Mixed	0.705	0.1225	27	0.9865
	Ayrshire	0.722	0.1000	6	
	Holstein/Freshian	0.712	0.1104	66	
	Jersey	0.756	0.0000	1	

Significant at *10%, **5%, ***1%

Source: Calculations by Author

From the outcome in Table 4.30, the education level of respondents and credit providers were statistically significant, suggesting that these variables made significant contributions to the technical efficiency of the smallholder dairy farmers under study. Conversely, variables such as level of mechanization, cattle breed reared, hiring machinery, and extension service providers were statistically insignificant at the 99% and 95% significance level. This implies that these variables may contribute to the technical efficiency of smallholder dairy farmers, though their contributions are insignificant.

Farmer technical efficiency declines with increasing technical inefficiency in production. The education level of dairy farmers plays a significant role in determining their technical efficiency, as it influences the skills acquired related to dairy farming. Kinyua (2019) further suggested that higher levels of education have positive effects on technical efficiency. Moreover, Kinyua's (2019) findings indicated that factors such as access to extension services postulated a negative impact on technical efficiency which is not the case in this study.

4.6 Factors Influencing Technical Efficiency in Smallholder Dairy Farmers

The study's second objective aimed to pinpoint the factors influencing technical effectiveness in dairy cattle production in Kinangop sub-county. The factors examined included gender of the farmer, age, education level, experience in farming, land ownership, access to irrigation water, access to extension services, access to credit services, grazing method, cattle breeds reared, dairy farming as the only source of income and society membership. An OLS efficiency model was applied to assess the impact of these factors on technical effectiveness in dairy cattle production in Kinangop sub-county, with detailed findings presented in Table 4.31.

Table 4.31: Estimates of the Technical Efficiency of Small Holder Dairy Farmers

Variable	Coefficient	t-ratio
const	0.623458***	10.62
GENDER	0.0400476	1.627
AGE	−0.000585626	−0.3925
LEVEL OF EDUCATION	0.0317079***	3.212
HOUSEHOLD SIZE	−0.00622485	−1.061
EXPERIENCE IN FARMING	0.00126994	0.9551
LAND OWNERSHIP	0.00284695	0.1646
GRAZING METHOD	−0.00955922	−0.4375
ACCESS TO EXTENSION SERVICE	0.0296661	0.8594
CREDIT	−0.0186569	−0.5565
IRRIGATION	−0.0482917	−1.057
CATTLE BREEDS	−0.00242593	−0.2024
DAIRY -SOURCE OF INCOME	−0.0205831	−0.9971
SOCIETY MEMBERSHIP	0.0770605**	2.399

Significant at *10%, **5%, ***1%

Source: Calculations by Author

From the results, the variables analyzed, including level of education gender, access to extension services, experience in farming membership to society and land ownership had positive coefficients. In the efficiency model, these positive coefficients signify a beneficial impact on the efficiency level. Conversely, a negative coefficient indicates a detrimental effect on the efficiency levels of the dairy farmers under study. It is important to note that as technical inefficiency in production increases, the farmer's technical efficiency decreases.

The highly significant constant term indicates a baseline level of technical efficiency even in the absence of the other specified factors. Its strong significance suggests the model's intercept is well-defined and statistically robust.The education level of dairy farmers plays a significant role in determining their technical efficiency.Education determine the skills acquired by the farmers in relation to the dairy farming. The results are in tandem with the findings of Kinyua (2019) which indicated that highest access of education had positive effects on technical efficiency.

The results however do not concur with the findings of Kinyua (2019) which indicated that factors including entry to extension services had a negative impact on technical efficiency. The results however do not concur with the findings of Aweer et al. (2020) indicated that concentrates feeds were fed most frequently than soya meal, maize germ, handmade dairy concentrate, and commercial dairy meal since this research didn't narrow down to fodder components. It is shown that food deficiencies were the root cause of low reproductive and productive efficiency.

Age and farming experience were highly correlated. Experience in farming increased with age. The two factors did not have impact or significantly influence TE. However (Kinyua, 2019)found that young farmers were more technically effect unlike otherwise. The significant of level of education may not have caused age to be significant because of urban rural migration.(Kamau et al., 2016)found that adoption of improved varieties (methods) especially by youthful farmers and increased access to credit facilities, which help farmers to purchase market inputs for coffee enterprise, would increase TE and ultimately coffee productivity. However, this research found that access to credit had a negative impact on TE. This was because of the high cost on loans from commercial banks where majority of respondents borrowed.

Society membership had a positive significant impact due to the many benefits members earned.(Maina et al., 2020) found that society members accessed cheaper loans unlike non-members. Extension services were fair prices by society thus giving them an edge over non-members.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The chapter brings together research findings, presenting them in a manner that is both logical and coherent. Consequently, the conclusion of this assessment is summarized within this section. Here, not only is there a concise summary of the results provided, but also conclusions and recommendations derived from the principal findings concerning technical efficiency levels and the factors influencing them are presented. Moreover, suggestions for further research are outlined, thereby laying the groundwork for future exploration in the field. This comprehensive approach ensures that the insights gained from the study are effectively communicated and serves as a valuable resource for both practitioners and researchers in the field of dairy cattle production efficiency.

5.2 Summary

Dairy cattle are primarily raised for milk production, with some breeds also serving for beef. Approximately 150 million people worldwide rely on milk and dairy products as essential food and income sources. Globally, cattle contribute 81% of milk, buffalo 15%, goats 4%, with the remainder from sheep and camels. Milk output is projected to grow faster than other major agricultural commodities over the next decade, reaching 1060 Mt by 2031. While high-income countries anticipate only 0.5% annual yield improvement, Southeast Asia and North Africa expect the highest growth at around 1% per year. Yield growth is generally expected to enhance production more than herd growth across most regions.

In Africa, dairy cattle farming is characterized by low output per cow due to frequent droughts and poor breeds. Kenya sources over 60% of its milk from improved breeds, 25% from indigenous cows, and the rest from goats and camels. Kenya ranks 5th in Africa for cattle herd size and 2nd after Ethiopia (3 billion liters/day) in milk production. Dairy farming is a significant economic activity in Kenya, involving 1.8 million smallholder farmers and contributing 14% to the agricultural GDP, besides creating employment. Nyandarua County is the eighth largest contributor to Kenya's GDP and the second-highest milk producer after Kiambu County. Dairy farming employs 80% of Nyandarua households, with a total dairy herd of 349,300 cows, most farms rearing two to three. The county produces approximately 296 million liters of milk annually, generating about Ksh. 13 billion to Nyandarua's domestic product in 2019 at an average price of Ksh. 32 per liter. Of the milk produced, 60% is traded informally, 40% in formal markets, and 20% is for home consumption. The annual per capita milk intake in Nyandarua is 114 liters, compared to the national average of 125 liters and the World Health Organization's optimal 209 liters.

This study aimed to assess technical efficiency among smallholder dairy farmers in Kinangop Sub-County, Nyandarua County, and identify influencing factors. A total of 100 respondents participated in the study. Descriptive statistics revealed that 60% of respondents were male, and the majority (44%) were aged 41-60 years. Educational attainment varied, with 37% having primary education as their highest level, followed by secondary education (30%) and certificate/diploma (25%). Land ownership was prevalent (59% owned land), while only 13% practiced irrigation. Dairy farming was the sole source of income for 46% of farmers, and 75% hired labor. The level of mechanization was predominantly low (57%), and similarly, hiring machinery was low (58%). A significant finding was that 58% of farmers were members of a society, and 86% had access to extension services, primarily from private hired officers (55%) and cooperative societies (22%). Access to credit was observed in 54% of farmers, mainly from cooperative societies (44%). Zero grazing was the main method for 46% of farmers, and 90% used concentrates. Holstein/Friesian (66%) was the most common cattle breed. Furthermore, 58% preserved silage, 60% preserved hay, and 51% purchased fodder. A high percentage (95%) fed farm residuals, and 100% utilized artificial insemination.

For continuous variables, the average household size was 4.73 members, and farmers had an average of 13.46 years of farming experience. They owned an average of 2.91 acres of land and rented about 0.98 acres. Approximately 1.46 acres were allocated to fodder production, with farmers feeding about 41.83 kg of fodder per cow per day. The average cost of a 70kg bag of concentrates was Ksh. 2,617, with farmers feeding 3.17 kg per cow per day. Daily hired labor averaged 4.67 hours, costing around Ksh. 477. Monthly expenditure on animal health was approximately Ksh. 2,622. Farmers typically had 3.72 dairy animals, with 2.31 animals milked, producing an average of 20.98 liters of milk daily and selling 18.84 liters at an average price of Ksh. 42.66 per liter.

Diagnostic tests confirmed the robustness of the econometric analysis: the Breusch-Pagan test (p-value = 0.0714) indicated no heteroscedasticity, and VIF values below 10 confirmed no multicollinearity. The Shapiro-Wilks test (p-value = 0.0625) suggested normality of the error term.

The Stochastic Frontier Analysis (SFA) revealed that the average technical efficiency for smallholder farmers was 71.1%, indicating that approximately 28.9% of farmers were technically inefficient. The R-squared value for the stochastic production function was 0.145, and the gamma (γm) parameter was 0.782, which implies that inefficiency effects significantly contributed to the total variation in output from the frontier. From the Maximum Likelihood estimates of the production model, amount of labor hired, area under fodder production, amount of fodder, and concentrates per animal per day all had a positive influence on dairy farming. Conversely, expenditure on animal health had an insignificant negative influence. The regression coefficients for the inefficiency model specifically indicated that membership to society and level of education were positive and statistically significant in influencing technical efficiency. Gender, experience in farming, access to extension services, and land ownership were positive but statistically insignificant. Other factors identified that influenced technical efficiency included access to irrigation water, household size, age of the farmer, method of grazing, and cattle breeds reared.

5.3 Conclusions

The conclusion of this study is that, the dairy farmers' production falls short the frontier output. This study revealed that the average technical efficiency of dairy farming was above average however, there is prospective for improving by production by putting more raising level of education of farmers and increasing membership to cooperative society. The results of technical efficiency analysis indicated that there existed technical inefficiency effects on dairy production, as depicted by efficiency model. Additionally, from the ML estimates of the production model show that the amount of labour hired , area under fodder production, amount of fodder and concentrates per animal per day had positive influence on dairy farming whilst, expenditure on animal health had a insignificant negative influence on dairy farming.

The study concludes that the smallholder dairy cattle farmers in Kinangop sub county are 28.9% technically inefficiency. The study results indicated that the technical efficiency of the dairy farmers was above average where all of the farmers were technically inefficient. The regression coefficients indicated that only society membership and level of education were positive and statistically significant. However, gender, experience in farming, land ownership were positive but statistically insignificant.

5.4 Recommendations

The study recommends that the smallholder dairy farmers in Kinangop sub county ought to strive to be technically efficient by joining the various societies that may be critical in providing credit, extension services among other services, and reducing expenditure on animal health by practicing animal husbandly. The study further recommends that the county government of Nyandarua to come up with policies that would aid the citizens in accessing extension services, enable farmers to join cooperative societies and improve access to higher levels of education providing incentives.

5.5 Areas for Further Studies

The study's recommendations extend beyond the immediate context of Kinangop sub-county, Nyandarua, advocating for broader research endeavors that encompass all 47 counties in Kenya. Such comprehensive studies would offer a panoramic view of the diverse factors influencing dairy farming practices and outcomes across different regions, facilitating the development of more targeted and effective policy interventions. Additionally, exploring additional variables beyond those considered in this study would enrich our understanding of the intricate dynamics at play within the dairy farming sector. By addressing the limitations of the current study and incorporating a broader range of variables, future research can provide deeper insights into the drivers of technical efficiency and financial performance among smallholder dairy cattle farmers, thus informing more robust strategies for enhancing productivity and sustainability.

Furthermore, future research endeavors should adopt a multidisciplinary approach that integrates both qualitative and quantitative methodologies. This holistic approach would enable researchers to capture the complexities and nuances of smallholder dairy farming, considering not only economic factors but also socio-cultural, environmental, and institutional dimensions. Investigating the socio-economic impacts of dairy farming on local communities would shed light on the broader implications of dairy production beyond economic metrics, fostering a more holistic understanding of its role in livelihoods and rural development. Moreover, exploring sustainable farming practices and innovative technologies can contribute to enhancing the resilience and environmental sustainability of the dairy sector, ensuring its long-term viability in the face of evolving challenges such as climate change and resource scarcity.

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APPENDICES

Appendix I: Introductory Letter

Dear Respondent

I trust this message finds you well. My name is Eric Kimani Mwaura. I am a Master of Economics (Policy and Management) student at Kenyatta University (KU). As part of the requirements for my degree, I am conducting a study on technical efficiency among smallholder dairy cattle farmers in Kinangop Sub-county.

The primary aim of my research is to establish the level of technical efficiency and identify its determinants among Kinangop dairy farmers. The insights gathered will contribute to policy formulation by providing valuable information to the government. To achieve this, I am utilizing questionnaires as a data collection method. I kindly request your assistance in providing reliable information related to the technical efficiency of smallholder dairy farming in Kinangop. Your insights and experiences will significantly contribute to the success of this research.

Please be assured that any information you provide will be treated with the utmost confidentiality and used exclusively for the purpose of this research. Upon completion of the study, I would be happy to share the final document with you upon request.

Your cooperation in this matter is highly appreciated, and your valuable input will contribute to the success of this research endeavor. If you have any concerns or questions, please feel free to contact me.

Thank you for considering my request, and I look forward to your support.

Yours Sincerely,

K102/CTY/26157/2018

Eric Kimani Mwaura

Master of Economics (Policy and Management) Student Kenyatta University (KU)

Appendix II: Questionnaires

Part A: General information of respondents

1. Name of region

----

2. Farmer Gender

----

3. Years of experience

0-5 [ ]

6-10 [ ]

11+ [ ]

Part B: Specific Questionnaires

Indicate the degree disagreement or agreement by marking the the table below in their respective columns. The ratings range from 1 to 5 as follows:

5: Strongly Agree; 4: Agree; 3: Undecided; 2: Disagree; 1: Strongly Disagree

Level of Technical Efficiency	**5**	**4**	**3**	**2**	**1**
We allocate a lot of time to feeding dairy cattle					
We pay attention to the requirement of fodder concentrates					
We ensure proper feeding of dairy by using stipulated fodder per cow per day					
We carry out proper calculation of monthly expenditures					
We ensure efficiency in dairy production to minimize wastage					

In your own opinion, how does technical efficiency improves dairy farmers' production among smallholder dairy cattle farmers.

…………………………………………………………………………………………………

……………………………………………………………………………………………

Determinants of Technical Efficiency

1. Farmer Demographics:

   Gender: [1] Male [0] Female

2. Education Level: [1] No formal education [2] Primary [3] Secondary [4] Tertiary [5] University

3. Household Information:

   Size of Household: ________

4. Primary Source of Income: [ ] Farming [ ] Other (Specify) ________

5. Farming Experience:

   Years of Farming Experience: ________

6. Land Ownership: [1] Owned [0] Not Owned

7. Grazing Techniques:

   Free-range [ ] Stall-feeding [ ] Other (Specify) ________

8. Access to Services:

- Access to Extension Services: [1] Yes [0] No
- Access to Financial Services: [1] Yes [0] No
- Access to Irrigation: [1] Yes [0] No

9. Primary Source of Income:

- Main Source of Income: [ ] Dairy Farming [ ] Other (Specify) ________

These statements aim to gather information on various factors that may influence the technical efficiency of dairy farming production. Respondents are asked to provide details related to their demographics, farming experience, household characteristics, grazing techniques, and access to essential services.

7. Do you own or rent land? *

Mark only one oval.

OWN RENT BOTH

2. How many acres of land do own? *

3. How many acres do you rent? *

4. How many acres have you allocated to animal grazing? *

5. How many acres have you allocated to fodder production? *

6. Do you practice irrigation farming *

YES

NO

ANIMAL PRODUCTION

IN THIS SECTION DATA ON DAIRY ANIMAL PRODUCTION SHALL BE ENTERED.

6. Is dairy farming the only source of income you have? *

Mark only one oval.

YES

No

7. IF NO in 1 above. are you formally employed or in business? *

Mark only one oval.

EMPLOYED BUSINESS CROP FARMING OTHER

8. Do you hire labour? *

Mark only one oval.

YES NO

9. IF YES in 3 above. How many hours of labour do you hire in a day? *

If no indicate 0.

i) 0 – 5 hours [ ] ii) 5 – 8 hours [ ] iii) Over 8 hours

10. How much do you spend on hired labour per day? *

If you don’t hire indicate 0.

11. Are you a member to a cooperative society? *

Mark only one oval.

Yes No

12. Do you access extension services? *

Mark only one oval.

Yes No

13. IF YES in 7 above. who offered the services (vet or agriculturalOfficers*)?

Mark only one oval.

GOVERNMENT

PRIVATE HIRED OFFICERS

FARMER TO FARMER

COOPERATIVE SOCIETY

14. Have you ever accessed credit for dairy farming purposes? *

Mark only one oval.

YES NO

15. IF YES in 14 above. who offered you the loan? *

Mark only one oval.

COOPERATIVE SOCIETY COMMERCIAL BANK

Other:

16. IF YES in 15 above. were you able to service the loan from dairy proceeds only?

Mark only one oval.

YES

No

17. Do practice zero grazing as the main method of grazing? *

Mark only one oval.

YES NO

18. Do you use concentrates? *

Mark only one oval.

Yes No

19. At what price do you acquire a 90kg bag? *

Mark only one oval.

Option 1

20. How many kgs of concentrate do you feed a cow per day on *

average?

21. Which cattle breeds do rear? *

Mark only one oval.

AYRSHIRE

HOLSTEIN/FRESHIAN

JERSEY

GUERNSEY

MIXED

22. How many kgs of fodder do you feed per day per animal? *

23. What is the amount of concentrates used per day per animal? *

(KES)

24. Do you preserve silage? *

Mark only one oval.

YES NO

25. Do you preserve hay (dry fodder) *

Mark only one oval.

YES NO

26. Do you buy fodder? *

Mark only one oval.

Yes No

27. IF YES in 18 above. how much did you spend on purchase of fodder? (KES)

28. Do you feed animals on farm residuals? *

Mark only one oval.

Yes No

29. Do you use AI? *

Mark only one oval.

Yes No

29. What was your expenditure on animal health last month? (KES) *

30. How many litres milk do produce daily? *

31. How many litres do you sell in a day? *

32. At what price did you sell milk? (KES) *

33.Would you be willing to participate in follow-up interviews or discussions related *

To this study?

Mark only one oval.

Yes No

34. If yes, please provide your preferred contact method (Phone/Email): *