PROFIT EFFICIENCY OF DAIRY FARMERS IN KENYA: A CASE STUDY OF SMALLHOLDER FARMERS IN THE RIFT VALLEY AND CENTRAL PROVINCE

(STOCHASTIC FRONTIER ANALYSIS AND APPLIED RESEARCH METHODS)

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Declaration

I declare that this dissertation is my bonafide work, developed with the guidance of my supervisors; and has never been submitted to any other institution, anywhere, for any award of any kind; and that all sources of materials used for this manuscript have been duly acknowledged. Any erroneous presentation remaining anywhere in the document is duly my responsibility.

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Approval

This is to approve that this dissertation is on record an original, developed by **Leone Iga**. **Mawa** under our supervision for the requirement of the award of Master of Science Degree in Research Methods of Jomo Kenyatta University of Agriculture and Technology.

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Dedication

This is yet another opportunity to thank my dear parents for the noble job in my upbringing and the gift of education. This dissertation is a special dedication to you Dad (R.I.P), Mum & Grandma, not forgetting Mr. Matuga John Yovan. You indeed laid the best foundation in my life according to God's supernatural plan. I also dedicate this research piece to all my other relatives and the great friends in life owing to your continuous support, encouragements and prayers.

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List of Abbreviations/Acronyms

AE	: Allocative Efficiency
AEZ	: Agro Ecological Zone
ASAL	: Arid and Semi-Arid Land
DEA	: Data Envelopment Analysis
EADD	: East Africa Dairy Development
FAO	: Food and Agriculture Organization
GDP	: Gross Domestic Product
GIS	: Geographical Information System
ICC	: Intra Cluster Correlation
ICRAF	: World Agro Forestry Centre
IFPRI	: International Food Policy Research Institute
ILRI	: International Livestock Research Institute
KARI	: Kenya Agriculture Research Institute
LM	: Lagrange Multiplier
MIC	: Marginal Input Cost
MLE	: Maximum Likelihood Estimate
OLS	: Ordinary Least Squares
SDP	: Smallholder Dairy Project
SFA	: Stochastic Frontier Approach
TE	: Technical Efficiency
USAID	: United States Agency for International Development
VMP	: Value of Marginal Product

Abstract

Kenya's dairy industry is among the best in the Sub-Sahara Africa. The dairy industry is an important source of household livelihood among the smallholder families. There is immense pressure on land due to the increasing population. The resultant effect on the dairy industry is a rising cost of producing milk by the smallholder mixed farmers who supply over 70% of the total milk consumed in the country. Studies on the economic efficiency of the smallholder dairy farmers are very important in the current production context. This study was conducted in the Rift Valley and Central Provinces of Kenya, while excluding the pastorally dominant cattle keeping communities. A multistage sampling procedure was used to select representative sample of dairy farmers into the study. Cross-sectional data on milk production and utilization in the past three months was collected from the dairy farmers using structured household questionnaires. The study adopted stochastic frontier approach for analyzing and estimating profit efficiency of the dairy farmers. The mean profit efficiency was 68%, and 54% of these farmers were skewed to profit efficiency of more than 70%. The least efficient farmer was 6.5% profit efficient, while the best farmer was 99% profit efficiency. The variance parameters of the stochastic frontier model were also very significant (p-value <0.001), indicating that the composed error term (v_i-u_i) dominated the measurement error and its distribution is stochastic. A gamma (γ) value of 0.91 was found and the computed variance-factor (γ^*) of 0.79 established, indicating a strong evidence of variation from the maximum profit frontier due to inefficient practices among the dairy farmers. Cost of produced fodder by the farmers significantly increased profit efficiency. On the other hand, cost of purchased fodder, conserved feed, water, milk transport and farm maintenance significantly reduced profit efficiency among the farmers. However, of the socio-economic variables explaining efficiency differences among the farmers, land sizes for fodder and for grazing cattle significantly increased profit efficiency. Efficiency decreased among the dairy farmers with age. Extensive dairy systems were more profit efficiency than intensive farmers. Hired labour, hired land and extension services led to significant decreases in profit efficiency. With an average of 68%, the dairy farmers' profit efficiency can be increased by 32% if their technical and allocative efficiencies can be improved. Efficient production technologies can greatly improve cost optimization of the farmers, as well as output maximization per unit input in milk production. Feed technologies commensurate with farmers' local conditions are therefore required, as fodder produced on firm has manifested. Institutional policy reforms targeting competitive dairy sector performance approaches are required so as to expand the productivity and profitability of the smallholder dairy farmers given the boosting growing demand for milk in and outside Kenya.

Key words: Stochastic Profit Frontier, Profit efficiency, Dairy farmer, Kenya

CHAPTER ONE

1.0 INTRODUCTION

Kenya's agricultural sector is an important income source for most of the rural poor. Generally 75% of Kenyans earn their living from farming either directly or indirectly. Agriculture alone contributes over 6% of foreign exchange earnings and provides raw materials for Kenya's agro-industries, which account for about 70% of all its industrial production (Dairy industry report, 2005). Kenya has one of the largest dairy industries in Sub-Sahara Africa and is largely self-sufficient in milk production (USAID, 2008; Dairy Industry Report, 2005). Milk production in Kenya is obtained mainly from cattle, more so the dairy herd. Small amounts of milk is also obtained from camels and goats.

Dairy development has been linked to significant contributions to livelihoods and income generation among smallholder farmers through the production of higher-value products as compared to most crops. Smallholder dairying is a source of income and employment generation, which includes both self-employment of farmers and market agents, but also hired labour on farm and in the market (; USAID, 2010). It is also reported that other less tangible returns to milk production include the value of livestock assets for finance and insurance functions. Staal *et al*.(2008) argued that, dairy development is linked to improved nutrition among the smallholder farmers and poor households where small amounts of milk consumed can result into dramatic improvement of nutritional status especially for children, nursing and expectant mothers. It also promotes soil fertility improvements among the poor through the usage of manure from the dairy cows, hence resulting into boosting of smallholders' crop yields on farms where chemical fertilizers are often unavailable and unaffordable.

1.1 Overview of Kenya Dairy Sector

The dairy industry accounts for 14% of Kenya's agricultural GDP and approximately 4% of overall national GDP. The industry generates an estimated 1million jobs at farm level, an additional 500,000 in direct wage employment and another 750,000 jobs in support services. The dairy sector is vital in poverty alleviation in both the rural and urban areas as it contributes to food production and nutritional security and increased household incomes (USAID, 2010).

SDP (2004), Agriculturistonline (2004) and IFPRI (2004) have reported that, two-thirds of the dairy cattle in eastern and southern Africa is found in Kenya. Per capita milk production levels double those found elsewhere on the African continent. USAID (2010) argued that Kenya is the largest producer of dairy products in Africa; with an estimated herd of 3.5 million improved dairy animals, 9 million zebus, 12 million goats and 900,000 camels. Cattle account for 88% of the milk produced while camels and goats account for the rest. In terms of milk consumption, Kenya also ranks as the top producer and consumer in Africa (USAID, 2010). These reports have also indicated that, with a per capita consumption of more than four times the average (25kg/yr) for sub-Saharan Africa; Kenya ranks amongst the highest in the world. Dairy contributes about 8% of the national GDP. An estimated 625,000 smallholder producer households, supplying 70% of the milk, earn their income from dairy production (FAO, 2011). The significance of dairy enterprise in supporting livelihoods in rural areas among smallholders, therefore, cannot be over emphasized.

East Africa Dairy Development (EADD) (2007) reported that smallholder families are unable to generate sustainable income from dairy business endeavors for numerous reasons, primarily due to deficits in knowledge, lack of finances for investment, production and business-skills which prevent their profitable participation in the dairy value chain. Baltenweck *et al*.(1998) reported that there is high competition for production resources among farmers in dairy production, subsequently leading to increased costs of production. Not wide research has been done on profit efficiency in Kenya apart from a few, for example: (e.g. Nganga *et al*, 2010; Otieno *et al*, 2005; Omiti *et al*, 2006). This study analyzed the economic efficiency of milk production by the small-scale farmers in Kenya.

1.2 Problem Statement

The Kenya dairy sector is facing challenges especially at the farm level. Productivity is relatively low due to poor animal husbandry, poor feeds, inadequate feeding and declining genetic base. Competition for land and water, and environmental constraints also remain strong issues to tackle. Given the low number of dairy cattle per farm of most smallholder families, economies of scale are practically infeasible to assume. Revenues hardly offset production costs of those with limited land resources and have to purchase feeds. The varied agro-ecological production conditions also present unique challenges to the farmers. Under these circumstances, the smallholder dairy farmers are subject to making hard and difficult choices in dairy production. Despite the remarkable contributions of the sector to the economy and the sound market prospects due to increasing milk demand, the smallholder farmers in Kenya's dairy industry are even likely to produce milk more costly rendering their dairy ventures unprofitable should the milk market price fail to adjust proportionately to the costs. This study therefore explored the levels of profit efficiency among the smallholder dairy farmers in the Rift Valley and Central Provinces of Kenya, and identified the determinants of profit efficiency among these farmers. Identification of the key cost components in production and establishment of feasible solutions to the challenges at farm level will enhance the productivity and profitability of dairy production among Kenya's smallholder dairy producers.

1.3 Study Objective

1.3.1 Main Objective

The main goal of the study is to determine allocative and technical efficiency of dairy production among smallholder farmers in the Rift Valley and Central Provinces in Kenya, and to identify the determinants of profit efficiency among the smallholder farmers.

1.3.2 Specific Objectives

1. To determine the gross margin per litre of milk produced by the smallholder farms
2. To determine the profit efficiency of smallholder dairy farmers
3. To identify the determinants of profit efficiency of the smallholder dairy producers

1.4 Research Questions

Objective one:

1. What are the main cost components of milk production of the households?
2. How much gross profit do farmers realize per litre of milk produced?
3. What is the net profit earned per litre of milk?

Objective two:

1. At what level of profit efficiency do the smallholder dairy farmers operate?
2. What are the significant costs influencing profit efficiency of the farmers?
3. How is profit efficiency distributed among the dairy farmers?

Objective three:

1. What are the determinants of profit efficiency among the dairy farmers?
2. How do the socio-economic groups compare for profit efficiency?

1.5 Significance of the study

The increase in grain prices due to rising demand in the current market, caused by the increasing population, is a potential threat to the dairy industry. This is due to competition in resource use, for example land, which the smallholder mixed crop-livestock farmers utilize for both crop production and livestock rearing. The rise in input prices impacts on milk production cost, especially if the producer relies heavily on purchased feeds. This subsequently drives up retail prices of milk for consumers and with subsequent reduction in overall demand assuming the market is price sensitive. Consumers are likely to resort to alternative imported milk sources should its price become cheaper than locally produced milk. It is imperative, therefore, to re-focus attention on the economic efficiency components of smallholder dairying in Kenya in the face of the rising production costs. Solutions to the inefficient practices of the farmers will enhance the survival of smallholder dairying in Kenya that employs a significant proportion of the country's population. This will help keep the farmers abreast and remain competitive in the industry. This study explored profit efficiencies of the smallholder dairy producers in Kenya's Rift Valley and Central Provinces, and identified the determinants of profit efficiency of the dairy farmers. The findings of this study add to the knowledge required for policy formation for improved smallholder dairying.

1.6 Scope of the study

In the face of increasing concerns on input prices and the growing demand for milk, appropriate allocation & utilization of inputs is crucial for the survival of a smallholder dairy farmer in the industry. This study identified the unit cost of milk production at farm level, unit gross profit of the farmers, profit efficiency as well as the determinants of profit efficiency of the smallholder dairy farmers in the Rift Valley and Central Provinces of Kenya. Data on household milk production details and utilization were examined. The study neither considered revenue generated from cattle sales nor cow replacement costs, mortality costs and other costs that would be hard to determine by the farmers. The study used stochastic profit frontier approach for studying the efficiency levels of the farmers.

1.7 Limitations of the study

Due to financial and time constraints, it was not feasible to cover the entire country during this study. For that reason, the study was limited to Rift Valley and Central Provinces of Kenya where there is vibrant smallholder mixed crop-livestock production among farmers. The farmers considered for the study were also limited to those of EADD project where interventions have been made, especially in breed improvements and milk market infrastructures. Data on milk production and utilization for the study was limited to the past three months only. This was to ensure accurate recall of production situations and associated revenues and costs which is highly unlikely for an entire production year.

CHAPTER TWO

2.0 Literature Review

This chapter compiles relevant literature on theoretical concepts of milk production & economics, efficiency theories and their measurements, as well as findings in similar studies that applied these theoretical concepts. The first section presents a brief overview of the significance of smallholder dairy keeping in developing countries. The second section presents literature on production factors that affect milk production on farm. It also explores the cost generating components of milk production on the farm. The third section of the chapter presents theories on allocative, technical and economic efficiencies and their applications. It is from these theories upon which the ideological conceptualization of this study has been built.

2.1 Significance of Dairy Keeping in Developing Countries

Bonnier, *et al.* (2004) argued that dairy cattle are kept all over the world. There are several reasons to keep dairy cattle at the household level. Short term reasons are for direct economic returns on products such as milk, meat, hides, manure and traction. Long term reasons may be for investment, bank and/or life insurance. Kenya has one of the largest dairy industries in Sub-Sahara Africa and developments in the industry span over a period of 90 years and have undergone various evolutionary stages, therefore making Kenya self-sufficient in milk production (USAID, 2010).

2.2 Factors affecting milk production

It is argued that, under normal situations, the milk yield of a particular dairy cow increases during the first six weeks of lactation and then gradually declines. The actual amount of milk produced is dependent on several factors, but majorly attributed to the breed of a cow, parity, season of calving, geographical location and management factors such as feeding, health and veterinary services (Bajwa, *et al*., 2004 and Rhone, *et al.*, 2007).

2.2.1 Dairy Breeds

In an effort to increase milk production, many farmers in Kenya have crossbreeds of the indigenous cows with exotic breeds on farms. The commonest and most important of these are Friesian, Ayrshire, Guernsey, Jersey breeds and Brown Swiss (Bebe *et al*, 2002). The rest of the cattle are either good for beef or as dual purpose animals.

2.2.2 Age, Stage of Lactation and Parity

Factors such as age, stage of lactation and parity are variably known to influence milk production of a dairy cow (ILRI, undated). In modern dairy farms, peak lactation of a cow is reported to be achieved between the 4th and the 6th week from the date of calving, and then a gradual decline until the cow reaches a dry period, usually after the 10th month. Epaphras, *et al.* (2004), presented that parity is positively associated with milk production. Johnson, *et al.* (2002) reported that the positive correlation of parity and milk yield could be partly explained by higher milk production capacity coupled with greater feed intake in older cows than young ones. It is further argued that cows in 4th and more parities were no longer better producers compared to those in their 3rd lactation. It is explained that, the older age may contribute to reduced milk production through turnover rate of secretory cells, with higher numbers dying compared to the newly produced active secretory cells. This is because fat tissue cells usually replace dead secretory cells (ILRI, undated).

2.2.3 Milking Frequency and Milking Interval

Fadden and Wall (2010) argued that cows are usually milked twice daily at equal intervals (12hour interval for 2 times milking). Cows milked at unequal intervals produce less milk than those milked at equal intervals. Milking twice a day yields at least 40% more milk than once a day. Milking even more than 3 times is still beneficial for as long as gains are more than the costs of producing the extra amounts of milk. However this practice has met criticisms, as it is believed to increase chances of mastitis.

2.2.4 Dairy feeding and water requirements

According to Falvey and Chantalakhana (eds. undated), the smallholder farmers of developing countries have limited resources available for feeding to their ruminant livestock. They often do not have the luxury of being able to select the basal diet, they use whatever is available and at no or low cost, which are essentially low digestibility forages and of low protein. Low input production systems are often used and in return the productivity per cow is relatively low.

Ranjhan (1994) and ICAR (1994, 1997), as cited in Falvey and Chantalakhana (eds.) stated that, feeding systems in smallholder dairying are primarily based on grazing of native pastures of low productivity which are often seasonal and hence oscillating a cows potential to produce effectively. Feeding concentrates to cows in commercial dairies is a common practice besides forage and fodder. Common salt and trace mineral mixture in the daily concentrate enhances productivity. It is also argued that, urea, molasses, mineral block licks containing deficient nutrients have proved especially useful under good management across the tropics. KARI (2012) and Falvey and Chantalakhana (eds.), reported that in the smallholder farming system, the production of forage and fodder is often a sideline activity that is integrated with other areas of agricultural production. However farmers benefit greatly in terms of reducing costs of milk production by growing fodder on their farms.

Beede (1994) argued that, water is the most important dietary essential nutrient for dairy cattle. Lactating cows require a large proportion of water relative to their body weight because milk is 87-88% water. Water balance of the animal is affected by total intake of water and losses arising from urine, faeces, milk, saliva, sweating, and vaporization from respiratory tissues.

2.2.5 Production Systems in Developing Countries

Dairy production systems vary enormously throughout the world in terms of farm size, agro-climatic zones and socioeconomic and political settings (Bonnier *et al*, 2004). Economics of dairying in the tropics is difficult to analyze at a single stage of the production-collection-processing-distribution-consumption continuum (ILRI (eds.)). Three systems commonly used for keeping cattle are the grazing-system, the grazing-with supplementary-feeding-system and the zero-grazing-system; each defined according to the way the animals are fed. The type of feeding determines the most possibilities and constraints in a system, for example labour use and production potential (Bonnier, *et al*, 2004).

Falvey and Chantalakhana (eds.) stated that, smallholder dairying is invariably part of a larger and more complex farming system that typically includes farm-produced inputs such as feeds, various off-farm inputs, family inputs of labour and management and outputs of various types. In another study by Sohal (1979), as cited in Falvey and Chantalakhana (eds.), dairy production systems in developing countries may be identified by a combination of characteristics. Using such breakdowns, analysts can then look at the strengths and weaknesses of each system and devise improvement or adjustment strategies. An alternative approach, which is more oriented towards farm-level management, resources and constraints places primary emphasis on feed resources available to smallholders (ILRI (eds.)). Earlier work by Wilkens, *et al* (1979) classifies production systems by management practices and feed sources at the farm-level.

Stall *et al.* (2003) reported that, in areas of greater land availability, less intensive feeding practices of combined grazing and stall-feeding, or only paddock grazing, are employed. Thus, farmers choose feeding systems which best utilize their relatively most scarce resource: land in the case of zero-grazing, and labour in the case of paddock grazing. Costs of milk production in turn reflect this substitution of primary inputs.

2.2.6 Climatic and Environmental factors

Falvey and Chantalakhana (eds.) presented that there are a number of elements in the environment which must be overcome if an animal is to reproduce and be efficient and highly productive. The major environmental constraints to high productivity in the tropics are ambient temperature and humidity, annual and seasonal availability of feed resources, internal and external parasites and a variety of bacterial and viral infections. The effect of climate, parasites and diseases on production can be minimized either through the use of resistant genotypes or through managerial interventions to the animals' environment. In most cases a combination of these two basic strategies is used. Controlling parasitic and other diseases is possible using known technologies, even in smallholder dairy systems, provided that there is sufficient economic return to justify the outlay on vaccines, anthelmintics and acaricides.

Joksimović-Todorović (2011), argued that thermal equilibrium, heat load and heat reduction issues are often of concern in dairy production in the tropics as they are directly linked to heat stress. Heat stress can lead to changes in the oestrus cycle, a reduction in conception rate, depression in milk yield and changes to milk composition.

2.3 Efficiency

Farrell (1957) defines efficiency as the ability to produce a given level of output at the lowest cost. Economic theorists have identified three sub-types of efficiencies namely: Economic Efficiency, Allocative Efficiency and Technical Efficiency. According to Chukwuji *et al* (2006), Technical Efficiency is the ability of the farm to produce a maximum level of output given a similar level of production inputs. Allocative efficiency is the extent to which farmers equate the marginal value product of a factor of production to its price. Economic efficiency combines both allocative and technical efficiency, in that, it is achieved only when the producer combines resources in the least combination to generate maximum output (technical) as well as ensuring least cost to obtain maximum revenue (allocative). Chukwuji *et al* (2006) therefore held the belief that if a firm is technically and allocatively efficient, then that firm is cost effective.

Herrero and Pascoe (2002), and Kumbakar and Lovel (2000) argued that in order to be economically efficient a firm must first be technically efficient. Profit maximization requires a firm to produce the maximum output given the level of inputs employed (that is, be technically efficient), use the right mix of inputs in light of the relative price of each input (that is, be input allocative efficient) and produce the right mix of outputs given the set of prices (that is, be output allocative efficient).

2.3.1 Allocative Efficiency Concepts

Shahooth and Battall (2006), argued that for the firm to realize allocative efficiency, two critical questions need to be answered; namely: 1) what is the optimal combination of inputs so that output is produced at minimal cost? 2) How much profit could be increased by simply reallocating resources? From this knowledge, the firm is directed to choose a combination of inputs to be used in right proportions and technically efficient at low input prices so that output is produced at minimal costs which results into profit maximization. Badunenko *et al*. (2006), presented that though there are new methods used to estimate allocative efficiency, traditionally it has been hard to estimate allocative efficiency without input and output prices. Based on this argument, some scholars like Farrell called it price efficiency, referring to the ability of a firm to choose the optimal combination of inputs given input prices.

Inoni (2007) defines allocative efficiency as the measure of how an enterprise uses production inputs optimally in the right combination to maximize profits. Thus, the allocatively efficient level of production is where the farm operates at the least-cost combination of inputs. Most commonly gains obtained by varying the input ratios based on assumptions about the future price structure of products and factor markets are often used. In the work of Chukwuji *et al* (2006), it is assumed that farmers operate in a fairly perfectly competitive market conditions to allocate resources for profit maximization. Such assumptions, in the view of Chukwuji *et al (2006)* include: farmers choose the best combination (low costs) of inputs to produce profit maximizing output level; there is perfect competition in input and output markets; producers are price takers and assumed to have perfect market information; all inputs are of the same quality from all producers in the market.

Allocative efficiency, according to Inoni (2007), can also be defined as the ratio between total costs of producing a unit of output using actual factor proportions in a technically efficient manner, and total costs of producing a unit of output using optimal factor proportions in a technically efficient manner. Thus for the farm to maximize profit, under perfectly competitive markets, which requires that the extra revenue (Marginal Value Product) generated from the employment of an extra unit of a resource must be equal to its unit cost (Marginal Cost = unit price of input) (Chukwuji, *et al*., 2006).

2.3.2 Technical Efficiency Concepts

Technical efficiency is associated with behavioral objectives of maximization of output (Battese and Coelli, 1995). However, this production objective cannot be carried out in isolation since a farm is considered an economic unit with scarce resources. When a producer with the aim of maximizing profit makes allocation mistakes that result in inefficiency, then the farmer is considered allocatively inefficient (Kumbhakar, 1994). Therefore, technical efficiency cannot be achieved in isolation but in consideration with other efficiencies that are always at play.

According to Esparon and Sturgess (1989), technical efficiency deals with efficiency in relation to factor- product transformation. For a farm to be called technically efficient, it has to produce at the production frontier level. This condition is somewhat practically hard to achieve in real terms, as argued out by Battese and Coelli (1995). The reason is usually due to random factors such as bad weather, or farm specific factors, which lead to producing below the expected output frontier. Efficiency measurement therefore attempts to identify those factors that are farm specific which hinder production along the frontier. Technical efficiency goes beyond evaluation based on average production to one that is based on best performance among a given category, though it is related to productivity where inputs are transformed into outputs. Secondly, efficiency measurement provides an opportunity to separate production effects from managerial weakness (Ogundari and Ojo, 2005).

In economic theory, a production function is described in terms of maximum output that can be produced from a specified set of inputs, given the existing technology available to the farm (Battese, 1992). When the farm produces at the best production frontier, it is considered efficient.

The most common assumption is that the goal of the producers is profit maximization; however, it is believed that the objectives and goals of the producer are intertwined with farmers' psychological makeup (Debertin, 1992). Technical efficiency is achieved when a high level of output is realized given a similar level of inputs. It is therefore concerned with the efficiency of the input to output transformation. Technical efficiency helps in understanding factors that shift production function upwards (Esparon and Sturgess, 1989).

2.3.3 Cost, Revenue and Profit Frontiers

Kumbhakar and Lovell (2000) stated that, besides the use of input and output quantities to describe the structure of production technology, addition of price information to input and output quantities is very useful. This is because the objective of firms is profit maximization; hence giving rise to the cost, revenue and profit frontiers. While a joint production frontier describes the best that can be achieved technically, these three frontiers describe the best that can be achieved economically. So they provide standards against which the economic performance of producers can be measured. Some studies have demonstrated that farmers typically behave in a risk-averse way (Hardaker *et al.*, 2004). Farmers often prefer production providing a satisfactory level of security even if this means sacrificing some income. For the farmer, the main issue raised by variability of price and production is how to respond tactically and dynamically to opportunities or threats in order to generate additional income or to avoid losses (Hardaker *et al.*, 2004).

2.3.4 Efficiency Measurement Techniques

Bera and Sharma (1999) argued that the production frontier defines the technical efficiency in terms of a minimum set of inputs in order to produce a given output or a maximum output produced by a given set of inputs. A production frontier refers to the maximum output attainable by given sets of inputs and existing production technologies. This approach involves selecting the mix of inputs which produces a given quantity of output at a minimum cost, namely the production frontier. If what a producer actually produces is less than what it could feasibly produce then it will lie below the frontier. The distance by which a firm lies below its production frontier is a measure of the firms inefficiency (Bera and Sharma, 1999).

Farrell (1957) was the first to empirically measure productive efficiency in terms of deviations from an ideal frontier. He also proposed a decomposition of economic efficiency into technical and allocative efficiency. Kumbhakar and Lovell (2000) argued that profit maximization requires a firm to be both technically efficient (by producing the maximum output given the level of inputs employed), as well as allocative efficient (by using the right mix of inputs, or producing the right mix of outputs given their relative prices, respectively).

Nevertheless, in real economic life, producers are hardly fully production efficient. The difference can be explained in terms of technical and allocative inefficiencies, as well as a range of unforeseen exogenous shocks, making it unlike all (or even any) producers, firms or, even, economies operate at the full efficiency frontier (Reifschneider and Stevenson, 1991). However, one of the main related questions is whether inefficiency occurs randomly, or whether some economic agents (producers, firms or economies) have predictably higher levels of inefficiency than others. That is the reason why estimating efficiency is one of the core tools of economic analysis. Firstly, efficiency estimation provides an indication of the percentage by which potential output could be increased, or potential cost could be decreased, in relation to the corresponding production frontier. The further below the frontier a producer lies, the more inefficient it is too.

Regarding that the production frontier cannot be observed directly, several techniques have been developed in order to estimate efficiency. As broadly described in Del Hoyo, Espino and Toribio (2004), and Kortelainen (2008), the main methods of production frontiers and efficiency estimation may be classified into two core groups:

a) Non - Parametric models, regarding Data Envelopment Analysis (DEA), developed by Farrell (1957) and Charnes, *et al.* (1978), and;

b) Parametric models, regarding Deterministic Frontier Analysis and Stochastic Frontier Analysis (SFA), developed by Aigner, *et al.* (1977), and Meeusen and van den Broeck (1977).

It is widely understood among researchers that both the DEA and SFA approaches have their individual strengths and weaknesses.

Cullinane, *et al.* (2006) argued that, the SFA approach has the advantage of allowing for random shocks and measurement error. It is also possible to analyze the structure, and investigate the determinants of producer performance using the SFA. Therefore it has a more solid grounding in economic theory. On the other hand, weaknesses with the whole family of econometric approaches to efficiency measurement (to which SFA belongs), as summarized by Cullinane *et al.*, (2006), are: -

1) It is risky to impose strong ***a priori*** assumptions on the production technology by choosing functional form (e.g. Cobb–Douglas, translog, etc.), given that most of the distributional characteristics of the production technology are a priori unknown.

2) The precise specification of the error structure is difficult (sometimes even impossible) to ascertain. In addition, such specification is likely to introduce another potential source of error.

3) The continuity presumed in this approach may lead to approximation errors”

Comparing DEA with the stochastic parametric frontier approach, DEA imposes neither a specific functional relationship between production output and input, nor any assumptions on the specific statistical distribution of the error terms. In so doing, the data are believed to be able to 'speak for themselves' and the DEA approach has the advantage of minimal specification error. However the DEA model does not allow for measurement error or random shocks, instead all these factors are attributed to (in)efficiency, a characteristic that inevitably leads to potential estimation errors (Cullinane *et al.*, 2006).

The study instrument was developed Based on these theoretical concepts in this chapter. The empirical and the analytical frameworks were also derived. For the measurement of profit efficiency, the SFA approach was adopted because stochastic frontier approach estimations incorporate the measure of random error and systematic error. This is because profits among dairy farmers may vary due to random variations in costs of production and also due to inefficient farming practices of farmers.

CHAPTER THREE

3.0 Methodology

This chapter presents information about the study area, the study population, sample size and sampling frame, it provides list of data variables, the data collection procedures and analysis procedures used in this study.

3.1 Description and Location of the Study Area

Kenya has a total land area of 591,958 Km^2, which comprises 98.1% land and 1.9% water (GoK, 2010b; FAO, 1996). Of the total land surface, 20% can be classified as medium to high potential arable land with the rest being classified as arid and semi-arid lands (ASALs). However, the arable land supports 80% of the human population while the ASALs support the remaining 20% in addition to 50% of the livestock and 80-90 percent of the wildlife resources in the country. Kenya has six distinct Agro Ecological Zones (AEZ). A further description of the AEZs of Kenya is provided in Section 3.1.1. The natural, climatic and other environmental conditions within which the dairy farmers operate are integral to the performance of the dairy cow and its management.

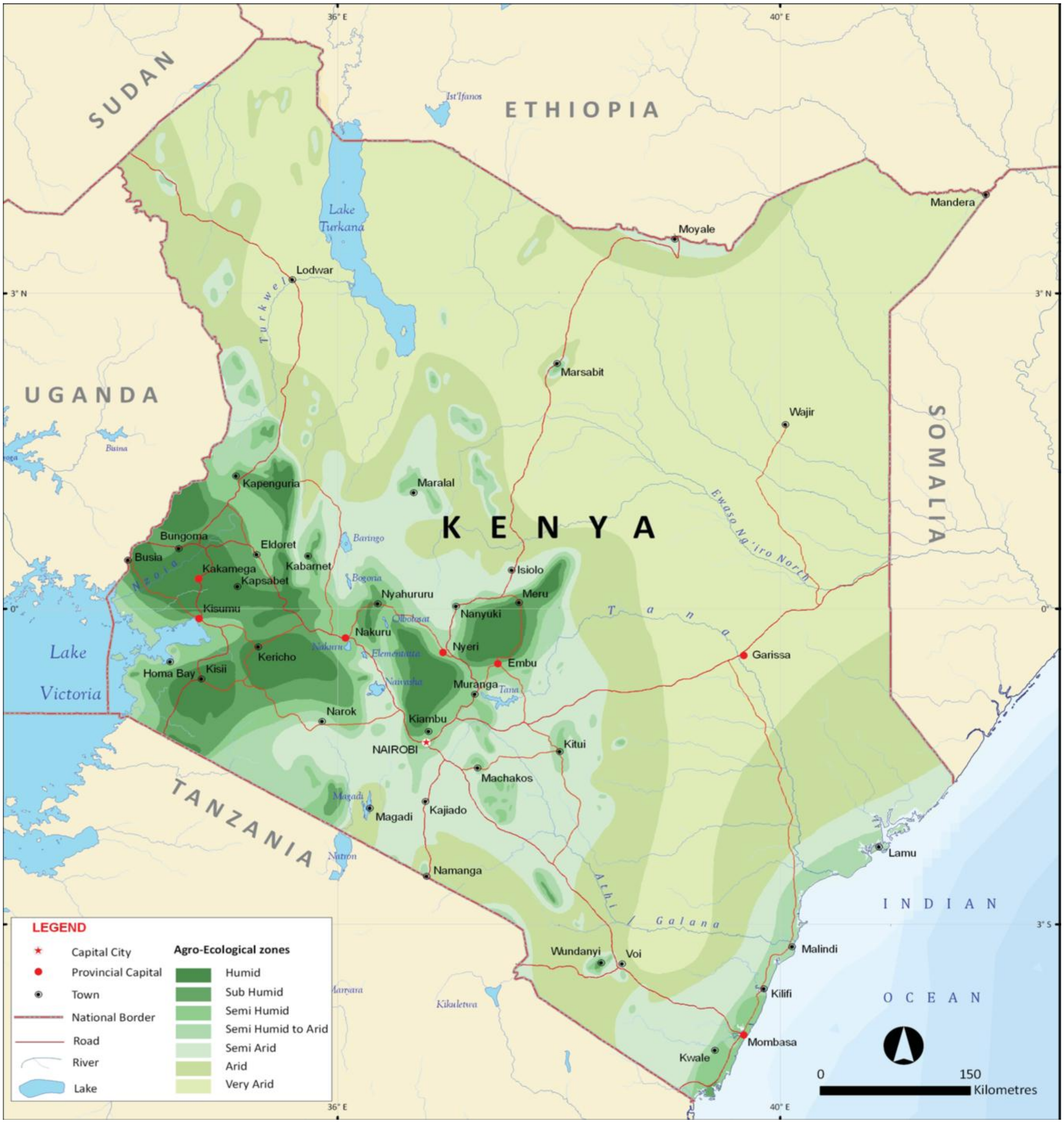
According to recent demographic projections by Index (2012), Kenya's current human population is approximately 43 million. 42.2% of this population are children (below 15 years), 55.1% adults, while the remaining 2.7% are the elderly (65+ years of age). The urban population is approximated at 22% while the 78% are rural dwellers mainly engaged in agricultural related activities.

Kenya is part of the wider East African region of Sub-Saharan Africa which is an agricultural economy of small-scale, resource-poor farm communities, half of them subsisting on less than $1 per day (EADD, 2007). Dairy farming in Kenya is mainly practiced in several parts of Rift Valley, Central, Eastern, Coast and Western Provinces; mostly practiced by small-scale holders, who account for 80% of the milk produced in Kenya, while large-scale farming accounts for the remaining 20% (Bebe, *et al*., 2003).

This study was conducted in Rift Valley and Central Provinces of Kenya where there is vibrant smallholder mixed crop-livestock production among farmers. The farmers considered for the study were also limited to those registered with the EADD project where interventions have been made, especially in breed improvements and milk market infrastructures. The EADD project focused mainly on improving small-holder dairy farming in mixed crop-livestock production systems and as such the pastoral communities in Kenya who own large herd sizes did not constitute part of the study group.

3.1.1 The Agro-Ecological Zones of Kenya

An Agro-ecological Zone is a land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use (NEMA, 2010; FAO, 1996). The essential elements in defining an agro-ecological zone are the growing period, temperature regime and soil mapping unit. Besides providing a platform for decision making in international and long term agricultural policy, AEZs guide extension agents in giving advice to farmers in the districts based on the differentiated system of showing yield probabilities and risks of a particular crop in a zoned area (NEMA, 2010; FAO, 1996). The AEZ of Kenya are grouped in terms of temperature belts defined according to the maximum temperature limits within which the main crops in Kenya can flourish. In other words, the AEZs are based on their probability of meeting the temperature and water requirements of the main leading crops. The categorization of the AEZ of Kenya is in Figure 1, where virtually 80% of the country lies in the Semi-Arid to Very Arid zones (ASAL), predominantly occupied by the pastoral communities and agro-pastoralists (FAO, 1996).



Source: NEMA 2010

Figure 1: The Agro Ecological Zones of Kenya

3.1.2 EADD milk domains in Kenya

East Africa Dairy Development (EADD), using Geographical Information System (GIS) layers, characterized the AEZs of Kenya using three indicators of:

1) Climatic characteristic - Length of Growing Period (LGP) that defines climatic potential;
2) Human population,
3) Access to Urban Center (as an indicator of market access) (EADD, 2010).

Using the median as the threshold for each indicator, the areas were further sub-divided into the following domains (Figure 2).

1) Low market access /Low population/ Low climatic potential

2) Low market access / Low population/High climatic potential

3) Low market access / High population/Low climatic potential

4) Low market access/High population/High climatic potential

5) High market access/Low population/Low climatic potential

6) High market access/Low population/High climatic potential

7) High market access/ High population/Low climatic potential

8) High market access/High population/High climatic potential

Given the production conditions of a domain, the farmer makes production decisions. How economically efficient the farmers is under such a domain was investigated in this study.

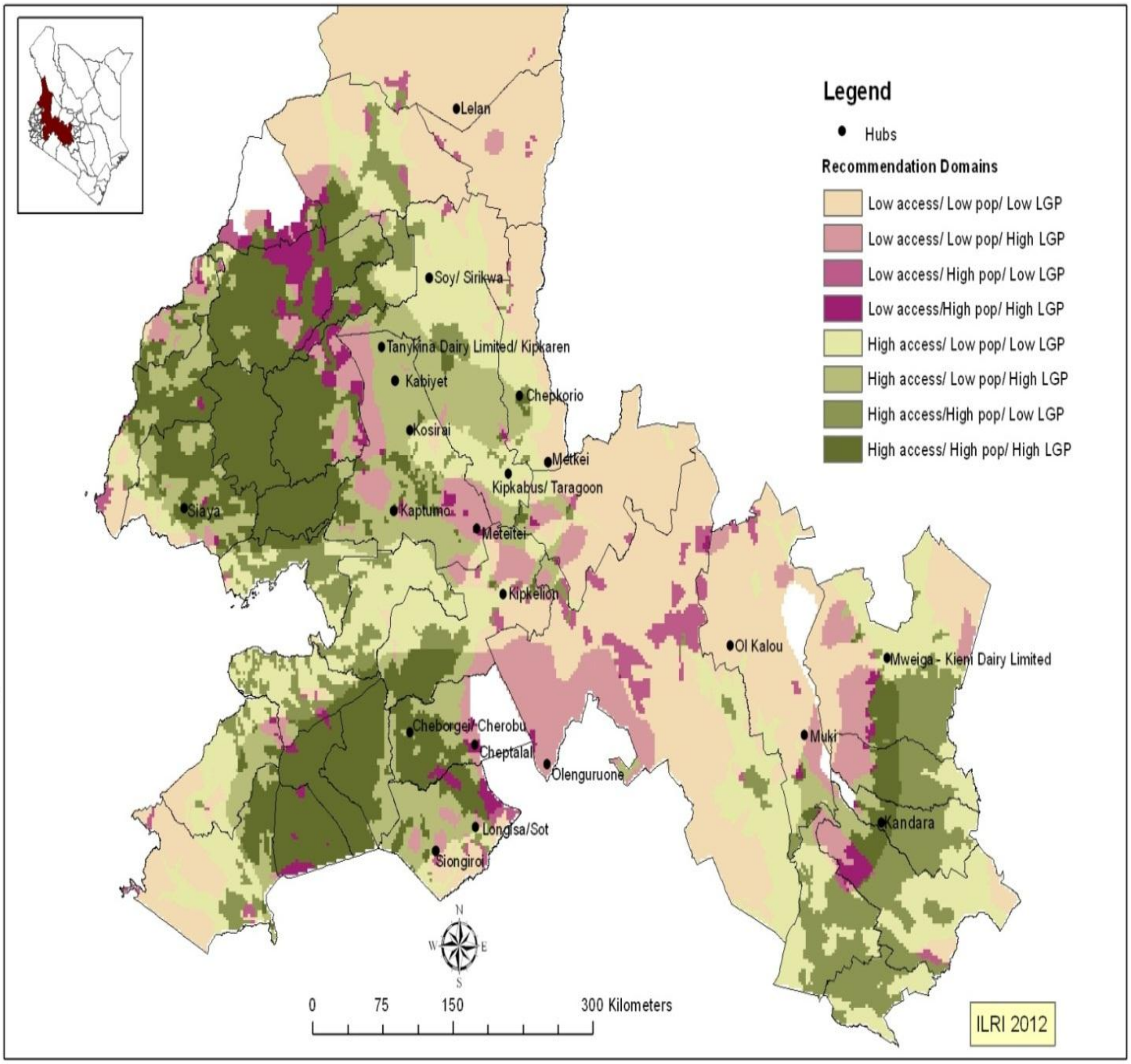


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Figure 2: East Africa Dairy Development Milk Domains in Kenya

3.1.3 Dairy production systems in Kenya

Production systems used by dairy farmers is largely described under two main systems namely:

1) Extensive production system - where the cattle are mainly grazed on available pasture.

2) Intensive system - where the dairy cattle are mainly kept under zero grazing.

The study adopted a simple categorization of production scales based on production system for managing the dairy cows on farm. The thresholds were arrived at using the EADD (2008) baseline data on household crop cum cattle farmers. Assigning international dairy scales to the Sub-Saharan Africa farms, who are often resource constrained, would not be an adequate representation and comparison.

Table 1: Production scale determined by production system

Production scale	**Production system**	
	Intensive	**Extensive**
Small-scale	≤ 3 Cows	≤ 15 Cows
Medium-scale	≥ 4 Cows	≥ 16 Cows

Source: EADD Survey, August 2012

3.1.4 Study Population and Sample Selection

According to the EADD Annual report (2011), Kenya is reported to have 21 milk hubs under the EADD project with 14 chilling plants owned by farmers groups and 7 by private processing companies. The total number of registered farmers equaled to 109,836. Full categorization of these farmers according to the socio-economic characteristics was not availed by the report and there was no accurate data. Sample size determination requires that a reasonable statistical power is maintained (Section 3.1.5). To simplify the complexity of the sample size selection, the EADD (2008) baseline data on household annual milk production was used as a basis to derive a required minimum sample size, as it was relevant and related to the present study. Total milk output per production scale was chosen as a basis for comparison of small scale and medium scale farmers, as economies of scale are likely to favour medium scale producers in terms of costs.

The formula in Equation 1 was adopted for obtaining a required minimal sample size per production scale based on the EADD (2008) baseline data on household annual milk output:

$$n = 2 \times \frac{\left(Z_{\frac{\alpha}{2}} + Z_{\beta}\right)^2}{d^2}\ \sigma^2 \qquad (1)$$

Where:-

n = number of households per stratum (production scale) (Table 2).

d = acceptable margin of error (that is, mean ± d = confidence interval), in this study taken as the difference in annual milk output between medium-scale and small-scale dairy households (Table 2 and Table 3).

σ^2 = variance of the estimated mean, assumed equal for each stratum (Table 3)

$Z_{\alpha/2}$ = significance level (taken at 5%) – signifying a 2-sided sample size; which equals 1.96 (Table 2).

Z_{β}= power of the test to identify a significant difference. The power is the ‘chance’ of this happening. 80% is the ‘commonly used’ power and for this study the Z-value is 0.84 (Table 2).

Table 2: Sample size estimation based on baseline data

<table>
<tr><th>Factor (x)</th><th>ICC</th><th>Variance</th><th>$Z_{\alpha/2}$</th><th>Z_{β}</th><th>$[Z_{\alpha/2}+ Z_{\beta}]^2$</th><th>n.unadj</th><th>Rounded n unadj'd</th><th>No. of Clusters</th><th>n unadj'd per cluster</th><th>K</th><th>Deff</th><th>Adj.n</th></tr>
<tr><td>Prod. Scale</td><td>0.1303</td><td>15674094</td><td>1.96</td><td>0.84</td><td>7.84</td><td>61.4</td><td>60</td><td>2</td><td>31</td><td>6.87</td><td>1.7648</td><td>55</td></tr>
<tr><td colspan="13">Average household milk output (litres) per annum</td></tr>
<tr><td colspan="2">Medium scale farms</td><td colspan="2">Small scale farms</td><td colspan="2">d</td><td colspan="2">rounded d</td><td colspan="2">d^2</td><td colspan="3">Variance</td></tr>
<tr><td colspan="2">3108</td><td colspan="2">930</td><td colspan="2">2178</td><td colspan="2">2000</td><td colspan="2">4000000</td><td colspan="3">15674094</td></tr>
</table>

Source: EADD baseline survey, 2008

Table 3**: Descriptive statistics of annual household milk production (litres)**

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
Medium scale	7	3108.386	2293.263	664.8	6841.3
Small scale	368	930.4356	4029.234	30.9	75719.3

Source: EADD baseline survey, 2008

Table 4**: Oneway ANOVA for annual household milk output for production scales**

Source	*SS*	*Df*	*MS*	*F*	*Prob > F*
Between groups	32584453	1	32584453	2.03	0.04551
Within groups	5.99E+09	373	16058173		
Total	6.02E+09	374	16102361		

Bartlett's test for equal variances: chi2(1)=2.5433 Prob>chi2=0.111

Source: EADD baseline survey, 2008

The estimated sample size (***n*** unadjusted) was approximately 62 for both scales of production for all the hubs. However due to issues of correlations in observations within a particular stratum, the sample size (***n***) estimated by the above formula was further adjusted to cater for the general class random effect model.

3.1.5 Sample Size and Design Effect

Farmers in a particular location are likely to exhibit similar characteristics in terms of average prices of input factors and output prices, as similarly argued by Alecxih *et al* (1998). This linearity in observations influences sample size of the study (Shoukriet *et al*., 2004). The reliability of statistical outcome measures is commonly assessed by estimation of the Intra Cluster Correlation (ICC) coefficient. Cluster sampling is usually convenient in such cases, but as argued by Shackman (2001), "selecting an additional member from the same cluster adds less new information than would a completely independent selection". Therefore the sample size needs to be adjusted so as to keep the statistical power intact. The independence of observations is investigated using the below equation (www.agreestat.com/book3):

$$X_{ij} = \mu + a_i + e_{ij} \quad \text{……………………………………………..………………………}2$$

Where:

$\mu = E(X_{ij})$,

$\{a_i\}$= the group effects and;

$\{e_{ij}\}$= the residual effects; are independently normally distributed with mean (μ) = 0, and variance σ_a^2 and σ_e^2 equal to1, respectively.

The variance of X_{ij} is:

$$\sigma_x^2 = \sigma_a^2 + \sigma_e^2 \quad \text{………………………… ……………………………………...….}3.a$$

The Intra Class Correlation (ICC) is defined as:

$$\rho_c = \frac{\sigma_a^2}{\sigma_x^2} \quad \text{…………………………………………………………….. }3.b$$

Table 5**:Intra cluster correlation (ICC) in production scale for annual milk output**

ICC	*Lower CI*	*Upper CI*	*Number of clusters (n)*	*Cluster size (K)*	*Var (residual)*	*Var (group)*
0.1303	-0.0517	0.3123	2	6.87	16058174	2405805

Source: EADD baseline survey, 2008

Thus, for example, in single stage cluster samples, the sample is not as varied as it would be in a random sample, so that the effective sample size is reduced (Levy and Leweshow, 1999). As cited by Shakman (2001), "the loss of effectiveness by the use of cluster sampling, instead of simple random sampling, is the **design effect"**. An argument is also raised that, the design effect is basically the ratio of the actual variance, under the sampling method actually used, to the variance computed under the assumption of simple random sampling.

The ICC is further extended to the design effect as illustrated by the formula below for adjusting the sample size obtained from equation (1):

Deff (Design effect) = 1+ ICC(K-1)…………………………………………………..(4)

Where: K = Average cluster size = 6.87

ICC = 0.1303

Adjusted n' = n x Deff ………………………………………………………………..(5)

Using this formula the adjusted sample size ***n*** per stratum equaled to 55 households per production scale (that is 110 households in total).

3.1.6 Sampling Frame and Sample Selection

In the ideal case, the sampling frame should coincide with the population of interest. In this study, a multistage sampling procedure was used to identify respondents from the various EADD milk hubs. A complete list of the hubs in Kenya was obtained and these included: Lelan, Mweiga, Olenguruone, Metkei, Cherobu, Chepkorio, Cheptalal, Olkalou, Sirikwa, Meteikei, Kaptumo, Kosirai, Kipkelion, Muki, Siongiror, Kabiyet, Tanykina, Taragoon and Sot. Representative sample of 10 hubs of 19 were selected using simple random sampling procedure. These were Singiroi, Olenguruone, Metkei, Cherobu, Kabiyet, Tanykina, Taragoon, Olkalou, Sirikwa and Sot (Figure 2).

Two strata were identified for production systems i.e. intensive and extensive systems. From each of the selected hubs, the lists of all the registered farmers were obtained. Farmers were then categorized according to production systems and scales (Table 1). A simple random sampling was then done to draw the estimated required sample size per strata per hub as summarized in Table 6.

Table 6: Sample size of farmers per milk hub

Production system	Production Scale	
	Small-scale	Medium-scale
Extensive	3	3
Intensive	3	3

Source: EADD Field Survey, August 2012

However due to the few numbers of medium scale farmers in most hubs, it was not possible to maintain the required sample size of the medium scale group. About 90 farmers were able to be interviewed in total during the study.

3.2 The Survey Instrument

A structured household questionnaire was used to collect data from the dairy farmers. Data was gathered on the dairy farms' operations in the past three months from the date of survey to ensure efficiency/accuracy in recall by farmers. SDP (2003) argued that, data collection based on single farm visits suffers from the difficulty of farmer recall over the entire annual period needed to capture seasonal changes. Hence longitudinal monitoring can be used to obtain more accurate data than is otherwise possible.

Cattle inventory records in the past three months were obtained. Milk yields per cow, the production system used for managing the herds, the related costs associated with on farm milk production i.e. feed, water, labour, animal health, farm maintenance, among others were recorded. Prices fetched per litre of milk, amount of milk consumed at home, milk given to calves and labourers were recorded. Data on whether households paid for water for cattle, get access to extension services, hired labour and used household labour were also collected. As feeds are a major production factor, details on fodder production on farm, concentrates purchased, fodder purchased, conserved feeds on farm and other inputs were recorded. The market channels used by households for selling milk, the quantities sold along these channels and the respective milk prices per litre were recorded. The detailed questionnaire for data collection is presented in Appendix 1.

3.3 Milk production details

Estimates of milk yields for every lactating cow for the past three months were recorded. Data on milk yield at calving, yield before the day of interview and the current lactation length was used to approximate the total milk per cow in lactation by regressing milk production levels the day preceding the survey and at calving against time. Lactating cows were grouped into two categories i.e. those whose current lactation length is greater or equal to three months; and those whose current lactation length is less than three months. The area under the lactation curve was calculated for these categories to get three months' milk yield estimates. These estimates were also validated with the total milk outs estimated from total milk sold along various channels, milk consumed at home, milk given to calves, milk given out and milk that got spoilt (if any). In the study, the number of times a farmer milks his cows per day during the lactation was investigated and the amount of milk obtained from each milking period recorded. Labour costs associated with milking of the cows for the chosen milking frequencies were established.

3.3.1 Milk Revenue Derivation

The dairy enterprise revenues considered were milk sales revenues and equivalent revenues from milk unsold but utilized at home. Daily milk consumed by households, milk given to hired labourers and milk given to calves are also part of the farm income but were valued at cost-price in order to obtain its equivalent revenues to the household. Daily milk sales; market channel (milk-buyer type) and the price paid to the farmer were also established to estimate revenue per litre of milk sold.

3.3.2 Production Cost Estimates

Costs at the farm level were categorized into variable costs and fixed costs. Quantities of concentrates, conserved feeds and fodder used were recorded. Prices of feeds and other production inputs were also obtained. Fodder quantities made own farm were costed at 50% of market price per unit of fodder in the study area (KARI, 2012; and ICRAF (undated)). This was approximated to the opportunity cost of land for other enterprises within the past three months period, but other input costs for producing fodder such as labour used were recorded elsewhere under labour costs.

Data on amount of hired labour used for dairy activities was recorded and costed. The type and cost of veterinary drugs used, extension services and breeding costs were recorded. The amount of family labour used for dairy production activities were established and their wage equivalents computed. Family labour was valued at 70% of the reported casual rural wage in the area. This reflects the assumption that the opportunity cost of family labour is below the wage rate. Simply because off-farm employment is not always readily available to farm family members, unless if the assumption is that, off-farm casual employment opportunities are available on every day during every season, which is not realistic (SDP, 2003).

Estimation of fixed costs was performed using the capital recovery cost method on enterprise structures and equipment, which takes into account the opportunity cost of capital. Cost of land used by the enterprise was included in the cost of grazing and fodder respectively and so did not constitute part of fixed cost.

Food-crop residues gathered on-farm and fed to cattle were not costed, nor were forages gathered off-farm, although the associated labour costs were included.

The value of milk given to calves was included under variable costs. Other variable costs comprised of hired labour, purchased feeds, feed conservation costs, water, animal health, breeding, extension and milk transport. Fodder costs produced on farm were assumed variable as land sizes allocated to fodder growth, seeds used for fodder establishment and labour costs are a function of herd size on farm.

Fixed costs included depreciation of machines, equipment and enterprise structures. Household labour wages were considered fixed as their input is relatively fixed per household. Costs for purchase of cattle and/or cattle replacement costs were not included in the study.

3.4 Data Analysis Procedures

A combination of theoretical and conceptual frameworks were adopted to provide the basis of analysis of the study objectives (Margeret, 1979; and Scriven, 1986).

3.4.1 Dairy gross margin analysis

Conventionally, profit is defined as the difference between revenue and costs. Based on the factors of milk production and the associated variable costs the total variable cost of milk was computed. The market price of milk was used to multiply milk quantity to arrive at milk revenue sold by the farmer. Unsold milk revenue was estimated by multiplying milk quantity by unit cost of milk production. Gross margins were obtained by getting the difference between the total milk revenue and the total variable cost of producing milk.

3.4.2 Dairy Profit Efficiency Analysis

a) Theoretical framework to efficiency analysis

Kumbhaker and Lovell (2000) and Herrero and Pascoe (2002), observed that in order to be economically efficient a firm must first be technically efficient. Profit maximization requires a firm to produce the maximum output given the level of inputs employed, use the right mix of inputs in light of the relative price of each input and produce the right mix of outputs given the set of prices. Parametric (Deterministic and Stochastic Frontier Approach) and non-parametric (DEA) methods are used for measuring farm efficiencies, and each with their own strengths and weaknesses. In this study, the stochastic frontier approach was used for determining profit efficiency of the dairy farmers.

The Stochastic Frontier model was independently proposed by Aigner, *et al.*, (1977) and Meeusen and van den Broeck (1977). A stochastic frontier production function is defined by:

$$Y_i = f(X_i;\beta) \exp (v_i - u_i),\ i = 1,2 \ldots.n \quad \ldots\ldots\ldots\ldots \quad (6)$$

Where Y_i is output of the i^{th} farm,

X_i = vector of input quantities used by the i^{th} farm,

β = vector of unknown parameters to be estimated,

$f(\ )$= represents an appropriate function (e.g Cobb Douglas, translog, quadratic etc).

v_i = symmetric error, which accounts for random variations in output due to factors beyond the control of the farmer e.g. Extreme weather conditions, Cattle disease outbreaks, measurement errors, etc.

u_i = non negative random variable representing inefficiency in production relative to the stochastic frontier.

The random error v_i is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$ random variables independent of u_i which are assumed to be non-negative truncation of the $N(0, \sigma_u^2)$ distribution (i.e. half-normal distribution) or have exponential distribution. Based on the assumption that u_i and v_i are independent, the parameters of the production frontier are estimated using the Maximum Likelihood method (MLE).

A number of functional forms [*f( )*] exist for estimating production functions. These include the Cobb-Douglas and the flexible functional forms namely: normalized quadratic, normalized translog and generalized Leontif (Abdulai and Huffman, 2000). Comparisons between the different functional forms have been made. It is argued that the Cobb-Douglas is restrictive compared to the more flexible functional forms such as the translog and quadratic forms (Abdulai and Huffman, 2000). Upton (1979) argued that the Cobb-Douglas function cannot show both increasing and diminishing marginal productivity in a single response curve. As a result it does not give a technical optimum and may lead to the over estimation of the economic optimum.

According to Abdulai and Huffman (2000), Ali and Flinn (1989); and Wang *et al* (1996), the translog model is widely used by researchers. Abdulai and Huffman (2000) however identified drawbacks in the translog model, that it has potential problems of insufficient degrees of freedom due to the presence of interaction terms. These interaction terms of the translog model do not have economic meaning (Abdulai and Huffman, 2000). This study encountered this challenge of choosing which variables to interact in the model that would make economic sense as the frontier model had diverse variables. Researchers such as Olayide and Heady (1982) have used the quadratic function to measure the direct effects of inputs on output but this approach seem unpopular among researchers, just like the transcendental functional form.

Despite the restrictive nature of the Cobb-Douglas functional form, it is popular among researchers, for example, Taru *et al.*,(2011); Ojo *et al*, (2006); Sanzidur (2003); Ekpebu (2002); Abdulai and Huffman (2000); Saleem (1988); Kaliranjan and Obwona (1994); Dawson and Lingard (1991); Yilma (1996); Nsanzugwanko *et al*, (1996); and Batesse and Safraz (1998). Ekpebu (2002) argued that the Cobb-Douglas functional form is useful in analysis of surveys where many variable inputs are involved and it is necessary to measure returns to scale, intensity of factors of production and overall efficiency of production. It provides a means of obtaining coefficients for testing hypotheses (Cobb and Douglas, 1928; and Erhabor, 1982). Ellebu, Koku and Ogidi (2003), as reported by Akighir and Shabu (2011), argued that the evidence of the superiority of Cobb-Douglas functional form is supported by its satisfaction of the economic, statistical and econometric criteria required unlike the other functional forms.

A production function y = f(x_1; x_2) is a Cobb-Douglas type if it can be written in the form:

$$Q = AX_1^a X_2^b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where Q = Output; X_1=Labour; X_2= Capital; parameters *A, a, and b (*later two being exponents*)* are estimated from empirical data, of which they have to be positive.

So the partial derivatives of Cobb-Douglas production function are:

$$MP_1 = \frac{dy}{dx_1} = aAX_1^{a-1}X_2^b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$MP_2 = \frac{dy}{dx_2} = bAX_1^{a}X_2^{b-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The absolute value of the slope of an isoquant is the technical rate of substitution (TRS). This TRS equals $MP_1=MP_2$ so that (2) and (3) imply that:

$$TRS = \frac{MP_1}{MP_2} = \frac{ax_1}{bx_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Equations (8) and (9) imply that the Cobb-Douglas technology is monotonic, since both partial derivatives are positive. Equation (10) demonstrates that the technology is convex, since the (absolute value) of the TRS falls as x_1 increases and x_2 decreases.

Applying the principle of returns to scale, a farm can only increase input usage to a certain maximum, beyond which it is not advisable. Suppose that all inputs are scaled up by some factor *t*. The new level of output is:

$$f(tx_1; tx_2) = A(tx_1)^a(tx_2)^b = t^{a+b}Ax_1^a x_2^b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Equation (11) is similar to: $f(tx_1; tx_2) = t^{a+b} f(tx_1; tx_2)$.

A farmer can increase returns to scale if: $f(tx_1; tx_2) > t\, f(tx_1; tx_2)$

Whenever $t > 1$, we have increasing returns to scale (i.e. if $t^{a+b} > t$), which is the same thing as $a + b > 1$.

Similarly, decreasing returns to scale arise if $f(tx_1; tx_2) < t\, f(tx_1; tx_2)$ i.e. whenever $t < 1$, there is decreasing returns to scale which occurs if $t^{a+b} < t$, *or* $a + b < 1$.

If $t^{a+b}=t$, and $a + b = 1$ then the cobb-douglas model shows constant returns to scale.

Based on this production function, using MLE the Cobb Douglas approach proceeds to estimating the allocative efficiency of a farm by computing the value of marginal product (VMP_i) for each factor of production which in turn is compared with the marginal input cost

(MIC_i). The β_is in equation (7) are estimated using Maximum Likelihood Estimates because the error term is assumed to be dual (i.e. $\varepsilon = v\text{-}u$).

Allocative Efficiency (A.E) $= VMP_i/P_i$ ………………………………..………..(12)

Where: P_i = Marginal cost of the i^{th} input.

It is often assumed that smallholder agricultural producers operate in a perfect competition where products are indistinguishable and there are many potential suppliers therefore making the farmer a price taker. If the individual farmer prices the product higher than the market price, he/she will not make any sales or make fewer sales, thus incurring losses. To avoid this condition the farmer has to go with the price determined by the industry in order to survive. Grazhdaninova and Lerman (2005) and Chavas *et al.(* 2005) presented that since farmers are price takers in the input market, the marginal cost of input i approximates the price of the factor i, PX_i.

Hence, if $VMP_i > PX_i$, the input is under used and farm profit can be raised by increasing the use of this input. Conversely, if $VMP_i < PX_i$, the input is overused and to raise farm profits its use should be reduced. The point of allocative efficiency (maximum profit) is reached when

$VMP_i > PX_i$

b) Conceptual Framework

Allocative efficiency of the farmer is measured in terms of how he/she uses production inputs optimally in the right combination to maximize profits (Inoni, 2007). Derived from the Cobb-Douglas production function, the allocative efficiency is estimated using the physical production relationships. On the other hand, technical efficiency of an individual farmer is defined in terms of the ratio of the observed output to the corresponding frontier output, given the available technology. Following Battese (1992) and Raham (2003), technical efficiency can be estimated using Cobb-Douglas frontier approach.

According to Battese (1992) and Battese and Coelli (1995), the popular approach to measure technical efficiency component is the use of frontier production function. However, Yotopoulos, *et al*. (1973) and Ali and Flinn (1989) argued that a production function approach to measure efficiency may not be appropriate when farmers face different prices and have different factor endowments. This led to the application of stochastic profit function models to estimate farm specific efficiency directly (Ali and Flinn, 1989; Sanzidur, 2003; and Ogundari, 2006).

Battese and Coelli (1995), Coelli, (1996) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. The advantage of Battesse and Coelli (1995) model is that it allows estimation of the farm specific efficiency scores and the factors explaining efficiency differentials among farmers in a single stage estimation procedure.

In this study, the Battesse and Coelli (1995) model was adopted by postulating a profit function, which is assumed to behave in a manner consistent with the stochastic frontier concept.

The stochastic profit function is defined as:

$\prod_i = f\,(P_{ij}, Z_{ik})\ exp\,(\varepsilon)$ ....(13)

The error term ε_i is assumed to behave in a manner consistent with the frontier concept (Ali and Flinn,1989), i.e.

$\varepsilon_i = v_i - u_i$ ....(14)

Where:

$\prod_i$ = normalised profit of the i^{th} farm defined as gross revenue less variable cost, divided by farm specific output price;

P_{ij} = price of j^{th} variable input faced by the i^{th} farm divided by output price;

Z_{ik} = level of the k^{th} fixed factor on the i^{th} farm.

v_i = random error term, $N(0,\sigma_v^2)$, i.e. independently normally distributed with mean of zero and variance of 1

u_i = one-sided disturbance form used to represent profit inefficiency and it is independent of v_i, and i = 1,2 ….., n, represent the individual farms in the study group.

The production/profit efficiency of farm i in the context of the stochastic frontier function is defined as:

EFF = $E[\exp(-u_i)/\varepsilon_i]$ = $E[\exp(-\delta_0 - \sum_{d=1}^{D}\delta_d W_{di})/ \varepsilon_i]$ ……………………………....…………(15)

Where:

E = expectation operator, which is achieved by obtaining the expressions for the conditional expectation u_i upon the observed value of ε_i ;

W_{di} = d^{th} explanatory variable associated with inefficiencies on farm i.

δ_0 & δ_d = unknown parameters jointly estimated using the maximum likelihood method with the stochastic frontier and the inefficiency effects functions simultaneously.

The likelihood function is expressed in terms of the variance parameters, sigma squared

$(\sigma^2) = \sigma_v^2 - \sigma_u^2$ and gamma (ɣ) = $\frac{\sigma_u^2}{\sigma^2}$ (Battesse and Coelli, 1995).

The parameter γ represents the share of inefficiency in the overall residual variance with values in interval 0 and 1. A value of 1 suggests the existence of a deterministic frontier, whereas a value of 0 can be seen as evidence in the favour of OLS estimation.

c) Model specification

Profit efficiency of the dairy farmers is defined as profit gain from operating on the profit frontier, taking into account farm-specific prices and factors. Given a farm that maximises profit subject to perfectly competitive input and output markets and a singular output technology that is quasiconcave, the actual normalized profit function can be derived. Farm profit is measured in terms of Gross Margin (GM) which equals the difference between the Total Revenue (TR) and Total Variable Cost (TVC), but not fixed costs as they remain fixed whether or not production has taken place, and to what scale production has been, that is:

$$GM(\prod) = TR – TVC = PQ - WX_i \text{ ……………………………………………....… (16)}$$

To normalize the profit function, gross margin ($\prod$) is divided on the both side of the equation above by P which is the market price of the output (litre of milk).That is:

$$\frac{\Pi(p,z)}{p} = \sum\frac{(PQ-WX_i)}{P} = \frac{PQ-WX_i}{P} = f(X_i,Z)\sum P_iX_i \text{ ....(17)}$$

Where:

TR = Total revenue,

TVC = Total variable cost,

P = Price of output (Q),

X = Quantity of optimized input used,

Z = Price of fixed inputs used,

$P_i = \frac{W}{P}$ = Normalized price of input X_i

$f(X_i, Z)$ = Production function.

The Cobb-Douglas profit function in implicit form which specifies production efficiency of the farmers is expressed as:

$\prod = f\,(P_{ij},Z_{ik})\,exp\,(v_i - u_i)$; i=1,2,3…..n representing the individual farms.

The profit efficiency is expressed as the ratio of predicted profit to the predicted maximum profit for a best-practiced dairy farming by the household as presented below:

$$\text{Profit efficiency } (E\prod) = \frac{\Pi}{\Pi_{max}} = \frac{\exp[\prod(p,z)]\exp(\ln v)\exp(\ln u)\Theta}{\exp[\prod(p,z)]\exp(\ln v)} \text{ …………..…… …………….(18)}$$

Where:

$\prod$ = Predicted profit;

$\prod_{max}$ = Predicted maximum profit on the frontier.

Firm specific profit efficiency is again the mean of the conditional distribution of u_i given by $E\prod$ and is defined as:

$$E\prod = E[\frac{\exp(\ln u_i)}{E_i}] \text{ ……………………………………………...……………………(19)}$$

$E\prod$ takes the value between 0 and 1.

If u_i is = 0 i.e. on the frontier, the firm is obtaining potential maximum profit given the price it faces and the level of fixed factors.

If u_i > 0, the firm is inefficient and losses profit as a result of inefficiency.

The inefficiency effect model can only be estimated if the efficiency effects are present. Because u_i is present in the model it implies that it is justifiable to employ the stochastic frontier approach *(*Aneani *et al. 2011)*.

In this study, the Battesse and Coelli (1995), and Coelli (1996) model was used to specify the stochastic frontier function with behavior inefficiency components and used to estimate all parameters together in one step maximum likelihood estimation. The Cobb Douglas functional form used to estimate profit efficiency of the dairy farmers is presented in Equation 20. In order to validate the efficiency estimates of the Cobb-Douglas functional form, the mean profit efficiency was compared to that obtained of Translog, Quadratic and Transcendental functional forms. The explicit Cobb-Douglas functional model is specified as follows:

$$\ln\prod = \beta_0+\beta_1\ln Z_{1i}+ \beta_2\ln P_{1i}+ \beta_3\ln P_{2i} + \beta_4\ln P_{3i} + \beta_5\ln P_{4i} + \beta_6\ln P_{5i} + \beta_7\ln P_{6i} + \beta_8\ln P_{7i} + \beta_9\ln P_{8i} + \beta_{10}\ln P_{9i} + \beta_{11}\ln P_{10i} + \beta_{12}\ln P_{11i} + \beta_{13}\ln P_{12i} +\beta_{14}\ln P_{13i} + \beta_{15}\ln P_{14i} +(v_i-u_i) \text{ …………………...(20)}$$

The inefficiency model (u_i) is defined by the equation below:

$$u_i = \delta_0 + \delta_1 T_1 + \delta_2 T_2 + \delta_3 T_3 + \delta_4 T_4 + \delta_5 T_5 + \delta_6 T_6 + \delta_7 T_7 + \delta_8 T_8 + \delta_9 T_9 + \delta_{10} T_{10} + \delta_{11} T_{11} + \delta_{12} T_{12}$$

The model variables are described in Table 7.

Table 7: Description of parameters in the stochastic frontier model & inefficiency model

Parameter	***Description***
β	Parameter coefficient of the respective stochastic frontier variables
$\prod$	Normalized profit (unit revenue less unit variable cost over unit milk price)
Z_1	Total number of cows per household
P_1	Average price of breeding services
P_2	Average price of animal health services
P_3	Average price of extension services
P_4	Average price of labour
P_5	Average price of purchased fodder
P_6	Average price of produced fodder
P_7	Average price of concentrates
P_8	Average price of conserved feeds
P_9	Average price of grazing
P_{10}	Average price of water
P_{11}	Average price of transport
P_{12}	Average price of milk given to calves
P_{13}	Average price of farm maintenance
v_i-u_i	Composed error term
δ	Regression coefficient of the respective inefficiency variables
T_1	Age of farm owner (years)
T_2	Size of fodder land (acres)
T_3	Size of grazing land (acres)
T_4	Hourly wage rates (Kenya shillings)
T_5	Production system (dummy: 1=intensive, 0=extensive)
T_6	Production scale (dummy: 1= small scale, 0= medium scale)

T_7	Gender (dummy: 1= male, 0= female)
T_8	Hired labour (dummy: 1= yes, 0= no)
T_9	Access to extension services (dummy: 1=yes, 0= no)
T_{10}	Paid extension service access (dummy: 1= yes, 0= no)
T_{11}	Paid water access (dummy: 1= yes, 0= no)
T_{12}	Hired land access (dummy: 1= yes, 0= no)

The basic structure of the Cobb-Douglas functional form is shared among all the other functional forms except for the following additional inclusions in other forms, that is:

The Translog model includes squared terms of the frontier variables, their interactions, as well as interaction of the inefficiency variables.

The Quadratic model includes squared terms of the frontier variables, but excludes their interactions. However, it also shares the interaction of the inefficiency variables like in the Translog and Transcendental functional forms.

The Transcendental model substitutes the squared terms of the Translog and Quadratic forms with actual normalized frontier variables. The interactions of the normalized frontier variables are also included as it is with the natural log interaction terms of the Translog and Quadratic functional forms. It also includes the interaction of the inefficiency variables.

Using the Frontier Version 4.1c of R 2.14.1 statistical software, the estimate for all parameters of the stochastic profit frontier function and the inefficiency model are simultaneously obtained in a single stage maximum likelihood estimation procedure (Coelli, 1996).

CHAPTER FOUR

4.0 Results and Discussions

4.1 Cost of Milk Production, Revenue and Profits of Dairy Farmers

4.1.1 Descriptive Statistics on Milk Production

The summary statistics of inputs used in milk production, their costs, milk prices fetched, revenues and profits for a quarter of a production year are presented in Table 8. The mean and median values have been illustrated as measures of central tendency. Measures of variability of items among the farmers have been shown by the respective standard deviations. The higher the standard deviation, the more varied the item is among the farmers (for example, milk revenues of the farmers, cost of fodder produced on farm, total variable costs incurred, etc.). Measures of spread have been summarized by the minimum, maximum and quartiles values of these items. These summarize the overall distribution of the variable term among the farmers. The estimates were made for all the farmers in the study group (n=85) based on the assumption that each farmer is subject to incurring these costs, but they can substitute some for other options available.

The average number of cows owned by a household equaled to 3. The land size under fodder production was 2.3 acres on average. Some farms relied entirely on grazing and did not incur costs on fodder purchases nor its production on farm. Similarly there was a high variation in land sizes for grazing cattle with a mean of 5.97 acres per household. The average number of hired labour used in cattle activity was 1 labourer per farm. Some households relied entirely on household labour for milk production.

Table 8: Descriptive Statistics of Milk Costs, Prices and Revenues per Farm

Variable Name	*Minimum*	*1st Qu.*	*Median*	*Mean*	*3rd Qu.*	*Maximum*	*Std Dev.*
Physical Inputs							
No. of cows on farm	1.0	2.0	3.0	3.3	4.0	11.0	2.0
No. of hired labour	0.0	0.0	0.0	0.5	1.0	2.0	0.6
No. of household labour	0.0	2.0	3.0	2.6	3.0	7.0	1.5
Acres of fodder	0.0	0.6	1.5	2.3	3.4	10.0	2.2
Acres of grazing land	0.0	0.0	0.0	6.0	0.0	500.0	52.4
Variable Costs							
Breeding	0.0	0.0	500.0	950.6	1300.0	10500.0	1608.4
Health	0.0	935.0	1990.0	2394.0	3190.0	9560.0	2015.0
Extension	0.0	0.0	0.0	102.3	0.0	1500.0	318.4
Hired labour	0.0	0.0	0.0	3551.0	6000.0	15000.0	4553.2
Purchased fodder	0.0	0.0	0.0	1004 .0	0.0	44000.0	4910.7
Concentrates	0.0	1673.0	2600.0	3745.0	5530.0	17120.0	3619.6
Farm produced fodder	0.0	5500.0	15000.0	23000.0	34380.0	100000.0	22444.6
Conserved feeds/forage	0.0	0.0	0.0	1248.0	0.0	22950.0	3782.9
Grazing	0.0	0.0	0.0	682.4	0.0	9000.0	1756.3
Water	0.0	0.0	0.0	216.9	0.0	13500.0	1468.6
Transport	0.0	0.0	180.0	596.6	967.5	4500.0	882.7
Milk to calves	0.0	0.0	0.0	2298.0	2866.0	22240.0	4488.3
Total variable costs	1600.0	16100.0	32020.0	38610.0	51490.0	174400.0	30084.7
Fixed Costs							
Depreciation	14.7	182.8	544.0	1458.0	1799.0	9729.0	2008.7
Household labour	0.0	668.9	1698.0	2209.0	3307.0	15790.0	2262.4
Total fixed costs	14.7	282.6	1618.0	2465.0	4379.0	14050.0	2771.4
TOTAL COST	2078.0	16620.0	33920.0	41070.0	57770.0	177900.0	31299.0

Milk Utilization							
Qty sold to Chilling plant	0.0	450.0	697.5	930.3	1080.0	4230.0	831.7
Qty sold to Individuals	0.0	0.0	0.0	128.7	180.0	1080.0	236.1
Qty sold to Private traders	0.0	0.0	0.0	34.5	0.0	990.0	148.8
Total Qty sold	0.0	540.0	855.0	1094.0	1508.0	4230.0	877.7
Unit price– Chilling plant	22.0	24.0	26.0	26.1	27.0	32.0	*
Unit price – Individuals	20.0	25.9	30.0	28.9	30.0	60.0	*
Unit price–Private traders	10.0	24.8	25.5	26.8	30.5	39.0	*
Average milk price	21.0	25.0	27.0	26.7	28.6	32.0	2.4
Qty to Calves	0.0	0.0	0.0	101.0	168.8	1350.0	211.0
Qty Consumed at home	0.0	180.0	270.0	317.6	360.0	1080.0	211.0
Qty to labourers	0.0	0.0	0.0	104.7	0.0	2700.0	426.4
Total Qty Utilized	0.0	202.5	360.0	523.3	607.5	3510.0	578.1
TOTAL MILK OUTPUT	180.0	821.2	1260.0	1617.0	2205.0	6210.0	1240.2
Total Rev. (Milk sales)	0.0	14580.0	22070.0	29170.0	39760.0	127400.0	24171.6
Total Rev. (Milk unsold)	0.0	4840.0	9511.0	13040.0	18380.0	50600.0	11774.0
TOTAL MILK REV.	5890.0	24130.0	35550.0	42210.0	53690.0	157500.0	27779. 7

n=85 ***Source****: EADD Survey, August 2012*

Feed costs constituted the greater proportion of farmers' cost of milk production. Among the cost components, fodder produced on farm constituted the highest percentage of variable cost with an average of Kshs 23,000 in the past three months. This was followed by cost of concentrates and cost of labour amounting to Kshs 3700 and Kshs 3500 respectively.

Household labour computed as a fixed cost of milk production also contributed significantly to overall total cost of milk production with a mean of Kshs 2,200 per household. The least cost was on extension services (average Kshs 100) because most farmers accessed unpaid extension services mainly from the Dairy Farmers' Business Associations (DFBA) & Government extension offices.

The average amount of milk produced by households was 1,600 litres with relatively high standard deviation. This variation was mainly attributed to the number of cows in lactation, varying lactation lengths, parity effects, among others.

Majority of farmers sold a greater portion of milk to the Chilling Plants (CPs) amounting to 930 litres on average. The least quantity was sold to private traders (35 litres). Despite the fact that Chilling Plants (CPs) offered the least price per litre of milk (Kshs 26) compared to Individual Consumers (Kshs 29) and Private Traders (Kshs 27), farmers sold substantial quantities of milk to the chilling plants. Although the study did not prioritize producer choice for market channels, the preference for chilling plants by farmers would be largely attributed to a couple of factors. These could range from: a) the capability and the reliability of CPs to buy and pay for every quantity a farmer is capable of supplying compared to traders and individual consumers; b) the relatively stable prices offered by CPs; c) the input incentives and extension services by some CPs to farmers on contractual basis; d) the belonging of some of the farmers' to such groups that actually own these chilling plants.

Farmers consumed substantial quantities of milk at home, amounting to 320 litres per household on average. This trend is encouraged among smallholder farmers for better nutrition as income generated by the households is not spent on purchase of milk from elsewhere. About 100 litres on average were given to labourers. Some portion of the produced milk was also used for feeding calves amounting to about 100 litres. Dairy households would be better off selling this milk if there were better calf feed alternatives. Farmers should not risk the welfare of the calf by denying it milk in the absence of appropriate options as this would lower the productivity of the calf. The study did not find any milk spoilage records among the households. This tends to suggest that the marketing strategies and available infrastructures have proved effective.

Overall, the average household revenue earned in a quarter of a year from milk amounted to KShs 42,000. Of this total, the revenue from direct milk sales approximated to KShs 29,000 and that of the unsold but utilized at home and given to labourers amounted to KShs13,000.

4.1.2 Unit Cost, Revenue and Profits of smallholder milk production

A summary of cost, revenue and profit per litre of milk of the farmers is provided in Table 9.

Table 9: Descriptive statistics of unit costs, revenue and profits per litre of milk

Variable Name	*Minimum*	*1st Qu.*	*Median*	*Mean*	*3rd Qu.*	*Maximum*	*Std Dev.*
Breeding cost	0.00	0.00	0.22	0.70	1.19	5.56	1.02
Health cost	0.00	0.85	1.35	1.98	2.20	9.18	2.05
Extension cost	0.00	0.00	0.00	0.13	0.00	2.78	0.48
Hired labour cost	0.00	0.00	0.00	2.57	3.14	25.01	4.31
Purchased fodder cost	0.00	0.00	0.00	0.47	0.00	14.38	1.82
Concentrates cost	0.00	0.66	2.44	2.98	3.98	15.56	3.13
Produced fodder cost	0.00	5.56	13.48	18.16	27.78	100.00	17.28
Conserved feeds cost	0.00	0.00	0.00	1.20	0.00	23.18	3.79
Grazing cost	0.00	0.00	0.00	0.54	0.00	7.41	1.42
Water cost	0.00	0.00	0.00	0.15	0.00	9.38	1.02
Transport cost	0.00	0.00	0.18	0.38	0.69	1.67	0.47
Milk to calves cost	0.00	0.00	0.00	2.25	1.30	41.18	5.99
Maintenance costs	0.01	0.14	0.37	1.23	1.47	8.45	1.87
Household labor cost	0.00	0.47	1.06	2.47	2.97	18.67	3.66
Total variable cost	1.78	11.44	22.83	29.24	42.40	119.60	22.84
Total fixed cost	0.01	1.06	2.34	3.70	4.22	19.66	3.97
Total unit cost	2.42	13.73	27.80	31.47	44.25	119.80	23.49
Unit revenue	13.63	22.30	26.83	28.92	31.56	89.48	10.94
Unit gross profit	1.143	11.800	15.870	17.060	20.590	55.870	9.10
Unit net profit	-64.960	-9.018	0.000	-2.101	7.368	22.230	15.44

n=85 **Source**: EADD Field Survey, August 2012

The average unit variable cost amounted to Kshs 29.2. The unit cost of produced fodder contributed significantly to this total variable cost with a mean of Kshs 18.16. The average unit fixed cost of milk amounted to Kshs 3.7. The overall average cost of milk per litre amounted to Kshs 31.47. The unit milk revenue received by households amounted to Kshs 29.4 on average. The unit gross profit received by households was Kshs 17. On average the farmers incurred net loss of Kshs 2 per litre of milk other than profits. However, there was a very high level of variation for net profit among the farmers.

4.2 Profit efficiency of the smallholder dairy farmers

The profit efficiency estimates obtained by the stochastic frontier function are presented and discussed in this section. The descriptive statistics of the variables used in the SFA model, as well as the diagnostics for heteroscedasticity and orthogonality conditions to accurate efficiency estimates of the stochastic frontier function are also presented and discussed.

4.2.1 Descriptive Statistics of variables used in the stochastic profit frontier model

Table 10 presents summary statistics of the normalized variable costs in the general stochastic frontier model used for estimating profit efficiency of the farmers. The normalized average gross profit per litre of milk was Kshs 0.62. Of the costs, fodder produced on farm was relatively higher than the rest (Kshs 0.74) on average. This was followed by cost of labour (Kshs 0.28), cost of conserved feeds (Kshs 0.2), cost of concentrates and cost of milk to calves (Kshs 0.13) respectively, cost of purchased fodder (Kshs 0.12), cost of grazing (Kshs 0.10). The other costs were relatively lower, but the least of all was cost of milk transport (Kshs 0.03).

Table 10: Descriptive statistics of the variables used in the general stochastic frontier model

Variable	Freq	Min	1st Qu.	Median	Mean	3rd Qu.	Max
Breeding	45	0.01	0.03	0.04	0.05	0.06	0.19
Health	78	0.00	0.04	0.06	0.08	0.10	0.37
Extension	8	0.01	0.02	0.03	0.04	0.07	0.11
Labour	41	0.03	0.08	0.13	0.20	0.28	0.83
Purchased Fodder	12	0.01	0.03	0.08	0.12	0.15	0.56
Produced Fodder	69	0.04	0.26	0.60	0.74	1.15	3.70
Concentrate	74	0.00	0.05	0.11	0.13	0.16	0.60
Conserved feeds	20	0.00	0.03	0.07	0.20	0.31	0.90
Grazing	17	0.00	0.05	0.07	0.10	0.12	0.28
Water	7	0.01	0.01	0.02	0.06	0.04	0.31
Transport	48	0.00	0.01	0.02	0.03	0.04	0.07
Calf milk	25	0.05	0.10	0.12	0.13	0.15	0.33
Gross margin	85	0.00	0.45	0.62	0.62	0.75	1.86

Source: EADD Field Survey, August 2012

4.2.2 Test for Heteroscedasticity

The independent variables used in the general model were tested for the presence of any heteroscedasticity which is often common in cross sectional data. Heteroscedasticity is known for violation of one of the requirements for OLS estimation (equal variance among observations). OLS is regarded by classical assumptions as the “Best Linear Unbiased Estimator (BLUE)”. In the presence of heteroscedastic disturbances, the efficiency of such OLS estimation is lost (Breusch and Pagan, 1979).

The Breusch-Pagan test was chosen to examine the presence of heteroscedasticity in the variables used in the SFA model as it is readily applicable in economic studies. The Breusch-

Pagan test was independently suggested by Cook and Weisberg (1983). The Breusch-Pagan model for estimating variances of the observations is presented below (www.wikipedia.org).

$$\sigma_i^2 = h(Z_i'\gamma) \quad \ldots\ldots (21)$$

Where $Z_i = (1, Z_{2i}, \ldots, Z_{pi})$ explains the difference in the variances.

The null hypothesis is equivalent to the (p -1) parameter restrictions:

$$Ho: \gamma_2 = \ldots = \gamma_p = 0 \quad \ldots\ldots (22)$$

The Lagrange Multiplier (LM) yields the test statistic for the Breusch–Pagan test:

$$LM = \left(\frac{\partial l}{\partial \theta}\right)' \left(-E\left[\frac{\partial^2 l}{\partial \theta \partial \theta'}\right]\right)^{-1} \left(\frac{\partial l}{\partial \theta}\right) \quad \ldots\ldots (23)$$

The following procedure was used to estimate the required statistic:

Step 1: Application of OLS regression model

$$y = X\beta + \varepsilon \quad \ldots\ldots (24)$$

Where:

y = natural log of normalized gross margin

X= Independent variable costs in the regression model

β = coefficients

ε = Error term (random noise) in the model

Step 2: Extract error terms, compute variance and generate e_i^2

Square error terms and divide each by the mean variance to obtain e_i^2.

Step 3: Performance of the auxiliary regression with $\boldsymbol{e_i^2}$ to obtain R^2

$$e_i^2 = \gamma_1 + \gamma_2\gamma_{2i} + \ldots + \gamma_{1p}\gamma_{pi} + \eta_i \ldots\ldots (25)$$

Where:

e_i^2 = squared error term divided by the variance (σ^2)

Other symbols in the equation are been defined earlier.

Step 4: Calculate the test statistic *LM*

The test statistic is the product of Coefficient of Determination (R^2) obtained by Step 2 and sample size ***n***:

$$LM = nR^2 \ldots\ldots (35)$$

The test statistic is asymptotically distributed as $\boldsymbol{\chi^2}$**(p-1)** under the null hypothesis of homoscedasticity.

The coefficient of determination (R^2) was obtained and the test statistic (*LM*), asymptotically distributed as $\boldsymbol{\chi^2}$***(p-1),*** was derived. A computed chi-square of 29.7 was identified. Studentized Breusch-Pagan (BP) test was performed in R statistical software directly, "which computes a score test of the hypothesis of constant error variance against the alternative that the error variance changes with the level of the response (fitted values), or with a linear combination of predictors (Fox, 1997)". The result showed a BP value of 26.2527, df = 13, p-value = 0.01572; an evidence that the computed chi-square is significantly greater than the critical value (22.36) at 5 percent level of significance. The null hypothesis of homoscedasticity is therefore rejected and a conclusion is drawn that there was heteroscedasticity in the data.

4.2.3 Correction for heteroscedasticity

Long and Ervin (2000) presented that correcting for heteroscedasticity improves the resulting coefficient estimates and are unbiased, with unbiased estimates of the standard errors. Several statistical methods exist for correcting for heteroscedasticity in cross sectional data by weighting each observation by the reciprocal of the variance (Green, 2000; Caroll and Ruppert, 1988). In this study the Weighted Least Squares (WLS) approach was adopted for correcting for heteroscedasticity. In the WLS approach all variables in the SFA model are multiplied by the inverse of the variance term (obtained in previous section). The variance reciprocal becomes the weighting function to transform the variables which are then orthogonalized and used in subsequent steps of the analysis.

4.2.4 Testing for orthogonality condition

The procedure for linear transformation, such as in Goldstein (1980), was used. A linear transformation is said to be orthogonal if it satisfies the orthogonality condition. OLS requires that the covariance between the independent variables and the error term should be zero.

$$\text{Cov}\,(x_i, e_i) = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. \ (36)$$

Based on the fact that the estimation of the SFA function is reliant on the distribution of the error terms, the independence of the variables in the inefficiency effects model need to be guaranteed from those of the the general stochastic frontier model. The orthogonality condition requiring a linear independent relationship is paramount. Violation of such a condition will result into a biased SFA estimation. The process was performed by regressing individual inefficiency variables against the natural logarithm of the variables in the Stochastic Frontier model. A high coefficient of determination is an indication of high dependence between the inefficiency factor and the variables in the frontier model. Table 11 summarizes the dependence levels of the proposed inefficiency variables shown by the value of coefficient of determination. Because there is high level of covariance between the inefficiency variables with the stochastic frontier variables, the residuals (ε_i) of the inefficiency variables were used instead in the estimation of the profit efficiency of the farmers. The error terms are orthogonal and have no covariance with the SF variables. The adjusted data was then used in the SFA profit frontier model.

Table 11: Orthogonality test results of the inefficiency model variables

Dependence variables	***R- squared***
Age of household head	0.3065
Acres of fodder land	0.3356
Acres of grazing land	0.1314
Hourly wage rate	0.4717
Production System	*
Production Scale	*
Gender of household head	*
Hired labour services	*
Access to extension service	*
Paid extension service	*
Paid water service	*
Hired land	*

***Source**: EADD Survey, August 2012* *"*" = NA for qualitative inefficiency factors*

4.2.5 Log likelihood estimates of profit efficiency of the smallholder farmers

The average profit efficiency estimated using the Cobb-Douglas functional form averaged to 68%. Compared to the other functional forms, the Quadratic functional model estimated similar mean efficiency of 68%. The Translog estimated an average efficiency of 67% while the Transcendental function estimated an average efficiency of 71% (Table 12). The Cobb-Douglas functional form outputs in Table 13 were used for further discussions of the study findings as it fitted the study data best, and also for reasons as discussed in Section 3.4.2 (a).

The variance parameter, sigma-squared (0.86), is statistically significant (p-value < 0.001), implying that the composed error term ($\varepsilon = v_i - u_i$) strongly dominates the measurement error. The gamma value also lies between 0 and 1, but closer to 1. A value of 1 would suggest a deterministic approach for the efficiency estimates because there is no random noise, while a value of 0 would mean OLS model is the best estimator because there is no inefficiency. A computed variance ratio (γ*)[1] of 0.79 also implies that 79% of the differences between observed and the maximum profit frontier is due to the existing variation in efficiency among the dairy farmers.

Additionally, the null hypothesis (***H_0*): $\gamma = 0$;** specifying that the inefficiency effects in the stochastic frontier are not stochastic is rejected because the value of gamma is significantly different from 0 (p-value < 0.001). Evidence of "goodness of fit" of the stochastic frontier model is provided by the likelihood ratio test results in Table 14. The p-value of the χ^2 is less than 0.001, signifying that the stochastic frontier model is a better estimator of profit efficiency of the farmers than the traditional OLS model.

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[1] $\gamma^* = \gamma / [\gamma + (1-\gamma)\pi/(\pi-2)]$ (Coelli *et al*., 1998)

Table 12: Profit efficiency estimates of the different functional forms

Variable name	*Parameter*	*Cobb Douglas*	*Translog*	*Quadratic*	*Transcendental*
Frontier model					
Intercept	β_0	-1.65***	-3.00***	-0.68	0.68
Ln Cows (size on farm)	β_1	0.00	0.53*	-0.20	-0.28
Ln Breeding	β_2	-0.01	0.02	0.00	-0.01
Ln Health	β_3	-0.00	-0.17	-0.04	-0.02
Ln Extension	β_4	-0.00	-0.25**	-0.07.	0.00
Ln labour	β_5	-0.00	-0.03	0.01	-0.01
Ln Fodder purchased	β_6	-0.05***	0.07	-0.05*	0.01
Ln Produced fodder	β_7	0.09***	1.40***	0.10***	0.07***
Ln Concentrates	β_8	-0.01	-0.18*	0.04	0.02
Ln Conserved feeds	β_9	-0.04***	0.07	0.05	0.03
Ln Grazing	β_{10}	-0.01	-0.02	-0.00	-0.03
Ln Water	β_{11}	-0.04*	0.14	0.09	0.02
Ln Transport	β_{12}	-0.03***	-0.02	-0.08*	-0.05*
Ln Calf milk	β_{13}	-0.01	-0.16***	-0.10*	-0.01
Ln Farm maintenance	β_{14}	-0.03***	-0.11.	-0.01	0.00
Ln Cows Sq.	β_{15}		-0.55**	-0.02	
Ln Breeding sq.	β_{16}		0.11*	-0.02	
Ln Health sq.	β_{17}		-0.03	-0.03	
Ln Extension sq.	β_{18}		-0.48**	-0.19	
Ln Labour sq.	β_{19}		-0.04	0.03	
Ln Fodder purchased sq.	β_{20}		0.33***	0.02	
Ln Produced fodder sq.	β_{21}		0.10*	0.04*	
Ln Concentrates sq.	β_{22}		0.05***	0.03*	
Ln Conserved feeds sq.	β_{23}		0.15*	0.09	
Ln Grazing sq.	β_{24}		0.00	0.01	
Ln Water sq.	β_{25}		0.59***	0.29	
Ln Transport sq.	β_{26}		0.08	-0.15*	

Ln Calf milk sq.	β_{27}	-0.24*	-0.12.	
Ln Farm maintenance sq.	β_{28}	-0.13*	0.03	
Ln Breeding* Ln Extension	β_{29}	-0.01***		
Ln Breeding*Ln Health	β_{30}	0.01		
Ln Fodder purch.*Ln fodder Prod.	β_{31}	-0.13***		
Ln Fodder Prod. *Ln Concentrates	β_{32}	-0.01.		
Ln Cows* Ln Labour	β_{33}	0.02*		
Ln Health * Ln Concentrates	β_{34}	0.01		
Ln Cows * Ln Health	β_{35}	0.05*		
Ln Cows* Ln fodder prod.	β_{36}	0.12		
Cows (total number on farm)	β_{37}			0.00
Breeding	β_{38}			-0.06
Health	β_{39}			0.17
Extension	β_{40}			-0.06
Labour	β_{41}			0.08
Fodder purchased	β_{42}			-5.53***
Fodder Produced	β_{43}			0.02
Concentrates	β_{44}			-0.29
Conserved feeds	β_{45}			-0.29
Grazing	β_{46}			-0.00
Water	β_{47}			-1.98*
Transport	β_{48}			0.82
Calf milk	β_{49}			-0.16
Farm maintenance	β_{50}			-0.03
Breeding * Extension	β_{51}			0.13
Breeding * Health	β_{52}			-0.02
Fodder purch. * Prod. Fodder	β_{53}			0.76***
Prod. Fodder * Concentrates	β_{54}			10.13
Cows * Labour	β_{55}			-0.00
Health * Concentrates	β_{56}			0.00
Cows * Health	β_{57}			-0.00

Cows * fodder prod.	β_{58}				0.06
Inefficiency model					
Intercept	δ_0	-4.95**	-0.91	-1.71*	-0.47
Age of household head	δ_1	0.01*	-0.06***	-0.03.	-0.03
Acres of fodder land	δ_2	-0.45***	-0.41***	-0.32**	-0.27.
Acres of grazing land	δ_3	-0.03***	-0.05***	-0.06***	-0.05*
Hourly wage rate	δ_4	0.20	0.25	0.39	0.05**
System (dummy:1=Int., 0=Ext.)	δ_5	1.00*	-0.28	-2.05**	-1.52*
Scale (dummy:1=Sml., 0=Med.)	δ_6	0.55	0.19	1.36.	0.87
Gender (dummy:1=Male, 0=Fem.)	δ_7	0.05	0.86	1.05	0.93
Hired labor (dummy:1=Yes,0=No)	δ_8	1.38**	-1.57***	0.15	-0.24
Access ext.(dummy:1=Yes, 0=No)	δ_9	1.42***	0.63	-0.13	-0.44
Paid ext.(dummy:1=Yes, 0=No)	δ_{10}	0.49	-0.84	-0.76	-0.42
Paid water (dummy:1=Yes, 0=No)	δ_{11}	-0.06	0.07	0.70	-0.42
Hired land (dummy:1=Yes, 0=No)	δ_{12}	1.03***	0.30	0.84.	0.70
Age * Size fodder land	δ_{13}		-0.04***	-0.02.	-0.01
Age * Size grazing land	δ_{14}		-0.00***	-0.00***	-0.00***
Age * Wage rates	δ_{15}		0.05*	-0.01	0.01
System * Scale	δ_{16}		0.19	0.54	0.67
Gender* Hired labour	δ_{17}		0.04	-0.14	0.14
Extension access * Paid extension	δ_{18}		1.00	-0.76**	-0.42
System * Access to Extension	δ_{19}		0.96	2.21	1.61*
Scale * Gender	δ_{20}		-0.25	-1.02	-1.03
Gender * Access to Extension	δ_{21}		-0.05	-1.15	-0.68
System * Gender	δ_{22}		-1.11	1.00**	1.00
Hired labour * Paid extension	δ_{23}		4.23***	2.89***	2.70**
Diagnostic statistics					
Sigma-squared ($\sigma^2 = \sigma_v^2 + \sigma_u^2$)	σ^2	0. 86***	0.21***	0.32***	0.17***
Gamma ($\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$)	γ	0. 91***	0.95***	0.96***	0.94***

Total number of observations	85	85	85	85
Log likelihood value	-24.40	11.93	2.76	3.90
Mean Efficiency	**0.68**	**0.67**	**0.68**	**0.71**

Source**: EADD Survey, August 2012* ***Signif. codes *'***'< 0.001, '**' < 0.01, '*' < 0.05, '.' < 0.1*

Table 13: Log Likelihood Estimates of the Cobb-Douglas Profit Function

Variable name	***Parameter***	***Coefficient***	***Std. Error***	***z value***	***Pr (>|z|)***
Frontier model					
Intercept	β_o	-1.65	0.33	-5.06	<0.001
Cows (number on farm)	β_1	0.00	0.02	0.16	0.870
Breeding	β_2	-0.01	0.01	-1.39	0.164
Health	β_3	-0.00	0.02	-0.03	0.980
Extension	β_4	-0.00	0.02	-0.24	0.814
Labour	β_5	-0.00	0.01	-0.63	0.532
Purchased fodder	β_6	-0.05	0.00	-13.89	< 0.001
Produced fodder	β_7	0.09	0.01	9.02	< 0.001
Concentrates	β_8	-0.01	0.01	-0.56	0.574
Conserved feeds	β_9	-0.04	0.01	-3.35	0.001
Grazing	β_{10}	-0.01	0.01	-1.04	0.297
Water	β_{11}	-0.04	0.02	-2.41	0.016
Transport	β_{12}	-0.03	0.00	-8.43	< 0.001
Calf milk	β_{13}	-0.01	0.01	-1.54	0.124
Farm maintenance	β_{14}	-0.03	0.01	-4.30	<0.001
Inefficiency variables					
Intercept	δ_0	-4.95	1.65	-3.00	0.003
Age of household head	δ_1	0.01	0.00	2.08	0.037
Acres of fodder land	δ_2	-0.45	0.05	-9.35	< 0.001
Acres of grazing land	δ_3	-0.03	0.01	-4.89	< 0.001
Hourly wage rate	δ_4	0.20	0.20	1.01	0.314
Production system (dummy)	δ_5	1.00	0.53	2.04	0.041

Production scale (dummy)	δ_6	0.55	0.39	1.39	0.163
Gender (dummy)	δ_7	0.05	0.54	0.09	0.927
Hired labour (dummy)	δ_8	1.38	0.43	3.18	0.002
Access extension (dummy)	δ_9	1.42	0.31	4.62	< 0.001
Paid extension (dummy)	δ_{10}	0.49	0.65	0.75	0.452
Paid water (dummy)	δ_{11}	-0.06	0.25	-0.25	0.801
Hired land (dummy)	δ_{12}	1.03	0.22	4.79	< 0.001
Diagnostic statistics					
Sigma-squared ($\sigma^2 = \sigma_v^2 + \sigma_u^2$)	σ^2	0. 86	0.21	4.57	< 0.001
Gamma ($\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$)	γ	0. 91	0.01	164.81	< 0.001
Total number of observations		85			
Log likelihood value		-24.40			
Mean Efficiency		**0.68**			

Source**: EADD Survey, August 2012* ***Signif. codes *'***'< 0.001, '**' < 0.01, '*' < 0.05, '.' < 0.1*

Table 14**: Stochastic frontier model compared with Ordinary Least Square model**

Likelihood Ratio (LR) Test

	Df	***LogLik***	***Df***	***Chisq***	***Pr(>Chisq)***
Model1: OLS (no inefficiency)	16	-56.354			
Model 2: Efficiency frontier effect	30	-24.404	14	63.898	1.232e-08

Source**: EADD Survey, August 2012* ***Signif. codes *'***'< 0.001, '**' < 0.01, '*' < 0.05, '.' < 0.1*

The estimated parameters of the Cobb-Douglas function are best explained as the elasticity of the explanatory variables in the model. Average profit efficiency of 68% implies that the dairy farmers are not fully profit efficient as 32% of a possible profit is being lost in their current dairy practices. As argued by Awudu and Eberlin (2001), the first-order coefficients of the functional forms are of less significance in interpreting the outputs of the model because they are not very informative, but rather the output elasticity for each of the inputs calculated at the variable means. The principle underlying elasticity is the measure of responsiveness of an output to unit increase in input. From the Cobb-Douglas model the elasticity with respect to cost of Purchased Fodder, Conserved Feeds, Milk Transport and Maintenance costs were statistically significant (p-value <0.001). The elasticity with respect to water was significant at 5% level of significance (p-value <0.05). The negative coefficient signs of these variables imply that they are significant at reducing profit efficiency among smallholder dairy farmers. The parameter estimates further indicate that a unit increase in the price of these variables i.e. Fodder Purchased, Conserved Feeds, Milk Transport, Maintenance costs and Water have the ability to decrease efficiency by 5.3%, 3.9%, 2.8%, 3.0% and 3.9% respectively.

The signs of the parameter coefficients for Breeding, Health, Extension, Labour, Concentrates, Grazing and Milk to Calves were negative implying that a unit increase in the price of these inputs also leads to a decrease in milk profits. However their decreasing effects on milk profits were insignificant.

The elasticity of dairy profits with respect to farm produced fodder was very positively significant (p-value < 0.001). The parameter coefficient for farm produced fodder in Table 13 means that a one percent increase in on-farm fodder cost contributed to 9% increase in profit efficiency. The elasticity of fodder produced on-farm is very encouraging and farmers should continue to utilize this feed option. In a study by KARI (2012), a similar finding was arrived at where farm produced fodder contributed significantly to dairy profitability among the smallholder dairy farmers in Kenya. On-farm produced fodder has multiplicative effects. It saves household income that would otherwise be used for purchasing feeds elsewhere. As on-farm produced fodder cost is mainly an implied variable cost, let alone cost of fodder seed, land rent, fertilizer and associated labour costs, households benefit more from on-farm produced fodder than purchasing fodder and they are able to afford other livelihood goods and services arising from such savings. It also has the advantage of being non-responsive to variable market prices. This cushions households from overall market price increases in feed resources that would further contract milk gross margins of farmers.

It was also observed that a unit increase in the number of cows of a household positively increased profit efficiency by 0.2%. Despite this positive elasticity, its increment in gross profits was not significant.

The critical production factors that decrease milk profits among the dairy farmers are purchased fodder, conserved feeds, purchased water, milk transport and farm maintenance costs. However costs of breeding, health, extension services, labour, concentrates, grazing and milk to calves are not critical at reducing dairy profit efficiency among the dairy farmers. The only critical factor that significantly increased profit efficiency among the dairy farmers is on-farm produced fodder. Farmers' investment in fodder production is therefore highly encouraged.

4.3 Determinants of profit efficiency among the dairy farmers

The classical interpretation of the inefficiency effects parameter coefficients is based on the significance of the signs. The values themselves do not mean anything and are usually ignored for interpretation. The coefficient signs are interpreted in the opposite way to those of the stochastic frontier coefficients. A negative sign indicates that the inefficiency variable increases efficiency, while a positive sign means a reduction in efficiency.

Table 13 summarizes the influence of the socio-economic variables (inefficiency effects) on profit efficiency of the smallholder dairy farmers. It was found that profit efficiency significantly increased with size of fodder land at farm level (p-value < 0.001). Similarly, profit efficiency increased with size of grazing land of the smallholder farmers (p-value < 0.001). These observations could be explained by the fact that farmers with relatively larger land sizes under fodder and those with reasonable land areas for grazing cattle incurred minimal variable costs compared to those with limited land.

The inefficiency factors that significantly reduced profit efficiency of the smallholder dairy farmers included: age of farm owner (p-value < 0.05), production system (p-value < 0.05), hired labour (p-value < 0.01), access to extension services (p-value < 0.001), as well as hired land for cattle enterprise (p-value < 0.001).

It was noted that profit efficiency of the dairy farmers decreased with age of the farm owner. Farmers in their 40s are likely experienced and still energetic in farming and are also likely to be more innovative and quick at adopting new technologies than the elderly farmers. This inverse relationship of old age with efficiency was also observed by other studies such as IIM/IFPRI (2003) and Al-hassan (2008). It should therefore not be interpreted from face value that the older the farmer the more profit efficient he/she will become. Although the older farmers can be technically efficient due to years of experience, as found out by other studies (for example, Taru *et al*., 2011 and Adebayo, 2006), it is possible to have the reverse with profit efficiency. The older a farmer becomes, the lower their mobility in participating in cattle activities especially if they own large herds. This is likely to prompt hiring of labour for feeding and milking activities on farm and consequential higher variable costs which eventually will lead to lowered profit efficiency. However, it is rather contradicting to find that older farmers above 50 years of age were more profit efficient on average than those below 50 years though not by a big margin (Table 16). This could possibly be due to a few farmers who were slightly above 50 years but had very high profit efficiencies possibly due to years of experience or knowledge of their farm managers. This coupled with the few numbers of farmers above 50 years of age, of this study, resulted in to higher average profit efficiency than the majority farmers below 50 years. But generally there was a high level of variation of efficiency among individual farmers of either group.

The study also found that farmers practicing extensive production systems were relatively more profit efficient than those of intensive systems (Table 15). This difference could arise due to the higher variable costs incurred in intensive systems due to higher feed costs and possibly hired labour costs. This could also be due to inefficiencies in resource allocation and utilization (Kumbhakar and Lovell, 2000). Efficient allocation of inputs for optimal returns by the intensive farmers would increase profit efficiency. Despite this advantage of extensive systems over intensive systems, extensive dairy production systems may soon or later become unsustainable for most smallholder dairy farmers in Kenya due to the declining land sizes and its competitive utilization for crop enterprises.

Table 15: Efficiency Distribution in Production Systems and Scales

Scale	**Extensive System**		**Intensive System**		**Average Efficiency**	
	Freq	Efficiency	Freq	Efficiency	Freq	Efficiency
Medium	7	0.71	30	0.65	37	0.67
Small	16	0.72	32	0.66	48	0.68
Average efficiency	23	0.71	62	0.66	85	0.68

Source: EADD Survey, August 2012

The study also identified that extension service delivery was significant but contrarily decreased profit efficiency other than increasing. Although extension cost was not significant in the frontier model, the access to extension services that is paid for by the farmer results into increased cost of milk production and eventual decrease in milk gross margins. Table 16 shows that farmers who did not access extension services were more profit efficient than those who accessed. This could have been possible due to farmers experience and knowledge of farm owners and their managers, as well as probable years of schooling (Taru *et al*., 2011 and Adebayo, 2006).

Table 16: Efficiency Distribution among other Socio-Economic groups

Socio-Economic Characteristic	Dummy	Frequency	Efficiency
Gender	Female	29	0.67
	Male	56	0.68
Age below 51 years	No	26	0.64
	Yes	59	0.69
Extension services	No	24	0.71
	Yes	61	0.66
Paid extension services	No	75	0.67
	Yes	10	0.72
Employed labour	No	45	0.72
	Yes	40	0.63
Paid water services	No	77	0.67
	Yes	8	0.71
Paid land services	No	64	0.68
	Yes	21	0.66

Source: *EADD Survey, August 2012*

The study identified that factors such as wage rate, production scale, gender of farm owner, paid extension services and paid water services were not statistically significant in the inefficiency model. Since they are not significant, a further discussions on these variables in explaining inefficiency differentials among the dairy farmers is not important (Taru *et al*., 2011).

4.4 Efficiency distribution among the dairy farmers

It was found that 54% of the dairy farmers were skewed to profit efficiency of more than 70% (Table 17). The least efficient farmer had a profit efficiency of 6.5% while the best farmer had

99% with an overall standard deviation of 0.2524. This indicates that at least half of the dairy farmers in the study area are relatively profit efficient. However a mean profit efficiency of only 68% implies that dairy profits can be increased by 32% if farmers' allocative and technical efficiencies can be improved.

Table 17: Profit Efficiency Indices of Dairy Farmers in Kenya

Efficiency Class Index	*Frequency*	*Percentage*	*Cum. Percentage*
0.00-0.10	2	2.4	2.4
0.11-0.20	3	3.5	5.9
0.21-0.30	3	3.5	9.4
0.31-0.40	6	7.1	16.5
0.41-0.50	6	7.1	23.5
0.51-0.60	8	9.4	32.9
0.61-0.70	11	12.9	45.9
0.71-0.80	14	16.5	62.4
0.81-0.90	14	16.5	78.8
0.91-1.00	18	21.2	100.0
Total	85	100.0	

***Source**: EADD Survey, August 2012*

Table 18 and Table 19 summarize profit efficiency distribution according to Milk Hubs and Milk Domains of the study area respectively. It was observed that the hub with the highest level of profit efficiency was Cherobu with an average efficiency of 82%. The worst hub was Olenguruone with a mean efficiency of 49%. Only 40 percent of the study hubs were able to achieve profit efficiency of greater than 70%.

Table 18: Efficiency distribution of farmers according to Milk Hubs

Milk Hub	*Frequency*	*Efficiency*
Siongiroi	10	0.64
Olenguruone	9	0.49
Metkei	9	0.75
Cherobu	10	0.82
Kabiyet	9	0.68
Tanykina	7	0.58
Taragoon	5	0.56
Olkalou	6	0.72
Sirikwa	10	0.78
Sot	10	0.66

Source: EADD Survey, August 2012

Table 19: Efficiency distribution of farmers according to Category of Milk Domain

Milk Domain Category	*Frequency*	*Efficiency*
1. LMA | LP | LCP	15	0.74
2. LMA | LP | HCP	19	0.57
5. HMA | LP | LCP	15	0.71
6. HMA | LP | HCP	26	0.65
8. HMA | HP | HCP	10	0.82

Source: EADD Survey, August 2012

In terms of milk domains, the best domain in the study area was Domain 8, characterized by high market access, high population and high climatic potential with an overall 82% profit efficiency. This result agrees with expected performance of a perfect market competition where forces of supply and demand drive the level of profits since no single firm is able enough to influence the price of either inputs or outputs. Farmers in such a domain have easy access to markets for inputs and for sale of milk. The many buyers and possibly sellers of inputs, as well as the suitable production climatic conditions of the domain render conducive environment for dairy production hence farmers were profit efficient. The worst domain was Domain 2 (57% efficient) which is characterized by low market access, low population and high climatic potential. The farmers in this domain are likely to face challenges of market accessibility and hence incur high transport costs, consumers are low in number and may drive down milk prices, and scarce labour availability that might be costly employ. These factors possibly eroded the profits of the dairy producers in this domain. However 60% of the domains achieved a profit efficiency of over 70% in general.

The mean profit efficiency of the dairy farmers in the Rift Valley and Central Province of Kenya compared with other studies indicates that the farmers are generally fair in profit efficiency than most of their counterparts in other places, but far weaker than developed country dairy producers. For example, Nganga *et al*. (2010) reported a mean profit efficiency of 60% among dairy farmers in Meru-South Districts in Kenya; Omiti *et al*. (2006) reported a mean efficiency of 82% among dairy farmers in Kenya. Binici *et al.* (2006) reported a mean profit efficiency of 50% among dairy farmers in Burdur province in Turkey. With the increasing competition for resources driving up cost of production among other factors, an average profit efficiency of 68% is an indicator that the farmers are truly lagging below the maximum profit frontier, and far lower than efficiencies of dairy industry leaders in the world whose efficiencies range from 80-98 percent.

CHAPTER FIVE

5.0 Summary, Conclusions and Recommendations

Smallholder dairying is an important economic activity among the mixed crop-livestock farmers in Kenya. The increase in grain prices due to rising demand created by the increasing population is a potential threat to the dairy industry. Land resource use has particularly become competitive for crop enterprises among the farmers. The price increases impacts negatively on milk production costs especially the cost of feeding livestock of the smallholders. If this cost of milk production is shifted to the consumers, they are likely to resort to alternative cheap sources elsewhere in the market, for example imported milk, than consuming locally produced milk. Economic efficiency solutions need to be identified for smallholder dairying in Kenya in the face of the rising production costs. This study explored profit efficiencies of the smallholder dairy producers in Kenya's Rift Valley and Central Provinces, and identified the determinants of profit efficiency of the dairy farmers using SFA estimation procedures. Household cross-sectional data was collected from 85 dairy farmers in the study area. Three months production situation at the farm in the past three months was investigated using structured questionnaires. This was to ensure accuracy in recall by the farmers which is highly unlikely for an entire production year.

The study found that feed resources constituted a major cost component of milk production among the smallholder dairy farmers. A unit volume of milk is produced at a variable cost of KShs 29.2 on average; and of this cost, fodder contributed significantly to the total variable cost. The overall unit total cost of milk production including household labour wage and asset depreciation amounted to KShs 31.5. The resultant unit gross margin, having deducted variable costs from unit revenue, amounted to Kshs 17. However the average net profit after subtracting unit total cost from unit revenue was KShs negative 2, implying that the farmers registered net loss on average.

The average profit efficiency of the smallholder dairy farmers equaled to 68%. The study identified that there was a significantly positive elasticity with respect to cost of fodder produced on farm. The attribute that fodder produced on farm increases profit efficiency is highly encouraged and farmers should continue to utilize this feed option other than purchasing fodder resources elsewhere if there is available land for its production. However, there was significantly negative elasticity with respect to cost of purchased fodder, conserved feeds, water for livestock, milk transport and farm maintenance costs. This means that profit efficiency decreases with respect to unit increase in the cost of these items among the smallholder dairy farmers. The influences of the following cost items in the stochastic frontier model were not significant, namely: breeding, health, extension services, labour, concentrates, grazing and milk given to calves.

In terms of efficiency distribution, 54 percent of the farmers were skewed to a profit efficiency of above 70 percent. The least efficient farm was 6.5 percent while the best was 99 percent profit efficient. There was a high level of variation in profit efficiency among the farmers. It was found that 79 percent of the differences between farmers' actual profit efficiency and the maximum profit frontier was due to inefficiencies in farmers practices.

The socio-economic variables that significantly increased profit efficiency among the smallholder farmers were: land area of the households planted with fodder and land area for grazing cattle. This is due to the reduced variable cost of milk production of these farmers because they are able to get feeds cheaply on farm.

The study found that profit efficiency decreased with age of the farm owner. This is mainly attributed to the higher production costs associated with the elderly farmers especially due to hired labour services used on farm, reduced mobility in participating in farming and in adopting new technologies that are more efficient than the traditional inefficient technologies in which they might be more experienced. It was also found that production system, extension services, hired labour and hired land significantly reduced profit efficiency of the smallholder farmers. Farmers practicing mainly grazing systems were more efficient than intensive systems where costs of feed resources become more prominent in variable costs and therefore less profitable in milk production. Because land sizes are on the decline for most smallholder farmers, improving the economic efficiency of intensive systems in dairy production is the ideal recommendation for milk producers in Kenya. The study identified that factors such as gender, scale of production, wage rates, paid extension and paid water services were not significant at influencing profit efficiency among the smallholder farmers.

With an average of only 68 percent, profit efficiency among the smallholder farmers can be increased by 32 percent if the smallholder farmers' allocative and technical efficiencies can be improved. Efficient production technologies will improve cost optimization of the farmers, as well as output maximization per unit input. Feed technologies commensurate with farmers' local conditions are therefore required as fodder produced on firm has manifested. Institutional policy reforms targeting competitive dairy sector performance approaches are needed so as to expand the productivity and profitability of the smallholder dairy farmers given the boosting growing demand for milk in and outside Kenya.

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APPENDICES

Appendix 1: Kenya Dairy Profitability Assessment Questionnaire

General Information:

Hub	
Respondent Name	
Gender	
Age	
Contact	
Country	
Enumerator Name	
Contact	
Date of interview	
Supervisor	
Date checked	

1. **Indicate the details for cattle kept on the farm in the last 6 months.** ***(NB: Only fill columns where there were any changes since the last visit in case the farm was surveyed during phase 1 of CoP)***

Animal type	**Breed** (codes)	**Number kept**	**Number purchased**	**Number of calves born**	**Number sold or given out**	**Number died**	**Value of cattle sold or given out**
Bulls (≥3 yrs)							
Castrated adult males (≥3 yrs)							
Immature males (< 3 yrs)							
Cows (calved at least once) DRY							
Cows (calved at least once) LACTATING							
Heifers							
Male calves							
Female calves							

	Breed codes			**13=** Ngada
1 =Hostein-Friesian (pure)	**4** = Ayrshire (cross)	**7=** Guernsey (pure)	**10=**Boran	**14=**Nsoga
2 =Hostein-Friesian (cross)	**5** = Jersey (pure)	**8=**Guernsey (cross)	**11=**Local Zebu	**15=**Red poll
3 =Ayrshire (pure)	**6**= Jersey (cross)	**9=**Sahiwal	**12=**Ankole	**16=** Other (specify)

2. **Milk production details:** Indicate details of milk production for **every LACTATING cow**.

	Cow ID	*Breed (use codes)*	*Age of cow (years)*	*Parity Number*	*Age at first calving*	*Calving interval (months)*	*Last calving date*	*Lactation length (months)*	*TOTAL DAILY MILK PRODUCTION (litres)*			
									Start of lactation		*Yesterday*	
									am	***pm***	***am***	***pm***
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

	Breed codes			**13=** Nganda
1 =Hostein-Friesian (pure)	**4** = Ayrshire (cross)	**7=** Guernsey (pure)	**10=**Boran	**14=**Nsoga
2 =Hostein-Friesian (cross)	**5** = Jersey (pure)	**8=**Guernsey (cross)	**11=**Local Zebu	**15=**Red poll
3 =Ayrshire (pure)	**6**= Jersey (cross)	**9=**Sahiwal	**12=**Ankole	**16=** Other (specify)

3. **What is the main system for keeping cattle (tick)?**

Mainly grazing (Free range or tethered) ☐ Mainly grazing with some stall feeding ☐
Mainly stall feeding with some grazing ☐ Mainly stall feeding ☐

4. **Milk utilization details(morning milk and evening milk)**

Indicate details on fresh milk utilization on an average day in the last 3 months

Fresh milk usage		Quantity per DAY (Litres)	Net Price per litre	Total value	Mode of payment	Who transported	Cost of transport
Milk sold to different buyers	**Chilling Plant**						
	Individuals						
	Private traders						
	Others						
Milk consumed							
Milk given out							
Milk given to calves							
Milk loss due to spoilage							
Mode of payment 1 =Cash daily 2=Cash at month end		**Who transported** 1= Farmer 2 = Hired transport, organised by farmer					

3= Bank 4= SACCO (***linked to Hub)/Village bank/FSA*** 5= other, specify	3 = Hired transport, organised by CP or DFBA 4= other, (specify)_________		

5. Have you sold **manure for the last three months?** [___]=YES [___]=NO **If no** skip to **Q7**

   If yes, what is the value of the sale? [_____________] (Local currency)
6. Have you **employed labour** for cattle activities in the last **three months?**

   [___] = YES [___] = NO **If No,** skip to Q8.

   If Yes, provide details on labour used on farm in the last 3 months.

	Name of labourer	Monthly wage	Activities engaged in (use codes)	Average proportion of a working day dedicated to each activity code
1				
2				
3				
4				
5				
6				

Farm activity codes:
1= Crop production 2= Cattle management (other than grazing or watering) 3= Fodder/feed related activities
4= Watering livestock 5=Grazing cattle 6= All 7= Other (specify)____

7. ***Household labour for livestock production***

Give details on **household members** who participate in **routine** cattle activities in the last **three months**

Activity	Male =1 Female=2	Average hours spent on cattle activity per day

Activity Code
1= Cut and carry fodder/feed **2=** Grazing **3=** Watering **4=** Milking **6=** Treatment **7=**Security **8=**Others **(**specify**)**_____________

8. Have you rented land for grazing cattle &/or growing feed/fodder in the last **three months**?
   Yes [___] No [___] **If No** skip to **Q10**
   If yes what is the approximate size of the land? [___] **Acres** or [_______] **Hectares**

   If yes, how much per month [____].
9. Have you paid for livestock water in the last **three months**? Yes [___] No [___]
   If Yes how much do you pay per month [______]

10. Give details on Fodder/forage **production** and **purchase**

	Indicate **quantity** and **cost** of feed produced and purchased for the last **three months**									
	Produced Feed	**Purchased Feed**								
	Acres/hectares planted (include hired land)	**Quantity**	Unit	Price per unit	Transport cost	Labour cost	Other cost	Total cost	Where purchased (**Codes**)	Payment mode (**Codes**)
Napier										
Hay										
Cut grass										
Green										
Dry cereal c										
Other										

Units	**Where Purchased**	**Payment mode**	
1 = Tons **2** = Stands or Bales **3** = Hand cart or wheelbarrow load **4** = Other(specify)________	**1**=Individual farmer **2**=Shop/agrovet **3**=Trader **4**=Others(specify)_____	1 =Cash daily 2=Cash at month end 3= Bank 4= SACCO (***linked to Hub)/Village bank/FSA*** 5= other, specify	

11. Give details on **Commercial feed**s **and cost**

	Indicate quantity and value of each feed for the last **three months**								
	Quantity	Unit	Price per unit	Transport cost (**Total**)	Labour cost (**Total**)	Other costs (**Total**)	Total cost	Where purchased **(Q10 codes)**	Mode of payment (**Q10 codes**)
1 = Dairy meal									
2 = Maize bran									
3 = Wheat bran									
4 = Maize germ									
5=Other (specify)__									
Units 1 = Kgs 2 = Standard sacks (specify Kgs)__________3 = Tons 4= Other (specify)________									

12. Have you conserved feed in the last three months? Yes [___] No [___]**If No** skip to **Q14**
If yes which type of conservation (codes) [____][____][____][____]

Provide details on **cost of conserving the major feed**

	Hay [1= baled 2=standing 3=other (specify) ______]		**Silage[1=tube 2=pit 3=above ground 4= other (specify)____]**	
Type (codes)				
Feed, specify (e.g. Lucerne, Rhodes, napier, maize)				
Unit(codes)				
Quantity				
Cost of gathering feed				
Total cost of harvesting/baling				
Total cost of handling (**labour**)				
Total cost of transport				
Total cost of processing				
Any other cost (specify)_______________				
Cost of materials and equipments for packaging/storage				
Storage material: 1_________________________				
2_________________________				
3_________________________				
Total Cost of transporting packaging materials				
Total Cost of additives e.g. molasses: 1_________________				
2_________________				
3_________________				
Total cost of handling (**labour**)				
Cost of maintaining the store				
Any other cost (specify)________________				
Utilization				
Quantities of the final products (**use same unit as above**)				
Quantity **fed** to cattle				
Quantity **sold**				
Value of feed **sold**				

Unit codes	**Storage materials codes**
1= Kgs 2= Tons 3= Standard sack 4= wheelbarrow load or hand cart 5= Pick-up load 6= Donkey cart load 7= Bales 8= Other (specify)	1 = bags 2 =silage paper 3=containers 4 = Tanks 5 = Other (specify)

Conservation Codes
1 = Tube Silage
2 = Above the ground
3 = Pit silage
4 = Box baling
5 = Machine baling
6 = Standing hay
7 = Stacking under shade
8 = Stacking in the store___________
9= Other (specify)______

13. Provide details on the following machines and equipment that household owns

Equipment	Number owned	Year purchased	Purchase price	% utilization in dairy activities for those used in other enterprises
Milking machine				
Milking buckets				
Milk churn(cans)				
Chaff cutter				
Bush knife				
Wheel barrow				
Bicycle				
Knapsack sprayer				
Others(Specify)__				

14. Provide details on animal health and breeding services that you have used in the last **three months**

Type of service/ treatment	Have you used for the last 3 months? **1**=Yes, **0**=No	**If yes,**		
		Who provided the service	**Total cost** (local currency)	**Mode** of payment
Anthelmintics (deworming)				
Vaccination				
Tick control				
Curative treatments				
Milking salve				
Teat disinfectant				
AI services				
Bull services				
Dehorning				
Other (specify) _______				

Service provider	**Mode of payment**
1 = Government/NAADs **2** = Private practitioner, independent 3= Private practitioner, **4** = Cooperative/ DFBA **5** =Farmer **6** = NGO, specify name **7** = Others (specify)____________	1 =Cash daily 2=Cash at month end 3= Bank 4= SACCO (***linked to Hub)/ Village bank/FSA*** 5= other, specify

15. Indicate the cost of livestock extension services including **training** events and **exchange** visits

Livestock extension service providers	**Number of visits in last 3 months**	**Cost in the last three months**	**Mode of payment (*codes in 17*)**
Government			
Private Practitioners			
DFBA/Cooperative/ farmer group			
Others, specify:__________			

16. Has anyone in the household obtained loan for dairy activities in the last **3 months**? Yes [ ] No [ ]
If No skip to Q18.
If **yes** give these details

Credit need	Source	Amount	Form of credit 1= Money 2= materials 3=Both	Monthly interest charged on loan in the last 3 months

Credit needs	**Credit Source**	6= Self Help Group
1=Purchase animals	1= Government agency/bank	7= SACCO (***Linked to Hub***)
2=Purchase feeds	2= commercial banks	8= Others (specify)______
3=Veterinary service	3= Informal lenders	
4=AI services	4=Cooperatives	
5=Shed expansion	5= NGO	
6= Other(specify)_________		

17. Do you keep cattle in a housing premise? [___] = YES [___] = NO **If No** skip to **Q19**
Provide details on **cost** of these building materials used in construction **including expansion**

Materials	Cost of dairy shed zero-graze unit (Local currency)	Cost of Boma or paddock (Local currency)
Wood		
Cement/Stone/Sand		
Thatch		
Iron sheets		
Nails		
Fences		
Labour		
Transport		
Others		
Total cost		
When was it built (**year)**		
Maintenance costs (past 3 months)		

18. Do you have any other cattle enterprise structure separate from shed [___] = YES [___] = NO

Structure	Total Construction Cost	Year Built	Annual Maintenance cost
Feed stores			
Biogas plant			
Other (specify)_________			

If you have Bio gas plant what is the approximate cost of fuel saved ***per month*** [_________]

THANK YOU

Appendix 2: Cattle inventory records of surveyed households in the past three months

Animal type	*Current herd size*	*Purchased*	*Calves Born*	*Cattle Sold*	*Deaths*
Bulls (>3yrs)	14	1	0	6	0
Castrated bulls	22	1	0	4	1
Males (<3yrs)	22	1	0	4	0
Cows (dry)	54	5	0	5	2
Cows (lactating)	109	16	0	6	5
Heifers	75	3	0	5	2
Male calves	50	0	23	6	3
Female calves	63	2	33	3	5
Overall	**409**	**29**	**56**	**39**	**18**

Source*: EADD Survey, August 2012*

Appendix 3: Cattle mortality rates of households in the past three months

Animal type	*NAR*	*Deaths*	*Mortality rates*
Bulls (>3yrs)	16.5	0	0.0
Castrated bulls	24.0	1	4.2
Males (<3yrs)	23.5	0	0.0
Cows (dry)	55.0	2	3.6
Cows (lactating)	106.5	5	4.7
Heifers	77.0	2	2.6
Male calves	43.0	3	7.0
Female calves	49.5	5	10.1
Overall	***395.0***	***18***	***4.6***

NAR = Number of animals at risk ***Source****: EADD Survey, August 2012*