ASSESSING THE ECONOMIC EFFICIENCY OF MILK PRODUCTION AMONG SMALL-SCALE DAIRY FARMERS IN MUKURWEINI SUB-COUNTY, NYERI COUNTY, KENYA

BY

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DECLARATION

This thesis is my original effort and work and the material in here have not been presented for a degree in any university. Any assistance sought from the work of others has been correctly acknowledged.

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DEDICATION

Dedicated to my loving parents, husband Julius and my beloved son Wilson.

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ABSTRACT

Kenya boasts of having the best dairy sector in the region. The sector is the best performing in the agricultural sector, contributing 17% to the agricultural gross domestic product (GDP) annually. It is dominated by small-scale farmers who account for the highest amounts of milk produced in the country especially in the Central and Rift Valley regions. These areas are most vigilant in dairy farming in Kenya and share ecological conditions and the same breed of animals, however, some areas produce the expected 20 litres per cow per day while others produce below that at about 5 litres per cow per day. Mukurweini sub-county in Nyeri County of Central region of Kenya is an area with intensive dairy farming but producing low amounts of milk, thus, the reason for selecting it for this study. Cross-sectional data on socio-economic factors and milk production in the past one month were collected from the 91 small-scale dairy farmers sampled in 2017, using semi-structured questionnaires. The study used the Stochastic Frontier model to analyze the technical, allocative and economic efficiency of milk production, while Tobit model was used to assess the factors associated with economic efficiency. The results indicated that the farmers had a mean of 68.7% in technical efficiency, 91.3% in allocative efficiency and 62.6% in economic efficiency. The results showed that the economic inefficiency among the farmers is mostly caused by low technical efficiency since the farmers indicated high levels of allocative efficiency. From the findings, there were considerable production inefficiencies and thus there was room for increasing productivity through the use of available inputs and reducing costs. Farmers having increasing returns to scale (IRS) showed that enhanced utilization of the available resources would yield a proportionate increase in the milk output. Increasing herd sizes, feeding animals with enough concentrates and ensuring the animals' health care costs are met were found to be some of the solutions to the low milk productivity among the small-scale farmers. At the same time, older farmers were found to be responsible for technical inefficiencies in milk production. The cost of concentrates and other feeds was found to be the major component of the total cost of dairy production. However, the allocative efficiency level among the farmers was quite high, an indication that the farmers in the study area, though resource-poor, were efficient at minimizing costs. The study indicated that age, household size, having dairy farming as the main source of income, hired labour and monthly cost of concentrates were the significant factors associated with economic efficiency among small-scale dairy farmers in Mukurweini. Price subsidies on dairy inputs, especially concentrates, as well as better milk prices, are some of the interventions that will see an increase in efficiency resulting in an increase in milk productivity.

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ACRONYMS AND ABBREVIATIONS

AE	Allocative Efficiency
ANOVA	Analysis of Variance
AU	African Union
DEA	Data Envelopment Analysis
EE	Economic Efficiency
FAO	Food and Agriculture Organization of the United Nation
GDP	Gross Domestic Product
IDF	International Dairy Federation
KCC	Kenya Co-operative Creameries
KDB	Kenya Dairy Board
MoA	Ministry of Agriculture
MoL	Ministry of Livestock
OLS	Ordinary Least Squares
SFA	Stochastic Frontier Analysis
SPF	Stochastic Production Frontier
TE	Technical Efficiency
USAID	United States Agency for International Development
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background

There has been an increase in the demand for milk as the world's population spills over the 7 billion mark (Gitau, 2013). However, milk production in the world has not matched the growing population; for the last twenty-four years, the world's milk production has increased by 32% but the world per capita milk production has decreased by 9% (Gitau, 2013). Dairy farming is a key sector in the economy of most countries in the world. However, the size and number of dairy farms depend on an individual country. According to an International Dairy Federation (IDF) Factsheet (2013), the world collectively produced 620.7 million tonnes of cow milk in 2011 and it was valued at 292 billion USD. This value accounted for 8.9% of the value of all agricultural products.

According to the United States Agency for International Development (USAID) (2010) in Sub-Saharan Africa, Kenya ranks second to South Africa in the production and consumption of dairy products. Moreover, the report further indicates that former Sudan is the largest producer of milk in the Common Market for Eastern and Southern Africa (COMESA). According to Lukuyu *et al*. (2007), there are over two million small-scale farmers who engage in zero or semi-zero grazing of cross-bred European breeds and local zebus in East Africa.

In Kenya, the dairy sector has great value to the national economy and is a major agricultural sub-sector that contributes 17% to agricultural gross domestic product and 4.5% to the total gross domestic product. Dairy farming is also a major source of income for small-scale dairy farmers who account for 70% of the total milk production in Kenya (Mawa *et al*., 2014). It is this income, as well as employment from the dairy sector, that has improved the small-scale farmer's livelihood (USAID, 2010). The sector has the capability to grow the Kenyan economy if well managed as well as cater for the 3-4% demand increase in annual milk consumption resulting from urbanization, increase in population, and rise in income (Wambugu *et al*., 2011). However, this goal will be highly influenced by the sector's level of production efficiency. The dairy sector constitutes the following estimated animals: 3.5 million exotic cattle, 14.1 million indigenous cattle, 27.7 million goats and 2.9 million camels (MoA, 2013). In a study carried out by Behnke and Muthami in (2011), they indicated that from the dairy animals, 4.8 billion litres of milk worth Ksh.257.11 billion were produced annually. Table 1 shows the status of the dairy sector in Kenya.

Table 1: Kenya dairy sector, facts and figures

Land surface	583,000 km².
Inhabitants	44 million
Main trading partners	Uganda, Tanzania, Great-Britain, Germany, South-Africa
Total milk production	5 billion kg
Production by smallholders	80%
Milk processed	30%
Raw milk market	70%
Smallholders	800,000
Medium / large scale farms	3,500
Milk consumption / capita	115litres/year
Active milk processors	30
Market leading milk processor	Brookside (44% of processed milk)
Income and employment in the dairy value chain for 1.8 million people	

Source: Ettema (2013)

About 60% of Kenya's milk comes from less than 10% of the country's landmass in the fertile regions of the country (Omore *et al*., 1999). These regions are primarily the former Rift Valley and Central provinces that are favoured by adequate rainfall and low temperatures which support vegetation, thus providing forage-based foods for the dairy cattle. Although these regions are suitable for dairy farming, Wambugu *et al*. (2011) established that most small-scale farmers faced low productivity of about 3.67 litres of milk daily in 2010 and they attributed the low productivity to the high costs of production faced by the farmers.

This low productivity capped with the high cost of production are indicators that milk production in the country is suffering from inefficiencies. However, Omore *et al.* (1999) stated that there are chances of increasing milk production by improving each cow's productivity to meet the growing demand for milk under all the inefficiencies. There was, therefore, need to carry out research to assess the milk economic efficiency of small-scale farmers, as well as identify factors influencing it. Such a study has been carried out by Mugambi (2014) within Embu and Meru counties, however, the farmers involved in this study had not previously been involved in any nutritional training.

Further, the study indicated that milk production in these Counties would be increased by 16.3% through better utilization of the available resources such as fodder, concentrates and lactating cows at no extra cost, while the cost of milk production could be reduced by about 4.4% without decreasing output. The previous study done in Mukurweini by Richards *et al*. (2016) found that feeding lactating cows an additional kilogram of dairy meal concentrate in the first 60 days of lactation resulted in an additional 0.21 litres of milk daily. The study also reported that feeding lactating cows with high protein fodder resulted in increased milk production.

1.2 Statement of the problem

According to Mawa *et al*. (2014), there is relatively low productivity of milk in Kenya which is attributed to poor feeding, substandard animal husbandry, the high cost of production and the competition between dairy farming and other farm enterprises, such as crop farming. All these and other factors can be seen as sources of inefficiencies for the small-scale farmers. Mutua (2015) noted that daily milk production per cow was 5.46 litres instead of over 12 litres while MoLD (2010) also stated that milk yield per cow has remained at 6 litres for the last three decades although there is a capability of 15 litres per cow.

In the country, the advocated annual per capita milk consumption by the World Health Organization (WHO) is 200kg, however, the annual per capita milk consumption was at 76.7kg (FAO, 2007). Moreover, according to Kenya Dairy Board (2012), milk consumption per person in a population yearly is at 115kg. This shows that there is a trend for increasing consumption but not at the recommended 200kg and perhaps this is an indication that milk is not readily available perhaps due to low milk production.

A number of studies on small-scale dairy farming have been conducted in Kenya with the purpose of identifying the status of milk production in the country. Examples of previous studies include: milk production and marketing (Ngigi, 2002; Staal *et al*. 2008); smallholder dairy profitability (Omiti *et al*. 2006); production systems (Bebe, 2003); and milk producers' profit efficiency (Nganga *et al.* 2010). In spite of the recommendations made by the various researchers, the average milk yield per cow has not increased and the amount of milk exported from Kenya to the Eastern African region has remained insignificant, in spite of the country having preferential access to the market (Mugambi, 2014). Very few studies on milk production efficiency have been done; an example is one done by Mugambi (2014) in Embu and Meru counties. However, no study has been done to assess the milk production efficiency among small-scale farmers in the study area after a number of years of partnership with a nongovernmental organization from Canada called Farmers Helping Farmers. Moreover, it is this particular training of farmers before the efficiency study that makes this study unique from that of Mugambi (2014).

The partnership aimed at training farmers on how to feed their cows better to increase milk production. After the partnership, a study by Richards *et al*. (2016) found that feeding lactating cows an additional kilogram of dairy meal concentrate in the first 60 days of lactation resulted in an additional 0.21 litres of milk daily. Even with the recommendation by Richards *et al*. (2016), the amount of milk production among the farmers was still low. It is after this discovery that the need for a study to assess the farmers' economic efficiency in milk production arose. This could assist in identifying how efficient the farmers were at utilizing the available resource and minimizing costs. There are also concerns by the Kenyan government and other policy-makers about milk production efficiency among smallscale farmers (FAO, 2010).

1.3 Objectives of the study

Broad objective:

The general objective of this study is to determine the economic efficiency of milk production among the small-scale dairy farmers in Mukurweini, Nyeri County.

Specific objectives:

1. To determine the technical and allocative efficiency of milk production among the smallscale dairy farmers in Mukurweini, Nyeri County.

2. To determine the factors influencing the economic efficiency of milk production among small-scale dairy farmers in Mukurweini, Nyeri County.

1.4 Research hypotheses

1. The small-scale dairy farmers in Mukurweini are technically and allocatively efficient
2. Farmer characteristics, economic factors, institutional factors and costs of inputs have no influence on the economic efficiency of milk production

1.5 Justification

As the country gears towards achieving the Sustainable Development Goals of poverty reduction and food security, dairy farming will play a key role since the dairy sector is a major agricultural sub-sector. This research will help achieve poverty reduction in that it highlights the factors that will heighten the capacity of the small-scale farmers to produce efficiently, thus increasing food availability, income and living standards of the rural people.

The recommendations from this study if put into practice will help in attaining Kenya's vision 2030 of creating globally competitive and prosperous country with high-quality life to make Kenya a middle-income country through improved nutrition and increase in income. An increase in milk productivity following the study's recommendation will also play a major role in achieving one of the Kenyan big four agenda of manufacturing and food security as there will be more milk which is a raw material for some of the manufacturing industries. Nyeri county government's vision of ensuring food and nutrition security of the county will also be partly actualized due to increased milk production in the county.

This study sought to identify any production inefficiency problems among small-scale dairy farmers and to prescribe measures to reduce the inefficiency. This information will hopefully help to increase the average daily milk production per cow from 5.46 litres to an expected amount of over 12 litres per cow daily (Mutua, 2015). This increased milk production will provide enough milk required to satisfy the demand for milk by the swelling population in most urban areas. The increased milk production efficiency will also play a major role in ending hunger by 2025 in accordance with the Malabo Declaration (AU, 2014).

The findings from this study will serve as reference material for future researchers on related topics as it would help other academicians who will study the same topic in their research. The study also highlights the areas of milk production efficiency that require further research. The scholars and researchers who would like to debate or carry out more studies on milk production efficiency might find this research useful.

CHAPTER TWO: LITERATURE REVIEW

2.1 An overview of the dairy sector in Kenya

The dairy sector in Kenya is a source of food, income and employment to a total of about four million Kenyans (Omiti *et al*., 2006). The dairy sector contributes about 4.5% to the total Kenyan GDP and 17% to the agricultural GDP (MoLD, 2010). In the sector, small-scale farming is taken to be the most significant in the country (Murage *et al*., 2011). The small-scale farmers contribute over 80% of the total milk in the country (KDB, 2012) but their productivity per animal still remains low (Karanja, 2003).

The dairy industry's growth in Kenya is being held down by low productivity (Rademaker *et al*., 2016). Machira (2014) attributed the low dairy production in the country to cold weather, insufficient rains and fodder, competition for land between livestock and crops, as well as late payments to the farmers by the processors. A report by Rademaker *et al*. (2016) indicated that small-scale farmers own 3-15 lactating cows, medium scale farmers own 15-50 lactating cows, while the large-scale farmers own over 50 lactating cows. The small-scale farmers hold their animals within their little pieces of land that range between 3 to 5 acres and are able to get an average of 5 litres per cow per day (FAO, 2011).

There has been an increase in the demand for large amounts of milk due to the following reasons. Firstly, the number of milk processing plants is on the rise, with the country boasting of about thirty processing plants, with the leading ones being Brookside Dairy Limited, New KCC, Githunguri and Daima. Their capacity has gone up from 2.9 million litres per day to over 3.5 million litres per day from 2013 to 2014 (Machira, 2014). Secondly, due to the increase in the number of middle-income consumers in the country, there has been a rise in the demand for cheese. According to a report by Euromonitor International on dairy in Kenya (2015), the rise in demand for cheese is as a result of an increase in the popularity of fast foods and a change in domestic cooking styles. Thirdly, there has been a growing new trend of milk dispensing machines in the supermarkets that require constant milk supply. The demand for milk is also expected to grow as a result of increased population, urbanization, the rise in disposable incomes, and diversification of food products (Euromonitor International, 2015). Due to all the above reasons, farmers need to keep abreast with the growing demand for milk by increasing their productivity and this is only possible if the farmers are producing efficiently.

2.1.1 Dairy production systems practised in Kenya and Mukurweini sub-county

The production systems in Kenya are majorly influenced by agro-climatic characteristics of an area, land productivity potential and prevalence of animal diseases (Wambugu *et al*., 2011). The dairy production systems practised in Kenya include intensive, semi-intensive and extensive systems. Intensive and semi-intensive production systems are majorly practised in the Kenyan highlands since they are highly populated (Odero-waititu, 2017).

Intensive production system practised in highly populated areas involve stall feeding/zero grazing which is characterized by cutting and carrying fodder to the cattle pens and is supplemented with purchased concentrates (Wambugu *et al*., 2011). Areas with less dense population practice semi-intensive production system where the animals are both stall-fed and freely grazed depending on the season (Mbugua *et al*., 1998). The extensive production system is practised in the sparsely populated areas where there are large tracks of land that are converted into ranches and the animals are allowed to graze freely in paddocks. This system is common in the Kenyan lowlands such as Marakwet, Kikambala in Kilifi and Matuga in Kwale (Odero-waititu, 2017). The small-scale dairy farmers in Mukurweini majorly practice intensive production system due to the small pieces of land.

2.2 Economic efficiency

According to Farrell (1957), the efficiency of a farm is its ability to produce the maximum amount possible of an output using the given inputs. He further went ahead to define economic efficiency as a product of technical efficiency and allocative efficiency. According to Cordeiro (2008), efficiency measure can be defined as either the variation between the actual and the maximum expected output for given inputs (output efficiency) or the difference between the actual and minimum expected input for given output (input efficiency). Economic efficiency can be attained by producing the maximum possible amount whilst using the least amount of resources available by incurring the minimum cost. There is not much difference between economic efficiency and production efficiency as they both use the same measure, however, production efficiency is treated as economic efficiency in some studies, such as the one by Mugambi (2014).

2.2.1 Technical efficiency

Technical efficiency is the capability of a farm to produce the maximum amount of output given a set of inputs while considering the underlying production function. According to Battese (1992), a production function is defined in relation to the maximum output that can be produced using the existing technology, given a set of inputs. According to Farrell (1957), technical efficiency can be measured by considering two approaches: the input-oriented approach where we seek to answer the question 'by how much can a number of inputs be proportionally decreased without altering the amount of output produced'. The output-oriented approach that seeks to answer the question 'by how much can the amount of output be proportionally increased without changing the amounts of inputs used’.

2.2.3 Allocative efficiency

Allocative efficiency, otherwise known as price efficiency, is the ability of a farm to use optimum amounts of inputs given their respective prices. It can also be defined as a ratio between the total cost of producing a unit of output in a technically efficient way using actual relative amounts of inputs and the total cost of producing a unit of output in a technically efficient way using optimal relative amounts of inputs (Masuku *et al*., 2014). A farm is said to be allocatively efficient when it is operating at a least-cost combination of inputs. Basically, allocative efficiency measures the success of a farm in choosing the optimal proportions. This success can be equated to profit maximization. However, for a farm to maximize profit in a perfectly competitive market, the Marginal Value Product (MVP) resulting from using an additional unit of input must be equal to its unit cost, that is, Marginal cost=Unit price of input (Chukwuji *et al*., 2006). Technical and allocative efficiency were distinguished by Farrell (1957) as measures of production efficiency.

2.3 Methods of efficiency measurements

After Farrell (1957) came up with a method of analyzing efficiency, different researchers; BravoUreta and Pinheiro, 1993; Coelli, 1995; Cooper *et al.* 2004; Kumbhakar and Lovell, 2003; Coelli *et al.* 2005 have introduced other techniques. These methods can be categorized into the parametric methods, an example of which was first developed by Aigner *et al*. (1977) and Meeusen and Broeck (1977), and the non-parametric methods that were first introduced by Charnes *et al*. (1978).

2.3.1 Parametric method

A popular example of the parametric method is the Stochastic Frontier Analysis (SFA) that gives efficiency estimates/scores of individual producers. The SFA has been used in numerous studies in agricultural economics and is preferred when dealing with any agricultural production research since it is able to explain the measurement errors and other statistical noise (it separates random noise from efficiency) (Coelli, 1995). It also allows for traditional hypothesis testing and grants room for single step estimation of inefficiency effects (Kumbhakar and Lovell, 2003). This method uses data to econometrically estimate the parameters of a hypothesized function using a set of Decision Making Units (DMUs).

Generally, it is assumed that producers aim to maximize profits or outputs and minimize costs or inefficiency, however, this is not normally achieved due to random statistical noise, such as rain failure. Due to differences in resource endowment, skills or knowledge, some farmers tend to be more efficient than others in production, therefore, SFA can be used to model these deviations. This approach was applied in this study as it provided an efficiency score for every individual farmer so as to identify who needed what intervention. It was also useful in identifying the key sources of inefficiency, based on the farmer characteristics for instance.

2.3.2 Non-parametric method

Data Envelopment Analysis (DEA) is an example of the non-parametric approach that compares every producer with the seemingly most efficient producer, that is, it is based on comparative analysis of the examined producers to their counterparts (Greene, 2007). According to Emrounejad (2000), DEA is an extension of Farrell's measure to multiple-input multiple-output scenarios and is operationalised using mathematical programming. The multiple input and output measures will then be transformed into specific estimates of efficiency. According to Wei (2014), DEA is more popular in studies in the field of agriculture, and it uses mathematical programming to come up with the efficient frontiers.

2.4 Determinants of efficiency

The studies done on milk production and in particular its economic efficiency, reveal various factors that influence the efficiency of the farms. These determinants can be categorized broadly into; farm and farmer characteristics, cost of inputs, economic factors and institutional factors.

2.4.1 Farm and farmer characteristics

Farm characteristics include; the distance of the farm to the market, size of farm, herd size while farmer characteristics include; age, education, household size, farming experience and off-farm income. The distance to the market determines a farmer's motivation to engage in dairy farming considering the milk is easily perishable. The closer the collection centre of the purchasing company to the farm the greater the chance of farmers taking part in dairy farming. This distance also influences the transportation costs incurred by the farmer and the less the transportation cost the more the farmers are involved in dairy farming.

Due to the increased population and especially in the highlands where dairy farming is best suited, the land is greatly fragmented leading to small farm sizes. This fragmentation limits the cultivating of enough fodder to feed the cows (Ichura, 2013) thus the farmers end up underfeeding their cows or purchasing fodder and that increase their production costs. The size of farms thus influences the level of efficiency. The herd size also determines the level of efficiency of a farmer, for instance, large herd sizes are easier to deal with when introducing most technologies such as electric milking machines and are more efficient in labour utilization. However, due to limited farm sizes and capital by the small-scale farmers, keeping large herds is not easy.

The household head's education level and age that is associated with farming experience are paramount to the decisions made by the farmers in matters such as the use of new technologies and utilization of the available inputs. The older farmers are seen to be less efficient as they are more reluctant to use the new technologies in dairy production (Omiti *et al*., 2006). The same finding was reported by Delgado *et al*. (2003). Farmers with more years of formal education tend to be more efficient, as they are enlightened on how to manage their farm and alleviate risks and uncertainties (Omiti *et al*., 2006).

In another study, Edrisinghe *et al*. (2010) stated that since education contributes directly to human capital, high education level helps in reducing inefficiency. Nyekanyeka (2011) stated that farming experience exposed farmers to many methods of dairy production, thus influencing their efficiency. The small-scale farmers with a high number of years of farming experience typically attain higher levels of economic efficiency (Nwanchukwu *et al*., 2007).

In dairy farming activities, human physical energy is a necessity. The individuals living in the household are a source of this physical energy. The number of individuals determines the available family labour for dairy farming and their involvement determines the level of output. However, depending on the number of individuals, the pressure to cater for their daily needs such as food and clothing adds strain to the capital or income that could have otherwise been ploughed into dairy farming.

Engaging in off-farm activities to earn income causes detraction from specialization in dairy farming (Mishra and Morehart, 2001). Specialization increases a farmers level of efficiency. According to Ichura (2013), the dairy industry in Kenya has been highly privatized and lacks government liberalization and the marketing has majorly been left to the private sector who take advantage of the dairy farmers by buying from them at low prices. This forces the farmers to seek employment or venture into other agricultural activities that have better returns. Mumba (2012) showed that off-farm income by the farmer influenced the decision of the small-scale farmers on whether to increase and improve the dairy milk production. Therefore, off-farm income has an influence on efficiency.

2.4.2 Cost of inputs

The cost of inputs affects milk production efficiency. For example, a study by Omiti *et al*. (2006) showed that the quantity of concentrate feeds required to produce a litre of milk in conjunction with high prices of the feeds have a negative influence on profitability as well as milk production efficiency. The prices of concentrates are high compared to the prices of other inputs in the dairy production. The high costs of concentrates due to high raw materials and fuel prices result in the setting of high prices by the manufactures which are almost unaffordable by the small-scale farmers considering small-scale farmers aim at minimizing costs in order to remain efficient (Kamau, 2011).

Over time the dairy farmers have been over-relying on rain-fed fodder thus they have amounts of fodder during the adverse weather conditions. These farmers end up purchasing the commercial fodder such as hay whose prices are normally escalated. There have been recommendations of some fodder plants such as lucerne and calliandra that are required by animals in small quantities and have increased milk output effect. However, according to Kiama and Nderitu (2009), farmers' knowledge of these alternative plants is limited.

Another high cost incurred by the farmers is that of veterinary services. An animals' health is vital to its level of milk production. Diseases such as mastitis and foot and mouth disease bring about a decline in the amount of milk produced by a cow. In as much as farmers want to deal with the diseases, the cost of the veterinary drugs, services and vaccines are high and most farmers are not familiar with the procedure of application (Ichura, 2013). Kavoi *et al.* (2010)

looked at the effects of animal health costs on dairy production and found that they have a negative influence on efficiency.

In the previous studies, such as those by Iruria *et al*. (2009) and Wilson (2010), labour has also been seen to influence how efficiently the farms operate. A high labour cost causes the smallscale farmers to shy away from hiring enough labour for their farms, thus the farmers end up operating inefficiently.

2.4.3 Economic factors

Economic factors include factors such as interest rates and taxes. Investing in dairy farming needs large capital and considering most small-scale farmers are not capital sufficient, they rely on taking credits to finance their dairy farming venture. Also, due to the prices of concentrates, the farmers take credit in form of concentrates from their dairy co-operatives. These credits normally attract interests that the farmers must pay. A study by Mugambi (2014) identified bank interest rates in Kenya as major contributors to the high cost of dairy milk production. When the banks impose high-interest rates, it would inhibit credit access and influence the developments that the small-scale farmers would undertake to improve their efficiency. The high rate of taxes on animal feeds or veterinary drugs increase the cost of milk production, therefore lowering the efficiency levels of the small-scale farmers.

2.4.4 Institutional factors

Access to credit and extension services enhance small-scale farmers' efficiency (Kavoi, 2010). Extension services are meant to offer small-scale farmers with information on new technologies and the recommended techniques of farming. Some extension services are normally linked with veterinary services such that one offering extension service can also offer the veterinary services to the farmers. The lack of extension services close to the farmers can be linked to low productivity. A study by Al-hassan (2012) indicated that access to extension services increased efficiency. Credit is important in matters concerning the adoption of new technologies in the dairy sector (Chidime, 2007). Access to credit by a farmer increases their capacity to expand their dairy venture and purchase of the necessary concentrates as well as treatment of their cows. Therefore, it has a positive effect on efficiency.

2.5 Theoretical framework

Farrell (1957) differentiated between technical and allocative efficiency as a measure of economic efficiency through the use of frontier production and cost function, respectively. This was an advancement of the work by Koopman (1951) and Debreu (1951). Farrell identified that Koopman (1951) and Debreu (1951) had not considered that production efficiency had a second component reflecting on the ability of the producers to choose the "right" technically efficient input-output vector considering the existing input and output prices. Economic efficiency is the overall performance measure. Most of the empirical studies on productivity and efficiency, such as this one, have their analytical framework provided by the economic theory of production (Mutoko *et al*., 2008). Farm-level production efficiency can be measured by estimating a production frontier that includes all the input or output data available for analysis (Binici *et al*., 2006). Farms operating on the production frontier are said to be efficient while those operating within the frontier are said to be inefficient since the farm is producing less output given its level of inputs. Farrell (1957) also illustrated how the overall efficiency can be divided into technical and allocative efficiency as shown in Figure 1.

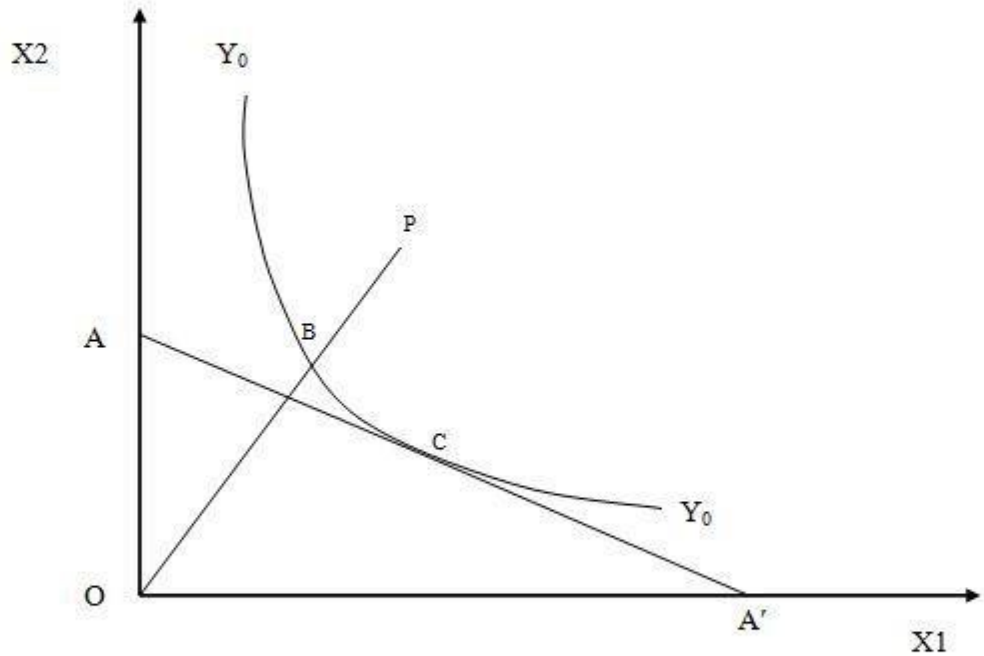

Figure 1: Relationship between technical, allocative and economic efficiency

Source: Farrell, 1957

Point P is technically inefficient as it is located on the interior of the production isoquant for output level Y_0; fewer amounts of inputs X_1 and X_2 could be used to produce the same level of output given the best practice frontier. Point B is technically efficient as it lies on the isoquant for output Y_0 but it is not allocatively efficient since it is not on the isocost line A. Point C lies at the tangency of isocost A and isoquant $Y_{0,}$ thus it is both technically and allocatively efficient, it is the point of economic efficiency (Schmidt *et al*., 1979).

Farrell's study had concerns about the human ability to measure prices accurately enough to make good use of allocative measurement. Thus, Charnes and Cooper (1985) noted this concern as the reason for the advancement of the study on efficiency. They also cite Farrell (1957) concern as one of the motivations for operational research and management science (OR/MS) emphasis on the measurement of technical efficiency.

CHAPTER THREE: METHODOLOGY

3.1 Conceptual framework

As shown in Figure 2, the environment that consists of the institutional environment, infrastructural environment and social/economic environment affects the household's decision making on dairy milk production as well as the farm and farmer characteristics and the institutional factors. The decisions made by small-scale dairy farmers in milk production are a result of interrelations between various factors, which can be classified into farm and farmers' characteristics, cost of inputs, and institutional factors. Some of these parameters can be controlled personally by the farmer, such as education level, size of the household, years of farming experience and the income earned off-farm, while other parameters are beyond farmers' control, such as the cost of inputs and institutional factors, for example, access to credit and extension.

The institutional factors such as access to credit influences the ability of the farmers to purchase inputs for dairy farming while access to market motivates the farmers' decision to venture into dairy farming, as there is a reliable market for their milk. Before making a decision to undertake dairy farming, a farmer will have to consider the cost of inputs to assess the profitability of the enterprise. A farmer's decision to invest in dairy farming is also influenced by various farm and farmer characteristics. For instance, the farm size will determine the herd size one can keep while farming experience and level of education will enable the farmer to make a more informed decision concerning dairy farming.

The decisions made will then determine whether the farmer is getting the maximum expected amounts of milk per cow while incurring the minimum cost of production. It is, therefore, the

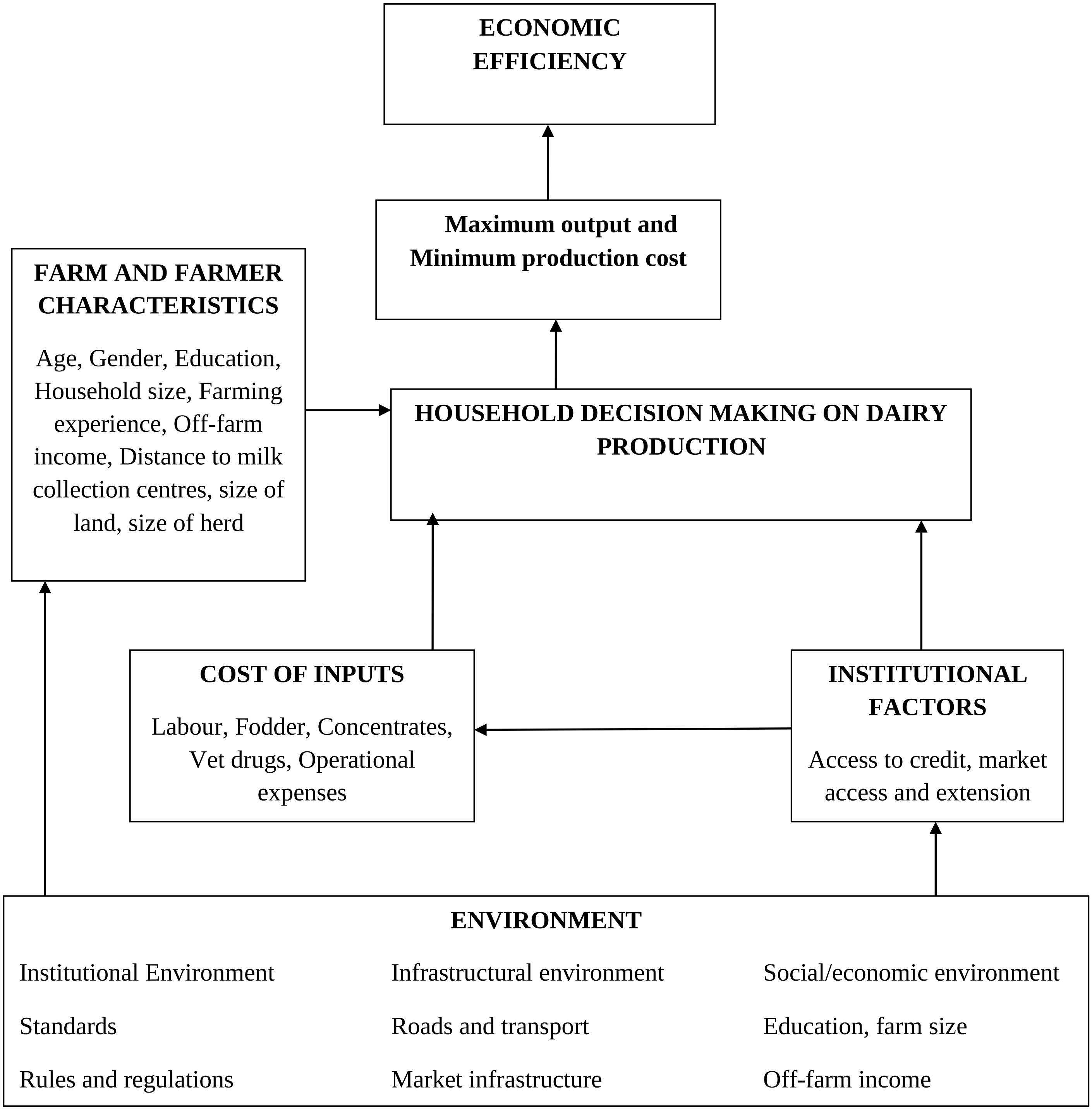

Figure 2: Conceptual framework showing links between factors influencing dairy production decisions and economic efficiency

Source: Author's conceptualization

relationships between all these factors that are responsible for which point the farmer produces on the production possibility frontier, be it within the frontier, in which case the farmers' milk production is efficient, or below the frontier, in which case the farmers' milk production is inefficient. Achieving both the allocative and technical efficiency is dependent on the decisions made and they, in turn, influence the economic efficiency of the farm. According to Delgado (2003) and Nganga (2010), farmers' attainment of economic efficiency, that is, technical and allocative efficiency, is highly dependent on the decisions they make.

It is to be noted that not all variables in the conceptual framework were used in the analysis model due to various reasons. For instance, farm size was not included in the model as we did not consider it to be a direct input affecting the amount of milk produced. Instead, the herd size was considered as it determines the total amount of milk produced by a farmer. Labour in terms of man-hours or wage rate was also omitted in the model as the farmers found it difficult to point out how many hours were solely dedicated to dairy farming activities considering the farmers practised mixed farming.

3.2 Study area

The study used data collected in Mukurweini, a sub-county in Nyeri County. Figure 3 represents the map of Kenya showing the location of Nyeri County, a map of Nyeri County and a map of Mukurweini. Nyeri County is found in Central Kenya and it lies at 1644 meters above sea level with a monthly range of temperatures between 12.8^{0}C and 20.8^{0}C and an annual rainfall of 1,200mm-1,600mm in the long rains and 500mm-1500mm in the short rains. The main agricultural activities in Nyeri County are cash crop farming of coffee and tea and horticultural farming of flowers and vegetables. However, due to diminishing land portions, most small-scale farmers are turning to dairy farming as their main agricultural activity.

Nyeri County has had an increase in the number of dairy farmers for various reasons. Firstly, adequate rainfall and low temperatures that favour and support vegetation thus providing fodder for the dairy cattle (Omore *et al*., 1999). Secondly, the county hosts two major milk processing and packaging companies, that is, Kenya Co-operative Creameries (KCC) and Brookside Dairy Limited hence the dairy farmers have a ready market for their milk. Moreover, the county has another ready market from the hotels that hosts tourists who visit the County due to various tourist destinations such as, Aberdare ranges, Mount Kenya National Park and private wildlife sanctuaries such as Ol Pejeta Conservancy and Lewa Wildlife Conservancy.

Thirdly, the County has well-tarmacked roads with the local feeder roads well murramed. This makes the transportation of milk to the collection centres and processing plants easy and timely. The water provision services are good and water is readily available straight from the taps thus there is enough drinking water for cattle in every home.

Mukurweini sub-county is found in the South Western part of the county. It is known for coffee farming, however, in recent days, dairy farming in the area is on the rise. The area has over 6,000 smallscale dairy farmers and they have collectively formed Mukurweini Wakulima Dairy Limited. The study focused on sampled farmers distributed across all locations of the sub-county.

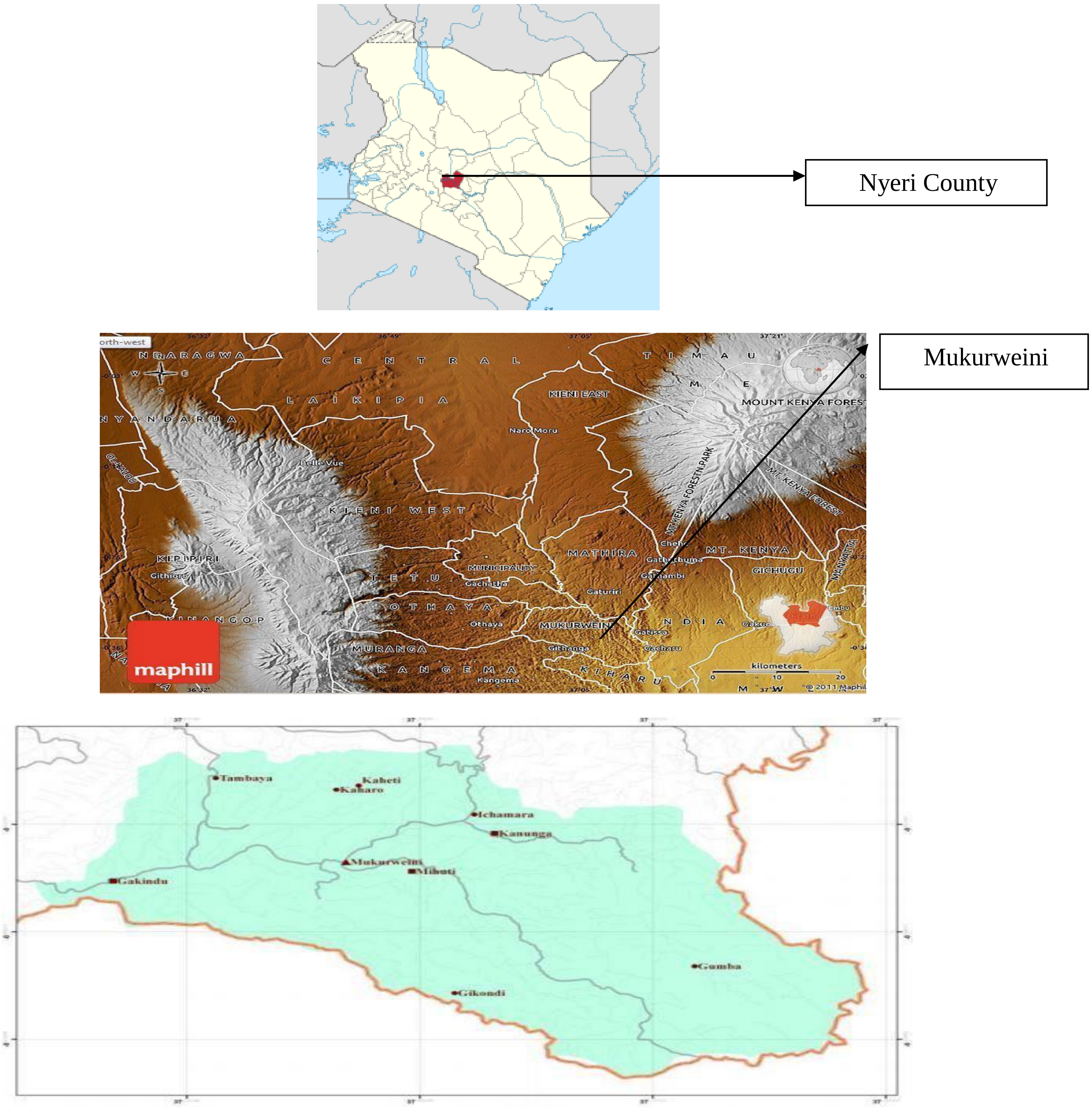

Figure 3: Map of Kenya showing Nyeri county, a map of Nyeri county showing Mukurweini sub-county and a map of Mukurweini showing main centres

Source: DURP, University of Nairobi, 2008

3.3 Empirical and model specification

The stochastic production frontier (SPF) model was composed by Aigner *et al*. (1977) and Meeusen and Van Den Broeck (1977). It has been made popular by studies of Bravo-Ureta and Rieger (1991), Sharma *et al*. (1999), Binam *et al*. (2004) and Taylor *et al*. (1986) who used it to analyze production efficiency. It uses the standard production function technique:

$$Y = f(x) \qquad (1)$$

Where Y represents the farms' output and X represents the vector inputs used in the production. The stochastic production frontier equation will, therefore, be written as follows:

$$Y_i = f(X_i; \beta) + \mathcal{E}_i \qquad (2)$$

Where:

$f(X_i; \beta)$ =	Suitable function, example Cobb-Douglas/ translog i=1,2,......N
Y_i =	Daily milk production in litres
X_i =	Quantity of inputs required in milk production
β =	Vector of the unknown parameter to be estimated
$\mathcal{E}_i$ =	Random error term that comprises of v_i and u_i, therefore

$$\mathcal{E}_i = v_i + u_i \qquad (3)$$

v_i is the ordinary two-sided error term assumed to have a mean of zero, constant variance, and to be normally identical and independently distributed. It takes into consideration the mysterious and uncontrollable factors outside the farmers' control. u_i is a one-sided error term and is an efficiency term that accounts for the shortfall from the stochastic frontier. $u_i \geq 0$, and if $u_i > 0$, the farm is below the frontier but if $u_i = 0$, the farm is on the frontier. Normally, u_i is said to have a half-normal error term and to be non-negative.

In order to analyze the economic efficiency, that is, technical and allocative efficiencies, a Cobb-Douglas production function that has been used widely in similar studies such as economic efficiency of the smallholder farmer in Swaziland by Masuku *et al*. (2014) and in Peshawar district by Sajjad and Khan (2010) was used instead of a transcendental logarithmic (translog) function. The reason for selecting either Cobb-Douglas function or translog function should be guided by the research objective, should be theoretically consistent and suitable for a given field (Mutoko *et al*., 2008). According to Tchale (2005), the function should be flexible and easily computed. The translog is more flexible than Cobb-Douglas however, it does not give coefficients with reasonable signs and magnitude due to the degrees of freedom and there is presence of multicollinearity among the variables (O'Neill *et al*., 1999). The Cobb-Douglas function is deemed appropriate since as it is simple, self-dual, allows examination of economic efficiency and has minimized empirical efficiency measurement effects (Kopp and Smith, 1980). However, it has a disadvantage in that it restricts the relationship between inputs, which are not quite rational. Despite the disadvantage, the generalised Cobb-Douglas function was used for this study as it can handle multiple inputs (Murthy, 2004). The Cobb-Douglas production function was expressed as follows, as specified by Battese and Coelli (1996):

$$Y_i = f(X_i; \beta) \exp V_i - U_i \qquad (4)$$

Where:

Y_i = Daily milk production in litres;

X_i = Quantity of inputs required in milk production; and

β = Vector of the unknown parameter to be estimated.

v_i is the random variable that is assumed to be independent and identically distributed (iid), normally distributed $N\ (0,\ \sigma_v{}^2)$, and independent of u_i. u_i is the non-negative random variable assumed to account for technical inefficiency effects in production, taken to be independent and identically distributed (iid) and normally distributed $N\ (0, \sigma_u{}^2)$.

3.3.1 Technical efficiency

To measure the technical efficiency, the Cobb-Douglas production function was used. Since the Cobb-Douglas production Equation 4 was non-linear, natural logs were taken to make the equation linear (linearization).

The Cobb-Douglas Equation 4 was linearized as follows:

$$lnY_i = ln\beta_0 + \beta_1 lnX_{1i} + \beta_2 lnX_{2i} + \beta_3 lnX_{3i} + \beta_4 lnX_{4i} + V_i - U_i \quad (5)$$

where:

Y= Total milk production in litres;

β =Vector of the unknown parameter to be estimated

X_1= Herd size (number);

X_2= Fodder in Kgs;

X_3= Concentrates in Kgs;

X_4= Animal health expenditure (Ksh) and

v_i and u_i= Error terms.

The technical efficiency (TE) was taken as a ratio of observed milk output to the corresponding frontier/expected milk output:

$$TE_i = Y_i/Y_i^* = f(X_i; \beta) \exp V_i - U_i / f(X_i; \beta) \exp V_i = \exp(-U_i) \qquad (6)$$

where, Y_i was the observed output, and Y_i^* was the frontier/expected output. TE_i should lie between 0 and 1. If U_i=0 then the farm is 100% efficient but if $U_i > 0$ the farm is operating inefficiently.

3.3.2 Allocative efficiency

A cost frontier of a Cobb-Douglas function structure was used to estimate the allocative efficiency as follows:

$$C_i = g(P_i; \alpha) \exp (V_i + U_i) \quad (7)$$

where: C_i was the cost of all inputs, g was a Cobb-Douglas function, P_i was prices of inputs used in production, α was the parameter to be estimated, and V_i and U_i were random errors taken to be independent and identically distributed (iid) and normally distributed $N\ (0,\ \sigma_v{}^2)$. U_i showed the level of allocative efficiency of a farm.

The Cobb-Douglas Equation 7 was linearized as follows:

$$\ln C = \alpha_0 + \alpha_1 lnP_1 + \alpha_2 lnP_2 + \alpha_3 lnP_3 + \alpha_4 lnP_4 + V_i + U_i \quad (8)$$

where: C=Total cost of milk production;

α =Vector of the unknown parameter to be estimated

P_1 = Cost of fodder;

P_2 = Cost of concentrates;

P_3 = Cost of animal health;

P_4 =Other operating expenses; and

v_i and u_i= Error terms.

The allocative efficiency (AE) was taken to be the ratio of expected minimum cost of production to the observed/actual cost of production, as is shown in Equation 9. The AE_i should lie between 0 and 1.

$$AE_i = C_i^* / C_i = \exp(U_i) \quad (9)$$

Maximum likelihood was used to estimate simultaneously the unknown parameters of the Cobb-Douglas stochastic frontier production and cost functions. The likelihood function is expressed in terms of the variance parameters and sigma-squared (total variance); $\delta^2 = \delta_v^2 + \delta_u^2$ where δ_v^2 is the variance of ν error and δ_u^2 is the variance of u error and they give the overall influence of all other factors not used in the estimation of milk production efficiency. The variance ratio gamma (γ) gave the proportion of total variation of the milk output from the frontier, which was explained by technical or allocative inefficiencies $\gamma = \delta_u^2 / \delta^2$ (Greene, 2007). γ must lie between zero and one, where zero will indicate that the deviation from production efficiency will be as a result of noise only and one will indicate that the deviation will be as a result of the farmer's production inefficiency (Battese and Coelli, 1995).

To come up with the technical and allocative inefficiency effects, μ_i, the following Equation 10 was considered:

$$\mu_i = \delta_0 + \delta_1 X_{1i} + \delta_2 X_{2i} + \delta_3 X_{3i} \quad (10)$$

where: μ_i = Efficiency score for farmer i;

δ = Vector of the unknown parameter to be estimated

X_1= Age (Years);

X_2= Education level of farmer (Years of formal education); and

X_3= Household family size (Number of members).

These variables were included in the model to show their possible influence on the efficiency of the farmers. It was assumed that farmers' decisions on dairy farming rely on their age, education level and household size. The economic efficiency of the farmer was taken to be the product of technical efficiency and allocative efficiency ($EE = TE \times AE$).

The estimating Equations 5 and 8 were each jointly estimated with Equation 10 using the Maximum Likelihood Estimation (MLE) procedure in FRONTIER 4.1. The one stage MLE method that is deemed superior to the two-stage method by Pitt and Lee (1981) was used. This was because it takes into account that the decisions made by the farmer will influence the choice of factors of production, while the two-stage method is limited due to inconsistency in its assumption in the independence of the inefficiency effects (it considers inefficiency as independent of production decisions that do not influence choice of inputs in the production process).

While computing the production and cost functions in the FRONTIER 4.1, the software provides both maximum likelihood estimates (MLE) and ordinary least of squares (OLS) estimates. To be able to identify which estimates were best suited for the data, the gamma (γ) was used. The generalised log-likelihood

Table 2 shows the expected signs for the variables used in the production and cost functions. An increase in herd size would mean an increase in the number of animals producing milk in the farm thus, this would increase the monthly milk production. Increasing the amount of fodder and concentrates fed to an animal was hypothesized to lead to an increase in milk production. According to Richards *et al*. (2016), an additional kilogram of fodder and concentrates would lead to an increase in the monthly milk production. Spending to ensure that one had a healthy animal was hypothesized to have a positive influence on milk production.

Fodder and concentrate costs constitute the largest proportion of dairy production costs. Any increase in these costs would result in an increase in the monthly total costs. An increase in animal health costs, which might result from treatment of diseases that could be controlled such

Table 2: Expected signs of variables used in the production and cost functions

Variables	Description	Unit	Sign
Technical Efficiency			
Monthly milk production (lnmnthmilkprodctn)	Dependent variable for T.E	Litres	
Herd size (lnherdsize)	No of dairy animal	No	+
Fodder (lnfodder)	Amount of fodder given to a cow per month	Kgs	+
Concentrates (lnconcentrate)	Amount of concentrates fed to a cow per month	Kgs	+
Animal health (lnanimalhealth)	Amount spent on animal health per month	Ksh	+
Allocative Efficiency			
Monthly total cost of production (lnmnthttlcost)	Dependent variable for A.E	Ksh	
Fodder cost (lnfoddercost)	Amount spent on purchasing fodder monthly	Ksh	+
Concentrate cost(lnconcentratecost)	Amount spent on purchasing concentrates monthly	Ksh	+
Animal health (lnanimalhealth)	Amount spent on animal health per month	Ksh	+
Operating costs (lnoperatingcost)	Amount spent on dairy operations monthly	Ksh	+

as mastitis, would raise the monthly costs. Operating costs such as repair and maintenance were hypothesized to lead to an increase in a farmer's monthly costs.

3.3.3 Assessing determinants of economic efficiency

There have been studies over the years to assess the relationship of various explanatory variables on the efficiency of the farmers. Such studies are by Mburu *et al*. (2014), Mutoko *et al*. (2008) and Nyagaka *et al*. (2009). A two-stage procedure was considered in this study. The same method was used by Dhungana (2004) and Mburu *et al*. (2014). The procedure's first stage involved computing the technical, allocative and economic efficiency scores using the FRONTIER 4.1 and the second stage involved transferring the efficiency scores to STATA and then regressing them on various explanatory variables using the Tobit model in STATA.

The estimating equation is as follows:

$$\mu_i = \delta_0 + \delta_1 X_{1i} + \delta_2 X_{2i} + \delta_3 X_{3i} + \delta_4 X_{4i} + \delta_5 X_{5i} + \delta_6 X_{6i} + \delta_7 X_{7i} + \delta_8 X_{8i} + v_9 X_{9i} + \delta_{10} X_{10i} \quad (11)$$

where: μ_i = Efficiency score for farmer i;

X_1= Age (Years);

X_2= Education level of farmer (Years of formal education);

X_3= Household family size (Number of members);

X_4= Distance to milk collection centre (Kms);

X_5= Dummy variable for dairy farming as main source of income (1=Yes; 0= No);

X_6= Dummy variable for cost of labour (1=Hired labour; 0= Did not hire);

X_7= Cost of fodder (Monthly in Ksh);

X_8= Cost of concentrates (Monthly in Ksh);

X_9= Dummy variable for credit (1=Acquired credit; 0= Did not acquire); and

X_{10}=Dummy variable for membership to a group (1=Yes; 0= No).

A two-limit Tobit model was suitable in this study since the efficiency scores are scaled between 0 and 1 (Mburu *et al*., 2014). The μ_i must lie between 0 and 1. The technical, allocative and economic efficiency scores were each regressed against the set of explanatory variables to identify which variables influenced them at three different levels of significance, that is, 1%, 5% and 10%.

3.4 Expected signs of variables estimating farmers' economic efficiency

Table 3 shows the expected signs of the variables used to estimate the farmers' economic efficiency. Age of the household head was considered in the study as it was assumed that he/she is in charge of making the household farming decisions. A positive relationship was hypothesized between the age of the household head and economic efficiency in that, older farmers tend to be more efficient as they are more likely to make reasonable and sound decisions concerning the dairy enterprise.

Education is key in agricultural production because it can instil in people knowledge and skills, which they can put to use during farming. Farmers that are more educated are less sceptical when it comes to adoption of new technology. In a study by Edrisighe *et al*. (2010), it was found that education serves as human capital in reducing inefficiency in dairy farming. Education was therefore expected to have a positive influence on economic efficiency.

Dairy farming can be labour intensive, thus the higher the number of people in the household, the more the labour is available for dairy farming activities, which will determine the output. However, large numbers of people in the household also mean that more capital is required to run the household activities, such as feeding and schooling of children, hence less capital will be

Table 3: Expected signs of variables estimating farmers' economic efficiency

Variable	Description of Variable	Unit of Measurement	Expected Sign
Age	Age of household head	Years	+
Education level	Number of years of formal education	Years	+
Household size	Number of household members	Number	+/-
Milk collection centre	Distance to milk collection centre	Kilometres	-
Main source of income	Dairy farming is the main source of income	1=Yes 0=No	+
Labour	Utilization of labour	1=Hired 0= Did not hire	+/-
Fodder	Cost of fodder per month	Kenyan shillings	-
Concentrates	Cost of concentrates per month	Kenyan shillings	-
Credit	Acquired credit for dairy farming in last one year	1=Acquired 0=Did not acquire	+
Group membership	Has membership to any group	1=Yes 0=No	+

allocated to dairy farming. Household size was therefore hypothesized to have both positive and negative influence on economic efficiency.

Distance to the milk collection centre affects the farmers' expenses as well as time management. The farmer living further away from the milk collection centre could incur a transportation cost and become fatigued. The added expense of transportation lowers a farmers' allocative efficiency that in turn negatively influence their economic efficiency. A farmer living close to the collection centre saves time as they deliver their milk on time and go back to cater for their other dairy farming activities. Therefore, distance to the milk collection centre was hypothesized to have a negative influence on the economic efficiency

Farmers that have dairy farming as their main source of income tend to put all their effort and time to dairy production. Due to the undivided attention to their dairy production activities, their productivity is improved. While those that have off-farm income as their main income activity decide to concentrate on the activity providing them with the off-farm income, in which case they will neglect dairy farming. It was thus hypothesized that having dairy farming as the main source of income will have a positive influence on economic efficiency.

According to Wilson (2011), low cost of labour results in higher dairy profitability in dairy farming. When the wages are low, the small-scale farmers are able to hire enough labour to work on the farm, hence, holding other factors constant, the farm will produce efficiently. Capital saved by paying low wage rates can be allocated elsewhere in the dairy enterprise. However, when the wage is high, farmers shy away from hiring enough labour and instead stretch out the available labour. This decreases the farm's economic efficiency Taking note of the above, labour was expected to influence economic efficiency both positively and negatively.

In Kenya, the amounts of fodder and concentrates used to produce a litre of milk and their high prices can have negative effects on profitability (Omiti *et al.*, 2006). If the cost of feeds, be it green/dry fodder or concentrates, is high, the small-scale farmers will purchase limited amounts of feeds and the cows will end up under-feeding, thus decreasing their productivity. The high costs of fodder and concentrates also constitute the highest portion of the total variable costs in dairy farming, thus lowering farmers' allocative efficiency. Therefore, it was expected that both costs of fodder and concentrates would have a negative effect on the economic efficiency of milk production.

The access to credit by small-scale farmers can increase their ability and chance of adopting new technology practices in dairy farming, as well as provide capital for the acquisition of fodder and concentrates. The credit can be in the form of money, fodder, concentrates or even heifers. By adopting better new technologies, farmers improve their efficiency and by purchasing enough fodder and concentrates, they increase their productivity. Access to credit was thus expected to positively affect the economic efficiency.

Farmers normally belong to a dairy association that deals with milk production and marketing. By so doing, the farmers in such association tends to have more information concerning dairy farming since the associations normally organize learning seminars and workshops for their members. These associations, as well as other self-help groups, provide support to their members through lending finances, table banking or providing inputs on credit. Being a member of a group or a farmers' association was hypothesized to positively influence the economic efficiency of the small-scale farmers.

3.5 Testing for the presence of inefficiency

Generalized Likelihood Ratio (LR) by Battesse and Coelli (1995) was used to estimate the inefficiency:

$$\lambda = -2\ \ln[L(H_0)] - \ln[L(H_1)] \qquad (11)$$

Where: $L(H_0)$ = value of likelihood function under nuthe ll hypothesis of total absence of inefficiency,

$H_0: \gamma = 0$

$L(H_1)$= value of likelihood function under alternative hypothesis of the existence of inefficiency,

$H_1: \gamma > 0$.

According to Greene (2007), the LR test is said to be a specification test that provides a superior explanation of relationships found within the data in comparison to the ordinary OLS in reference to average response function. This test has approximately a chi-square or a mixed chi-square distribution with degrees of freedom equal to the difference between the parameters involved in the null hypothesis H_0 and alternative hypothesis H_1. This chi-square is used to determine the level of significance and if inefficiency effects are present, where the difference exists. According to Xue (2006), the LR test yielded by MLE is more numerically stable than the F-test yielded by the OLS.

This log-likelihood ratio (LR) was also used to check which model was a better fit of the data, either the stochastic frontier model (MLE) or the deterministic frontier model (OLS). The deterministic frontier model provides one error term and it implies that all residuals are inefficiencies. The stochastic frontier model has two additive error terms and has an advantage over the deterministic frontier model approach as it includes an error term that accounts for the random noise and external shocks beyond the farmer's control.

3.6 Research design

This was a follow-up study of the farmers who had been involved in a two months nutritional training trial in 2013 and were involved in a nutritional study on impacts of dairy meal feeding interventions on early lactation milk production by Richards *et al*. (2016). Observations from the trained farmers were made at a single point in time (panel data). Both qualitative and quantitative data were used in assessing the economic efficiency.

3.7 Sampling technique, data sources and collection

The farmers were sampled using the purposive sampling technique because they had been involved in a two months nutritional training trail in 2013. The nutritional training trail had purposively sampled the farmers on the basis that they had a new-born dairy calf and recently calved dairy cow (Richards et al., 2016). The selected sample of respondents was interviewed using semi-structured questionnaires. Farmer, farm, cow and cow feeding characteristics were collected.

The study used cow and farm level primary data that was collected from a selected sample of small-scale dairy farmers through an interview using a semi-structured questionnaire (Appendix I) in the month of April 2017. The sample was selected from the Mukurweini Wakulima Dairy Limited that has an approximate membership of 6,000 active members and had been trained on how to feed their cows better. A total of 109 farmers had been involved in the nutritional study, however, by the time of this study, some of the farmers had abandoned dairy farming while others had migrated, thus only 91 farmers participated in this study. Both quantitative and qualitative forms of data were collected.

3.8 Data analysis

The statistical package FRONTIER 4.1 was used to estimate the technical and allocative efficiency scores, as well as come up with estimates for the factors influencing the technical and allocative efficiency. STATA was used to estimate the Two-limit Tobit model so as to identify the factors that significantly influenced technical, allocative and economic efficiency. STATA was also used to compute the descriptive statistics.

3.9 Model diagnostic tests

Heteroskedasticity

This is a situation whereby the variance of the error term is not constant. That is, there is a violation of the OLS assumption BLUE (Best Linear Unbiased Estimator). The explanatory variables used in the model were tested for any heteroskedastic disturbances using the BreuschPagan test.

Multicollinearity

This term can be replaced by the word collinearity. It refers to a situation whereby two or more independent variables in the regression model are highly correlated. According to Greene (2000), this problem leads to large standard errors and low significant levels for coefficients of one or both of the collinear variables, resulting in a misleading conclusion. This study used the analysis of correlation matrix to check for multicollinearity.

Log-likelihood ratio

The LR is used to test the goodness of fit of a model to a set of data. In this study, LR was used to test the hypothesis that OLS production function was a better representation of the data rather than the stochastic Cobb-Douglas function. It was also used to test the hypothesis of lack of inefficiency among the farmers.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Description of small-scale dairy farmers in Mukurweini.

4.1.1 Socio-economic characteristics

The mean age of the household head of the sample was 57 years. The oldest dairy farmer in the sample was 87 years while the youngest was 33 years, as indicated in Table 4. This mean age is similar to a report by the Government of Kenya (2012) that stated that the average age of a Kenyan farmer is 60 years. The report attributed this to the fact that the younger generation shy away from engaging in agriculture and focus more on employment in the "white collar" jobs.

The mean years of formal education were found to be 8 years, an indication that the majority of the household heads from the sample had at least attained primary level education. Other studies on small-scale farmers reported similar findings such as that by Mutoko *et al*. 2008. Some of the farmers had not gone to school at all, while the farmer with the highest number of years of formal education had attained an undergraduate degree.

The average years of experience in dairy farming were 22 years. The farmer with the least experience had practised dairy farming for 5 years, while the one with the highest experience had been in the practice for 60 years (Table 4). More experienced farmers have been shown to have a higher probability of using better farm practices (Nyekanyeka *et al*., 2011). According to Gitau (2013), farmers with a higher number of years in dairy farming are better equipped with measures of dealing with challenges involved in dairy farming compared to inexperienced farmers.

Table 4: Descriptive statistics of socio-economic characteristics of small-scale dairy farmers

Variable	Unit	Mean	Std Deviation	Min	Max
Age of household	Years	57.21	12.91	33	87
Education	Years	8.88	3.14	0	16
Dairy farming experience	Years	22.66	13.04	5	60
Household size	Number	3.57	1.69	0	8
Farm size	Acres	1.90	1.51	0.125	9
Hired labour	Dummy (1=yes 0=no)	0.41	0.49	0	1
Access to credit	Dummy (1=yes 0=no)	0.85	0.36	0	1
Dairy farming as main source of income	Dummy (1=yes 0=no)	0.79	0.41	0	1

Source: Author's computation from household survey data, 2017 (The source remains to be the author in all the tables and figures that follow unless specified otherwise).

The household size, defined by the number of people that had lived in the household the previous 12 months, had a mean of 3 people. Some households did not have any family member in the household, instead, there were casual labourers who were in-charge of the activities on the farm. The household with the highest number of members was found to have eight people. The household size can be said to be an indicator of labour availability (Osotimehin *et al*., 2006). Households with more members have more labour available to cater to their dairy production activities.

The average farm size (both owned and rented) was 1.90 acres with a standard deviation of 1.51, an indication that most farmers in Mukurweini are small-scale farmers. The farm sizes ranged between 0.125 acres and 9 acres. This finding is similar to a study carried out in the same area by Theuri (2012) who reported that small-scale coffee farmers had farm sizes less than 5 acres. The small land sizes compel the farmers to use the available land intensively to meet their family food demand and allocate little or no land for forage cultivation (Kilungo *et al*., 1999).

Table 4 shows that the majority (49.3%) of the small-scale farmers relied on family labour for their dairy farming activities rather than hired labour (41.7%). This finding tallies with that from a study by Staal *et al*. (2003) that found 60% of the households depended on family labour for their dairy production activities.

The majority (84.62%) of the sampled farmers had access to credit, and this can be attributed to the fact that most of the dairy farmers in Mukurweini are members of the Wakulima Dairy Cooperative that offers credit services to the farmers. In this case, the credit was in the form of cash, commercial feeds, heifers or artificial insemination services. The credit would later be recovered through deductions from monthly milk sales. Phiri (2007) observed that farmers having access to credit increased their probability of adopting new and improved technologies in dairy farming. The results indicated that 79.12% of the farmers relied on dairy farming as their main source of income, while 20.88% relied on other main sources, such as formal employment, casual employment or businesses.

From the study, all farmers had received extension services from different service providers in the past year. Most of them (64.84%) had received extension services from the Wakulima Dairy extension officers, while the second highest number had received extension services from both the Wakulima Dairy extension officers and from private individuals (Figure 4). The Wakulima Dairy extension officers offer veterinary services, such as disease treatment, deworming and vaccination.

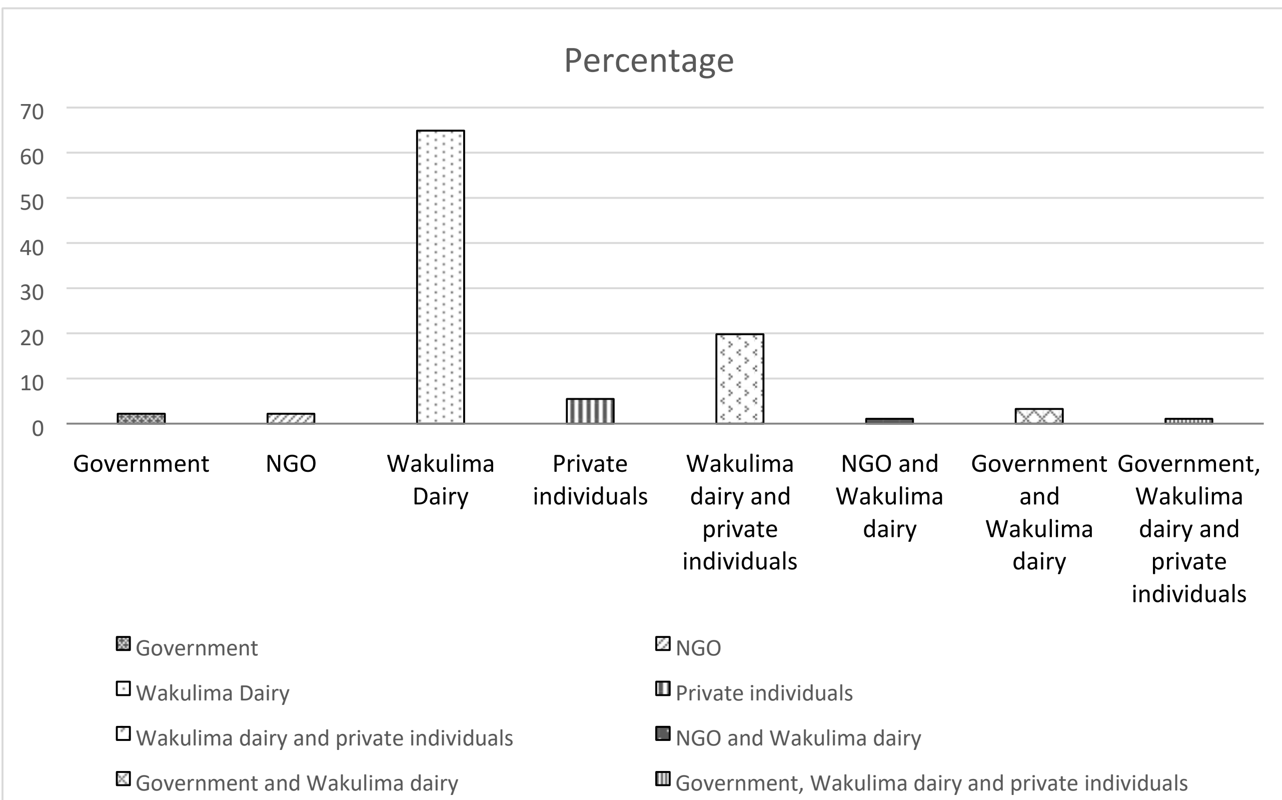

Figure 4: Extension service providers for the dairy farmers in Mukurweini Kenya

The company also organizes learning seminars and workshops for the farmers. According to Makokha (2007), the knowledge passed on during extension is important in influencing the farmers to adopt the new and improved technologies for their dairy production.

4.1.2 Summary statistics of variables used in the production and cost function

Summary statistics of variables used in the production and cost function of the frontier analysis are presented in Table 5. The mean monthly milk production per cow was found to be 492.69litres with a standard deviation of 427.51 litres. A study by Sajjad and Khan (2010) also found a high standard deviation in mean monthly milk production. The mean herd size in terms of the dairy animals of the small-scale farmers was found to be 2 cows, with a standard deviation of 2 cows. A study by Mgomezulu (2002) corroborates these results, as he found that the smallscale farmers own between two and three cows.

The monthly average amount of fodder fed to the individual animal was 1561.44kgs with a standard deviation of 68.55kg. A study by Mugambi (2014) found that the daily average fodder fed to each cow was 52.12kg. This finding by Mugambi (2014) is similar to the results of this study as the monthly average of 1561.44kg translates to an average of 52.05kg daily. The farmers in the area of study relied primarily on both bought and self -cultivated fodder for their cows. The average monthly cost of fodder was Ksh.6, 954.62 with a standard deviation of Ksh.9, 515.89. The minimum amount spent on purchasing fodder was zero not considering the opportunity cost, implying that some farmers solely relied on self-produced fodder for their feeding, while the large amount spent (Ksh.45,000) can likely be attributed to the drought that had hit the area during the period of the study. The drought forced most farmers to rely on purchased fodder and its prices had been hiked due to high demand and low supply.

The mean concentrate per animal in a month was 93.06kg with a standard deviation of 84.34kg. The maximum amount of concentrates per cow in a month was 456.01kg while the minimum was 84.34kg. The large variability may be because some of the farmers had inadequate capital to purchase concentrates whose prices tended to be high thus they provided small quantities. According to Omore *et al*. (1999), some farmers tended to feed their lactating cows with a flat rate of 2kg per day throughout the lactating period instead of varying the concentrate amounts with the milk production level and lactating period.

Table 5: Summary statistics of variables used in the production and cost function

Variable	Unit	Mean	Std deviation	Min	Max
Monthly milk production	Litres	492.69	427.51	60	2,460
Herd size	No	2	2	1	17
Monthly fodder/cow	Kgs	1,561.44	68.55	1,424	1,700
Monthly concentrates/cow	Kgs	93.06	84.34	84.34	456.01
Monthly cost of animal health	Ksh	308.85	300.14	16.67	1,700
Cost of concentrates	Ksh	4,286.26	1,760.16	1,010	9,250
Cost of fodder	Ksh	6,954.62	9,515.89	0	45,000
Operating expenses	Ksh	3,248.68	11,061.16	50	58,700

Monthly mean of the concentrate cost was found to be Ksh.4, 286.26 with a standard deviation of Ksh.1, 760.16. The cost of the concentrates was the second highest cost that the farmers incurred, after the cost of fodder.

The monthly animal health cost per cow had a mean of Ksh.308.85. The health cost constituted expenses such as deworming, artificial insemination, vaccination and treatment of any disease. Most of the farmers' cow health cost was on deworming and artificial insemination. The monthly mean for other dairy operating expenses was found to be Ksh.3,248.68. These expenses included repair and maintenance of the sheds, the building of sheds, purchase of a chaff cutter, silage construction, and purchase of milking equipment.

4.2 Distribution of efficiencies among small-scale dairy farmers

Small-scale farmers' technical efficiency ranged from a minimum of 39.60% to maximum of 95.95% with a mean of 68.68% as shown in Table 6. Considering the mean, there is an indication that farmers had a loss of 31.32% in milk production due to technical inefficiencies. In another study of small-scale dairy farmers in Embu and Meru by Mugambi (2014), it was found that the mean technical efficiency was 83.7%. Considering Embu and Meru have similar climatic conditions with Mukurweni, the results indicate that farmers in Mukurweni were less efficient and had the potential to increase their efficiency. The distribution of the technical efficiency indicates that majority of the farmers operate between 51-90% efficiency scores, while 11% of the farmers operate in a technical efficiency score of below 50%. This means that the farmers from the study area have the potential to decrease the amounts of inputs used without reducing their milk production by improving their technical efficiency.

Table 6: Efficiency distribution (numbers and proportions) of small-scale dairy farmers

Efficiency (%)	TE			AE			EE		
	No	%	Cum	No	%	Cum	No	%	Cum
91-100	5	5.5	100	67	73.6	100	3	3.3	100
81-90	20	22.0	94.5	14	15.4	26.4	12	13.2	96.7
71-80	18	19.8	72.5	3	3.3	11.0	13	14.3	83.5
61-70	19	20.9	52.7	5	5.5	7.7	22	24.2	69.2
51-60	19	20.9	31.9	1	1.1	2.2	21	23.1	45.1
1-50	10	11.0	11.0	1	1.1	1.1	20	22.0	22.0
Sample size	91								
Min (%)	39.60			35.58			31.19		
Max (%)	95.95			99.99			94.89		
Mean (%)	68.68			91.32			62.62		

Key; TE- Technical efficiency, AE- Allocative efficiency, EE- Economic efficiency

The small-scale farmers' allocative efficiency scores range between 35.58% and 99.99% with a mean of 91.32%. Average farmers would save a cost of 8.8% if they were to operate at the same level with the most allocatively efficient farmer (1- (91.32/99.99)*100), while the most allocatively inefficient farmer would save a cost of 64.42% by operating at the level of the most efficient farmer (1- (35.58/99.99)*100). The high mean allocative efficiency score, as well as the fact that most farmers operated at an allocative efficiency score above 90%, indicates that the farmers at the study area are efficient at saving costs. The mean of 91.32% is contrary to the

57.3% found in a study by Nyagaka *et al*. (2009) and Binam *et al*. (2005) who got a value less than 91.32% for small-scale farmers in Cameroon meaning that small-farmers at the study area were competent at saving costs.

The economic efficiency of the small-scale farmers had a mean of 62.62%, which ranged between 31.19% and 94.89%. If the least efficient farmer were to get to the level of the most economically efficient farmer, the farmer would lower costs by 67% (1- (31.19/94.89)*100), while an average farmer would lower cost by 34% (1- (62.62/94.89)*100). These results indicate that most farmers in the study area could reduce cost by about 34% if they would decrease input use to an efficient input level and achieve an optimal input combination considering input prices and technology. The results of the study imply that the economic inefficiency of dairy farmers in the study area was primarily caused by farmers' failure to maximize milk production rather than failure to minimize the cost of production, since the mean technical efficiency score (66.7%) was lower than the mean allocative efficiency score (91.32%).

The mean economic efficiency of 62.62% was lower than the 79.8% found by Masuku (2014) in a study of small-scale dairy farmers in Swaziland. However, the findings of our study were similar to a mean of 69% achieved by Kibiego *et al.* (2015) in their study of assessing the economic efficiency of dairy production systems in Uasin Gishu county. A majority of the farmers operated below 70% level of economic efficiency in our study, an indication that there is potential for improvement among the dairy farmers

4.3 Technical efficiency among small-scale farmers in Mukurweini, Nyeri County

The Cobb-Douglas stochastic production function results are presented in Table 7. Both maximum likelihood (ML) estimates and ordinary least squares (OLS) are presented for comparison. The sigma-squared, gamma and log likelihood variance parameters in Table 7 provide results on the behaviour of the error term and the model goodness of fit. The variance parameter gamma is a ratio of inefficiency error term ($\delta_u{}^2$) to the total sum of errors ($\delta_u{}^2 + \delta_v{}^2$), that is, $\gamma = \delta_u{}^2/\delta_u{}^2 + \delta_v{}^2$. The variance related to inefficiency effect in this case was about 91% of the total variance, while the other 9% represented the stochastic random errors. This result is an implication that the one-sided error (inefficiency) is a major component of the total variance, and that 91% of the observed variance among dairy milk producers was as a result of differences in their technical efficiencies such as poor utilization of available inputs such as concentrates.

To identify the appropriate model to use, the variance parameter gamma (γ) was used. The gamma value should lie between 0 and 1, where a value of 1 justifies the use of the maximum likelihood efficiency estimates, as there is no random noise, while a value of 0 means OLS is the best estimator, as there is no stochastic noise. In this study, the value of variance parameter gamma was 0.9082, thus the use of ML estimates was justified. The value was also significant at 1%, an indication that there was inefficiency in dairy milk production among the small-scale farmers in Mukurweini. Therefore, the null hypothesis that there was a total absence of inefficiency among the small-scale dairy farmers was rejected as it is in equation (11). The results for multicollinearity showed that there was no collinearity among the independent variables (Appendix II).

The null hypothesis (H_0), specifying the OLS production function, had the value of the restricted log-likelihood function as -1.8098, while the alternative hypothesis (H_1), specifying the stochastic Cobb-Douglas function, had the value of the unrestricted log-likelihood function as

7.4289. Thus the log-likelihood function values were used to calculate the LR (λ), λ=-2 (-1.8098-7.4289)= 18.4774. This calculated value exceeds the critical χ^2(5%,1d.f.) value of 3.84 at 5% level of significance. Hence, the null hypothesis specifying that the OLS production function was

Table 7: OLS and ML estimates of a stochastic frontier production function

Variable	Prm	OLS estimates			ML estimates		
		Coefficient	Standard error	*t*-ratio	Coefficient	Standard error	*t*-ratio
Constant	β_0	-0.0102	4.5134	-0.0022	0.8975	3.9268	0.2286
LnHerdsize	β_1	0.9623***	0.1427	6.7415	0.8129***	0.1278	6.3628
LnFodder	β_2	0.6497	1.4215	0.4570	0.4303	1.2323	0.3492
LnConcentrates	β_3	0.0737*	0.0491	1.5005	0.0949**	0.004	2.4042
LnAnimalhealth	β_4	0.0755	0.0751	1.006	0.1571**	0.0616	2.5515
Inefficiency model							
Constant	δ_0	0			-0.1589	0.3359	-0.4733
Age	δ_1	0			0.0098**	0.0036	2.7518
Years of education	δ_2	0			-0.0067	0.0114	-0.5845
Size of household	δ_3	0			0.0034	0.0231	0.1459
Variance							
Sigma square	$\delta 2$ γ	0.0645			0.0688***	0.0178	3.8712
Gamma		-			0.9082***	0.0943	9.6298
Log-likelihood function	LH LR	-1.8098			7.4289		
Log Likelihood ratio					18.47		

Asterisks show significance at the following levels: *10%; **5%; ***1%

an adequate representation of the data was rejected. This result indicated that the stochastic Cobb-Douglas function was a good fit for the data.

The test for whether the small-scale dairy farmers were technically efficient was also done using the LR test. This involved testing the null hypothesis H_0: $\gamma=0$ that there was no technical inefficiency among the farmers against the alternative hypothesis H_1: $\gamma>0$ that the farmers were technically inefficient. The computed LR value of 18.47 was greater than the Kodde and Palm critical value of 10.371 for 5 degrees of freedom at 5% level of significance. Kodde and Palm critical values are used for the LR test whenever the hypothesis is one-sided (Coelli *et al*., 2005). From the LR test, the null hypothesis was rejected, an indication that the farmers were technically inefficient.

There was the expected positive relationship between the coefficients in the stochastic frontier and the monthly milk production. This implies that by increasing the herd size, amount of concentrates and providing inputs for maintaining a healthy animal, the output would also be increased (that is, they positively influence milk production). The herd size was significant at 1% level of significance while concentrates and animal health inputs were significant at 5% level of significance. Amount of fodder was found to be insignificant.

In the technical inefficiency model, age was the only variable in the inefficiency model that was significant at 5% level of significance. This result shows that inefficiency in milk production was significantly higher among the older farmers than the younger farmers. The skills and knowledge in dairy farming that the older farmers possessed could have deteriorated over time, perhaps becoming irrelevant due to changes in technology and environment thus increasing their inefficiency. Also, farmers could have diversified into other farming activities thus paying less attention and increasing inefficiency in milk production.

Herd size was measured in terms of the number of dairy lactating cows owned by an individual farmer and its coefficient was found to have the highest magnitude (0.8129). Herd size was found to be significant at 1% level of significance. While holding other inputs constant, a 1% increase in the number of lactating cows would result in 0.8129% increase in the monthly milk production. This shows that an increase in herd size leads to a substantial increase in milk produced in a household. A study by Mugambi (2014) also found herd size as the variable with the highest impact on total milk production, as well as a study by Cabrera *et al*. (2010). Amount of concentrates fed to each cow per month was found to be significant at 5% level of significance. The partial elasticity of the amounts of concentrates was found to be 0.0949, an indication that 1% increase in the amount of concentrate fed to each animal *ceteris paribus*, can result in a 0.0949% increase in the milk output thus increase productivity. A study by Kilungo *et al*. (1999) also found that the amount of concentrate fed to each cow influenced milk production. This result shows the importance of providing dairy animals with enough concentrates to boost their milk output. Richards *et al*. (2016) found that an additional 1 kg of dairy meal concentrate fed to a cow per day resulted in an increase of 0.53 kg/cow/day in milk output. The difference in the results considering the two studies involved the same sample of farmers could be attributed to the cow's lactation period. Richards *et al*. (2016) focused on cows in early lactation where milk production is associated with the amount of concentrates fed to a cow, while this study was not specific on the lactation period since each farmer's cow was at a different lactating period.

The animal health variable was considered in terms of cost spent on ensuring the lactating cow remained healthy, for example, deworming costs, cost of vaccinating the animals against the prevalent diseases and cost of treatment of any disease. This variable was found to be significant at 5% level of significance and indicates that a 1% increase in the amount spent on animal health, other factors held constant, would result in an increase in milk production by 0.1571%. This finding signifies the importance of having healthy dairy animals.

The partial elasticity of the inputs is provided by their respective coefficients. Their magnitudes are less than one, an indication that monthly milk production (output) is elastic with respect to changes in herd size, amount of fodder, amount of concentrates and animal health cost. This elasticity means that a 1% increase in these inputs would result in a less than 1% increase in monthly milk production. Through the summation of all the estimated coefficients in the stochastic Cobb-Douglas function, the value of returns to scale (RTS) was found to be 1.4952.

This meant that the farmers were operating at stage one (I) of production (RTS>1), which implies that a unit increase in all inputs will more than double their output (Increasing returns to scale). This stage is irrational, as the farmers can improve their scale of production efficiently by using more inputs such as concentrates, increasing the herd size and spending on animal health.

4.4 Allocative efficiency among small-scale farmers in Mukurweini, Nyeri County

The Cobb-Douglas cost function results from the stochastic frontier model are as indicated in Table 8. To determine whether to consider the results from the OLS model or results from ML estimates, the LR value was calculated from log-likelihood functions from both models as follows: λ=-2 (-67.4922- 122.86)= 110.7356. This value was greater than the critical $_{\chi}^{2}$ (5%, 1) value of3.84 at 5% level of significance, thus the ML estimates model was deemed to be a better representation of the data. The null hypothesis of γ=0, indicating that the farmers were allocatively efficient, was rejected at 5% level of significance. The LR value of 110.74 was greater than the Kodde and Palm critical value of 10.371 for 5 degrees of freedom, which shows that the small-scale dairy farmers were not allocatively efficient, that is, there is an opportunity for the farmers to efficiently allocate their scarce financial resources in dairy milk production.

The gamma was found to be significant at 1% level of significance, an indication that there was the presence of allocative inefficiencies among the small-scale dairy farmers in the study area. The gamma value of 0.999 shows that 99% of the total variance was as a result of inefficiencies. Hence, the variables in the inefficiency model, as well as other socio-economic variables not included in the model, could be used to explain 99% of the estimated allocative inefficiency. The results for multicollinearity showed that there was no collinearity among the independent variables (Appendix II).

To measure the amount a farmer spends above the minimum possible cost of production for a specified level of output, allocative inefficiency is employed. The mean allocative inefficiency from the frontier output was found to be 112.37%. This result indicates that farmers in Mukurweini incurred a 12.37% cost above the minimum cost incurred by the most efficient farmer. These 12.37% costs are associated with inefficiency.

The allocative inefficiency values were used to compute both the average and individual allocative efficiency scores that are required in calculating the economic efficiency of farmers. The computation involves using the allocative inefficiency value to divide the percentage base allocative efficient level (100) (Mutoko *et al*., 2008). In this case, the mean allocative efficiency score will be $\frac{100}{112.37}$= 0.89. The 89% allocative efficiency score shows that the farmers are quite efficient in minimizing their costs.

As stated in Equation (8), the dependent variable was the total monthly costs of dairy production and the independent variables included the cost of concentrates, cost of fodder, cost of animal health inputs, and cost of other operating expenses. The coefficients of the variables are shown in Table 8. All coefficients have the hypothesized sign, and they were all significant at 1% level of significance. The significant intercept is an indication that there exists some computable fixed

Table 8: OLS and maximum likelihood estimates of the stochastic frontier cost function

Variable	Prm	OLS estimates			ML estimates		
		Coefficient	Standard error	*t*-ratio	Coefficient	Standard error	*t*-ratio
Constant	β_0	0.0443	0.2380	0.1861	0.3868***	0.0078	49.836
LnFoddercost	β_1	0.4417***	0.026	16.995	0.4683***	0.0084	55.481
LnConcentratecost	β_2	0.4894***	0.0762	6.4189	0.467***	0.0043	108.68
LnAnimalhealth	β_3	0.0511**	0.0315	1.6227	0.0256***	0.0020	12.614
LnOperatingcost	β_4	0.2014***	0.0204	9.8521	0.0467***	0.0043	10.906
Inefficiency model							
Constant	δ_0	0			-2.5824***	0.6715	-3.8457
Age	δ_1	0			0.0037	0.0096	0.3872
Years of education	δ_2	0			0.0775***	0.0134	5.8009
Size of household	δ_3	0			0.2459***	0.0243	10.101
Variance							
Sigma square	$\delta 2$ γ	0.0141			0.0812***	0.0094	8.615
Gamma		-			0.999***	0.0000	565459
Log-likelihood function	LH LR	67.4922			122.86		
Log Likelihood ratio					110.74		

Mean allocative inefficiency 112.37%

Asterisks show significance at the following levels: *10%; **5%; ***1%

costs in dairy milk production. The intercept result shows that the farmers would still incur 0.39% of the total costs even if they were not to engage in dairy milk production and their variable cost was zero. This could be attributed to the opportunity cost of capital and land invested in dairy milk production.

In the allocative inefficiency part of the model, a negative sign on the intercept coefficient meant that there were other variables not included in the model that would significantly decrease the allocative inefficiency, that is, increase allocative efficiency. Both years of education and household size coefficients were found to be positive and significant at 1% level of significance.

The positive sign on their coefficients meant that an increase in either of them would lead to an increase in allocative inefficiency, which implies that more years of education was associated with an increase in allocative inefficiency. Since people that are more educated tend to have higher levels of knowledge and easily adopt new technologies, they may apply or adopt technologies that they do not require for their production, thus incurring an unnecessary cost. The results also indicate that an increased size of the household was associated with an increased allocative inefficiency, a situation that is likely to be attributed to the fact that large households tend to allocate funds to family necessities. This finding was different from that of Tijjani and Bakari (2014), where it was found out that as the household size increased, the allocative efficiency decreased among rice farmers in Taraba state Nigeria.

The cost of fodder coefficient had the highest magnitude compared to other costs. It was found to be positive and significant at 1% level of significance. The result shows that 1% increase in the amount spent on fodder will likely result in a 0.468% increase in the total cost of production. The high contribution of the cost of fodder to the total cost of production could be attributed to the fact that during the time of the study, the area of study was facing drought and most farmers had resulted to purchasing fodder (green and dry fodder) for their animals. Also, due to the drought, the prices of the fodder had gone up, causing the farmers to spend more on purchased fodder. Under normal conditions, farmers stated that they would primarily rely on fodder they produced in their farms and would purchase little amounts of fodder to supplement their own production and at relatively low prices. However, Omiti *et al*. (2006) found that fodder expenses accounted for the largest portion of total variable costs, irrespective of the weather conditions. This contradiction could be because the farmers in the study area depended on own produced fodder while those involved in Omiti's study relied on purchased fodder.

There was an insignificant difference between the coefficients of the cost of fodder and the cost of concentrates. The cost of concentrates coefficient was also found to be positive and significant at 1% level of significance. A 1% increase in the cost of concentrates would likely result in 0.467% increase in the total cost of production, *ceteris paribus*. This shows that the cost of fodder constitutes a high portion of the total variable cost of production. This finding was similar to a study by Mbilu (2015), in Njombe district Tanzania, where it was found that maize bran, sunflower seedcakes, leaf meal and mineral salts (concentrates) constituted 45% of the variable costs.

The third variable, cost of animal health, was found to have a positive coefficient that was significant at 1% level of significance. Holding other factors constant, a 1% increase in the cost of animal health inputs would result in a 0.026% increase in the total cost of milk production. Cost of animal health inputs constituted the expenses of keeping the animal healthy such as deworming costs, vaccination costs and treatment costs. However, it had the least impact on the total cost of milk production, and this can likely be associated with the fact that most of the animal health services in the area of study were provided at low prices by the government and the Wakulima Dairy cooperative.

The coefficient associated with the cost of other operating expenses was also found to be significant at 1% level of significance. An increase in this cost by 1% would result in an increase of 0.047% of the total cost of milk production. These other operating expenses included: purchase of milking equipment, repair and maintenance of the cowshed, construction of the silage, purchase of a chaff cutter, and building of feed storage capacity. These costs tend to vary from time to time depending on the prices of particular commodities associated with them. For instance, during the time of the study, the prices of most commodities were high as a result of feed shortages and the high inflation rate in the country then.

To come up with economic efficiency (EE) scores, a product of technical efficiency (TE) and allocative efficiency (AE) was calculated (EE=TE*AE).

4.4 Factors influencing the economic efficiency of milk production among small-scale dairy farmers

The Breusch-Pagan test indicated that there was no heteroskedasticity in the regression model for factors influencing technical and economic efficiency the computed p-values for technical and economic efficiency were 0.68 and 0.42, respectively, which were not significant at 10% level of significance. However, there was the presence of heteroskedasticity in the regression model for factors influencing allocative efficiency. The p-value was <0.001, a sign of high significance. To correct for the heteroskedasticity, robust standard errors were used in this case. The results for multicollinearity showed that there was no collinearity among the independent variables (Appendix II).

Table 9 presents results from a Tobit model for the determinants of technical efficiency, allocative efficiency and economic efficiency. The Tobit model used by Bravo-Ureta and Pinheiro (1997) was considered for this analysis since efficiency is bounded between zero and one. Ten variables were regressed against the technical efficiency score, allocative efficiency scores and economic efficiency scores

From the results, age, dairy farming as the main source of income and hired labour coefficients were the statistically significant variables that influenced technical efficiency. The age was significant at 1% level of significance and the negative sign indicated that age had a negative influence on technical efficiency. This implies that in this population older farmers were technically inefficient compared to young farmers. Elderly farmers may not be strong enough to carry out intensive dairy farming activities and they tend to be resistant to the adoption of new technologies.

The coefficient on having dairy farming as the main source of income had a positive sign and was significant at 10% level of significance. This shows that farmers who concentrated primarily on dairy farming were more technically efficient, as they might have been keen on dairy production so as to sustain their income. This finding is similar to that of Mutoko *et al*. (2008) who found that farmers who engaged in off-farm income earning activities rather than concentrating in maize production as the main source of income were less technically efficient in maize production.

Table 9: Parameter estimates of determinants of technical, allocative and economic

Variable	Technical efficiency		Allocative efficiency		Economic efficiency	
	Co-efficient	*t*-ratio	Co-efficient	*t*-ratio	Co-efficient	*t*-ratio
Age of household	-0.0049***	(-3.49)	-0.0015	(-1.34)	-0.0058***	(-4.08)
Years of Education	0.006	(1.03)	-0.0066	(-1.59)	0.0002	(0.04)
household size	-0.0097	(-0.87)	-0.0222*	(-1.91)	-0.0265***	(-2.70)
Distance to milk collection centre	0.0105	(0.62)	0.0173	(1.32)	0.0224	(1.22)
Dairy farming main	0.079*	(1.94)	0.0223	(1.04)	0.0858*	(1.95)
source of income	-0.0711**	(-2.04)	-0.0290	(-1.00)	-0.0848**	(-2.36)
Hired Labour	0.0000	(0.09)	-0.0000	(-1.12)	-0.0000	(-0.60)
Monthly fodder cost	-0.0000	(-1.20)	-0.0000**	(-2.06)	-0.0000**	(-2.41)
Monthly concentrate cost	0.0083	(0.23)	0.003	(0.12)	0.0023	(0.06)
Acquired loan	-0.0068	(-0.19)	0.0474	(1.32)	0.0336	(0.92)
Membership to group	0.9526***	(7.39)	1.1638***	(10.01)	1.0718***	(8.17)
Constant						
R-squared	0.3143		0.3175		0.3666	

Asterisks show significance at the following levels: *10%; **5%; ***1%

The hired labour coefficient was found to be significant at 5% and it negatively influenced technical efficiency. This finding may be attributed to the intensity of dairy farming activities. Dairy farming is labour intensive and requires continuous labour input, thus prompting hiring labour in the farm. However, the hired labour tends to spend a limited amount of time on dairy farming as they multitask with other farming activities in the farm, thus contributing to the inefficiency of dairy milk production. This finding is similar to that of Onumah *et al*. (2009) where they reported that women who hired labour for fish farming in Ghana were technically inefficient in fish production.

The household size and monthly concentrate costs were the only variables whose coefficients were found to significantly affect the allocative efficiency, at 10% and 5% levels of significance respectively. The household size coefficient was found to negatively influence the allocative efficiency, an indication that as the number of household members increased, the allocative efficiency declined. Larger households can cause a diversion of funds to the family maintenance, potentially leaving the dairy enterprise struggling financially. Tijjani and Bakari (2014) reported similar results.

The monthly cost of concentrates also had a negative influence on allocative efficiency due to the negative sign on its coefficient. This result meant that an increase in the cost of concentrates could result in a decline of the farmers' allocative efficiency. It implies that farmers can aim at minimizing the amount spent on concentrates in order to increase their allocative efficiency.

The coefficients of age, household size, hired labour and cost of concentrates were found to be statistically significant and they all had a negative influence on economic efficiency. Only the coefficient of having dairy farming as the main source of income was significant and had a positive influence on economic efficiency.

The coefficient of age was negative, implying that older farmers were less economically efficient than the younger farmers. A farmer turning one year older could reduce their economic efficiency by 0.0058%. As stated earlier, older farmers are not strong enough to carry out the intensive dairy farming activities and are quite reserved in taking up new technologies. Gitau (2013) reported similar findings in his assessment of the effects of age on milk production of farmers in Nyandarua and Nakuru.

A study by Mawa *et al*. (2014) found that age reduced profit efficiency among dairy farmers in Rift Valley and Central Kenya while Dipeolu and Akinbode (2008) reported that technical inefficiency among pepper farmers in South-west Nigeria increased with age. In contrast to these findings, other studies found that age was a representation of farming experience and older farmers were more efficient. Coelli et al. (2002) observed such results in a study of rice farmers in Bangladesh. In other studies like those of Mumba (2012) and Masuku (2014), they found that age had no significant effect on the economic efficiency of small-scale farmers.

The household size coefficient was also negative and statistically significant at 1% level of significance. These findings indicated that an increase in the number of members living in a given household would result in a decline in the farmer's economic efficiency. These results are similar to those of a study by Nyekanyeka (2011) who found that an increase in household size resulted in an increase in inefficiency among small-scale dairy farmers in Lilongwe. Some studies, however, found a positive association between increased household size and economic efficiency. They attributed this finding to the fact that more household members increase family labour, thus saving hired labour costs. For example, Mutoko *et al*. (2008) found that family labour enhanced technical efficiency among maize farmers in North-west Kenya.

The coefficient of having dairy farming as the main source of income was found to be positive and significant at 10% level of significance. This implies that farmers who concentrated and invested majorly on dairy farming as their major source of income were more economically efficient. This result shows that dedication to dairy farming activities increases efficiency.

Mutoko *et al*. (2008) also found that farmers who concentrated on maize production as their main source of income rather than off-farm income were more economically efficient due to their efforts to make their farming is successful.

The hired labour coefficient was found to be significant at 5% level of significance and negatively influenced the economic efficiency. The negative influence could be attributed to the fact that hired labour increases the total dairy production costs that might, in turn, decrease the allocative efficiency of a farmer and finally bring about economic inefficiency. This result is in contrast with a study by Adewuyi *et al*. (2013) who reported that hired labour for cassava production in Osun state Nigeria increased efficiency and profitability of cassava production.

The cost of concentrates coefficient was found to be significant at 5% level of significance and it negatively impacted on the economic efficiency of the farmers. This result implies that an increase in the cost of concentrates would result in a decline in economic efficiency, which could be attributed to the fact that an increase in the cost of concentrates lowers allocative efficiency that results in a decrease in economic efficiency of small-scale dairy farmers.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The study found that an average household head involved in dairy farming in Mukurweini is over 50 years, has acquired primary education and has engaged in dairy farming for a period of over two decades. The results also showed that an average household has three members and owns less than two acres of land. The majority of the households depended on family labour for their daily dairy farming duties. Majority of the sampled farmers have access to credit and rely wholly on dairy farming as their main source of income. Mukurweini has a variety of extension service providers, however, most of the farmers receive the veterinary services from the Wakulima Dairy Cooperative. The average herd size among the farmers was found to be two cows, while the mean monthly milk production per household was about 500kgs. The fodder and concentrate costs are the highest composition of the dairy production variable costs.

The study revealed that most farmers have a technical efficiency of above 50%, with a majority operating over the 80% level of efficiency. Majority of the farmers are good at minimizing costs as they have allocative efficiency level above 90%. However, when the technical and allocative efficiency are combined to come up with economic efficiency, most of the farmers are operating below the 70% level of economic efficiency. The results also indicated that if the average farmers were to operate at the same level as the most economically efficient farmer, they would cut down on cost by about 30% by just using the inputs efficiently and combining the inputs appropriately while considering their prices. The economic inefficiency among the dairy farmers in the study area is more a result of technical inefficiencies than allocative inefficiencies.

The study found that an increase in the herd size, amount of concentrate per animal or the amount spent on animal health would result in an increase in milk production. The increasing returns-to scale shows that farmers are resource-poor but are fairly efficient in the utilization of resources, thus an increase in the use of any resources can produce a corresponding increase in the output. All variables included in the cost function (fodder cost, concentrate cost, animal health cost and other operating costs) were found to significantly increase the total cost of production. This implies that any cost incurred in the dairy production would significantly affect the total cost of production.

Technical efficiency was found to decrease with the age of the household head and hired labour while having dairy farming as the main source of income was found to influence it positively. These results may reflect older farmers being less likely to adopt new technologies. The factors identified to negatively influence allocative efficiency were the household size and monthly concentrate costs. The two variables increase farmers' expenses, leading to a strain in the available capital that can be used toward dairy farming. Factors found to be negatively correlated with economic efficiency were the age of the household head, household size, hired labour and monthly concentrate costs. Age and hired labour could affect efficiency in terms of the time and energy required by dairy farming, while household size and concentrate cost are responsible for increased expenditure. Having dairy farming as the main source of income was found to have a positive influence on the economic efficiency of the farmers. Farmers that rely on their dairy farming for maintenance and source of income may put more effort in the dairy farming.

5.2 Recommendations

5.2.1 Recommendations for policy intervention

The findings indicate substantial production inefficiencies among the small-scale dairy farmers. Therefore, there is room for increasing productivity through the proper use of the available inputs, as well as improving efficiency through production cost reduction.

The cost of concentrates and animal health service constitute most of the dairy production variable costs. Efforts to subsidize the dairy inputs would reduce the cost of dairy milk production by a huge margin. Most farmers in the study area complained of a continued increase in the price of concentrates and animal health service. The dairy cooperative, which is the major buyer of milk in the study area, should find means of subsidizing the concentrates and other dairy inputs such as animal drugs for the farmers. Subsiding the fodder and concentrate prices, especially during the dry season, would enable the farmers to continue producing milk in the same capacity as when there is plenty of fodder. The cooperative could also produce own fodder and supply to the farmers at affordable prices.

Encouraging and training farmers to grow properly harvest and store high-protein fodder on their farms (such as leguminous shrubs, desmodium, leucine, and/or sweet potato vines) by the relevant stakeholders would also help reduce reliance on expensively purchased fodder. The farmers should further be trained on how to make silage so as to cater for the fodder needs during the dry seasons. The farmers should also take advantage of the new technologies such as hydroponics fodder whereby fodder is planted without water and is ready in six days. Disease prevention strategies would also be helpful, such as the promotion of vaccine and teat dip use. The government and other concerned stakeholders should focus on training the farmers on various disease prevention methods as well as readily avail the necessary vaccines.

Seeing that age the dairy farmers' efficiency, there should be incentives for young farmers to engage in dairy farming. Such incentives could be better milk prices by the dairy cooperative or special training programs and awards for best or most improved young farmer. The increased milk prices could also enhance efficiency, as farmers would be contented with having dairy farming as their major source of income, therefore, putting their energy and concentration into dairy farming.

5.2.2 Recommendations for further studies

To address the issue of high cost of concentrates, an alternative, such as cheap homemade concentrates, should be introduced and promoted. The need for cheap homemade concentrates will necessitate a research on the production of improved and cost-effective concentrate that suits the farmers' budget.

Since older farmers were found to be inefficient, it was not certain that they were only inefficient at old age as they may have been inefficient when they were younger as well. Since this cross-sectional study cannot determine if efficiency declines over time, a cohort study following the efficiency of farmers over time could determine if efficiency declines over time.

The results found that increasing the herd size by the small-scale farmers would significantly increase their milk production. However, increasing the number of lactating cows would be challenging to small-scale farmers due to high cost. Thus, a study should be done to identify means of improving the cow's productivity of the current herd size that the farmers have.

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Appendices

Appendix I; Household survey questionnaire

Questionnaire .... number

__ ....Date of interview___________________________________............

Name of enumerator .... Phone number..

Name of respondent

Type of household; 1= Male headed 2= Female headed

Are you the household head? 1= Yes 0= No

1.1	Sub County	
1.2	Location	
1.3	Village	

SECTION 1: HOUSEHOLD INFORMATION

1.4. How many people are living in your household during the last 12 months?

	1.5	1.6	1.7	1.8	1.9	1.10
NO	**Name**	**Age (years)**	**Sex 1= Male 2= Female**	**Relation to house hold head SEE CODES**	**Level of education in years**	**Major income activity SEE CODES**
1						
2						
3						
4						
5						
6						

7						
8						
9						
10						

CODES 1.8 1= Head 2= Spouse 3= Child 4= Other (specify)	 1.10 1= Farmer 2= Formal employment 3= Casual labour 4= Business man/ woman 5= School going 6= Other (specify)

1.11. Dairy farming experience in years____

1.12. What is the distance to the nearest: Mainroad(all weather road/tarmac)(km) .... Market centre(km) ....

1.13. Distance to milk collection centre(km) ....

1.14. What is the type of the nearest main road?

1= Tarmac, 2= Murram, 3= Earth, 4= Others (specify) ....

1.15. Which means of transportation do you use to deliver milk to the nearest milk collection centre (circle all that apply)?

1= Private car, 2= Public service vehicle, 3= Motorcycle, 4= Bicycle, 5= Walking, 6= Others(specify)

....

1.16. Size of the land owned (bought and rented) (acres)...

1.17. Size of your land owned (bought and rented) under dairy farming(acres)..................................

1.18. Which other agricultural enterprises do you engage in other than dairy farming?.....................

SECTION 2:COW INFORMATION ON PRODUCTIVE PERFORMANCE 2.1.

Number of dairy cattle ....

COW#	**2.2 Type of Breed 1= Local 2= Friesian cross 3= Jersey cross 4= Guernsey cross 5= Ayrshire cross 6= Others, specify**	**2.3Production Stage 1= Early<100 dim 2= Middle 3= Late>200**	**2.4 How many times per day do you milk your cows? 1= Once 2= Twice 3= Three times**	**2.5 How many litres of milk do you get from each cow per day?**
1				
2				
3				
4				
5				

2.6. In the last 12 months, where did you acquire information on production practices (circle all that apply)?

1= Neighbors, 2= Own knowledge, 3= Television, 4= Radio, 5= Newspapers, 6= Workshops and seminars, 7= NGOs, 8= Government staff, 9= Others(specify) ....

2.7. Where do you make your farm purchases (circle all that apply)?

1= Agro-vet store, 2= Local shops, 3= Farmer groups, 4= Government supply, 5= Others(specify)

....

SECTION 3: INFORMATION ON FEEDING

3.1. What is the source of your forage feed in the last 12 months (circle all that apply)?

1= Own production

2= Buying

3= Others(Specify)____

3.2. For own production, which forages do you grow (circle all that apply)?

1= Napier grass, 2= Rhodes grass, 3= Desmodium, 4= Sweet potato vines, 5= grass silage, 6 = maize silage, 7 = hay, 8 = Others(Specify) ....

3.3. What is the size of your land under forage? ______________________________

3.4. For bought forages in the last month,

3.4.1 Which forages do you purchase(circle all	**3.4.2 What is their unit of measure**	**3.4.3 What quantity did you purchase per day**	**3.4.4 What is the price per unit**

that apply)			
Napier grass			
Grass silage			
Maize silage			
Hay			
Desmodium			
Sweet potato vine			
Protein forages [e.g.Lucerne,alfafa, clover (specify)]			
Others(specify			

3.5. Are these amounts similar to other months in the last year?

1= Yes 0= No

If no, please describe differences in other months ……………………………………………………………

____

3.6. Do you face problems with shortages of forages for feeding your cows?

1= Yes 0= No

If yes

3.7. What are the major problems with forage feeding (circle all that apply)?

1= Inadequate land, 2= Labour availability, 3= Unreliable rainfall, 4= High prices per unit of forage, 5= Others (specify)

3.8. What concentrates did you supplement the animals within the last month (circle all that apply and complete)?

3.8.1Types of concentrates	**3.8.2 Number of times fed/ day;** **1. Once** **2. Twice** **3. Thrice** **4. > Thrice**	**3.8.3 Quantity fed to lactating cow at one moment**	**3.8.4 Cost of feed**	
			Unit of measure	**Price**
Dairy meal				
Wheat bran				
Maize jam				
Vitamin/mineral Powder				
Vitamin/mineral block				
Others(Specify)				

3.9. Are these amounts similar to other months in the last year?

1= Yes 0= No

If no, please describe differences in other months ....

____

3.10. Do you face any problems with concentrates feeding?

1= Yes 0= No

If yes,

3.11. What are the problems with supplement feeding (circle all that apply)?

1= High cost of concentrates, 2= Inadequate availability, 3= Inconsistent supply, 4= Others (specify) ....

SECTION 4: WATER SOURCES AND CONSUMPTION

4.1. What is the source of water for your cows to drink (circle all that apply)?

1= Tap water, 2= Bore hole, 3=Stream, 4= River, 5= Other (specify) ....

____

4.2. How many times a day do you provide water to your animals in a day? (Specify number of times or "always available")

4.3. What quantities of water do you provide to your cows? (specify amount in litres/ cow or "always available") ....

4.4. What materials do you use for watering the animals (circle all that apply)?

1= Bucket 2= Cemented water trough 3= Others(specify)________________________________

4.5. What equipment do you use for milking the cow and transporting the milk, and their cost (circle all that apply)?

Equipment	**Total Cost**
1= Jug(s)	

2= Bucket (s)/ pail(s)	
3= Others (specify)	

SECTION 5: COST OF LABOUR

5.1. For the last 12 months, who is usually involved in dairy activities (circle all that apply)?

1= Family members

2= Hired workers

3= Both

If family,

5.2. How many people are normally involved?

Individual	**Number of individuals**
Male	
Female	

If hired workers,

5.3. How many workers do you hire?

1= 1 worker, 2= 2 workers, 3= 3 workers, 4= Over 4 workers

5.4. How much do you pay each worker per day?____

5.5 Do you hire workers seasonally? Yes or No

If yes,

5.6 What months do you hire workers ____

SECTION 6: VETERINARY COSTS

6.1. In the last twelve months, have you accessed veterinary services?

1=Yes 0= No

If yes,

6.2. What service did you seek (circle all that apply)?

1= Vaccination, 2= Mastitis treatment, 3= AI services ,4= Deworming, 5= Spraying,

6= Others (specify)____

6.3. How much money (Ksh) did you spend on the service for each animal in the last 12 months (to nearest 100 shilling)?

Services	**Cow #1**	**Cow#2**	**Cow#3**	**Cow#4**
Vaccination				
Mastitis treatment				
AI services				
Deworming				
Spraying				
Others (specify)				

6.4How often do you deworm the cow? ....

____

6.5. Other than the veterinary services, feed and labour expenses, did you have any other dairy operating expenses in the last 12 months?

1= Yes 0= No

If yes,

6.6.Which expenses are they? (Specify)

....

___

6.7. How much did the above expenses (6.6) cost you?

___

SECTION 7: INFORMATION ON MILK MARKETING

7.1. What is the current selling price per litre of milk(Ksh)?________________

7.2. What and when was the highest and lowest selling price you had in the last 12 months?

Highest: ________ in _________(month)Lowest: __________ in __________(Month)

7.3. Whom do you sell your milk to (circle all that apply)?

1= Neighbors, 2= Local shops/hotels, 3= Middlemen, 4= Processor, 5= Dairy cooperative, 6 = other (specify) _________________________

7.3a. Which market is your main market where you sell the most milk? __________

7.3b What are the reasons for selling milk at this market (circle all that apply)?

1= Better price, 2= NGOs encourage it, 3= Direct cash payment, 4= Closer to the farm, 5= Others (specify) ....

7.4.Which form of milk do you sell at your farm (circle all that apply)?

1= Raw, 2= Fermented, 3= Chilled

7.5. What is your average sale of milk per day in litres during the last month? 7.6.

How much is the transportation cost to the market (Ksh)? ---

7.7. What problems do you face with marketing of your milk (circle all that apply)?

1= Low milk prices, 2= Long distance, 3= Late payments, 4= Other (specify) ....

7.8.Which item has the most annual costs on your dairy farm?

1= Feeds, 2= Veterinary, 3= Marketing, 4= Labour, 5= Others (specify)

SECTION 8: INSTITUTIONAL AND INCOME INFORMATION

8.1. Are you a member of any development group (eg. women's group)?

1= Yes 0= No

If yes,

8.2. What is the nature of the group?

1= Formal 2= Informal

8.3. What type of group is it?

1= Young farmers group, 2= Women's group, 5= Others (specify) ....

8.4. How long have you been a member of the group?

8.5. What major service is offered by the group (circle all that apply)?

1= Credit service, 2= Marketing information, 3= Marketing of products, 4= Transportation, 5= Provide supplies, 6= Others (specify)

....

8.6. In your opinion how important are the following factors in influencing your decision to join/ form a group.

Factor	**Relative importance**		
	1=very important	**2=sort of important**	**3= not important**
Market access			
Provide farm supplies			
Organizing learning seminars			
Number of group members			
Leaders who are dedicated to serve			
Fairness in distribution of benefits among members			
Good quality of services offered			
Leader transparency in financial matters			

8.7. Who has provided dairy extension services in your area in the last 12 months (circle all that apply)?

1= Government 2= NGO (Specify) ________________ 3= Wakulima Dairy 4= Private company (eg. bank) 5. Other (Specify) __________________

8.8.Do you have access to credit for your dairy enterprise?

1= Yes 0= No

If yes,

8.9. What type of loan?

1= Cow/Heifer loan, 2= Cash loan, 3= Feed loan, 4= Other loans (specify) ....

8.10. What is the source of loan?

1= Dairy cooperative, 2= Bank, 3= Table banking(chama), 4= Relatives and friends, 5= Agricultural finance, 6= Others(specify)____

8.11. Have you received a loan in the last 12 months?

If Yes

8.12. What amount of loan did you get?____

8.13. What was the purpose of the loan you obtained?

1= Buy medicines, 2=Buy feed, 3= Purchase cow/heifer, 4= AI services, 5= Others(specify) ....

____

8.14. Has/was the loan repaid in full?

1=Yes 0= No

If no,

8.15.Why?

....

____

8.16. What are the most important benefits from your dairy farming(in order of importance)?

-- _______

-- _______

-- _______

8.17. What are the key challenges in your dairy production enterprise(in order of importance)?.

8.18. Is dairy farming your main source of income?

1= Yes 0= No

If yes,

8.19. How much is earned from the dairy enterprise per month (nearest 100 shillings)? _______

8.20. Who controls the income from the dairy farming enterprise (circle all that apply)?

1= HOUSEHOLD head, 2= spouse, 3= other specify

8.21. What are the other sources of income?

	SOURCES	**ESTIMATED AMOUNT EARNED IN THE LAST MONTH (Ksh) (TO THE NEAREST 100 SHILLINGS)**	**Who controls the income from this source? (1= HOUSEHOLD head 2= spouse 3= other specify)**
1	Other farming activities (specify)		

2	Formal employment (more than 20 hours per week?		
3	Casual labour (20 or less hours per week)		
4	Self-employed Business man/ woman		
5	Remittances (e.g cash transfers from government or NGOs) and gifts		
6	Others, specify:		

8.22. Are these amounts similar to other months in the last year?

1= Yes 0= No.

8.23. If no, please describe differences in other months

....

....

....

8.24. Estimate your expenditures in the last month for the following;

EXPENSE	**AMOUNT (Ksh) to the nearest 100 shillings**
Dairy enterprise	
Food	
School fees	
Medical care	
Clothing	
Entertainment	
Savings	

Donations	
Others (specify)	

8.25. Are these amounts similar to other months in the last year?

1=Yes 0=No

8.26. If no, please describe differences in other months

Appendix II; Analysis of correlation matrix

Qn_1_4_peo~H- Household size

	Herdsize	fooder	Concen~e	Animal~h	HHAGE	HHEDUY~R	Qn_1_4~H
Herdsize	1.0000						
fooder	-0.0050	1.0000					
Concentrate	0.2572	-0.0190	1.0000				
Animalheath	0.4316	0.1533	0.2805	1.0000			
HHAGE	-0.0543	0.0887	-0.0087	0.1347	1.0000		
HHEDUYEAR	0.2116	0.1041	0.0987	0.1941	-0.2578	1.0000	
Qn_1_4_peo~H	-0.0579	-0.0761	0.1669	0.0545	-0.4657	-0.0329	1.0000

VAR00003-Operating expenses

	Qn_1_4~H	feedcost	concen~t	Animal~h	VAR00003	HHAGE

	HHEDUY~R					
Qn_1_4_peo~H	1.0000					
feedcost	-0.0873	1.0000				
concentrat~t	0.2628	0.1610	1.0000			
Animalheath	0.0545	0.2255	0.3537	1.0000		
VAR00003	0.3377	0.0199	0.3876	0.2154	1.0000	
HHAGE	-0.4657	-0.1285	-0.0436	0.1347	-0.0955	1.0000
HHEDUYEAR	-0.0329	0.0968	0.1584	0.1941	0.1212	-0.2578	1.0000

Qn_8_18-Dairy farming main source of income

Qn_8_11-Acquired loan

Qn_8_1-Group membership

Qn_1_14-Distance to milk collection centre

Qn_1_4_peo~H- Household size

	HHAGE	HHEDUY~R	labour	feedcost	concen~t	Qn_8_1~f	Qn_8_~hs	Qn_8_1~p	Qn_1_~nc	Qn_1_4~H
HHAGE	1.0000									
HHEDUYEAR	-0.2646	1.0000								
labour	0.1425	0.0596	1.0000							
feedcost	-0.1565	0.0724	0.2187	1.0000						
concentrat~t	-0.0568	0.1087	0.2919	0.1443	1.0000					
Qn_8_18_Da~f	-0.1088	0.0088	0.0930	0.0100	0.3237	1.0000				
Qn_8_11_Re~s	-0.0768	0.1924	-0.2286	0.0334	0.0290	-0.0582	1.0000			
Qn_8_1_Mem~p	0.0443	-0.0629	-0.2462	-0.3036	-0.0180	-0.0196	0.1287	1.0000		
Qn_1_14Dis~c	0.1565	-0.1110	0.0967	0.1003	0.0305	0.0611	-0.0640	-0.0280	1.0000	
Qn_1_4_peo~H	-0.4448	-0.0418	-0.1573	-0.0375	0.2613	0.2946	0.2568	-0.0465	-0.1723	1.0000