

**EVALUATION OF MILK PRODUCTION EFFICIENCY
OF DAIRY FARMS IN EMBU AND MERU COUNTIES,
KENYA**

By

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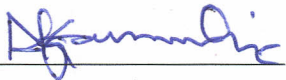
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**A RESEARCH THESIS SUBMITTED TO THE SCHOOL OF
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KENYATTA UNIVERSITY**

MARCH, 2014

DECLARATION

I, David Kimenchi Mugambi, declare that this thesis is my original work and has not been presented for the award of a degree in any other university or any other award

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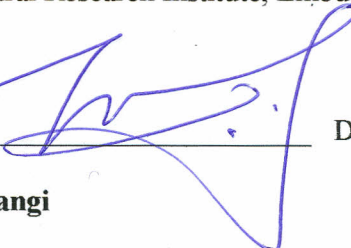
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DEDICATION

To

My wife

Josephine Nguta Mugambi

And

Our children

George Bundi and Sharon Kathure

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ABBREVIATIONS AND ACRONYMS

ASDS – Agricultural Sector Development Strategy

CE-Cost Efficiency

CES-Constant Elasticity of Substitution

COMESA- Common Market for Eastern and Southern Africa

CP-Crude Protein

DEA-Data Envelopment Analysis

DFA-Distribution Free Approach

DLPO-District Livestock Production Officer

DVO-District Veterinary Officer

EAC- East African Community

EADD-East African Dairy Development

E & SA- Eastern and Southern Africa

FAO- Food and Agricultural Organization

FAOSTAT- Food and Agricultural Organization's Statistics

FDH-Free Disposal Hull

FIAS- Foreign Investment Advisory Services

GDP- Gross Domestic Product

GoK- Government of Kenya

ICIPE- International Center for Insect Physiology and Ecology

ICRAF- International Center for Research in Agro-Forestry

IFC-International Finance Corporation

IFCN-International Farm Comparison Network

ILRI-International Livestock Research Institute

ISI-Import-Substitution Industrialization

KARI-Kenya Agricultural Research Institute

KCC- Kenya Cooperative Creameries

Kg- Kilogram

MLE-Maximum Likelihood Estimate

MoLD-Ministry of Livestock Development

MoSPND-Ministry of State, Planning, National Development and Vision 2030

MPO-Milk Producer's Organization

NKCC-New Kenya Cooperative Creameries

NALEP-National Agriculture and Livestock Extension Programme

PDLP-Provincial Director of Livestock Production

RoK- Republic of Kenya

RTS>Returns to Scale

SD-Standard Deviation

SDP- Smallholder Dairy project

SFA- Stochastic Frontier Analysis

SHT- Southern Highlands of Tanzania

SPSS- Statistical Package for Social Sciences

TE-Technical Efficiency

TFA-Thick Frontier Approach

US- United States

WHO- World Health Organization

ABSTRACT

Despite Kenya's long dairy farming history spanning about 100 years, favourable climatic conditions and a 3.5 million national herd, milk per capita consumption is low (76.7 kg) and export quantities (milk) to the regional market where its products enjoy preferential access are negligible. These observations raised the question of farm level milk production efficiencies. This study evaluated milk production efficiency of dairy cow farms in Embu and Meru counties of Kenya, using the stochastic frontier approach. Data were randomly collected from 135 dairy farms and were supplemented with information from other dairy industry stakeholders. The sample size was determined using the Cochran's (1977) formula. Data were analyzed using the SPSS, Frontier 4.1 c and STATA computer softwares, where both descriptive and inferential statistics were derived. Stochastic frontier production and cost functions were estimated using the maximum likelihood estimation technique. The farms were characterized and both technical and cost efficiencies estimated. Each of the efficiencies was then related to milk production cost to establish the cost reduction potential. Results revealed that the number of lactating cows and the amounts of roughages, concentrates, and mineral supplements were the major factors influencing milk output, while the prices of roughages and labour were the major factors associated with the total production costs. The dairy animals received inadequate feeds and mineral supplements. The animals were overstocked and underfed in an average two-acre mixed crop-livestock farm. The mean farm technical and cost efficiencies were 83.7 and 95.6%, respectively, and therefore inefficient. These results implied that milk production could be increased by 16.3% through better use of available resources given the current state of technology without extra cost, while its cost could be decreased by about 4.4% without decreasing output. The milk production model coefficient was 2.11. It was shown that roughage and labour could substitute for one another to reduce dairy farming costs. Optimization of farm efficiencies and taking advantage of economies of scale through increased production inputs could be part of short-term measures to address the challenges facing smallholder dairy farming. It was recommended that farmers specialize in either dairy or crop farming. Those choosing dairying, require shifting from the Friesians and Ayrshires to the smaller dairy breeds such as Jerseys, for they require less feed quantities in milk production. The researchers require identifying the least-cost combination ratio for roughages and labour inputs. The policy makers should provide legal guidelines to ensure that sub-division of agricultural land is minimized and further, promote both enterprise specialization and approaches that make the farm inputs such as concentrates and mineral supplements affordable.

Key words: Technical and cost efficiency, stochastic frontier, smallholder dairy farming

CHAPTER ONE: INTRODUCTION

1.1 Background

Livestock provides over half the value of global agricultural output and its increased promotion is pressing given the rapidly growing demand for animal products (Moran, 2009). Global milk demand is growing by 15 million tons per year, mostly in developing countries driven by population growth and rising incomes. This offers the dairy sector opportunities for income generation and improved nutrition (Staal and Kaguongo, 2003; Moran, 2009). It is estimated that around 150 million smallholder dairy farming households are engaged in milk production, the majority of them in developing countries (FAO, 2010a). This implies that making smallholder dairy farming more competitive would be a powerful tool for reducing poverty (FAO, 2010b); a major opportunity for the world's poor people.

As the liberalization of world trade continues and the international competition for markets accelerates, dairy farmers must consider their competitiveness (Roche and Newman, 2008). At the moment, the low productivity and relatively high dairy input costs increase milk production costs (Schantz, 2006), thus reducing its market competitiveness when compared with milk from other countries. There is a felt need therefore, for smallholder dairy farms to assess and improve their milk production efficiency levels with a view to enhancing their product's market access.

The period between 2000 and 2009 saw the annual global milk production growth average 2%, while the African region average was 3.7%. Kenya's growth was only 1.4% over the same period (FAO, 2005). Kenya's dairy sub-sector spans about a century and ranks among the largest in sub-Saharan Africa (Ngigi, 2004). The national herd size is approximately 3.5 million (MoSPND, 2009). The sub-sector accounts for about 3.5% of the National GDP and contributes to the livelihoods of about four million Kenyans through food, income and employment (Omiti *et al*, 2006). The stated government policy in the national food policy and the Kenya dairy development policy is to maintain a position of broad self-sufficiency in food crops, milk and meat production. The policy further seeks to establish reserve stocks that will ensure both the security of food supply and an equitable distribution of foodstuffs to each section of the community.

Despite the apparent positive status of dairy farming in Kenya, various indicators show that the sector is under performing. South Africa, a country whose dairy herd size averages 0.5 million, produced about 3 billion kg of milk in 2009, while Kenya's herd of 3.5 million managed about 4 billion kg (Wambugu and Kirimi, 2010). With the same yield proportionality, Kenya would have produced over 20 billion kilograms. Unfortunately Kenya's per cow yield has remained at an average of 6 kg over the last 30 years (MoLD, 2010). The country's per capita milk consumption is about 76.7 kg, while the WHO's recommendation is 200 kg (FAO, 2007). The surplus milk in Kenya would access the regional market where the country's products enjoy

preferential treatment. This is mainly through benefits bestowed to the members of the regional trade blocks such as East African Community (EAC) and Common Market for East and Southern Africa (COMESA) (RoK, 2007). The amount of Kenyan milk sold to this market is however, negligible.

Various studies on diverse aspects of dairy farming have been carried out to understand the status of milk production and marketing in Kenya, with a view to increasing the capacity to tap into the existing market opportunities. Some of the areas covered by past studies include: production systems (Bebe, 2003); genetics (Kahi *et al*, 2004); nutrition (Ongadi *et al*, 2006); farm-level milk production (SDP, 2006; Gamba, 2006; Baltenweck, 2006; Kimenju and Tschlerley, 2008); smallholder dairy profitability (Omiti *et al*, 2006) and farmers' adoption of production technologies (Makokha *et al*, 2007).

What is notable from the above scenario is that Kenya has failed to take advantage of its large dairy herd to raise its per capita milk consumption and increase sales to the milk deficient regional markets. Although many recommendations were made from previous studies, the required gains have not yet been made. There is therefore need for better understanding of the production efficiency of dairy farms in the country, which is the focus of this study.

1.2 Statement of the Problem

Available evidence suggests existence of dairy farming inefficiencies in Kenya. Compared to other countries with similar grade of dairy cows, Kenya's

yields are low and costs per unit of production high. This problem of low milk quantities and its high production costs has persisted despite the many recommendations (Bebe, 2003; Kahi *et al*, 2004; Ongadi *et al*, 2006; Omiti *et al*, 2006 and Staal *et al*, 2008). This negative situation has led to decreased milk demand and therefore low consumption. Were the country to double its milk production and lower costs, the recommended per capita consumption would still not be achieved, let alone the leaving enough for export. Reviewed literature indicated a gap in the knowledge on the actual level of efficiency of dairy farms in Kenya. This study, therefore, attempted to address this by estimating the level of efficiency of smallholder dairy farms in Kenya.

1.3 Study Objective

The broad objective of this study was to evaluate milk production efficiency of dairy cow farms in Embu and Meru Counties of Kenya.

The specific objectives were:

- i. To characterize dairy cow farms in Embu and Meru Counties of Kenya.
- ii. To determine the technical and cost efficiencies of dairy cow farms in the study areas.
- iii. To determine the potential reduction in milk production costs through optimized efficiencies.

1.4 Research Questions

The study analyzed the following questions:

- i. What are the inherent characteristics of dairy cow farms in Embu and Meru Counties of Kenya?
- ii. What are their technical and cost efficiency levels?
- iii. What factors determine technical and cost efficiencies among dairy farms in the study areas?
- iv. To what extent can increased dairy farm production efficiencies lower the cost of milk production?
- v. How does the potentially reduced cost of milk production relate to the prices of raw milk offered in the market?

Hypotheses

Hypothesis 1: Dairy farms in Embu and Meru counties are technically efficient. $H_0; u=0$, the null hypothesis specifies that each farm is operating on the technically efficient frontier. This is rejected in favor of the presence of inefficiency effects.

Hypothesis 2: Dairy farms in Embu and Meru counties are cost efficient. $H_0; u=0$, the null hypothesis specifies that each farm is operating on the cost efficient frontier. This is rejected in favor of the presence of inefficiency effects.

1.5 Significance of the Study

Motivated by the desire to contribute to the consolidation and maximization of the dairy farming gains, many researchers have carried out many studies (Kimenju and Tschery, 2008; Ongadi, 2006; Gamba, 2006; Baltenweck, 2006 and Omiti *et al*, 2006) and yet indications are that the country has not

optimized on the dairy sub-sector's potential. This study was carried out to partly answer the question on how well the dairy farmers were allocating and utilizing inputs in the farm, and partly determine the socio-economic characteristics that influence that managerial ability, with the view to providing further information on how to optimize farm productivity. Efficiently produced milk is more affordable and more competitive in both the local and external markets. The results from this study will contribute to:

- i. Broadening the understanding of dairy industry stakeholders on the dairy farming efficiency levels and options for improvement.
- ii. Providing a basis for the formulation, implementation, and evaluation of policies and programmes focused on the improvement of the dairy sector.
- iii. Informing public and private extension service providers, the agri-based learning institutions and the Agricultural Sector Development Strategy (ASDS) document.
- iv. Enriching available literature on dairy farming and identifying opportunities for further research.

1.6 Assumptions

The assumptions of this study were that the smallholder dairy farmers would faithfully respond to the questionnaire items and that they would be able to recall some past occurrences related to their farming operations where records were not available. The next one was that no external factors such as floods and disease incidences would occur during the survey period leading to

an increase on the operational costs. The next assumption was that the milk producers are capable of and the support institutions are willing to partner to increase milk production efficiency through provision of services and financial resources. The last assumption was that the infrastructure and business environment will continue to entice producers to increase their herds' productivity.

1.7 Scope of the Study

This study focused on the milk production efficiency, specializing in dairy farms characterization, both technical and cost efficiencies of the farms, and determination of how low the cost of milk production could decrease in a potential case of optimized efficiencies. The study population constituted of dairy cow farms in Embu East and Igembe South Districts in Embu and Meru Counties of Kenya, respectively.

1.8 Theoretical and Conceptual Framework of the Study

1.8.1 Theoretical Framework: Production Efficiency Measurement

Production is the process of combining materials and forces to create goods and services (Beattie and Taylor, 1985), while the production process efficiency is indicated by what a decision making unit produces relative to what it could feasibly produce (Hoyo *et al*, 2004). Producers are hardly fully efficient. The estimation of production efficiency has remained an area of research in developed and developing countries and particularly more important for developing countries where potentials to increase agricultural production through enhancing cultivated area and developing and adopting

new technology are very limited (Kibaara, 2005). Farrell (1957) made the first attempt to measure productive efficiency empirically, and following the works by Koopmans (1951) and Debreu (1951), he defined cost efficiency and then decomposed it into its technical and allocative components.

1.8.1.1 Efficiency Measurement Approaches

Various approaches have been applied to measure production efficiencies. The main ones include the average production function and the frontier production function approaches. The average production function approach has been used extensively in traditional agriculture to measure resource allocative efficiency. Estimation of an average function (using ordinary least squares approach) only reflects the technology set employed by an average firm (Haghiri, 2003). This approach however, has been criticized for among other reasons, not distinguishing between allocative and economic efficiency because it ignored the technical efficiency of the farmers (Ghatak and Ingersent, 1984).

(i) Frontier Production Function Approach

Since Farrell's original work in 1957, the frontier methodology has been extensively used in applied production analysis. Frontier models developed on Farrell's work can be classified into two broad categories: Parametric and Non-parametric frontiers. Parametric frontiers rely on a specific functional form and can be classified into deterministic frontier and stochastic frontier. The frontier is referred to as deterministic if all the observations lie on or below the frontiers and stochastic if observations can be above the frontier due

to random effects (Hassan, 2004). Parametric techniques are regression-based approaches in general.

The main benefits that result from estimating frontier functions are; first, when a frontier function is estimated, the result is strongly influenced by the best performing firm, and therefore the frontier reflects the technology set that the most efficient firm employs. Second, frontier functions provide a useful performance benchmark. These functions normally represent best practice technology, against which the efficiency of other firms within the industry can be measured. It is for this reason that frontier estimation continues to attract attention in the empirical economics literature (Haghiri, 2003). In addition, unlike the non-frontier models, a frontier model can provide firm specific efficiency measures to the researcher. Another advantage of the frontier methodology is that the word 'frontier' is consistent with the theoretical definition of a production, cost, and profit function, i.e., a solution to a maximum and minimum problem (see, Bravo-Ureta and Pinheiro, 1993).

(ii) Deterministic Frontier Production Approach

In a deterministic production frontier model, output is assumed to be bounded from above by a deterministic (non-stochastic) production function. However, the possible influence of measurement errors and other statistical noise upon the shape and positioning of the estimated frontier is not accounted for. In other words, deterministic models assume that any deviation from the frontier is solely due to inefficiency (Greene, 1993; Haghiri, 2003; Zaimova, 2011); therefore, they are very sensitive to outliers.

1.8.1.2 Stochastic Frontier Production Function

Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) independently proposed a stochastic frontier production function with a two-part “composed” error term. Stochastic frontier production models use a composed error structure with a one sided component and a two sided symmetric term. One-sided component indicates technical/cost inefficiency effects associated with technical/cost inefficiency of a firm while two-sided component accounts for measurement errors in production and other random effects which are not under management control.

Stochastic frontier production approach was used in this study. The approach was chosen on the basis of the variability of dairy production, which is attributable to climatic hazards, physiological health and insect pests, on the one hand, and, on the other hand, because information gathered on production is usually inaccurate since small farmers do not have updated data on their farm operations. The parametric approach makes it possible to estimate a frontier function that simultaneously takes into account the random error and the inefficiency component specific to every farm.

Non parametric models are based on mathematical programming techniques. The approach assumes that random error is zero so that all unexplained variations are treated as reflecting inefficiencies. The efficiency of a firm is measured relative to the efficiency of all the other firms subject to the restriction that all firms are on or below the frontier (Mbaga *et al.*, 2003).

1.8.2 The Conceptual Framework of the Study

Literature (MoLD, 2010) indicates that Kenya's per cow milk yield is relatively low compared to the animals' genetic potential and the per capita (milk) consumption less than the recommended amount. The amount of Kenyan milk offered in the other East African countries has been low in quantity terms, though its products enjoy preferential market access under regional trade agreements.

The conceptual framework developed for this study show the linkages between both the causes and the effects of both low input allocation and low milk production efficiency. To clarify on the existing scenario, factors such as inflation, weather conditions, poverty levels, animal diseases, status of the road net work, market access and the increasing human population are linked. Low farm milk yields are conceptualized as resulting from low inputs into the dairy enterprise and low milk production efficiency. The low inputs are visualized as being partly related to small farm land sizes, high input costs, and inadequate information by the farmers. The region's high and increasing population implies decreasing land size per person, thus less land committed to production of dairy feeds.

The unmatched increase disparity in the number of livestock farms against a constant number of livestock extension staff implies low extension staff to farmer ratio. Other factors suspected to influence farming efficiency include farmer education level, dairy farming experience, attendance to business related course(s) and membership to local common interest groups that may be

helpful in passing information about dairy farming, among other important life aspects

cost, making milk expensive and unaffordable to many potential buyers. Such milk would also not compete in terms of cost leadership in any market, at a time when markets are liberalized. Figure 1.1 provides the conceptual framework.

1.9 Operational Definition of Terms

Allocative efficiency can be defined as the ability of a firm to utilize the cost-minimizing input ratios or revenue-maximizing output ratios. A firm is allocatively efficient if it uses the optimal combination of inputs with respect to their prices.

Cost efficiency is derived from a cost function in which the variable, cost, depends on price of variable inputs, quantity of outputs, random errors and (in) efficiency. Cost efficiency shows how far the firm's cost relative to its best practice cost is.

Dairy cattle comprise pure and cross-bred dairy cattle that can produce milk for consumption and/sale.

Efficiency refers to how well or how effectively a decision making unit combines inputs to produce an output.

Extension (advisory service) is a series of embedded communicative interventions that are meant, among others, to develop and/or induce innovations which supposedly help to resolve problematic situations (Leeuwis and Ban, 2004).

Evaluation is the assessment of the status of both the technical and cost efficiencies levels of dairy cow farms.

Milk yield is the amount of milk produced by a cow or a cow herd in a dairy farm.

Technical efficiency of a farm refers to the ratio of actual to best practice (or “frontier”) production (De Koeijer *et al*, 2002).

CHAPTER TWO: LITERATURE REVIEW

2.1 An Overview of Dairy Farming

Globally, agriculture provides a livelihood for more people than any other industry, with livestock providing over half the value of the output. Livestock contributes to rural livelihoods through employment and poverty relief by integrating with and complementing crop production (Moran, 2009). The entire cattle population in the world in 2005 was approximated 1 372 million heads (FAOSTAT, 2010). A large proportion of the cattle population constitute of dairy animals. The dairy sector plays an economically important part in the agriculture sector in most industrialized and many developing countries. Global dairy trade is currently dominated by EU (27%), New Zealand (26%), Australia (13%) and USA (8%) in quantity terms (Wambua and Miencha, 2007).

According to Staal *et al.* (2007), milk production in developed countries is commercialized, industrialized, practiced under large-scale production systems and has integrated marketing systems. They described milk production in most developing countries as being traditional and small-scaled subsistence farming; having multiple objectives, with low input and outputs and having nutrient deficits in both farm and household. They added that milk marketing system in developing countries has diffuse market structure; consisting of many small-scale market agents, artisanal processing, labour-intensive

handling and transport methods, great diversity in market behaviour and roles, and no voice in dairy sector policy making.

Smallholder livestock keepers represent almost 20% of the world population and steward most of the agricultural land in the tropics (McDermott *et al.*, 2010). It is estimated that there are about 150 million small-scale dairy farming households globally, majority of them being in developing countries. Growing consumer demand for dairy products in developing countries, driven by population growth and rising incomes, offers important market opportunities for smallholders (IFCN, 2009). It has been estimated that annual consumption of milk and dairy products in developing countries will more than double (i.e. from approximately 168 to 391 million tonnes) between 1993 and 2020 (Thorpe *et al.*, 2000).

**Table 1.1 Per Capita Consumption of Milk by Region – 1987 and 2007
(Kg/Capita/Year)**

Region	Per capita consumption		Annual Growth (percent)
	1987	2007	1987-2007
Developed	208.7	213.7	0.1
Developing	37.5	55.2	2.0
Sub-Saharan Africa	31.4	30.2	-0.2
World	77.9	84.9	0.4

Source: FAOSTAT.

The smallholders however, are affected by trade liberalization which increasingly exposes them to competition from large-scale corporate dairy enterprises that are able to respond more rapidly to changes in the market environment (FAO, 2010). Dairy consumption levels in developed countries are constant or falling. Dairy enterprises operating in these developed countries are facing limited market growth opportunities in volume terms as per capita consumption levels are already among the highest in the world (table 2.1). Due to these limited opportunities in those countries, multinational dairy companies are often attracted by strong market growth potential in developing countries (Knips, 2005).

Making smallholder dairy production more competitive could be a powerful tool for reducing poverty, raising nutrition levels and improving the livelihoods of rural people in many developing countries (FAO, 2010). If organized, small-scale milk producers have the potential to compete with large-scale and capital-intensive farming systems in developed and developing countries (IFCN, 2009).

Table 2.2: Milk Production by Region (Million kilograms)

Region	2000	2005	2007	2008	2009	Cumulated Annual growth 00/09
World	491948	547371	572487	584164	587446	2.0 0%
Africa	19629	23470	27020	27199	27223	3.70%
Kenya	-	3455	3736	3885	4040	1.4%

Source: International Dairy Federation; World dairy situation, 2010 (Brussels, 2010).

In between the years 2000 and 2009, the annual global growth in milk production averaged 2% while Africa's growth was higher at 3.7% (table 2.2). Over the same period however, annual milk production growth rate in Kenya averaged 1.4% as compared to 9.2% experienced between 1980 and 1990 (FAO, 2005a).

2.1.1 Dairy Farming in Africa

The countries that produce and process most milk in Africa are Egypt, Kenya, South Africa, and Ethiopia. (de Vries, 2012). Milk production in Africa is far below demand. A large part of the continent, local production is not high enough to meet consumer requirements; countries turn to imports. In urban African markets, a large part of available dairy products, and above all skimmed milk powder, are imported from Europe (Sers, 2010). African demand for milk has seen a large increase due in part to growing urbanization. In the continent, both urban and rural populations are growing. Across all regions with large numbers of smallholder farmers, rural land holdings are contracting in size, a trend contrary to that in the Americas over the last century, where farm sizes grew as rural populations fell. Smallholder livestock production on mixed crop–livestock farms remains dominant in the Sub-Saharan Africa region (McDermott *et al*, 2010). Poorly functioning markets, weak domestic demand, and lack of export possibilities are major constraints to Africa's dairy growth prospects (Diao and Hazell, 2004).

In sub-Saharan Africa, animal products account for 25% of the value of all agricultural products, and of this, milk accounts for 46%. Livestock thus

sustain the employment and income of millions in sub-Saharan Africa, 70% of who are rural based (Winrock International, 1992). It is anticipated that as African economies grow and diversify, more rural people will migrate out of livestock production and other forms of agriculture and the remaining smallholder systems will consolidate, specialize and become more commercialized (McDermott *et al*, 2010).

In South Africa, declining producer prices coupled with increasing production costs, resulted in a significant number of farmers leaving the industry. This resulted in shifts in the important production regions and huge improvements in technology, which led to changes in management systems, cost structures, number of cows in herd and production per cow. The average milk producer now produces 17.3 kg per cow per day (MPO, 2010). Mkhabela (2011) concludes that the survival of the dairy farmer hinges on becoming cost efficient and having more business acumen which requires technical efficiency. The picture painted by this literature on the South African dairy industry mirrors what the Kenyan dairy sub-sector may have to bear with in the near future, because just like in South Africa, producer prices in Kenya remains unchanged as the production costs are constantly increasing.

2.1.2. Dairy Farming in East Africa

According to Ngigi (2004), Eastern Africa is one of the world's most important regions for smallholder dairy development. The region is predominantly rural, with over 80 per cent of its inhabitants deriving its

livelihood heavily from agriculture. It holds over 40% of Africa's cattle resource of about 222 million.

Dairy animals in East Africa may be genetically improved indigenous cattle, crossbred or exotic dairy cattle. Reliable supply of improved animal genetics is a major barrier to increased smallholder dairy production and sustainability across East Africa. Very few systems exist for the supply of either improved indigenous cattle breeds or for artificial insemination (AI) to provide cross-bred cattle (McDermott *et al*, 2010).

Dairy markets in East Africa are largely informal, with the high transaction costs being part of the barriers. Simply imposing a formal milk market model (required chilling and pasteurization) is likely to succeed only in urban areas. Upgrading the capacity, practices and standards among informal market players is likely to improve performance, lowering transaction costs and greatly improving market performance (Kaitibie *et al*, 2008). The quantity of milk produced in the East African region is lower than demand.

2.1.3 Dairy Farming in Kenya

The modern dairy industry in Kenya can be traced back to the beginning of the 20th century, with the introduction of exotic dairy breeds by European settlers and subsequent upgrading of local zebu cattle through crossbreeding (Lekismono *et al*, 2006). History shows that the country's dairy industry has evolved through a sequence of four distinct phases:

The first phase; 1900 - 1953, a period that coincided with the early integration of Kenya into expanding world capitalism. Kenya served as a peripheral economy. During this time, the Kenyan dairy industry was dominated by large-scale settlers.

The second phase; 1954 - 1962, a period that coincided with the introduction of import-substitution industrialization (ISI) in the colony and the consequent need to develop large and growing local markets to support the industrialization.

The third phase; 1963 - 1980s, a time that corresponded to a period of greater shifts from large-scale to smallholder dairying and with incremental modifications of dairy marketing policy from a farmer-controlled dairy industry to one tightly controlled by the government. These three phases provide a chronology of events that led to the fourth phase, which run from 1992 to the present time (Ngigi, 2004).

The market liberalization initiatives of the mid-1980s affected marketing of most livestock products, including milk. This partly led to the decline in performance of the Kenya Cooperative Creameries (KCC). With liberalization, marketing was left in the hands of private livestock dealers who were not adequately prepared to respond to the challenges. The poor state of roads and inadequate market infrastructure constrained the development of efficient livestock markets, making the returns to farmers' relatively low (RoK, 2008).

Kenya has more dairy cattle than any other country in Africa; over three million crossbred and grade cows, which is more than the combined total of the rest of Eastern and Southern Africa, including South Africa (SDP, 2006). The country's dairy cattle are estimated at 3.5 million head and are mainly kept in medium-to high-rainfall areas. The key dairy breeds are Friesian, Ayrshire, Guernsey, Jersey and cross-breeds (RoK, 2008). It is widely cited that about 70-80% of milk production comes from smallholders, with the remainder from large commercial farms, estimated at about 5,000 (IFC, 2007).

Several factors, which include the presence of significant dairy cattle populations, the historical importance of milk in the diets of most Kenyan communities and a suitable climate for dairy cattle have contributed to the success of dairy production by smallholders in Kenya (Conelly, 1998; Thorpe *et al*, 2000). Most smallholder farmers however view dairy as a subsistence activity and not as a business. Though dairy is an important source of income, they do not see it as a business where the aim is to maximize income and minimize costs. For many producers keeping cattle is cultural and meets the need for domestic consumption while providing some cash flow (RoK, 2004). Kenya's milk yields at 1800 kg per cow remain significantly below international standards; South Africa and Argentina have yields ranging between 2,500 and 3,500 kilograms per cow per year, while the USA stands at an average of 9,000 kilograms per cow per year (EADD, 2008).

Livestock feed costs in Kenya account for between 60-80 percent of the production costs depending on the intensity of production. Comparatively,

even where production systems (production approaches in the developed world) are advanced, the cost of feeds still account for more than 50% of the total production costs. This proportion means that other necessary additional inputs into the production system (labour, breeding, power, water, medication and services) contribute relatively low to the total cost. The cost of commercial feeds is of great concern to all the stakeholders in livestock sub-sector. High feed costs affect competitiveness of Kenya's livestock products in the international market (RoK, 2008).

Cost control is an issue at the foundation of this industry. Farmers lack the knowledge or business skills to measure their costs per kilogram of milk produced. Benefits of additional feed or animal care are rarely examined in the context of increasing yields. Farmers rely on cash flow from the informal milk markets whose flow cannot sufficiently allow for investment in production (EADD, 2008).

Strong research and extension institutions are pertinent for enhancing competitiveness in the livestock industry and increasing livestock productivity. Currently, most of the livestock related research and technological development in the country is funded by the Government mainly through KARI and public universities. Other institutions which undertake livestock research include the International Livestock Research Institute (ILRI), the International Center for Insect Physiology and Ecology (ICIPE) and International Center for Research in Agro-Forestry (ICRAF). The Ministry of Livestock Development is the main provider of livestock

extension services. Other providers include agro-veterinary pharmaceutical companies, animal feed manufacturers, milk processors, Non-Government Organizations and Community Based Organizations (RoK, 2008).

Since the year 2000 annual milk growth rate in Kenya has averaged only 1.4% as compared to 9.2% experienced between 1980 and 1990. The national population growth rate is estimated at 2.8%. This is an indication that annual milk growth rate in Kenya continues to lag behind the projected consumption and population growth rates (FAO, 2005a).

2.1.4 Key Literature on Dairy Farming in Kenya

The dairy industry stakeholders require enough, relevant and timely data and information for quality decisions regarding the sub-sector. The following are some of studies on dairy farming that were carried out in the past in Kenya.

Musalia *et al.* (2007) carried out a study on smallholder dairy farms in Butere/Mumias and Kakamega districts of Western Kenya to establish the dairy production practices and constraints in the industry. The study revealed that the milk production was low (16.6 kg of milk per capita), the average herd size was 4.2; those in milking producing 8.0 kg/animal per day and the average land size was 6 acres. The number of dairy animals in the area was limited by diminishing land sizes and scarcity of pastures and fodder crops. Although over 90% of the milk was consumed locally, the local demand was above supply. Their opinions were that future development in dairy should

depend on intensification, introduction of genetically superior breeds, availability of dairy support services, increased use of dairy inputs and training in intensive dairy husbandry techniques. They recommended that farmers be trained and encouraged to consider dairying as a business.

The study's main gap was that the cost of milk production was not considered before the practice was promoted as a business. This study builds on Musalia's work by both characterizing the dairy farms in Embu and Meru Counties of Kenya and further determining whether promotion of dairy intensification and breed improvement are the best options under the current smallholder dairy production system.

Bebe *et al.* (2003) studied breed preferences and breeding practices in smallholder dairy systems of the central highlands of Kenya. Results revealed that Friesian was preferred in zero-grazing systems because of her feeding behaviour and body weight and market demand for economic reasons attached to salvage value. On the other hand, Ayrshire was preferred under semi-zero and free grazing systems because of her ability to graze well in open pastures and for having less frequent disease incidences than Friesian. Large breeds were crossbred between themselves whereas small breed (Guernsey) was upgraded using large breeds. The farmers associated large breeds with high milk yield.

These findings were important to the dairy industry stakeholders. However, there was a need to further assess whether the unselective feeding behaviour

by Friesian resulted from physiological demand for feed by the animal or if it actually led to increased milk yields relative to other breeds. The concern arises because Wakhungu *et al.* (2000) showed that Friesian was outperformed by small breeds (Guernsey and Jersey) in milk yield per lactation, fitness traits and production efficiency. The current study builds on the results by Bebe *et al.* (2003), by determining the significance of the breed in relation to milk yields.

Wambugu and Kirimi (2010) assessed the competitiveness and profitability of dairy farming in Kenya. Findings showed that over 80% of dairy farming households in central highlands kept upgraded dairy animals. Milk productivity (kilograms) per cow by Agro regional zones (2010) ranged from a low of 498 kg in the western lowlands to a high of 2,036 in the Central highlands; with a national mean of 1,344 kg. Dairy farming though attractive to the farmers, was marginally profitable. Some of the challenges identified include high cost of inputs, seasonal productivity and poor market infrastructure. This study builds on Wambui and Kirimi's work by determining the scale economies of production and the contribution of each input to both milk yield and cost of production. The contribution of both the farm and farmer socio-economic characteristics such as the size of land owned, dairy farming experience, age of the farmer and his/her formal educational level were determined.

In a study on the dairy industry in Kenya, Karanja (2003) found the cost of milk production to vary within and across the various production systems. The

smallholder zero-grazing farmers had the highest cost of production (about Ksh. 15/ kg), attributable to the system's dependence on high levels of supplementation with purchased feeds and high labour input for cutting Nappier grass and other fodder. The small and medium scale open grazing farms had lower cost (about Ksh. 10.50/ kg, but rose to about 15.10 when land rent was considered) of production, and the large-scale farms had the least costs (about Ksh. 12.30/ kg) (Table 2.3). Comparison of the local production costs with those attained in New Zealand indicated that on average the Kenyan production costs were at least 27% higher, implying reduced competitiveness of the local dairy products.

Karanja (2003) recommended that the cost structure, processing efficiency, and utilization of economies of scale and size be reviewed. Karanja's (2003) comprehensive study only missed out on the input and output relationships, an area that the current study addressed.

Table 2.3: Comparison of Milk Production Costs and Producer Prices in Kenya, New Zealand and Australia, 2000/01

	Small scale Zero- grazin g	Medium scale open grazing	Large scale open grazing	New Zealand owner	New Zealand sharemilke	Australia
Total cost (Ksh.)	14.9	10.5	12.3	7.95	8.5	10.05
Producer price (Ksh.)	15	12	14	10.35	10.35	12

Source: Kenyan-Tegemeo farm surveys; New Zealand-DEXCEL (1999/00) farm survey; Australia-DRDC (2002) (Quoted from Karanja, 2003).

This study further verified the existing relationship between the current costs of production and the producer price, after a period of about ten years.

2.2 Production Efficiency Concept

Efficiency is the relationship between what any decision - making unit produces and what it could feasibly produce, under the assumption of full utilization of the resources available (Hoyo *et al*, 2004). According to Kumbhakar and Lovell (2000) efficiency represents the degree of success which producers achieve in allocating the available inputs and the outputs they produce, in order to achieve their goals namely, to attain a high degree of efficiency in cost, revenue, or profit. Efficiency thus, is the ability of a decision-making unit to obtain the maximum output from a set of inputs (output orientation) or to produce an output using the lowest possible amount of inputs (input orientation).

Profit maximization requires a firm to be both technically and allocatively efficient (Kumbhakar and Lovell, 2000). Nevertheless, producers are hardly fully productively 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 to operate at the full efficiency frontier (Reifschneider and Stevenson, 1991). 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 (Kokkinou and Geo, 2009).

2.2.1 Production Efficiency Measurement: A Theoretical Background

The measurement of productive efficiency has important implications for both economic theory and economic policy. Its measurement allows one to test competing hypotheses regarding sources of efficiency or differentials in productivity (Lovell, 1993). Moreover, such measurement enables us to quantify the potential increases in output that might be associated with an increase in efficiency (Farrell, 1957).

The basis for frontier analysis was developed from the theoretical literature on productive efficiency, with the work of Koopmans (1951), Debreu (1951), and Shephard (1953). Koopmans laid out a mathematical definition of technical efficiency: "A producer is technically efficient if, and only if, it is impossible to produce more of any output without producing less of some other output or using more of some input." Debreu and Shephard introduced a distance function as a way of modeling multiple-output technology, and more importantly as a way of measuring the radial distance of a producer from a frontier in either an output-expanding direction (Debreu) or an input-conserving direction (Shephard, 1953).

Farrell (1957) provided a measurement application on U.S. agriculture and was the first to measure productive efficiency empirically. He showed the definition and decomposition of cost efficiency into its technical and allocative components and used linear programming techniques to estimate efficiency. His study on efficiency measurement led to the development of several approaches to efficiency and productivity analysis. These approaches include;

the stochastic frontier production (Aigner *et al.*, 1977; Meeusen and van den Broeck, 1977), distribution free approach (DFA) and the thick frontier approach (TFA) (all parametric), and Data Envelopment Analysis (DEA) (Charnes *et al.*, 1978) and the free disposal hull (FDH), (both non-parametric).

2.2.2 Parametric and Non-Parametric Efficiency Measurement Approaches

In parametric approaches, a functional form is assumed and econometric methods are used to estimate the functional form. A functional form is imposed on the production function and assumptions about the data are made (Chirwa, 2007). Parametric estimation of the production function is mostly performed by employment of stochastic frontier analysis (SFA), which accounts for both inefficiency and random noise effects. Given the fact that production processes in dairy farming are stochastic, the choice of SFA for efficiency measurement seems obvious. However, an important weakness of the SFA is that parametric restrictions on the production technology can confound the efficiency results (Lovell, 1993; Bauer, 1990b, and Reinhard *et al.*, 1999).

Nonparametric frontiers do not impose a functional form on the production frontiers and do not make assumptions about the error term. Contrary to econometric approaches, programming approaches avoid the problem of misspecification of functional form (of both technology and inefficiency). Also, programming approaches can easily handle disaggregated inputs and multiple output technologies (Charnes *et al.*, 1997). However, empirical

implications of these models are extremely difficult due to rigorous data requirements. In addition to the inputs and outputs data, it is necessary to have information on expected values of all variables, variance-covariance matrices for all variables, and probability levels at which feasibility constraints are to be satisfied (Lovell, 1993).

The most popular non-parametric approach has been the data envelopment analysis (DEA), Chirwa (2007). DEA approach has two disadvantages: it does not allow direct hypothesis testing (Ray, 2004) and derived measures of inefficiency are confounded with the effects of noise, measurement error, and exogenous shocks beyond the control of the production unit (Färe *et al*, 1985 and Ray, 2004). Another problem that might occur with use of DEA models refers to the dimensionality of the input/output space relative to the number of observations in the cross-section. The dimensionality problem arises when the number of observations is relatively small compared with the number of inputs and outputs used (Suhariyanto, 2000).

2.2.3 The parametric Frontier Approach

This is a preferred approach in estimating the efficiency of dairy farms, based on the variability of dairy production. The variability is attributable to climatic hazards, physiological health and insect pests, on the one hand, and, on the other hand, because information gathered on production are usually inaccurate since small farmers do not have updated data on their farm operations. The parametric approach makes it possible to estimate a frontier

function that simultaneously takes into account the random error and the inefficiency component specific to every farm (Lovell, 1993).

Further, reviewed literature on comparisons between DEA and SFA (the most common techniques), suggests that relative efficiency is given to approximately the same firms regardless of the method used, and that DEA technical efficiency scores are generally equal to or lower than the corresponding SFA scores. Lower efficiency scores are expected since DEA is deterministic and reports all deviations from the frontier as inefficiency (Brümmer 2001; Sharma *et al*, 1999). Choice of method to assess the efficiency scores is thus partly a matter of taste of the researcher (Hansson, 2007).

2.2.3.1 Stochastic Production Frontier Efficiency Estimation

The stochastic production frontier proposed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) is motivated by the idea that deviations from the production 'frontier' might not be entirely under the control of the firm being studied. In line with this thinking, it is held that any particular firm faces its own production frontier, and that frontier is randomly placed by the whole collection of stochastic elements which might enter the model outside the control of the firm.

This study uses a panel data version of Aigner *et al.* (1977) approach, following the Battese and Coelli (1995) specification, in which the technical inefficiency is estimated from the stochastic frontier and simultaneously explained by a set of variables representative of farmers' characteristics. This

approach avoids the inconsistency problems of the two-stage approach used in previous empirical works when analyzing the inefficiency determinants. In effect, relative to the two-step approach, the one-step approach presents the advantage of being less open to criticism at the statistical level, and helps in carrying out hypothesis testing on the structure of production and degree of efficiency.

Kumbhakar *et al.* (1991) and Battese and Coelli (1995) were the first to suggest that determining the factors responsible for inefficiency is an essential component of efficiency analysis. The important task is to relate inefficiency to a number of factors that are likely to be determinants, and measure the extent to which they contribute to the presence of inefficiency. Kumbhakar *et al.* (1991) and Battese and Coelli (1995) suggested that under the assumption of truncated normal one-sided error term, the mean of the truncated normal distribution could be expressed as a function of certain covariates, a closed form of likelihood function can be derived, and the method of maximum likelihood may be used to obtain parameter estimates, and provide inefficiency measures. The maximum likelihood estimate (MLE) method has been found to be significantly better than Corrected Ordinary Least Square (COLS) where the contribution of the inefficiency effects of the total variance is large, and is the preferred estimation technique whenever possible (Coelli *et al.*, 1998). The Battese and Coelli (1995) model can be expressed as:

$$Y_i = f(x_i; \beta) + \varepsilon_i \quad \text{where, } i=1, 2, \dots, N \quad (1)$$

$$\varepsilon_i = v_i - u_i \quad (2)$$

where Y_i represent the output level of the i^{th} sample farm; $f(x_i; \beta)$ is a suitable function (such as Cobb-Douglas or translog production functions) of vector, x_i , of inputs for the i^{th} farm and a vector, β , of unknown parameters. ε_i is an error term made up of two components: v_i is a random error having zero mean, $N(0; \sigma_v^2)$ which is associated with random factors such as measurement errors in production and weather which the farmer does not have control over and it is assumed to be symmetric independently distributed as $N(0, \sigma_v^2)$ random variables and independent of u_i .

On the other hand, u_i is a non-negative random variable representing the inefficiency, which is assumed to be distributed independently and obtained by truncation at zero of the $N(\mu_i, \sigma^2)$ distribution. The mean of this distribution is assumed to be a function of a set of explanatory variables:

$\mu_i = \delta_i + z_{it}$ and then, the inefficiency term is:

$$\mu_{it} = \sum_{i=1}^N \delta_i Z_{it} + W_{it} \quad (3)$$

Where Z_{it} is a $(M \times 1)$ vector of variables that may have effects over firm efficiency, δ_i is a $(1 \times M)$ vector of parameters to be estimated and W_{it} is a random variable defined by the truncation of the normal distribution with zero mean and variance σ^2 .

Given that technical efficiency is the ratio of observed production over the maximum technical output obtainable for a firm (when there is not inefficiency), the efficiency index (TE) of firm i could be written as:

$$TE = \frac{f(X_i; \beta) \exp(v_i - u_i)}{f(X_i; \beta) \exp(v_i)} = \exp(-u_i) \quad (4)$$

2.2.3.2 Stochastic Cost Frontier and Efficiency Estimation

A stochastic cost frontier model estimates a frontier model with econometric methods. The econometric frontier model estimates the frontier and measures the distance between the inefficient units and the frontier by the residuals. This is an intuitive approach adopted in traditional econometrics. However, when we assume that the residual has two components (noise and inefficiency); we have the stochastic frontier model. Therefore, the main issue in econometric frontier models is the decomposition of the error terms.

To measure the cost efficiency of individual producers, we use the stochastic frontier methodology of Aigner *et al.* (1977). In this method, a producer's observed total cost is modeled to deviate from the cost-efficient frontier due to random noise and possibly cost inefficiency. For the i^{th} firm,

$$\ln TC_i = f(\ln Y_i, \ln w_j) + \varepsilon_i \quad (5)$$

where TC_i is the total cost, Y_i is output, and w_j are input prices. In equation 5, ε_i is a two-component disturbance term of the form:

$$\varepsilon_i = v_i + u_i \quad (6)$$

where v_i represents a random uncontrollable factor and u_i is the controllable component of ε_i . In equation (6), v_i is independently and identically distributed with zero mean and σ_v standard deviation, i.e., $v_i \sim N(0, \sigma_v^2)$. The term u_i is distributed independently of v_i and has a half-normal distribution, i.e., u_i is the

absolute value of a variable that is normally distributed with zero mean and standard deviation σ_u , $N+(0, \sigma_u^2)$.

The literature suggests two methodological approaches for analyzing the sources of cost efficiency based on stochastic cost functions. The first approach is the two-stage estimation procedure in which first the stochastic production function is estimated, from which efficiency scores are derived. In the second stage the derived efficiency scores are regressed on explanatory variables using ordinary least square methods or tobit regression. This approach has been criticized on grounds that the firm's knowledge of its level of technical inefficiency affects its input choices; hence inefficiency may be dependent on the explanatory variables. The second approach advocates a one-stage simultaneous estimation approach as in Battese and Coelli (1995), in which the inefficiency effects are expressed as an explicit function of a vector of farm-specific variables. The cost inefficiency effects are expressed as;

$$u_j = z_j \delta \quad (7)$$

where for farm j , z is a vector of observable explanatory variables and δ is a vector of unknown parameters. Thus, the parameters of the frontier production function are simultaneously estimated with those of an inefficiency model, in which the cost inefficiency effects are specified as a function of other variables.

2.3 Empirical Efficiency Literature on Dairy Farming

This sub-section reviews the studies on the estimation of dairy farm efficiencies in various countries including Kenya. The sub-section is useful

because it gives information on the variables used and methods of analysis that have been used in the determination of efficiency in dairy farming.

2.3.1 Literature on Technical Efficiency

Wubeneh and Ehui (2006) estimated a stochastic production frontier model in measuring the technical efficiency of dairy farms in the Central Ethiopian highlands. The Cobb-Douglas functional form was specified with the dependent variable being milk output. The explanatory variables used were number of local breed cows, number of cross-bred cows, and the quantity of concentrate, family labour hours, hired labour hours, and veterinary and other costs. The results showed that concentrate and forage feeds and expenditures on veterinary services were significant determinants of milk production. The average efficiency level of the farmers was 79%. The findings of this study remain significant because they indicate what inputs can be increased to increase milk outputs. However, inclusion of the size of land owned was necessary. Ranaweera (2007) found access to land for production of dairy forage and fodder being a critical issue if productivity gains in the sector were to be achieved. It would also have been necessary to determine the efficiency determinants.

Wang (2001) analyzed the technical efficiency of Pennsylvania dairy farms using a stochastic production frontier based on a randomly selected cross-sectional sample. The Cobb-Douglas functional form was specified, with the maximum likelihood techniques used in the estimation. The technical efficiency measure was broken down into different farm sizes. The dependent

variable was milk output in a farm. The explanatory variables were the total hours by the family and hired labour, capital (user cost of capital equipment) and total grain and forage consumed in the farm. All the explanatory variables were positive and significant. The mean technical efficiency was 85%. Large farms were more efficient than the smaller farms.

Although the findings of this study were quite significant, inclusion of the kind of breed reared as an explanatory variable could have added value to the study. Genetic improvement has significant impact on dairy farming growth and development (Staal *et al*, 2008). Further, estimation of an inefficiency model with hypothesized inefficiency determinants could have provided a wider range of information.

Alemdar *et al*. (2010) assessed the technical efficiency of small-scale milk production in Turkey using a Cobb-Douglas functional form. Five inputs; grains and concentrates, green and dry fodder, labour, veterinary costs and other costs. There were four inefficiency variables; herd size, cow quality, source of labour and share of milk in gross return. Among all the inputs, it was only labour that was not significant. Among the inefficiency determinants, it was only the cow quality that was significant. The mean technical efficiency was 78%. The gaps in this study were mainly on the exclusion of important variables such as number of cows in milk, breed and the amount of mineral supplements to the herd. Bhuyan and Postel (2009) in the north eastern United States found high number of milking cows having a positive impact on the net

farm income; an additional milk cow typically added 11 900 kg of milk to annual production in 2005.

Saravanakumar and Jain (2007) estimated the technical efficiency of dairy farms in Tamil Nadu using stochastic frontier production methods. The Cobb-Douglas functional form was estimated. The variables comprised of fixed investments on the dairy farms, quantity and price of feeds and fodders fed to individual animals, labour utilization pattern, veterinary and miscellaneous expenses, quantity of milk produced and price realized. The coefficients for the value of green fodder and concentrate were statistically significant. The mean technical efficiency was 82.1%. The results of this study confirmed the significance of roughage and concentrate in dairy farming. However, the cow breed, the size of the land owned and the amount of mineral supplements remain a lacuna in this study.

In a study on the effect of traditional practices in the efficiency of dairy farms in Wisconsin, Cabrera *et al.* (2010) employed the stochastic frontier production function using the Cobb-Douglas functional form. The variables comprised of fixed investments on the dairy farms, quantity and price of feeds and fodders fed to individual animals, labour utilization pattern, veterinary and miscellaneous expenses, quantity of milk produced and price realized. The coefficients for the value of green fodder and concentrate were statistically significant. The mean technical efficiency was 88%. Out of the variables hypothesized to determine inefficiency; milking frequency, family labour, feed/cow and the making of the total mixed ration were statistically

significant. This study's results confirmed the significance of roughage and concentrate in milk production, but failed to include the amount of mineral supplements as well as the kind of breed kept as variables.

In a study to determine the reasons for variations in the levels of efficiency in smallholder dairy farms in Sri Lanka, Edirisinghe *et al.* (2008) used a stochastic production frontier and employed the Cobb-Douglas functional form. The dependent variable was the income generated from dairy production activities. The explanatory variables were: the expenditure on buying feed, number of animals in milk, number of hours spent in dairy activities per day and expenditure on veterinary services and medicine. The variables included in the inefficiency model were: age of head of household (representing the human capital gained through experience), square of age, gender, number of years in education, whether farmer is full-time/part-time farmer, whether the farmer plans for the herd or not, number of visits by veterinary officer to the household during the year, whether household head had a training on dairy activities before or not and farmers' valuation of the health and productivity of animals. Human capital was found to play a key role in developing efficiency. Further, the analysis revealed the importance of veterinary services in income generation to poor farmers. The analysis revealed that the mean efficiency of the sample was 52 percent. The results of this study were significant in that they amplified the significance of the human capital, an aspect that has been avoided by many studies. The study however ignored potential variables such as the cow breed and the size of land owned.

2.3.2 Literature on Cost Efficiency of Dairy Farms

Lucila *et al.* (2005) measured the cost efficiency in smallholder dairy farms in Northeast Thailand using the stochastic cost frontier approach, employing the translog cost frontier model. The dependent variable was total annual cost per farm. The explanatory variables constituted of annual milk production per farm, the average price of feed concentrate per kg, average price of roughage per kg, the average wage rate per hour and the value of capital stock per farm. The results showed that the cost elasticities with respect to output, input prices, and capital stock as positive. The dairy farms feeding their cows purely with commercially produced feed concentrates were more cost efficient than those using either a combination of commercial and homemade feed concentrates or purely homemade feed concentrates. The authors linked this to their smaller herd size that did not require more labour hours beyond what the family members could handle. This result is curious and contrary to expectations as it does not validate the hypothesis that feed technologies using locally available feed ingredients contribute to more cost efficient feed use. This study failed to address the input and output substitutions, as well as the cost of mineral supplements in the model which would have provided further information to the farmers.

The variables hypothesized to affect the cost inefficiency of dairy farms included a binary variable for the type of feed user, ratio of males to females, age, milking cows to herd size ratio, milk yield, feed concentrate to roughage ratio, percentage of homemade concentrate to total feed consumed, land to

labour ratio, and dummy variables for the provinces included in the study. Results showed that age, milking cows to herd size ratio and milk yield per cow were shown to be inefficiency reducing. The cost efficiency increased with higher levels of milking cows-herd size ratio, but declined with herd size. Based on previous studies, the suggested ratio of milking cows is 70-75 percent of the herd (Skunmun and Chantalakhana, 2000).

Kavoi *et al.* (2010) measured the economic efficiency for smallholder dairy cattle in the marginal zones of Kenya using a stochastic frontier translog cost function approach. The dependent variable was the natural logarithm of the total variable costs of milk production. The total variable cost was the sum of expenditures for concentrates, mineral salts, milking serve, hay, locally purchased feeds, tick control, cattle treatment and labour. The independent variables used were natural logarithms of milk output value, price of animal feeds, price of animal health, labour wage rate, and quantity of own produced feeds as well as areas of dairy grazing as fixed inputs.

The variables that were hypothesized as being responsible for the estimated farm-specific cost inefficiencies were; age of the dairy manager, years of schooling (for dairy manager), square of years of schooling, years of dairying experience, number of extension visits, number of milking cows, dummy variable = 1 if farmer kept dairy records and 0 otherwise, dummy variable = 1 if farmer stored feeds on farm and 0 otherwise, distance from farm to the water point for cattle (Kilometers), dummy variable = 1 if farmer used credit and 0 otherwise, dummy variable = 1 if dairy manager had off-

farm employment and 0 otherwise, ratio of walking distance to the tarmac distance from homestead and dummy variable = 1 for transitional zone IV and 0 otherwise. Road infrastructure, extension and credit significantly reduce cost inefficiency. Keeping dairy records and eight years of primary level of education were the key characteristics influencing efficiency. The findings showed that cost inefficiency ranged from 0.01 to 81.11, with a mean of 27.45%. This study was comprehensive and its recommendations were very applicable in similar regions of the country. However, a study covering the country's highlands where most dairy cows are kept by smallholders and modeling for both land size and the effect of intensification on the cost of production was necessary.

William and Juan (1985) evaluated the operating cost efficiency on Pennsylvania dairy farms using a linear programming model. Large differences in individual farm measures of efficiency were found within each of the four herd size groups analyzed. The least efficient farms were two to three times more inefficient than the most efficient farms. Variance of cost efficiency decreased for increases in herd size group; larger herds being more homogenous in cost efficiency. Results indicated that farms with a high percentage of hired labour and where the number of heifers per cow was higher, cost efficiency was highest. Herds producing higher levels of milk per cow were only marginally more cost efficient than lower producing herds. The findings are quite applicable in countries where farms are large and where opportunity cost of labour is low. There was a need however, to show the

potential contribution of animal feeds in the study region, for they have a direct impact on reproduction.

Alvarez *et al.* (2008) classified dairy farms according to their level of intensification by using a cluster analysis and estimated independent stochastic cost frontiers for each group of farms to calculate their levels of efficiency using the translog functional form (Christensen *et al.*, 1971). The dependent variable was the average total cost, and the independent variables included the milk output, the price of feedstuffs and a herd price.

The empirical results showed that intensive farms were closer to their cost frontier than extensive ones, suggesting a positive relationship between intensification and efficiency. They also established that extensive farms, if managed efficiently, could compete with intensive farms because they produced at a lower cost. This result agreed with Tauer (2001), who suggested that efficient small farms could be cost competitive but, on average, they tended to be less efficient than large farms. On the other hand, cost efficiency depended critically on input prices. There was a need to additionally analyze the relationship between costs of production under intensification and the potential reduction of the costs in case of optimized cost efficiency.

Tauer and Mishra (2006) estimated a stochastic cost function using a function of dairy cow numbers on the farm and an error term. The cost of milk production by farm size was decomposed into frontier and efficiency components with a stochastic cost curve using data on 755 USA dairy farms

from the year 2000. The results showed higher costs of production of many smaller farms as being caused by inefficiency. The 50-cow farm had a frontier cost of production of \$10.05 and an inefficiency cost of \$10.27 for a composite cost of \$20.32. In contrast, the 1,000-cow herd had a frontier cost of production of \$9.27 and an inefficiency cost of \$2.82 for a composite cost of \$12.09. The implication was that larger farms were more efficient than the smaller ones. The study provided enlightening findings considering that most countries have both large and small dairy farms. The study however failed to analyze the inefficiency determinants other than farm size, with the view to informing the dairy industry stakeholders on what to do considering that in many developing countries a large proportion of dairy farmers are smallholders.

Yamamoto (2000) used linear programming techniques to calculate the efficiencies for a sample of Hokkaido dairy farms during the year 1989. The average farm operated at 71 percent efficiency. The correlation results indicated that higher overall cost efficiency levels were associated with larger herd size, higher milk production per cow, higher farm income per cow, higher milk production per working hour and lower share of farm produced feed.

One disadvantage of the non-parametric approach is its sensitivity to outliers; incorporation of stochastic elements into the model would relax the assumption that the entire deviation of a farm from the frontier is due to inefficiency.

2.4 Overview of the Literature

Reviewed literature (IFCN (2009), Staal *et al.* (2007) and Wambua and Miencha (2007)) has shown that the developed nations produce enough milk for their own consumption and for export. Demand for milk in these countries has reached the highest levels; offering no foreseeable milk market in their countries. Developing countries produce much less milk than their demand; they import from the developed nations to cover the deficit. Milk demand among the developing countries is still rising because the human population and incomes are also rising.

Kenya's large dairy herd suffers from low per cow productivity resulting from many challenges. Studies carried out in the country have identified poor cow breed, insufficient feeds and supplements, seasonal productivity and negative cultural influences leading to overstocking. There was however a lacuna on the information on how well the dairy farmers were able to utilize the amounts of resources they had, as well as their ability to use information of the input prices in choosing what input to buy so as to minimize their farming costs. This study sought to fill these gaps.

The literature on technical efficiency has provided insight into the commonly employed functional form, the various variables that influence milk production and the different factors included in the inefficiency model. All the studies estimating the technical efficiencies employed the Cobb-Douglas functional form and many chose milk yield as the dependent variable. Most of

the studies used variables that are consistent with economic theory, and therefore, were useful in deciding what variables to use in this study.

The main explanatory variables were cow breed, quantity of concentrate and grain fed to cows, family labour hours, hired labour hours, total forage consumed in the farm, the number of adult cows in the herd and number of animals in milk. The others included the quantity of milk produced and price offered, the value of land used, veterinary and other costs, fixed investments on the dairy farms, the total cost of purchased feedstuffs, total expenses related to crop production and the expenditure on buying feed for animals. Results revealed that concentrate, forage feeds, and expenditures on veterinary services, labour, and capital were significant at 5% level. Some of the inefficiency model variables included; milking system, milking frequency, age of head of household, gender, number of years in education, whether farmer is full-time/part-time farmer, number of visits by veterinary officer, whether household head had a training on dairy activities before or not, and farmers' valuation of the health and productivity of animals.

The literature on cost efficiency provided information on both the parametric and non-parametric approaches to cost efficiency measurement. There was evidence that both approaches converged on the level of average efficiency, but diverged on scoring individual producers. The most common approach was the parametric approach, with the translog model being the model of choice. The cost of dairy farming was the preferred dependent

variable, while milk output per farm, the average prices of concentrate, roughage, labour and animal health were the main explanatory variables.

Some of the gaps noted in literature included absence of efficiency studies on dairy farming in Kenya and exclusion of potentially informative variables such mineral supplements and dairy herd size, in studies carried out elsewhere. Many studies (Wubeneh and Ehui (2006) and Wang (2001)) did not hypothesize and estimate an inefficiency model with a view to identifying the inefficiency determinants. These kinds of gaps were focused on in this study. In the study, both the technical and cost efficiencies of dairy cow farms in Embu and Meru counties were estimated. Many variables (see chapter three) including those thought to influence dairy farming efficiency were modeled for and estimated.

CHAPTER THREE:

RESEARCH METHODOLOGY

3.1 Estimated Models with Regard to Dairy Farming Efficiency

3.1.1 Econometric Stochastic Production Frontier Function

A farm's milk output can be summarized by a production function, specified in actual values and natural logarithms (ln) as:

$$\ln y_i = \ln A \sum_{i=1}^N \beta_i \ln x_{ij} + v - u \quad (8)$$

$$u > 0,$$

$$i = 1, 2, 3, \dots, N;$$

$$j = 1, 2, 3, \dots, N.$$

where y_i is the i^{th} dairy farm's milk output in a day; x_{ij} is a vector of quantities of j inputs (Herd size, milking herd size, breed, roughages, concentrates, mineral supplements, labour, land size, chaff-cutter) used by the i^{th} dairy farm; A and β are unknown parameters to be estimated. $v_i \sim N(0, \sigma_v^2)$ is the usual disturbance term, which captures random variation in farm milk yield, due to factors out of its control. On the other hand, u_i is a non-negative random variable representing the inefficiency, which is assumed to be distributed independently and obtained by truncation at zero of the $N(\mu_i, \sigma_u^2)$ distribution. The mean of this distribution is assumed to be a function of a set of explanatory variables:

$$\mu_i = \delta_i + z_{it} \quad (9)$$

where Z_{it} is a $(M \times 1)$ vector of variables that may have effects over firm efficiency, δ_i is a $(1 \times M)$ vector of parameters to be estimated. Both v_i and u_i are statistically independent of each other, are independent and identically distributed across observations. The total variation in milk output from the frontier level of output attributed to technical inefficiency is defined by $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. The variance parameter γ lies on the interval $[0, 1]$.

3.1.2 Econometric Stochastic Cost Frontier Function

To measure the cost efficiency of individual dairy farms, the stochastic frontier methodology of Aigner *et al.* (1977) was used. In this method, a dairy farmer's observed total cost is modeled to deviate from the cost-efficient frontier due to random noise and possibly cost inefficiency. For the i^{th} firm,

$$\ln TC_i = f(\ln Y_i, \ln w_j) + \varepsilon_i \quad (10)$$

where TC_i is the total cost, Y_i is milk output, and w_j are input prices. In equation 10, ε_i is a two-component disturbance term of the form:

$$\varepsilon_i = v_i + u_i \quad (11)$$

where v_i represents a random uncontrollable factor and u_i is the controllable component of ε_i . In equation (11), v_i is independently and identically distributed with zero mean and σ_v standard deviation, i.e., $v_i \sim N(0, \sigma_v^2)$. The term u_i is distributed independently of v_i and has a half-normal distribution, i.e., u_i is the absolute value of a variable that is normally distributed with zero mean and standard deviation σ_u , $N+(0, \sigma_u^2)$.

3.1.3 Definition and Measurement of Variables

Inputs:

MILK PRODUCTION: Total herd size (counted); milking herd size (counted as the total number of lactating cows); breed (observed and compared to photo card); roughages (kg) (amount per cow per day); average amount of concentrate (kg) (ascertained by re-weighing the amount in a vessel used by the farmer in feeding a cow per day); average amount of mineral supplements (kg) (obtained from farmer's response); average number of labour hours spent on herd per day (hours) (average time taken on dairy farming activities in a day by either a family member or hired or both); land size owned (Acres) (obtained from the farmer's response) and chaff-cutter ownership (presence or absence of chaff-cutter in a farm, obtained by observation and/farmer response).

Output

YIELD: the actual milk output from all the lactating cows in a farm (each cow's yield was also obtained).

Costs

FARM COST: the total cost of maintaining a dairy herd per day (calculated by adding up all the costs of inputs provided to the herd in a day). The total cost were arrived at by adding: total cost of the average amount of roughages per cow per day (kg); average price of mineral supplements to the herd/day (Ksh); average cost of labour per day (Ksh); and the price of the amount of

concentrate fed a cow per day. The prices were obtained from the farmer. A further clarification is provided in Table 3.1.

Table 3.1: Variables and their Data Generation Method

Variable	Method of data generation/measurement
Production Function Variables	
Herd size	Data provided by farmer/counting
Milking herd size	Data provided by farmer/counting
Chaff-cutter	Observation
Labour time	Estimation
Breed	Photo-card
Roughages	Estimation
Concentrates	Re-weighing amounts in the containers usually used
Minerals	Farmer response based on routine purchases
Land size	Farmer response
Total Farm Cost on inputs	
Cost of roughages	Amount roughages per day X price per kg
Cost concentrates	Amount concentrates per day X price per kg
Cost of mineral supplements	Amount of minerals per month X price per kg
Cost of labour	Average pay/hour X number of hours worked/day
Farmer Characteristics	
Formal Education(years)	Farmer response
Age (years)	Farmer response
Experience (years)	Farmer response
Extension service availability	Farmer response
Group membership	Farmer response
Attendance to business courses	Farmer response

Source: Compiled by the author, 2012

3.2 Design of the Study

A descriptive survey research design was employed in this study where sampled respondents were targeted for data collection. Survey research is a systematic method for studying behavior that cannot be observed or experimented on directly (Guerin and Dohr, 2010). In a sample survey, the researcher gathers information from the responses of part of the population of

interest. In this study, quantitative approach was used in the collection and analyzes of the data.

3.3 Study Site

Since the main objective of the study was to evaluate the milk production efficiency of dairy cow farms, and that over 70% of the national milk output comes from the smallholders, the focus was on a region where milk production is mainly from the smallholders. Data and information for this study were collected from respondents in Embu (appendix 1) and Meru (appendix 2) Counties of Kenya. Smallholder dairy farmers in the two counties produce over 95% of the milk (PDLP, 2009). The recommendations of this study could be applied in similar regions in the country such as Kiambu, Kisii and Taita Taveta. Embu East and Igembe South Districts within the respective Counties were selected because farmers in the two Districts operate in different socio-economic environments, which offered an opportunity for both comparison and possible wide regional applicability for the study results.

Embu and Meru Counties lie on the Eastern Central highlands of Kenya on the north eastern side of Nairobi. Embu County is at 0030° S, $37 30^{\circ}$ E and Meru at 0° , $38 00^{\circ}$ E. They cover an area of 2826.4 and 6924 km², respectively. The main soil type in the two Counties is clay-loam. They have two rain seasons (March to May and October to December). The rainfall totals for the two counties range in-between 600-2200 and 400-2600mm,

respectively. The temperature ranges for the respective counties are; 12-27 and 11.4-28⁰C (Kenya decides, 2012; Jaetzold *et al*, 2006).

The two Counties border Mt. Kenya and the region is ideal for dairy farming. Areas of high altitude (between 1200 and 2300 metres above sea Level) in both counties have high human populations leading to small land sizes per person, averaging two acres per household. The continued subdivision of arable land has reduced its economic viability (Jaetzold *et al*, 2006). The populations for Embu and Meru Counties according to the 2009 census data were 516,212 and 1,356,301, respectively (RoK, 2010).

Embu County has five administrative Districts while Meru has eight. Three Districts of Meru County (Imenti South, Meru Central and Imenti North) have similar climatic characteristics to those of Embu County (all border Mt. Kenya) and were therefore not included in the study. The sample for this study was drawn from Embu East and Igembe South districts (sub-Counties) within the Embu and Meru Counties, respectively. The two are about 130 km apart.

Embu East borders Mt. Kenya on its North West and is about 170 km from Nairobi. It has about 3000 dairy farms whose part of the milk is sold to either New Kenya co-operative creameries or Brookside Dairies (DLPO, 2009). Igembe South District is on the Nyambene Ranges about 320 km from Nairobi. It is a milk deficit region with an approximate 1200 dairy farms (PDLP, 2009), surrounded by other milk deficient Districts of Tigania, Tharaka and Isiolo. Milk prices are relatively higher than Embu's, at an

average of Ksh. 35.3. Milk Price in Embu fetches an average of Kshs. 20.4.

The Embu and Meru communities share social-cultural activities and beliefs which include having household chores performed by women and cattle owned by men.

3.4 Population and Sampling Procedures

The population of interest constituted of dairy farms in Embu East and Igembe South Districts in Embu and Meru Counties, respectively. Cochran's (1977) formula was used to calculate the sample size, where by:

$$n = \frac{Z^2 P \% * Q\%}{e^2} \quad (12)$$

Where;

n = the desired sample size. Z = the value corresponding to the level of confidence required (in this case, 1.96, corresponding to 95%), $P\%$ = proportion belonging to the specified category. $Q\%$ = proportion not belonging to the specified category. $e\%$ = the margin of error required (in this case 5%).

The sample size obtained was thus:

$$n = \frac{(1.96)^2 * 0.9 * 0.1}{0.05^2} \quad (13)$$

$$=135$$

The target population was 4,200 dairy farms (3000 in Embu East and 1200 in Igembe South) (PDLP, 2009). The obtained sample size of 135 was proportionately divided between the two study districts (96 farms for Embu East and 39 for Igembe South).

Multi-stage sampling technique was used in this study to first select Embu and Meru Counties as explained in section 3.3, followed by a second stage of selecting the Embu East and Igembe South Districts from each of the respective counties. Random sampling was used in selecting the dairy farms. Farms in all the divisions (Runyenjes and Kyeni in Embu East and Kangeta, Maua, Athi, Kanuni and Athiru Gaiti in Igembe South) within the study Districts were targeted for sampling (Table 3.2).

Table 3.2: Sample Size Distribution (Proportionate) Among the Divisions

District	Division	Population (Dairy Households)	Sample size
Embu East	Runyenjes	1750	56
	Kyeni	1250	40
Igembe South	Maua	220	7
	Kangeta	150	5
	Athi	280	9
	Kanuni	300	10
	Athiru Gaiti	250	8

Source: Own compilation from Eastern PDL (2009)

3.5 Research Instruments

Primary data were gathered from various categories of the dairy industry stakeholders in the study area. The first category constituted of the dairy farmers and was the main data source. The others included a milk processor (New KCC management), heads of livestock production and veterinary departments, two private veterinary practitioners and six agro vet dealers.

A survey questionnaire was used as the main data collection tool in this study, where data was gathered by administering the questionnaires to the dairy farmers. The questions were always read out to the respondents by the

research assistants (trained by the researcher while pre-testing the questionnaire). The other stakeholders (Appendix 3) were interviewed using interview schedules. Reviewed literature (Jaetzold *et al*, 2006; DLPO, 2009; PDLP, 2009; MoSPND, 2009; and www.opendata, 2011) provided secondary data and information.

3.6 Pre-Testing the Instrument

In order to ensure validity and accuracy, the questionnaire and the interviewing schedules were pre-tested before use in field data collection. The pre-testing aimed to ensure the questions made sense and were not too burdensome. Pre-testing was carried out amongst twenty randomly selected dairy farmers in Embu west District, Embu County, within the month of April, 2010. The language used, data generation potential, and clarity of the questionnaire items was tested and the necessary adjustments made. Ten research assistants were trained at the time of instrument pre-testing (five from each sub-County).

3.7 Data Collection Procedures

Data were collected from primary and secondary sources. Respondents were briefed about the nature of the study and were informed about the confidentiality and privacy of the information they were to provide before getting their responses. They were assured that nothing contained in the questionnaire would be used to put them in any kind of trouble. They were given the option of filling in the information by themselves or get assistance from the research assistants.

The author personally interviewed the other industry stakeholders (DLPOs and DVOs in charge of the study Districts, the NKCC manager, two private veterinary surgeons and six agro vet dealers). The surgeons, each from each study district, were the only ones operating there. Embu East had had 11 agro vet dealers while Igembe South had 14. Both questionnaire and interview schedule items were administered from the months of April to September, 2010. The author used pre-written interview schedules in interviewing the respondents.

Secondary data were collected from reports and other literature obtained from the Ministries of Livestock Development, Agriculture and the Ministry of State for Planning, National Development and Vision 2030. Secondary data were collected on household size, average land size per household, soils, actual district sizes and their geographic location, crops grown, population figures for people and all livestock types, milk marketing centres, milk prices and data on livestock input prices.

3.8 Data Analysis and Model Specification

Data were first entered into the Excel spread sheet which was followed by its cleaning and coding. Any double entries, missing values or outliers were addressed at this point. A statistical software package; the Statistical Package for Social Sciences (SPSS) (Version 11) was used to analyze the data on the characterization of the dairy farms and on the effect of improved farm efficiencies on production costs. The descriptives were in the form of

numerical values such as percentages and means and graphs such bar and pie charts.

Data analyses on the technical and cost efficiencies were based on inferential statistics, and were carried out in FRONTIER 4.1c econometric software (Coelli, 1996). The package provides two assumptions about the distribution of the error term, half normal and truncated normal. Maximum likelihood method was used to estimate both the production and cost functions from which the efficiency levels (technical and cost) of each dairy farm were derived.

The Frontier package uses a three-step procedure in estimating the maximum likelihood estimates of the parameters of stochastic production function. First, Ordinary Least Squares (OLS) method is used to obtain the estimates of the coefficients of the function, with the assumption that there is no inefficiency. All estimators from the OLS, with the exception of the intercept, are unbiased. In addition, σ_v^2 and σ_u^2 are computed. The computed values of these variances are used to obtain the following: $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$. The value of γ lies between zero and one. Second, a two-phase grid search is conducted to evaluate the likelihood function using a number of values of γ between zero and one. The values of OLS estimates of intercept and variance σ^2 are adjusted according to the Corrected Ordinary Least Squares (COLS) formula presented in Coelli (1995). The slope estimates from OLS are retained. Third, the best estimates, those corresponding to the largest log-likelihood from the second step are used as starting values in an iterative

procedure, using the Davidon-Fletcher-Powell (DFP) Quasi-Newton method, to obtain the final maximum likelihood estimates.

Individual farm level technical efficiencies were estimated and their relative inefficiencies simultaneously explained by a set of variables representative of farmer characteristics. The Cobb-Douglas functional form was specified and estimated in this case because it provides an adequate representation of production technology as long as the analysis is interested in efficiency of production and not the structure of the production technology (Taylor *et al.*, 1986). Its specification is very simple, focuses on the error term (Kumbhakar and Lovell, 2000). The function has been widely used to analyze production efficiency in both the developing and developed countries (Bravo-Ureta and Rieger, 1991). Its production function (Cobb and Douglas, 1928) was modified, specified and presented as;

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1ij} + \beta_2 \ln X_{2ij} + \beta_3 \ln X_{3ij} + \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij} + \beta_6 \ln X_{6ij} + \beta_7 \ln X_{7ij} + \beta_8 \ln X_{8ij} + \beta_9 \ln X_{9ij} + V_{ij} - u_{ij} \quad (14)$$

where \ln represents logarithm to base e ; subscripts ij refers to the j^{th} observation of the i^{th} farmer; Y is the total milk output by a farmer (Kilograms); X_1 represents the total herd size owned by a farmer; X_2 is the milking herd size (lactating cows); X_3 represents the cow breed; X_4 represents the amount of roughages fed to the herd per day (kg); X_5 is the average amount of concentrate feed fed per farm per day (kg); X_6 represents the average amount of mineral supplements allowed to the total herd per month (kg); X_7 is the average number of labour hours spent on dairy herd per day

(hours); X_8 represents the size of land owned by a farmer (Acres) and X_9 represents the presence or absence of chaff-cutter technology by the dairy farm.

It is assumed that the technical inefficiency effects are independently distributed and u_{ij} arises by truncation (at zero) of the normal distribution with mean μ_{ij} and variance, δ^2 , where μ_{ij} is defined as:

$$\mu_{ij} = \delta_0 + \delta_1 \ln Z_{1ij} + \delta_2 \ln Z_{2ij} + \delta_3 \ln Z_{3ij} + \delta_4 \ln Z_{4ij} + \delta_5 \ln Z_{5ij} + \delta_6 \ln Z_{6ij} \quad (15)$$

where μ_{ij} represents the technical inefficiency of the i^{th} farmer; Z_1 is the number of years of formal education; Z_2 Farmer's age in years; Z_3 Farmer's experience in years; Z_4 is the extension service availability (Yes/No); Z_5 group membership and Z_6 is the attendance to any business course.

In order to analyze the cost efficiencies of smallholder dairy farms in the study area, a stochastic cost frontier approach was adopted. A translog cost function was considered to concurrently explain the milk production and cost functions of the dairy farms; being the most flexible form of a cost function. The advantage of the translog specification over that of Cobb-Douglas is that the one-sided error component u_i now captures both input oriented technical and allocative inefficiency (Nadolnyak *et al*, 2000, as quoted by Lucila *et al*, 2005). The model was run using the FRONTIER 4.1c econometric software. Maximum likelihood estimation was employed to estimate simultaneously the parameters of the stochastic translog cost frontier and the cost inefficiency model. The translog function (Christensen *et al*, 1971) is specified as:

$$\ln (TC/cfeed) = \beta_0 + \beta_y \ln output + \sum_{j \neq y} \ln (p_j/cfeed) + \frac{1}{2} \beta_{yy} (\ln output)^2 + \frac{1}{2} \sum_j \sum_{h \neq j} \ln (p_j/cfeed) * \ln (p_h/cfeed) + \sum_{j \neq y} \ln output * \ln (p_j/cfeed) + v_i + u_i \dots (16)$$

where TC is the actual total cost of production; cfeed is average price of concentrate feed per day; the other input cost, p_j , are the input prices. After normalizing the total cost and the input prices by the price of concentrate feed and expressing all the variables in logarithms, the estimating equation becomes:

$$tcost = \beta_0 + \beta_1 outpt + \beta_2 rfeed + \beta_3 minsuppls + \beta_4 labr + \frac{1}{2} \beta_5 outpt^2 + \frac{1}{2} \beta_6 rfeed^2 + \frac{1}{2} \beta_7 minsuppls^2 + \frac{1}{2} \beta_8 labr^2 + \beta_9 outptrfeed + \beta_{10} outptminsuppls + \beta_{11} outptlabr + \beta_{12} rfeedmin + \beta_{13} rfeedlabr + \beta_{14} minsupplslabr + v_i + u_i \dots (17)$$

(where, tcost= total cost of production (Ksh); outpt= total farm milk output/day (Kg); minsuppls= total price of mineral supplements to the herd/day (Ksh); labr= average cost of labor per day (Ksh); outpt² = output x output; rfeed² = roughage feed x roughage feed (kg); minsuppls² = mineral supplements x mineral supplements (kg); labr² = labour x labour (Hr); outptrfeed= output x roughage feed; outptminsuppls= output x mineral supplements; outptlabr= output x labour; rfeedmin= roughage feed x mineral supplements; rfeedlabr= roughage feed x labour; minsupplslabr= roughage feed x labour).

To determine the potential reduction in the cost of milk production through efficiency optimization, calculations based on proportions were carried out. Information regarding technical and cost efficiencies as well as the average

cost of milk production was obtained from the results on the second objective. The technical efficiency was first related to the potential yields with the assumption of 100% efficiency. The next step was to determine the new average cost after the daily milk yields increased, assuming 100% technical efficiency.

The other calculation was on what would be the reduction in average cost, if farms were to operate at 100% cost efficiency. The last action was to calculate the potentially achievable reduction in the cost of milk production, if both technical and cost efficiencies were to be optimized.

The mathematical formulas applied were as follows:

1. Assuming optimal technical efficiency (100%) was to be achieved, the daily farm milk yield would be;

$$100/X_1 * Y \quad (18)$$

where;

100=100% achievable TE level; X_1 = achieved TE level (%), Y = Average yield per farm per day (kg).

2. New average cost per kg, if the TE was to be optimized; *Ksh.*

$$C_1/(100/X_1 * Y) \quad (19)$$

where;

Ksh. C_1 =total daily dairy farm cost; $100/X_1 * Y$ =Achievable milk yield (kg), if TE equals 100%.

3. New average farm cost of producing $100/X_1 * Y$ kg (in a case where CE is optimized):

$$\frac{X_2}{100} \times C_1 / (100 / X_1 * Y) \quad (20)$$

Where;

X_2 = achieved cost efficiency of dairy farms in the two study districts.

CHAPTER FOUR:

RESULTS

This chapter presents the results on dairy farming efficiency estimates obtained through the various analytical methods and tools as described in chapter three. The chapter is divided into four sections. The first section elaborates the characteristics of the dairy cow farms. The second section details the technical efficiencies while the third section provides the cost efficiencies. The fourth section presents the relationship between efficiencies and the cost of milk production.

4.1 Dairy Farm Characterization

4.1.1 Socio-Economic Characteristics

This sub-section presents results on the herd size, feeds and supplements, dairy breeds, land sizes, amounts of dairy labour, chaff-cutter ownership and milk yields.

4.1.1.1 Dairy Cattle Herd Size

A large proportion of farms (71%) had between 2 and 5 animals. The numbers of milking cows per farm were between 1 and 5, with 82% of them being up to two. There was a positive and significant correlation between the milking herd size and the total farm milk yield ($r = 0.46$; sig. (2-tailed) = 0.000, sig. level = 0.01, $N=135$). The average herd size was 3.93. There were 530 animals in the sample farms, with 50% (265 cows) being mature cows, 79% (210 cows; about 40% of the total herd) of which were lactating (Tables 4.1), producing an average of 1933 kg per day.

Table 4.1: Frequency Distribution of Animals per Farm in Embu East and Igembe South Districts

No.	2 Sites – Embu E Embu and Igembe (Percentage)	Embu E (Percentage)	Igembe South (Percentage)	Embu: Milking (Percentage) N=94	Igembe: Milking (Percentage) N=36
1	9.6	7.3	15.4	59.38	43.59
2	22.2	21.9	23.1	29.17	20.51
3	13.3	14.6	10.3	7.29	15.38
4	21.5	25.0	12.8	1.04	10.26
5	14.1	13.5	15.4	0	2.56
6	7.4	7.3	7.7	0	0
7	4.4	5.2	2.6	0	0
8	2.2	1.0	5.1	0	0
9	4.4	4.2	5.1	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	.7	0	2.6	0	0

Source: Field survey data, September, 2010

4.1.1.2 Feeds and Supplements

The average amount of roughages fed to cows per day was 52.2 kg (SD= 11.47), ranging between 25 and 90 kg (Table 4.2). Majority of the farmers (over 95%) fed their animals on Napier grass. The correlation ($r = 0.31$, sig. =.01, $N = 135$) between the amount of roughage fed and the farm milk yield was significant ($p=0.000$).

It was only about 12% of the farmers who conserved and stored roughages for use during the dry season. Majority of the farmers (about 90%) did not cut their Napier at the recommended physiological age of about three feet high. It remained in the farm as standing hay. Others cut it when it was younger, shorter, watery and less nutritious. Most farmers (71%) had zero-grazing units which were not constructed to the recommended dimensions. The farmers

depended on carpenters without training on the construction of zero-grazing units. These units ended up being poorly drained, a condition that allowed biting flies to thrive during the wet season.

Table 4.2: Quantities of Roughages, Concentrates, and Mineral Supplements fed to the Animals

	Embu East (n=96) ^(c)	Igembe South (n=39) ^(c)	Overall (n=135) ^(c)	Recommended optimal ^(b)
Mean amount of roughage feeds/day (kg)	51.9 (11.6 ^a)	52.8 (11.4)	52.2 (11.7)	75-105
Mean amount of concentrate feeds/day (kg)	2.2 (1.2)	2.1 (1.4)	2.2 (1.8)	Variable
Mean amount of mineral supplements/herd/month (kg)	4.2 (3.3)	4.5 (4.0)	4.3 (3.5)	3/milk cow

^a The standard deviation in parenthesis

^b Vary with breed, age, size, and physiological status of the animal

^c Sample size

Source: Field survey data, September, 2010

Dairy animals were fed on about 2.2 kg (Table 4.2) concentrate feed with a range of between 0.5 and 7 kg per cow per day. Most farms (75.6%) indicated that commercial concentrates were of low quality as indicated by poor responses in milk yields and at times cheated on the weight. All the farmers felt that the cost of concentrates was high relative to both the past costs and the current farm-gate milk prices. The correlation coefficient ($r = 0.37$) between the amount of concentrate fed and the milk yield was positive and highly significant ($p = .000$) (Table 4.3).

Table 4.3: Summary of Bivariate Correlations between Farm Based Socio-economic Variables in Embu East and Igembe South Districts

	Embu E (N=96)	Igembe (N=39)	S Overall (N=135)
Correlation between breed and roughage feed	.359**	.249	.320**
Correlation between breed and concentrate feed	.232*	.581**	.371**
Correlation between mineral supplements and milk yield	.402**	.822**	.584**
Correlation between breed and land size	.225*	.179	.203*
Correlation between the land size and milk yield	0.091	.410**	.214*
Correlation between calving interval and milk yield	-.285**	-.086	-.226*
Correlation between the amount of labour used and milk yield	.392**	.590**	.518**

*=10%; **=5%

Source: Field survey data, September, 2010

The main concentrate (over 90%) in use was dairy meal (a type of concentrate feed containing all the ingredients a cow requires), followed by bran (a milling by-product), with less than 2% using pollard.

Farms provided an average of 4.3 kg (Table 4.2) of mineral supplements ranging between 0.5 and 22 kg per month. The average amount per animal per month was 1.1 kg.

The quality of brands in the market was reported to vary in quality among brands and even within brands over time. The correlation between the quantities of mineral supplements and milk yield was positive (0.584) and significant ($P=0.000$; sig. 0.01 level, 2-tailed).

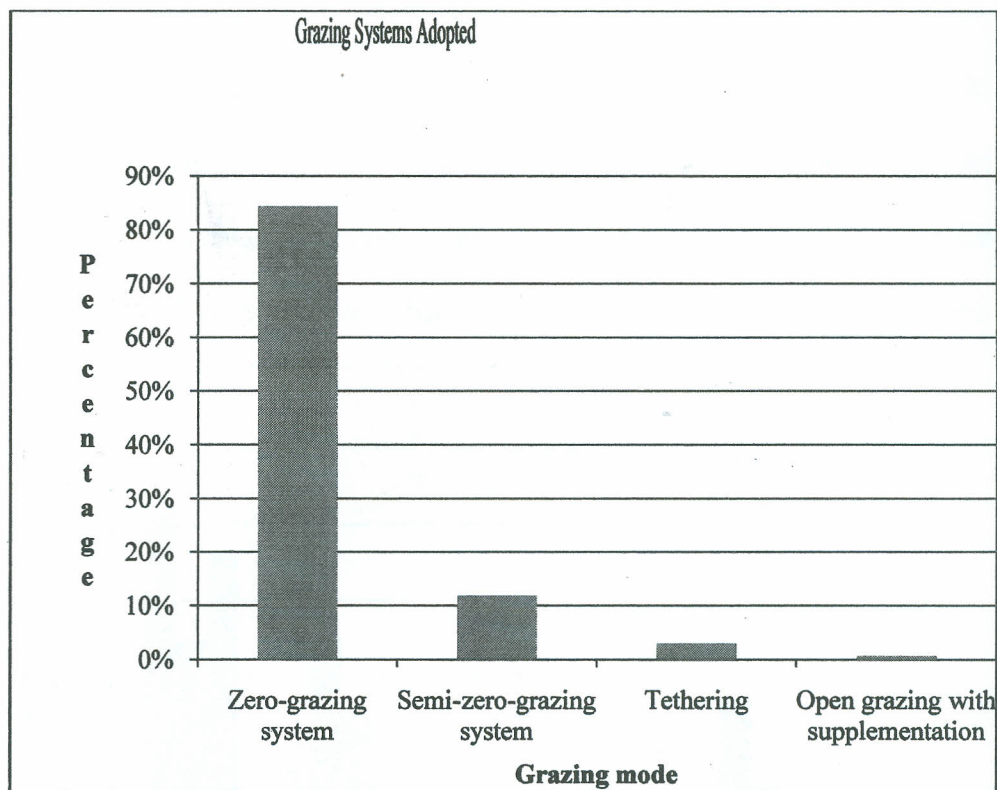


Figure 4.1: Grazing Modes Practiced

Source: Field survey, September, 2010

Zero-grazing mode constituted 84%, semi zero grazing 11.9%, tethering 3%, and open-grazing at supplementation 0.7%. Different grazing modes had different milk yield averages; zero-grazing mode had 15.73 kg (N=114) semi-zero-grazing mode had 8.75 kg (N=14), tethering with 3.5 kg (N=2) and open-grazing with supplementation had 10 kg (N=1) (Figure 4.1). The mean dairy farm costs were Kshs. 587.5, 338.5, 262.2, and 187.9 for the zero-grazing,

semi-zero grazing, tethering, and open-grazing with supplementation, respectively. They respectively had Kshs. 37.3, 38.7, 74.9, and 18.8 as their mean cost of producing a kilo of milk.

4.1.1.3 Breed

Friesian constituted 47% of the dairy animals, Ayrshires 26%, and cross-breeds were 16% (Figure 4.2). Farms with Friesians produced more milk. Igembe South District had more cross-breeds than Embu East and an equal number of Friesians and Ayrshires. The average milk yield per cow in Igembe District (8.4 kg) was less than that of Embu East District (9.6).

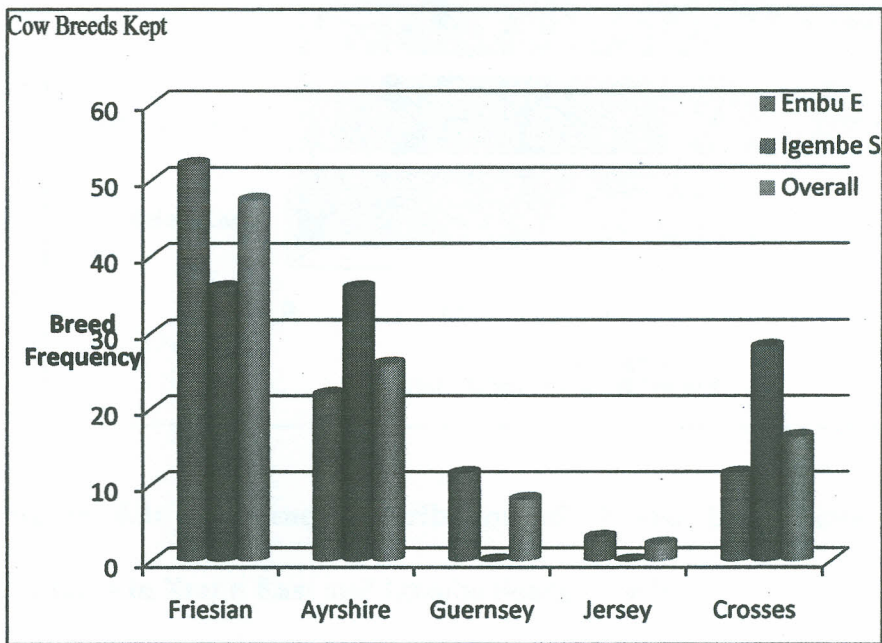


Figure 4.2: Distribution of Dairy Breeds in Embu East and Igembe South Districts

Source: Study results, 2012

4.1.1.4 Land

Most farms (92%) own land sizes ranging between 0.4 and 5 acres (Figure 4.3). The average land size was two acres. About 47% of the dairy farmers have part of their land parcels approximately 3.3 km away from the farm. Correlation between the land size and milk yield was insignificant. Available land was shared with other enterprises because all the farmers were mixed crop-livestock farmers (Appendix 7).

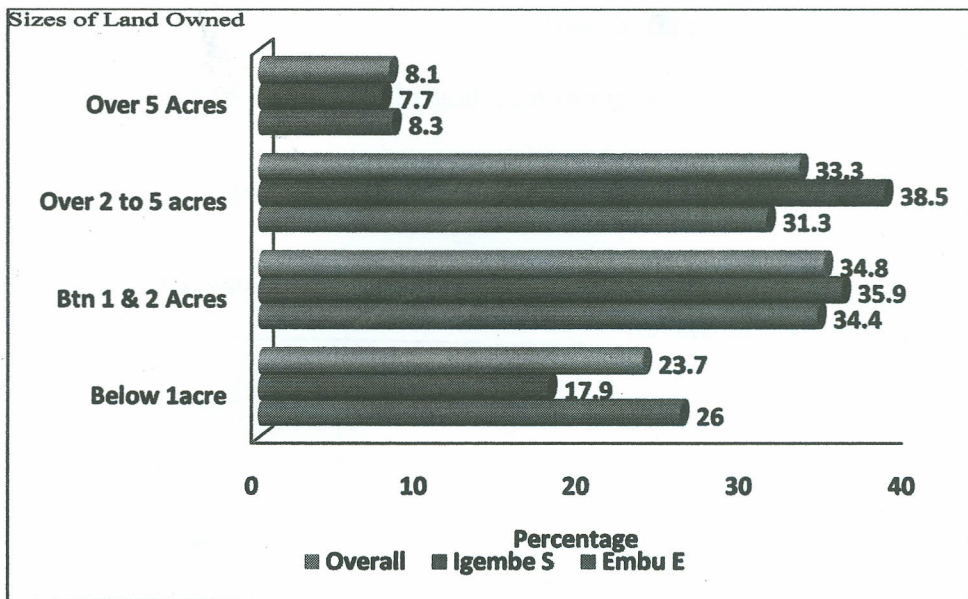


Figure 4.3: Frequency Distribution of Owned Land Sizes by Dairy Farmers in Embu East and Igembe South Districts

Source: Field survey results, 2012

Animal feeds were supplemented from external sources. Land set aside for growing Napier grass averaged 20% of the available farm land.

4.1.1.5 Herd Labour

The number of labour hours per day ranged between 2 and 30, with a mean of 8.7 (SD= 5.01). Labour in this case was considered to be all that time taken by a person undertaking a dairy related activity, irrespective of its type. It included the time taken travelling to collect fodder materials from the farm, milking, animal spraying, grazing, and cleaning of the zero-grazing unit, among others (Appendix 3). The average labour per cow per day was 2.2 (Table 4.4). The correlation ($r=0.518^{**}$) between farm milk yield and the amount of labour was positive and significant ($p=.000$; at .01, 2 tailed).

Table 4.4: Average Time Spent on a Dairy Farm per Day

	Minimum	Maximum	Mean	Std deviation	Labour hours/animal
Two sites combined	2	30	8.71	5.01	2.2
Embu East	2	15	8.17	3.43	2.1
Igembe South	4	30	10.69	7.34	2.66

Source: Sample survey data, September, 2010.

4.1.1.6 Chaff-Cutter Ownership

It was only about 23.7% of the dairy farms that owned chaff-cutters; 76.3% (N=135) of the dairy farms lacked them. However, contrary to expectations, the results showed no statistical relationship between chaff-cutter ownership and milk yields.

4.1.1.7 Milk Yield and Calving Interval

The simple average milk per cow was 9.3 kg (the breed averages were: Friesian-12.2; Ayrshire-10; Guernsey-6.8; Jersey-6; Cross-breeds-6.5) with a

range of between 1 and 29 kg. Cows in Embu East District produced more milk (9.6 kg) than those in Igembe South District (8.4). However, the former district had less average yield (13.7 kg) per herd than the later District (18.5 kg), mainly due to the fact that the later had a larger lactating herd. The average daily herd milk yield was 15.0 kg with a range of between 1 and 68 kg. Two (2) and four (4) dairy farming households in Embu East and Igembe South districts respectively, had no lactating cows during the data collection period, and were therefore not included in the determination of the averages.

The average calving interval was 588 days (about 1 year and 7 months) (ranging between 370 and 1300; N = 114; SD = 214). This parameter varied in the two sites with Embu East having a mean of 606 days ranging between 370 and 1300 (N = 83; SD = 228) while Igembe South had an average of 547 days (ranging between 380 and 970; N = 35, SD = 145). The breeds had the following average lactation lengths; Friesian-582, Ayrshire-550, Guernsey-638, Jersey-553, and Cross-breeds-603.

4.1.2 Dairy Farmer Characteristics

This sub-section presents results on farmer's formal education level, age, experience, group membership and business course attendance.

4.1.2.1 Formal Education Level

About 40% of the dairy farmers had primary and 37% had secondary school level of education (Table 4.5) (the number of years in school were used to classify the levels). There was a weak correlations between farm milk yield and the farmers' formal education level ($r=0.200$, $p =0.02$). It was also weak

when correlated with the breed kept ($r=0.1$, $p=0.24$). However, there was a positive and significant correlation between chaff-cutter and education level ($r=0.3$, $p=0.00$).

Only one third (33%) of the dairy farmers had attended short courses in animal husbandry. In addition, it is only 22% of farmers who had attended business related courses. A positive correlation between milk yield and attendance to business course was established.

Table 4.5: Frequency Distribution (%) of Education Level Attained by Dairy Farmers in Embu East And Igembe South Districts

Education level	2 sites combined (N = 135)	Embu E (N = 96) (N=96)	Igembe South (N = 39)
None	0.7	1	0
Primary	40	41.7	30.8
Secondary	37	34.4	48.7
Middle-level college	19.3	20.8	15.4
University	3	2.1	5.1

Source: Field survey data, 2012.

Departments of livestock production and agriculture in the study Districts, offered short non-residential courses on agri-business management at no cost to farmer groups on demand. There were opportunities for trainings through common interest groups under any agricultural commodity enterprise.

4.1.2.2 Age and Experience of the Dairy Farmer

About 36% of the farmers were between the ages 36 and 45 years, while about 20% were between 46 and 55. Farmers in Igembe south were younger than those in Embu East district (table 4.6). The proportion of farmers aged

between 36 and 45 years was highest in both districts. Correlation between milk yield and the age of the farmer was insignificant (Table 4.8). In addition, the correlation between the age of the farmer and chaff-cutter ownership was also insignificant.

Most dairy farmers were experienced in dairy farming. About 90% of them had more than 5 years experience. Eleven farmers (8% of the farmers) had experience above 35 years. Correlations between milk yield per farm per day and the experience of the farmer in dairy farming was not significant. A further correlation between farmer experience and chaff-cutter ownership was insignificant too.

Table 4.6: Proportion (%) of Dairy Farmers by Age Bracket

Age bracket (Years)	Combined data (N = 135)	Embu East (N = 96)	Igembe South (N=39)
Below 25	1.5	1	2.6
26-35	12.6	9.4	20.5
36-45	35.6	34.4	38.5
46-55	20.0	18.8	23.1
56-65	17.8	20.8	10.3
66-75	7.4	9.4	2.6
Over 76	5.2	6.3	2.6

Source: Field survey data, 2012.

4.1.2.3 Group Membership

Only 34.8% of the farmers were members of agricultural farmer groups. There was a positive and significant relationship between group membership and ownership of the larger breeds (Friesian and Ayrshire), but the correlation between one being a member of a group and the amount of milk yield per day was insignificant ($r = -.080$, $p = .355$) (Table 4.7). There was a positive

relationship between ones membership to a group and owning a chaff-cutter and none when correlated with the number of labour hours allocated to the dairy animals.

Table 4.7: Bivariate Correlations between Farm Based Socio-Economic Variables in Embu East and Igembe South Districts

	Embu (N=96)	East Igembe (N=39)	South	Overall (N=139)
Correlation between Formal Education Level and milk yield	.085	.396*		.200*
Correlation between Farmer's Age and milk yield	.090	-.018		.018
Correlation between Experience and milk yield	.096	-.050		.012
Correlation between Group Membership and milk yield	.185	.000		.080
Correlation between Business Course Attendance and milk yield	.128	.190		.186*
Correlation between extension service availability and milk yield	.029	-.003		.025

*Significance at 0.1

Source: Field survey results, 2012.

4.1.3 Other Farm and Farmer-Related Socio-Economic Factors

4.1.3.1 Raw milk Price/Kilogram

The average price at the farm gate level was Ksh. 24.4 (SD = 7.22), with a range between KSh.15 and 40 per kilogram. In Embu East, the mean milk price was Ksh.20.4 (ranging between Ksh. 15 and 30, SD =2.48, N = 96), while the mean for Igembe South was Ksh. 35.18 (ranging between Ksh. 25 and 40, SD = 4.45, and N = 39). There was a positive and significant correlation ($r=0.242$, $p=0.005$) between milk yield per farm per day and its price. Milk prices over the preceding five years showed Embu's remaining within the Ksh. 15-30, while Igembe's rose to maximum of Ksh.60, particularly during the months of October when supplies were insufficient.

4.1.3.2 Source of Household Income

A substantial number of farmers (44%) indicated that dairy farming was their main source of income. The others were distributed as follows: 26%, salaried/ waged labour; 26%, crop farming; and about 4.4% commercial business. There were only small differences between the two districts. The main source of household income in Embu was dairy farming at 46%, followed by salaried/waged employment at 32.3%, and then crop farming at 20%. In Igembe, crop farming (mainly Miraa) led at 41% followed closely by dairy farming at 39%. The waged/salaried employment was at 10%. Though farmers in both districts depended on commercial business for household

incomes to some extent, Embu East was at 2% while Igembe South was higher at 10%.

4.1.3.3 Farmers' Perception of Constraints to Dairy Farming

The main constraints highlighted in the study area were the high costs of breeding stock and animal feeds, adverse weather fluctuations, unsupportive government policies and expensive breeding services (Figure 4.4). The high cost of breeding stock is correlated with the observed long calving intervals (588 days against 365) while the high cost of feeds is related to the small land sizes per household and the adverse weather conditions.

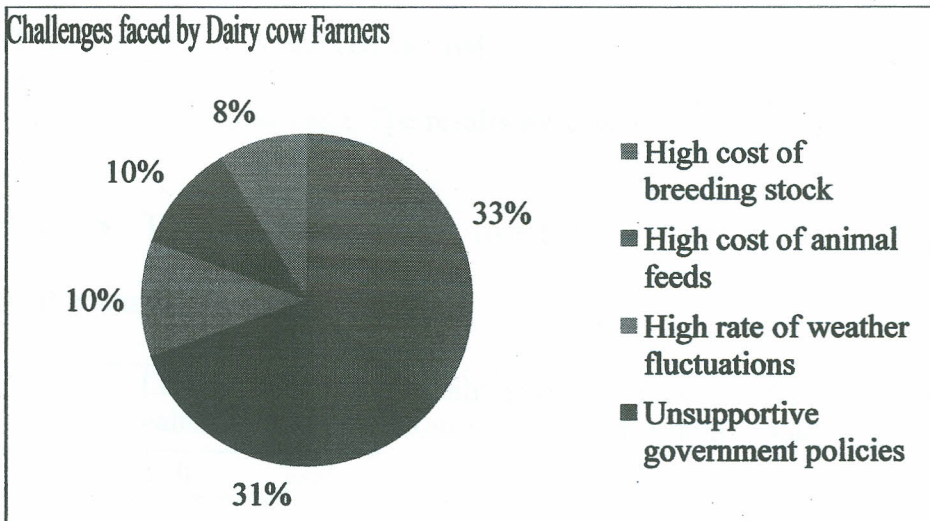


Figure 4.4: Challenges Faced by the Dairy Farmers in Embu East and Igembe South Districts

Source: Field survey results, 2012

The result on the unsupportive government policies and the high cost of breeding services are also linked.

4.2 Technical Efficiency of Dairy Cow Farms

4.2.1 Hypothesis, Statistical and Econometric Tests

4.2.1.1 Hypothesis Testing Results

The two tests carried out in this sub-section were on the appropriate distribution of inefficiency (half normal vs truncated normal) and the test for the absence of technical inefficiency. The following were the results obtained:

(i) Test on the Appropriate Distribution of Inefficiency (Half Normal Vs Truncated Normal)

Test for half-normal distribution of error term was carried out. From the model results, the values of the log likelihood were 19.20 and 19.46 for the half normal and the truncated normal models respectively. The number of degrees of freedom was eight. The results were as indicated in table 4.8.

Table 4.8: Tests of Half-Normal ($\mu=0$) Vs Truncated Normal ($\mu\neq 0$) Distribution

	Log-likelihood value		Likelihood Ratio test χ^2	Degrees of freedom	Critical Value	Reject/ do not reject
	$\mu=0$	$\mu\neq 0$				
Hypothesis $H_0; \mu=0$	19.20	19.46	0.52	8	15.51	Do not Reject

Source: Field survey results, 2012

The table shows that the critical χ^2 value exceeded the computed χ^2 value, indicating that the test was not significant and hence the null hypothesis of half-normal distribution was not rejected.

(ii) Hypotheses on Zero Technical Inefficiency in Milk Production

In conducting this test, the null hypothesis was specified as each farm was operating on the technically efficient frontier. This was rejected in favour of the presence of inefficiency effects. The gamma parameter was 0.98 and significant at 1 percent probability level. This implied that about 98 per cent of the disturbance term was due to inefficiency.

4.2.1.2 Statistical and Econometric Tests for Data on the Dairy Farms

(i) Test for the Percentage Deviation from the Mean Milk Output that is Explained by the Model Inputs (R^2 Square)

In this study, where the dependent variable was milk yield and the independent variables were chaff-cutter ownership, the amount of roughages, total land size owned, milking herd size, dairy breed, number of labour hours per day to the herd, amount of concentrates per cow per day, amount of mineral supplements per month and the herd size, the R^2 square was 0.78 (adjusted R-square=0.76) (SE=5.79) (appendix 4). The aim of the regression was to find the best betas that could minimize the sum of squares of the deviations.

(ii) A Test on Whether Modeled Dairy Farming Inputs Assisted in Predicting the Milk Output (F-test)

The F-value and its corresponding p-value for this study's production model were; F-value, 49.454; p=0.000, respectively (appendix 4). If the F was not significant, it would mean that the use of the modeled inputs did not assist in predicting the milk output. While the F-value indicates whether the model

as a whole is significant, it also tests whether R-square is significantly different from zero.

(iii) A Test for the Normal Distribution of Data on Milk Production

A histogram of residuals helps to check the assumption about normal distribution.

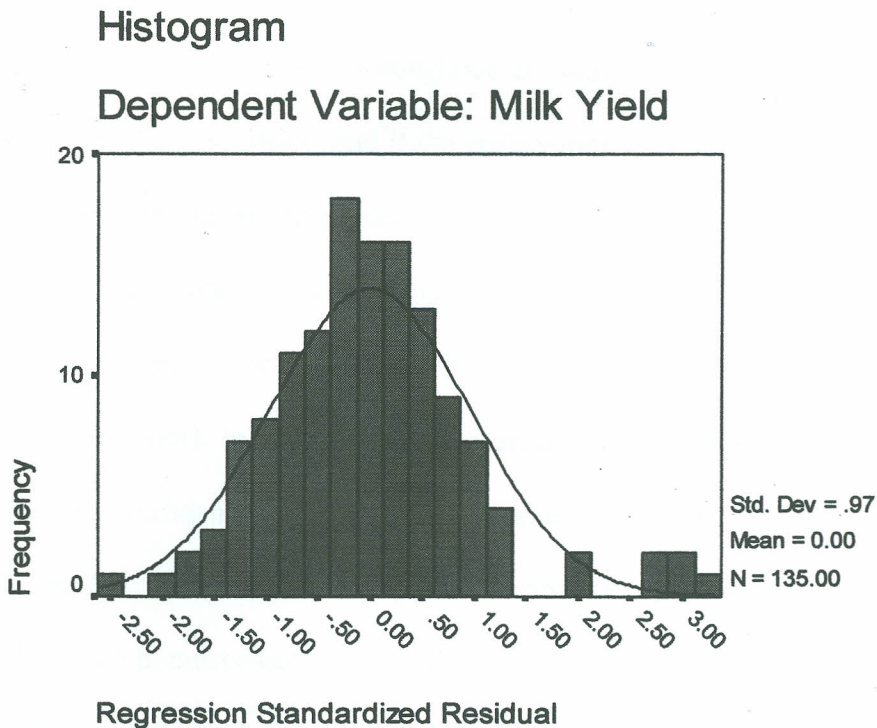


Figure 4.5: A Histogram of Residuals in a Model on Milk Production in Embu and Meru Counties

Source: Field survey data, September, 2010

A histogram of residuals from data on this study was as presented in figure 4.5. The residuals should roughly look like a normal distribution. Although it is not necessary that individual data be normally distributed, highly skewed values tend to produce heteroscedastic effects. Strongly multi-modal histograms might indicate a mixture of more than one population in the data.

(iv) A Test for Constant Variance in the Errors Made on Dairy Farm's Sample Data (White's test of homoscedasticity)

One of the key assumptions of the ordinary regression model is that the errors have the same variance throughout the sample (in which case the data are said to be homoscedastic and if the error variance is not constant, they are said to be heteroscedastic). Heteroscedasticity in an otherwise properly specified linear model leads to unbiased but inefficient parameter estimates. The ordinary least squares (OLS) estimator is no longer BLUE (best linear unbiased estimator). In such a case, the standard errors and t-tests are wrong, making the confidence intervals and hypotheses tests not to be relied on. Based on the results (from STATA software) of this study however, the hypotheses on homoscedasticity could not be rejected;

H_0 : Homoscedasticity

H_a : Unrestricted heteroscedasticity

$\text{Chi}^2 (53) = 60.04$

$\text{Prob Chi}^2 > = 0.2359$ (appendix 9).

We fail to reject the null hypotheses of homoscedasticity even at the 10% level of significance.

(v) Test for the Level of Multi-collinearity Amongst the Modeled Milk Production Variables

Multicollinearity inflates the standard errors, making it impossible to determine the relative importance of the predictors (independent variables). One of the methods of determining the degree of multicollinearity is to calculate the variance inflation factors (VIF) for each predictor x_j :

$$VIF_j = \frac{1}{1-R_j^2} \quad (21)$$

where R_j^2 is the coefficient of determination of the model that includes all predictors except the j th predictor.

Table 4.9: VIF and Tolerance Levels of Various Independent Variables on a Model of Milk Production in Embu and Embu Counties of Kenya

Variable	VIF	Tolerance (1/VIF)
Herd	1.15	0.87
Milking Herd	1.13	0.89
Breed	1.42	0.70
Roughage feed	1.19	0.84
Concentrate feed	1.44	0.69
Mineral concentrate	1.51	0.66
Labour	1.48	0.68
Land	1.12	0.90
Technology	1.26	0.80

Source: Study results from STATA software package.

VIF is a measure of how much the variance of an estimated regression coefficient increases (inflated by multicollinearity) if the explanatory variables are correlated. The higher the value of VIF the greater is the degree of collinearity. As a rule of thumb, if the VIF of a variable exceeds 10, which

will happen if R^2_j exceeds 0.90, that variable is said to be highly collinear (Gujarati, 2004). However, VIFs over 2.50 start to indicate relatively high levels of multicollinearity. The results obtained in this study were as shown in table 4.9, and they indicated low levels of multicollinearity.

Multicollinearity is also said to be a problem if a tolerance is 0.05 or less. The VIF is simply the reciprocal of the tolerance level ($1/\text{tolerance}$). In this study, no predictor variable had a value lower than 0.5 (table 4.9), which is a further indication of minimal collinearity among the variables. Another check for collinearity is the Durbin–Watson statistic. Normally its value should lie between 0 and 4. A value close to 2 suggests no correlation. The Durbin–Watson statistic in this study was 1.81, which further confirmed that multicollinearity was low among the predictor variables.

4.2.2 Elasticities of Milk Output in Response to Individual Inputs (MLEs)

The stochastic frontier production function estimates of the sampled dairy cow farms in both Embu East and Igembe South districts (combined) were presented in Table 4.10 (also refer to appendix 5). The gamma estimate of $\gamma = 0.98$ indicates that 98% variation in milk output was due to the inefficiency factor (u_i). The estimates suggest that milking herd size, roughage feed, concentrate feed, mineral supplements and labour are the most important determinants of raising milk outputs in smallholder dairy enterprises, while the total herd size, breed, and land size have no significant effect on dairy output in Embu and Igembe. The estimated elasticities of the total herd size, breed,

land size are relatively small (at approximately 0.06, 0.05, 0.07, respectively), suggesting that they were not significant limitations.

Table 4.10: Parameters of the Cobb-Douglas Frontier Model for Milk Production Embu and Meru Counties of Kenya

Variable	Parameter	Coefficient	Standard Error
Total herd size(X_1)	β_1	0.06	0.11
Milking Herd size(X_2)	β_2	0.76***	0.11
Breed kept (X_3)	β_3	0.05	0.08
Roughage feed (Kg) (X_4)	β_4	0.51**	0.18
Concentrate feed (Kg) (X_5)	β_5	0.59***	0.09
Mineral supplements (Kg) (X_6)	β_6	0.28***	0.07
Labour (Hours/day) (X_7)	β_7	-0.19**	0.09
Land size (X_8)	β_8	0.07	0.09
Chaff-cutter ownership (X_9)	β_9	-0.03	0.04
γ		0.9800**	

***, ** Significance at 1% and 5% levels (one-tail test), respectively

Diagnostic statistics

Log likelihood function = 19.2

LR test of the one-sided error = 20.6

Source: Field survey results, 2012.

4.2.3 Sum of Elasticities of Milk Output in Response to Modeled Inputs

Determination of elasticities is necessary for the estimation of responsiveness of milk yield to inputs. Since the model is a log linear, the coefficients represent elasticity of milk yields with respect to the inputs. Summation of the partial elasticity of production with respect to every input for a homogeneous function (all resources varied in the same proportion) was 2.11, representing a returns-to-scale coefficient.

If all factors are varied by the same proportion, the function coefficient indicates the percentage by which output will be increased. In this case, the production function can be used to estimate the magnitude of returns-to-scale. Constant returns-to scale, only holds if the sum of all partial elasticities is equal to one. If this sum is less than one, the function has decreasing returns-to-scale: if more than one, as in this case, an increasing returns-to-scale exists.

4.2.4 Technical Efficiency Estimates of Dairy Cow Farms

Dairy farm efficiencies ranged between 37.2 and 96.9% (appendix 6), with mean estimate of 83.7% (table 4.11). The efficiency distribution showed that about 88.2% of the dairy cow farms attained over 71% efficiency levels. This 83.7% level of efficiency indicates that only a small fraction of the output can be attributed to wastage. The results showed that farmers could improve on their efficiencies by about 16.3 percent on average. Potential increases in milk yields through increased technical efficiencies exist among all the farms. Those farms already with high and those with low efficiency levels would have proportionately lowest and highest milk yield increases respectively, in cases where efficiencies were to be optimized.

Table 4.11: Distribution of Technical Efficiencies Among Dairy Farmers in Embu and Meru Counties

	Embu (n=96)	E Igembe (n=39)	S Overall (n=135)
Frequencies (%)			
0-39	1.0	0	0.7
40-49	0	10.3	3
50-59	4.2	5.1	4.4
60-69	2.1	7.7	3.7
70-79	12.5	15.4	13.3

80-89	37.5	35.9	37
90-100	42.7	25.6	37.8
Range Between the Highest and lowest Efficiencies			
Max	96.9	94.8	96.9
Min	37.2	41.3	37.2
Mean	85.5	79.3	83.7
Std dev	10.4	15.4	12.3

Source: Field survey results, 2012.

4.2.5 Determinants of Technical Efficiency of Dairy Farms

Although the assessment of the degree of efficiency is important, it is additionally necessary to identify the sources of variation in technical efficiency among farmers. In this light, the inefficiency effects model was estimated. The results (Table 4.12) showed all the hypothesized determinants of efficiency were insignificant. The estimated elasticities of the education level, farmer's age, experience, extension service availability, and business course attendance were negative as expected, but all of them were not statistically significant.

Table 4.12: MLEs of Hypothesized Milk Production Inefficiency Determinants

Variable Inefficiency effects	Parameter	Coefficient
Formal Education level (years)	δ_1	-3.67
Farmer's age (Years)	δ_2	-1.66
Experience (Years)	δ_3	-0.91
Extension service availability	δ_4	-0.59
Membership to group (Dummy)	δ_5	0.88
Business course attendance	δ_6	-1.57

Source: Field survey results, 2012

A negative sign of the parameters in the inefficiency function implies that the associated variable has positive effect on technical efficiency and a positive sign indicate the reverse is true.

4.3 Cost Efficiency Estimates of Dairy Cow Farms

4.3.1 Hypotheses Testing Results

(i) Test on the Appropriate Distribution of Inefficiency (Half Normal Vs Truncated Normal)

From the model results, the values of the log likelihoods were 271.42 and 271.97 for the half normal and the truncated normal models respectively. The results were as indicated in table 4.13.

Table 4.13: Tests of Half-Normal ($\mu=0$) Vs Truncated Normal ($\mu\neq 0$)

Distribution

	Log-likelihood value		Likelihood Ratio test χ^2	Degrees of freedom	Critical value	Reject/ Do not reject
	$\mu=0$	$\mu\neq 0$				
Hypothesis $H_0; \mu=0$	271.42	271.97	1.11	13	22.36	Fail to Reject

Source: Field survey results, 2012

From the above therefore, it can be concluded that the error term had a half-normal distribution.

(ii) Hypotheses on Zero Cost Inefficiency in Milk Production

In conducting this test, the null hypothesis was specified as each farm was operating on the cost efficient frontier. This was rejected in favour of the presence of inefficiency effects. The gamma parameter was 0.82 and

significant at 1 percent probability level. This implied that about 82 per cent of the disturbance term was due to inefficiency.

4.3.2 Elasticities of Dairy Farming Costs in Response to Modeled Independent Variables (MLEs)

The stochastic frontier cost function estimates of the sampled dairy cow farms in both Embu east and Igembe south districts (pooled) are presented in Table 4.14.

Table 4.14: Parameters of the Translog Stochastic Cost Frontier Model for Milk Production in Embu and Meru in Kenya

Regressors	Parameter	Coefficient	Standard Error
Output	β_1	0.03	0.04
Roughages	β_2	0.27 (3.34***)	0.08
Minersuppls	β_3	0.05	0.07
Labour	β_4	0.46 (5.57***)	0.08
Output*Output	β_5	0.03	0.03
Roughage*Roughage	β_6	0.38 (3.57***)	0.11
Miner.suppls*Miner.suppls	β_7	0.11	0.98
Labour*Labour	β_8	0.06	0.05
Output*Roughages	β_9	0.03	0.05
Output*Miner.suppls	β_{10}	0.02	0.02
Output*Labour	β_{11}	-0.02	0.06
Roughage*Miner.suppls	β_{12}	-0.08	0.06
Roughage*Labour	β_{13}	-0.15 (-2.33**)	0.06
Miner.suppls*Labour	β_{14}	0.03	0.04
Sigma-squared		0.00**	0.01
Gamma		0.82***	0.11

***, ** Significance level at 1%, and 5% respectively

Diagnostic statistics

Log likelihood function = 271.97

LR test of the one-sided error = 17.67

Note: All explanatory variables are in natural logarithms.

Source: Computer print-out of Frontier 4.1c.

4.3.3 Dairy Farming Cost Elasticities in Response to Input Prices and Output

The cost elasticities with respect to output and input prices had a positive effect on costs, conforming to the basic properties of the cost function that satisfy the cost minimization assumption. It is not possible to produce a positive output with no costs, following the assumption on strictly positive prices and that at least one input is required to produce an output.

The output elasticity was positive (0.03) but not significant. The coefficients on roughage feeds (0.27) and labour (0.46) imply that an increase in each of the two variables will increase total costs. The two were statistically significant at 1% level. The coefficient of the mineral supplement (0.05) is small and insignificant.

4.3.4 Elasticities of Dairy Farming Costs on increased Inputs and Output

There was no strong empirical support for diseconomies of scale as the coefficient of output^2 , while positive (0.03), was not statistically significant. Cost elasticity with respect to roughage feeds (0.38) indicates diseconomies of scale, given the statistically significant positive coefficient of rfeed^2 . The coefficients for the others: minsuppl^2 (0.11), and labr^2 (0.06), are positive indicating that diseconomies of scale are realized as the volume of produced milk increases, but lacks statistical support as their coefficients are insignificant.

4.3.5 Elasticities of Dairy Farming Costs in Response to Two Independent Variables used Together

The coefficient for $r_{feedlabr}$ (-0.15) was negative and significant at 1% level. The negative parameter estimate for $r_{feed} \times labr$ indicates that roughage feed and labour substitute for one another in production, so costs are reduced by using them together. The coefficients for $outptrfeed$ (0.03), $outptminsuppls$ (0.02), $outptlabr$ (-0.02), and $minsupplslabr$ (0.03) are small and insignificant.

4.3.6 Cost Efficiency Estimates of Dairy Farms

The discrepancy between observed cost and the frontier cost was due both to technical and allocative inefficiencies.

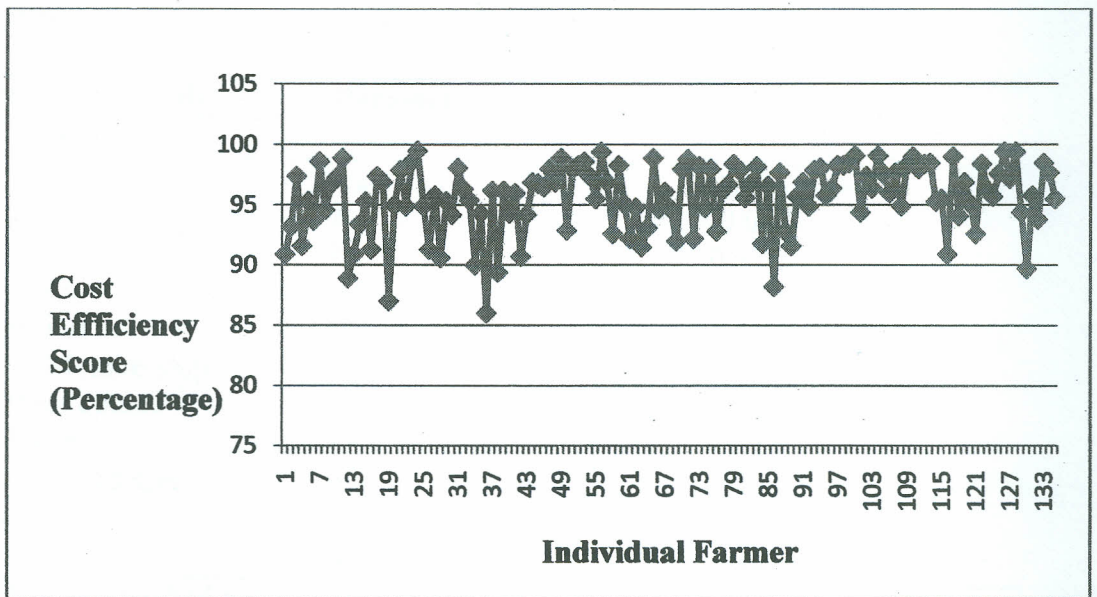


Figure 4.6: Distribution of Efficiency Scores by Dairy Farmers in Embu East and Igembe South Districts

Source: Field survey results, 2012

Cost efficiency estimates ranged from a low of 86 to a high of 99.5% (Figure 4.6 and appendix 6), with an average efficiency estimated at 95.6%. The means for Embu East and Igembe South Districts were 95.2 and 96.6%, respectively.

4.3.7 Determinants of Cost Efficiency in Dairy Farming

Many variables were hypothesized as determining cost efficiency. The results were as shown in table 4.15. A negative sign of the parameters in the inefficiency function implies that the associated variable has positive effect on cost efficiency and a positive sign indicate the reverse is true.

Table 4.15 MLEs of Hypothesized Cost Efficiency Determinants in Milk Production

Inefficiency Model Variable	Parameter	Coefficient^a
Constant	δ_0	0.06
Education	δ_1	-0.03
Age	δ_2	0.02
Experience	δ_3	-0.00
Extension	δ_4	0.01
Group Membership	δ_5	-0.03
Business course	δ_6	-0.00
Herd size	δ_7	-0.30
Milking herd size	δ_8	0.01
Breed	δ_9	0.04
Land	δ_{10}	-0.04

^aNo variable had a statistically significant coefficient

Source: Survey results, 2012

4.4 Potential Reduction in Milk Production Cost by Optimizing Farming Efficiencies

Efficiency is one of the approaches that a producer can apply to reduce the cost of production. In this study, the cost of maintaining a dairy herd per day producing 15 kg on average was Ksh. 551.1 at an average of 83.7% and 95.6% technical and cost efficiency levels, respectively. If an assumption of zero technical inefficiency is made, implying a 100% efficiency level, average milk output per herd per day would rise to 17.9 kg. The optimized efficiency would reduce the cost of producing a kilogram of milk from Ksh.36.7 to 30.8.

If this cost reduction as a result of improved technical efficiency is coupled with a further 4.4% reduction resulting from optimized allocative efficiency, the new cost of milk production per kilogram at the farm level would reduce to Ksh. 29.2. The total decrease in milk production cost would be about 20.4%. However, the average price of milk would still remain lower than the average farm-gate price at Ksh. 24.4/kg. Dairy farmers in Embu had an average milk production cost of Ksh. 35.4 while those in Igembe had Ksh. 38.0. Their respective farm-gate milk prices were Ksh. 20.4 and 35.3, respectively (Table 4.16).

Table 4.16: Summary of Production, Efficiencies, and Potential Milk Production Cost Reductions based on Optimized Efficiencies

	Embu East	Igembe South	Overall
Average Herd Size	3.89	4.03	3.93
Per Cow Yield (Kg)	9.6	8.4	9.3
Average Milking Herd Yield (Kg)	13.7	18.5	15
Average Price (Ksh./Kg)	20.4	35.3	24.4
Average Revenue/herd	280.8	653.4	381.9
Total Cost (Ksh.)	35.4/kg (485.5/herd)	38.0/kg (703.3/herd)	36.7/kg (551.1/herd)
Average Gross Margin	-204.7	-49.9	-166.5
Mean TE	85.5%	79.3%	83.7%
Mean CE	95.2%	96.6%	95.6%
Proportion with positive GM	10.42%	23.10%	14.1%
Increase in Milk output due to TE optimization (KG)	16.0	23.3	17.9
Possible reduction in milk cost as a result of optimized TE	35.4-30.3=5.1	38.0-30.2=7.8	36.7-30.8=5.9
Possible reduction in milk cost as a result of optimized CE	35.4-33.8= 1.6	38.0-36.8=1.2	36.7-35.2= 1.5
Decrease in milk production cost with optimal TE and CE	35.4-(5.1+1.6) = 28.7	38.0-(7.8+1.2) =29	36.7-(5.9+1.5) =29.3
Correlation between GM and TE	.281**	.445**	.301**
Correlation between GM and CE	-.063	-.057	-.064
Correlation between GM and Milk Price	.304**	.173	.270**

** Significance at 5% level

Source: Field survey, September, 2010.

Potential Contribution of Optimized Efficiencies in Reducing the Milk Production Costs

To compute the potential reduction in cost of milk production through optimized technical efficiency (TE), first, the achieved average farm milk yield (at 83.7% efficiency) was increased by assuming 100% technical efficiency, i.e.

$$100\% \text{ (optimal technical efficiency)} / 83.7\% \text{ (achieved TE)} * 15 \text{ (Achieved yield)} \\ = 17.9 \text{ kg.} \quad (22)$$

In this case, milk yields rises by 2.9 kg (i.e. 17.9-15). This yield increase would result from efficiency optimization without addition of inputs (i.e. no extra costs). This would imply a decrease in cost of producing a kilogram of milk, as shown below.

The original cost per kilogram was;

$$(i). \text{ Ksh. } 551.1 \text{ per herd} / 15 \text{ kg (average herd yield)} = \text{Ksh. } 36.7. \quad (23)$$

New cost in case of optimized technical efficiency (TE);

$$\text{Ksh. } 551.1 \text{ per herd} / 17.9 \text{ (anticipated herd yield)} = \text{Ksh. } 30.8 \quad (24)$$

The difference in the cost of producing a kilogram of milk resulting in optimized TE would be;

$$\text{Ksh. } 36.7 - 30.8 = \text{Ksh. } 5.9. \quad (25)$$

Following a similar method, cost reductions per kilogram of milk were Ksh. 5.1 and 7.8 for Embu East and Igembe South Districts, respectively.

Potential cost reduction through optimized cost efficiency was achieved by undertaking the following computations;

(i). Initial cost of milk per kilogram;

$$\text{Ksh. } 551.1 \text{ per herd}/15 \text{ kg per herd} = \text{Ksh. } 36.7. \quad (26)$$

(ii). Cost reduction based on potentially optimized cost efficiency (CE);

$$95.6\% (\text{achieved CE})/100\% (\text{optimal efficiency}) * \text{Ksh. } 36.7 = 35.1 \quad (27)$$

This shows that cost reduction resulting from optimized cost efficiency would be; $\text{Ksh. } 36.7 - 35.1 = \text{Ksh. } 1.6$ (28)

Following a similar method, potential cost reductions per kilogram of milk in both Embu East and Igembe South Districts were Ksh. 1.6 and 1.2, respectively.

The new cost of producing a kilogram of milk in a case of optimized technical and cost efficiencies in the study area would therefore be,

$$\text{Ksh. } 36.7 - (5.9 + 1.6) = \text{Ksh. } 29.2 \quad (29)$$

CHAPTER FIVE:

DISCUSSION

5.0 Introduction

This chapter presents a discussion of the results obtained on the efficiency of dairy cow farms in Embu and Meru Counties of Kenya. The discussion is based on the three specific objectives and five research questions that were raised in Chapter 1 and investigated through a survey whose results were presented in Chapter four. The specific areas focused on are the farm and farmer characteristics, the technical and cost efficiencies and the relationship between the efficiencies and the cost of milk production.

5.1 Dairy Farm and Farmer Socio-economic Characteristics

5.1.1 Dairy Farm Characteristics

In this study, over 95% of the dairy farmers zero-grazed their animals. They owned land sizes averaging two acres; cows being relatively overstocked and underfed. They practiced mixed farming where dairy cows, among other livestock were reared alongside crop farming (Appendix 7). Competition for land resource allocation among the different farm enterprises was stiff, fuelled by the differences in the relative prices of inputs and outputs. For instance, as the tea payments per kilogram to the farmer were on an upward trend, the price of tea crop fertilizer was not concurrently increasing. Comparatively, as the price of milk per kilogram remained unpredictable, the price of concentrate feeds was rising. Milk prices were dictated by the processors; New KCC and

Brookside Dairies Ltd (in Embu, as prices in Igembe were determined through demand and supply mechanisms and were relatively higher).

The probable reasons for practicing mixed crop-livestock farming were that the farmers were more food secure in this kind of practice or because they lacked incentives to specialize. The crop-livestock system has the advantages of allowing diversification of risks, and recycling wastes thus preventing nutrient losses, adding value to crops and crop products while providing cash for purchasing farm inputs. The crop-livestock farming system buffers against climate fluctuations, offers diversified income sources and alternative use for low-quality roughage. However, it requires 'double' expertise and it is hard to upscale either of the two (livestock or crops) because there occurs increased demand for area of land required for a given Production (Lungu, 2000). The challenges of crop-livestock systems are such enormous due to inadequate land and correspondingly high population of humans and livestock (Adamu and Odion, 2000).

One of the plausible reasons for not adhering to the dairy stocking rate in the study region was that it was not based on economic viability only. Most Kenyan communities have traditionally kept livestock for subsistence, prestige, and as a form of insurance against drought. The animals also served other social needs like paying the bridal price and traditional ceremonies (RoK, 2008). To many farmers, dairy farming was an innovative way of growing wealth through keeping animals that utilized farm-by products such

as maize stovers and bean straw, which would have otherwise end up being wasted.

There were other several factors that made farmers to increase their herd sizes. About 20% of the farms kept bulls that were used on ox-carts to transport the farm products and by-products from far-off plots. The ox-carts were also hired to households who did not have their own, earning some extra income to the owners. In addition, about 5% of farms had breeding bulls, further raising the number of none milking dairy animals in the herd. Manure from the animals was used on crops, which indirectly motivated an increase in the number of cattle. Although the given reasons justify larger herds in the study region, results showed that increases in milk output led to increased production costs, confirming diseconomies of scale with regard to herd sizes. Selective culling of some adult animals should be encouraged in an effort to keep only an economically productive herd size. Record keeping would play a major role in identifying animals for culling, but this action was not common among the dairy keepers.

It was observed that land allocation proportion to the adopted enterprises remained almost constant even as land size varied amongst the farmers. This implied that any increases in land size would lead to a proportionate increase in land size allocated for fodder and pasture establishment, and not necessarily enterprise specialization. This practiced mixed crop-livestock farming on small land sizes resulted in low economies of scale in smallholder dairy farming.

Among studies relating land size and dairy farming is Díaz and Sánchez's (2006) study which showed small and middle-sized farms (acres) being positively correlated to milk yields, but was contradicted by Cabrera *et al.* (2009) whose finding was that such farms had negative correlation. The difference between the two could be resulting from the level of intensification, where the former could have dwelt with intensified and the later extensive dairy farming. This study's finding was that farm land size had no relationship with the amount of milk a farm produced.

It should be noted that both Díaz and Sánchez's (2006) and Cabrera *et al.* (2009) studies were among dairy farms in the developed world, where milk production is practiced by farmers with single objectives on the enterprise, requiring high levels of inputs and producing high output levels. The Western world farmers practice dairy farming under commercialized, industrialized, large-scale production systems having integrated marketing systems (Staal *et al.*, 2007), which is not the case in Kenya. Most dairy farms in Kenya are situated in the high rainfall potential regions, where the highest number of the country's human population lives and where land per household continues to reduce due to continued subdivision over time.

The insignificance of land size (a proxy to the amount of roughages produced in the farm) in relation to milk yields was probably because the animals were already overstocked and that part of the roughage feeds was sourced externally. This implies that yields would most likely correlate positively with the quantity sourced from outside the farm. However, there is

need to assess which is the better business option between stocking animals based on farm resources and overstocking, with the view to buying feeds from outside the farm. Based on the results that roughage has no economies of scale in milk production, it is suggested that the animals are stocked based on the farm resources; they are deemed to be more affordable.

Although the number of dairy animals a farm kept was larger than the quantity of feed resources it could produce for most of the year, still results showed a positive correlation between milk yields and the herd size. However, the relationship was not statistically significant. Farmers supplied their animals with feeds sourced from outside the farm. The observation that an increase in the number of animals would raise milk yields per farm was a common finding. Bhuyan and Postel (2009) found an additional milk cow in USA typically adding 11 900 kg of milk to annual production. Comparatively, an increase in the number of dairy cattle cannot realize an equal amount in the study region. The existing herd in the study area could only yield about one quarter of the USA cow per annum. In a study to examine the impact of practices commonly used by dairy farmers in the US and the effect of intensification on the performance of the farms, Cabrera *et al.* (2009) empirically showed that the variable with the highest impact on production was the number of cows on the farm. In addition, Moreira and Bravo-Ureta (2010) reported that herd sizes were significant in increasing milk yields.

The conclusions of the above studies support this study's findings towards the conclusion that an increase in the number of dairy animals should lead to

an increase in output quantities. However, such expectations are only possible when all other related basic requirements increase proportionately. An increase in herd size requires proportionate increases in key inputs such as feed and labour. A common finding in this study was that a typical household could be occupying only two acres of land and concurrently accommodates a homestead, dairy cattle (as many as four), other livestock species as well as various types of crops. The recommendation by the Ministry of Livestock Development is that one acre of land is set aside for pasture and fodder production for each dairy cow and its calf (MoLD, 2003), which was not observed in the study area. This situation applies in all high potential dairy production areas in the country.

In this study, roughages represented all types of dairy cow feeds such as hay, stover, straw, napier grass (used in over 90% of the farms), farm weeds, and edible tree cuttings, but excluding water, mineral supplements and concentrate feeds. Roughages constitute the bulk of the feeds to dairy cattle. The average amount of feed per cow was 52 kg against a recommended average of 100 (MoLD, 2003). Inadequate dairy feeding in the study area partly led to reduced individual cow milk yields, relative to their genetic potential. The amount of roughage fed to a dairy cow was a major factor in milk production in the region. Among the many possible reasons leading to low roughage quantities was the farmers' dependence on rain-fed fodders and pastures. It was reported that weather in the study area had become irregular in terms of timeliness, quantities and regional spread in the preceding years.

This kind of weather behaviour is part of the climate change threats to food production. There is a need for the policy makers to come up with mitigation measures mainly on rain water catchment, storage and use.

When short-term feed alternatives such as farm-weeds during the rainy season were available, farmers in the study area did not harvest Napier; it remained as standing hay. The recommended height of Napier at harvesting is 3 feet, for this is the growth stage when it is most nutritious (MoLD, 2009). Similarly, Njarui *et al.* (2011) found farmers in semi-arid Kenya failing to feed Napier grass to animals when natural and other cultivated pastures were available, instead feeding it during the dry season. In these two cases (the study area and the semi-arid Kenya), farmers did not take advantage of the excess quality fodder; storing it at the recommended maturity stage. According to Njoka-Njiru *et al.* (2006), Napier grass contains moderate crude protein (CP) content (6-12%) during the wet season, but declines to less than 5% during the dry season. The implication of this finding is that Napier quality and its harvestable quantity were lost particularly when the number of harvesting times reduced, in effect leading to a loss in economic gains from the plot.

A further finding was that losses of roughage feeds occurred at the farm level, during transportation and the dairy feeding point. Losses occurred when cutting of feed materials was above the ground at a higher point than the recommended two inches level, some materials were left at the farm during transportation and some other materials were lost by falling off to the ground

where they were left or irredeemably soiled. Further losses occurred when such materials were poorly chopped and ingestion by the animals became difficult. Soiling of feeds was also common among poorly constructed zero-grazing units. It is important minimize these kinds of losses to improve on the economic efficiency of a farm. Knowledge on how best to harvest the feed materials, use of efficient transportation means and improving on the dairy housing structures could offer some remedy.

Milk yields followed the feed quantity trend, with the average milk output being 9.3 kg against a potential of 15-20 kg per day (MoLD, 2003). Although breed improvement has a significant impact on dairy production (Staal *et al*, 2008), there is a need for dairy farmers to match a breed with its feed requirements. Owuor and Ouma (2009) found inadequate feeds being a major constraint in dairy productivity among smallholder farmers in western Kenya. Many other studies have reported similar findings to those of this study (Singh and Sharma, 2011; Alemdar (2010) among small scale milk producers in Turkey; Moreira and Bravo-Ureta (2010) among farmers in the Southern Cone Countries; Saravanakumar and Jain (2007) in India; Burki and Khan (2007) in Pakistan; Edirisinghe (2007) in Sri Lanka, and Wubeneh and Ehui (2006) in Ethiopia).

The roughage feeds contributed the highest proportion of the total cost of milk production in the study farms (appendix 8). Many other studies including Alvarez *et al.* (2005, 2008) and Lucila *et al.* (2005) had similar findings. The roughages were found to contribute 53.9% of the total dairy farming cost per

day which rose to about 73% when concentrates and mineral supplement costs were added. Lucila *et al.* (2005) in Thailand showed feed (all feeds together) costs to smallholder dairy accounting for an average of 63% of the total costs.

This study did not establish any economies of scale in relation to the costs of the roughage feeds used by the farmers in Embu and Meru Counties. This finding has negative implications especially in a region where land sizes per household are not big enough for the farmers to grow their own, which are considered cheaper than those bought from elsewhere. According to Pichet (as cited in Lucila *et al.* 2005), scientific evidence from many developed dairy producing countries have shown that milk production is much more dependent on the quantity and quality of feed rather than on the genetic makeup of the animal. The implication of this finding is that dairy farming will depend on adequate and affordable roughages, which could be better achieved where farm sizes are not severely limited.

About 23.7% of dairy farmers owned chaff-cutters; use of a chaff-cutter was expected to increase the efficiency of forage utilization, thus reducing wastage and increasing milk yields. Statistical results showed insignificant results. This was a curious result because other studies provided contrary outputs. Cabrera *et al.* (2009) suggests that an increase in use of technology leads to an increase in total dairy farm yield. Staal *et al.* (2008) adds that improved technology reduces production costs and induces shifts towards more commercial systems. Further, Short (2000) and El-Osta and Johnson

(1998) found improved technology to positively correlate with dairy farms' profitability.

This study showed that roughages and labour substitute for one another in milk production, so costs are reduced by using them together. Kavoi *et al.* (2010) in a study on measurement of economic efficiency for smallholder dairy cattle in the marginal zones of Kenya reported similar findings regarding roughage feeds and labour. The implication of the study here is that efficiency in labour utilization (which would reduce labour needs) is one of the options for decreasing dairy farming costs. Further, increased efficiency in roughage use would reduce wastage, and therefore reduced need for labour, which could decrease the total cost. In a case where quality roughages are available at a lower cost than would be grown by the farmer, then, that would lead to a decrease in labour costs and at the same time the total dairy farm costs. It is noteworthy that farmers are price-takers as pertains to the price of labour. The labour wage paid per unit of time is uniform in a region; individuals cannot determine how much to pay their workers.

This study's finding was that the number of labour hours invested in dairy farming was 37% above the minimum requirements per cow per day. This period of time is much more than the recommended 1.6 hours (5 cows per workman per day) (MoLD, 2003). In Pakistan, FIAS (2006) found labour input on dairy cattle to be approximately 50% above the minimum recommendation. Nivievskyi and Taubadel (2008) indicate that labour intensity in dairy farms increases the cost of milk production making it

uncompetitive in the market. It was noted that labour productivity in the area was low relative to the realized milk yields. This finding indicates an urgent need to reduce the amount of labour to the dairy herd. Although labour productivity on smallholder dairy farms is currently low, it could be easily improved by adopting better farm management practices (efficiency improvement), expanding dairy herd sizes (increase in operational scale) and increasing milk yields (mainly per cow milk yields).

The proportion of the total dairy farming cost arising from the cost of labour was large. This labour cost contributed to increased cost of milk production, raising it higher than its farm-gate price. The farmers were price takers for both labour input as well as milk price. The long distances (averaging 3.3 km) between the dairy farm and the other owned plot(s) could be probable cause of exaggerated labour input. The implication of this finding is that farmers can only benefit by increasing on their labour use efficiency and/ consolidate their land plots.

Farmers in both districts reported threats to the dairy enterprise in relation to labour requirements. *Miraa* (*Muguuka* variety), for example, was reported as increasing in popularity in Embu East District where it was reported to demand less labour while paying more returns than the dairy sector. This already is the norm in Igembe South. *Miraa* crop once mature requires no weeding costs, with the only labour requirement being harvesting. The payments for *Miraa* products are on cash basis while those of competing enterprises such as dairy and tea are not. There a risk that eventually *Miraa*

will displace dairy farming in the area. According to Staal *et al.* (2008) dairy farming is a labour intensive venture that would be a casualty to any new enterprise that is less laborious and with better returns. In view of the fact that dairy farming directly offers food, incomes and employment at the farm level, there is need to ensure its continuity. Concerted effort by the industry stakeholders targeting increases in household land sizes, labour use efficiency, decreased taxation on the ingredients for concentrate making, improved rural access roads and easing access of loans to the farmers, could ensure competitiveness of dairy farming.

Concentrates are made up of high energy sources such as grains, a high protein source such as soybean and a mineral mixture (Louw, 2009). They include commercial products such as dairy meal as well as milling by-products such as wheat bran, maize bran, maize germ, and pollard (Maina, 2008). They are low in fibre and easy to digest.

Most dairy farmers (96%) used concentrate feeds to supplement the roughages, with dairy meal being the most common, followed by bran. They used an average of 2.2 kg of dairy meal per cow per day. It was not clear why dairy farmers used almost equivalent concentrate quantities. Lukuyu *et al.* (2011) found farmers in central province and Northern regions of Rift valley province providing concentrates based on a flat rate of 2 kg per cow per day. Njarui *et al.* (2011) in the semi-arid tropical Kenya found farmers providing an average of 2 kg dairy meal per cow per day, irrespective of the cow's lactation stage. Extensionists indicated that concentrate quantities should

increase with increasing milk yields, so that a high milk yielder gets more and vice versa.

The quantity of concentrate feeds fed to dairy cows correlated positively with milk yields in the study area. An increase of concentrates by 10% increased milk yield by 5.9%. Saravanakumar and Jain (2007), Binici *et al.* (2006), Wubeneh and Ehui (2006) reported close results to those of this study. The type and amount of concentrate to feed an individual cow should depend on the quality of forage a cow is provided with and the amount of milk produced. The most economical level of feeding concentrates is the point at which the monetary value of the last amount of additional concentrate added to the ration equals the monetary value of the extra milk produced as a result of that extra unit of concentrate (Lukuyu *et al.*, 2007). The plausible reasons for underfeeding animals with concentrates are its cost, farmers not keeping production records, lack of information on its importance and learning from the other practicing farmers and less from the extension service providers. Cows receiving low quality roughages do not sufficiently respond to concentrates, through increased milk yields.

This study's finding was that an increase in mineral supplements by 10% would increase the milk yield by 2.8%. Unfortunately, the average amount of mineral supplements provided per cow per month was 1.1 kg as opposed to an average of 3 kg per month at 100 g/day (MoLD, 2003). Although some minerals are present in roughages and concentrates, dairy cows require regular supply of additional minerals (*ad libitum*). This is done by offering on a daily

basis access to commercial mineral supplements (Lukuyu *et al*, 2007). Dairy cattle require about 21 minerals in order to optimize on both milk production and reproduction. A calcium or phosphorus deficiency for instance, can cause a drop in milk yield, slowed growth, lack of appetite and poor conception (Louw, 2009). There is a felt need for farmers to provide their dairy cattle with enough and quality mineral supplements with the view to increasing milk yields.

The average calving interval of the dairy cows in the study area was 588 days. Other past studies in the country obtained different but close intervals to that of this study. Such studies include; Staal *et al*. (1998) around Nairobi obtaining 591 days and Ongadi *et al*. (2006) in Vihiga coming up with 560 days. The most plausible cause for long calving interval by a dairy cow is underfeeding. Dairy farmers are advised to have their cows served between the sixtieth and the ninetieth day after calving down which ensures a calf once a year per cow (MoLD, 2003). Prolonged calving intervals imply fewer calves and less peak milking periods in an animal's life-time, thus reduced economic gains by the farmer.

The most popular breed in the study area was Friesian, closely followed by Ayrshire. These two breeds were preferred by majority of the farmers due to their perceived high milk production potential (Lukuyu *et al*, 2011). This finding is in agreement with Bebe's (2003) finding in the Kenya highlands. These breeds are heavy feeders taking an average of 100 kg of fresh roughage per day, including about 3 kg mineral supplements per month (MoLD, 2009).

The finding that farmers were unable to provide enough feeds and supplements to the kept animals, imply that cows whose demands are lower such as Jersey, should be adopted. It is only a negligible number of farmers who kept Jerseys, owing to their perceived lower milk production potential.

Friesian and Ayrshire breeds under normal conditions yield the highest amount of milk among the dairy cows (MoLD, 2003); implying that genetic improvements towards these two breeds would lead to improved milk output. This study's finding however was that breed was not a major factor in milk yield. The animals were overstocked and underfed, a plausible reason for not optimizing on their production. Wakhungu (2000) recommended that Kenyan smallholder farmers be encouraged to keep smaller dairy breeds such as Jerseys because their feed requirements were lower than the Friesian, the Ayrshire or their crosses. Unless cow feed resources are plentiful and cheap, economic efficiency would favour cows with moderate size (Van Oijen *et al*, 1993).

A farmer can achieve the highest achievable cost efficiency regardless of the breed kept, if management errors are reduced. A commonly held belief is that high yielding breeds led to higher cost efficiencies, resulting mainly from the economies of scale. However, in this study these animals caused a bigger challenge to production efficiency particularly due to the small land sizes owned and consequently their underfeeding. The type of breed kept had no effect on cost efficiency.

5.1.2 Dairy Farmer Characteristics

Most dairy farmers in the study area were literate (99%) with the minimum level of formal education being seven years of schooling. The two study sites showed no noticeable difference in education level attained. The relationship between formal education and milk yields or any other aspect of dairy farming was insignificant.

The *a priori* expectation on formal education is that it would make farmers less conservative and more receptive to new technology and innovation (Oluwatusin, 2011). Formal education may achieve this by improving on the quality of labour, enable farmers to adjust to the existing situations and through its effect on input utilization (Moock, 1981). In the same vein, Udomsak and Khanna (2004) attributes Thailand's low dairy production efficiency to the farmers' lack of formal education. Other studies sharing the same view include; Singh and Sharma (2011), Edirisinghe (2007), and Wubeneh and Ehui (2006).

Kalirajan and Shand (1985) indicate that education and training have a strong and positive relationship with technical efficiency, especially among low-income farmers. Further, Hashmi (2004) and Tzouvelekas *et al.* (2000) indicate that farmer's education has significant power in explaining variation in economic efficiency; the ability to use knowledge of the existing input prices to choose an optimal input combination, and then efficiently use those inputs optimally to produce the maximum yields. Additionally, McBride and Greene (2007) associate dairy farm operators having less than a high school

education with higher economic costs. However, Makokha *et al.* (2007) indicates that although education is important, specialized information is more critical to adoption than just formal education.

Some other studies showed improved farm efficiency does not depend on formal education. Owuor *et al.* (2004) and Owuor and Ouma (2009) for instance, found higher farmer education levels not only being irrelevant, but contributed to farming inefficiency. The most probable reason for this could be that the academic elite in Kenya rely on employed workers/labourers who remain unsupervised, while they themselves work elsewhere. Such workers could either commit less time of the day to dairy operations or waste dairy inputs. On the middle ground however, are Battese and Coelli (1995), whose finding showed that the farmer's formal education increased efficiency at lower levels but decreased at higher levels.

From the preceding findings, one is not able to clearly conclude on the role of education in the efficiency of farming operations. Farming operations appear to be influenced by many other factors which dictate whether the impact of formal education will be felt or not. In the current study, though formal education has insignificant contribution to efficiency, the high proportion of those literate among the dairy farmers (99%) relative to the national average of 74% (RoK, 2007), indicates a positive correlation with adoption.

This study's finding indicates that the farmers depended on farmer-to-farmer extension, regardless of the education level. This dependency is supported by the finding that most farmers shared many operational errors such as poor milking methods and poor feed storage and utilization. Additionally, the small scale dairy farming operation probably was not motivating enough to arouse the intellectual demand of those formally school-educated. The implication of the high technical and cost efficiency levels for most farmers despite the big difference in the number of schooling years is that achieving high efficiency does not require many years of formal education.

This study found no significant relationship between the dairy farmers' age and experience and the technical and cost efficiencies in milk production. This was an unexpected finding because one would be expected to continue learning by doing with advancement in age, therefore becoming more efficient; a common finding of many studies. Edirisinghe (2007) for instance, indicate that advancement in operator's age increases efficiency and thus productivity. Similarly, Lucila *et al.* (2005) found experienced farmers being more cost efficient than their younger counterparts. Bhuyan and Postel (2009) found the operator's age having a positive correlation with net farm income. Further, Battese and Coelli (1995) reports a decrease in inefficiency with respect to farming experience for farmers in two villages in India. They interpreted this as implying that these farmers gained more years of farming

experience through “learning by doing,” thereby becoming more efficient. Similar results were reported by Amaza and Maurice (2005).

Contrary to the findings of the above cited studies, Ajibefun (2008) indicated that aging may lead to reduction in the level of technical efficiency because older farmers have less physical efforts to put into their farming operation. Nchare (2007) obtained results indicating that advancement in age led to decreases in dairy farming efficiency. Further, Owuor and Ouma (2009) showed that older farmers resisted modern technologies, preferring tested methods of production. Idiong (2007) indicates that being an experienced farmer is not enough to significantly cause one to attain higher levels of efficiency, if one cannot rearrange his inputs to obtain higher output levels with a given technology. On the middle ground however, is Sipiläinen and Lansink (2005) who analyzed the learning effect on the efficiency of organic versus conventional dairy farms in Finland and found seven years being the inflection point.

Most dairy farmers in the study areas were middle-aged. Igembe South District had younger farmers compared to Embu East. This aspect on Igembe indicates some relationship with the proportionately many cross-bred animals they kept, as compared to Embu East. New dairy farmers feel safer with less vulnerable animals such as cross-breeds as opposed to the pure stock. Probably due to the high deficit and consequently the attractive price of milk in Igembe South, a new generation was venturing into dairy farming. There was no identifiable motivation for indulging in the same in Embu East

District. Milk prices were lower than the cost of production, after all the inputs including the family labour were costed. On average, both the older and the younger farmers were fewer than those at the middle age in the two study sites. This however, would be expected in most third world communities where the older are fewer and the youth have many options.

Over 95% of the dairy farmers were over 30 years of age. One would expect younger people to have higher efficiencies than the older ones, based on the intensive labour requirement in dairy farming. On the other hand, one would anticipate that older farmers have more experience than the younger ones, which could improve on their cost efficiencies. Both age and experience were shown to be irrelevant in dairy farming efficiency. A possible reason for their insignificance could be the uniformity in the type of breed kept, underfeeding and milk yields, irrespective of the farmer's age. The other probable reason is that most of the dairy farmers have no motivation to improve on their productivity.

Extension is a series of embedded communicative interventions that are meant, among others, to develop and/or induce innovations which supposedly help to resolve problematic situations (Leeuwis and Ban, 2004). Such interventions are made by trained experts to recipient farmers. In this study the experts were among others, persons trained in livestock production and health with a minimum of a two-year post-secondary education.

In this study, availability of extension service had no effect on the technical and cost efficiencies of dairy farms. The probable reasons leading to this could be ineffective extension service or poor extension message adoption, a fact related to the question of smallholder dairy profitability. Adoption of extension messages involve extra costs that farmers may not afford. This study's finding is similar to that of Binici *et al.* (2006) in Burdur province of Turkey that extension programs explained little on the variation in farm production efficiency. The following are the other studies that found an inverse relationship between extension service availability and the farm efficiency; Owuor and Ouma (2009), Idiong (2007) and Amaza and Maurice (2005).

Contrary to the preceding studies, Edirisinghe (2007), Nchare (2007), and Wubeneh and Ehui (2006) found increased extension service to increase productive efficiency of farms. Further, O'Neill and Matthews (2000) studied the role of agricultural extension on farm efficiency in Ireland and found a positive relationship between these two variables.

In the study area, extension messages were largely disseminated by public livestock extension personnel. According to the Department of Livestock Production personnel on the ground, the ratio of smallholder livestock farms to the number of government livestock extension providers was 1: 4,000 in the two study Districts against the FAO's recommendation of 1: 400. This is an indication that farmer-extension staff contact was inadequate. The high

number of small-scale farmers against the few qualified and available personnel was a major constraint to extension service provision.

Poor adoption of extension service was evidenced by several observations. The amount of labour utilized was above the required levels, feeds were poorly utilized leading to costly wastage, cows had long calving intervals, animals were overstocked and farmers did not keep records which made the analysis of the enterprise performance difficult. The other indicators included poor agronomic fodder and pasture management, late or early harvesting of farm fodder materials, cutting and drying of napier as a method of conservation, feeding cows with uncut or long pieces of feed materials, poor milking methods and generally poor animal living environments (most farmers had poorly designed zero-grazing units, making the animals uncomfortable for optimal production).

The implication of this study's results is that the availability of extension service does not affect milk production efficiency in the study area. If there is no other reason to motivate the farmer to seek for new and better knowledge and technologies to improve on their performance, they end up depending on other farmers for information regardless of its quality. Further, there was a common perception by farmers' that extensionists advised on the adoption of modern techniques of production which involved extra costs. Although this may be partly true, none-profitability of dairy farming may have been the major reason for farmers not adopting extension service messages.

Membership in agricultural activity-related farmer groups affords farmers the opportunity of sharing information on modern production practices by interacting with their peers (Idiong, 2007), which partly implies farmer-to-farmer extension. This is anticipated to improve on the farmers' performance on condition that the shared information is correct and superior. This study found no statistical significance of farmer group membership in milk production efficiency, indicating that such membership is not relevant to dairy farming efficiency among dairy cow farms in the study area. This finding is related to that of Nchare (2007) that productive efficiency of farms decreases when the owners join farmer groups. This could be possible in cases where the farmers are self employed, such that whenever one left the farm for group meetings, the farm is neglected and consequently efficiency decreases. However, this finding contradicts Owuor and Ouma's (2009) finding which showed farmers belonging to groups being more efficient than those not.

This study established that the agricultural sector ministries were on a more than ten-year-period farmers' mobilization drive to form 'common interest groups' for improved extension service delivery and lowering of the farmer's operational costs achieved by product bulking and marketing through farmer federations. It was reported that at the beginning of the community mobilization period, many farmers joined groups but more than half of those groups crumbled when largely no anticipated gains trickled down through the implementers. This was attributed to high dependency syndrome by the recipient communities. There is a need to support farmers for learning tours to

places where farmer groups have succeeded, particularly those undertaking similar activities and in comparable agro-ecological zones. It is necessary that areas of group leadership, financial management and information sharing be addressed. According to Mugambi (2008), farmer groups fail to meet their objectives because their leaders provide poor leadership and are not transparent in managing the organizational finances.

This study found over half of the farms utilizing family labour. The implication here is that when other activities such as attendance to group meetings compete for time resource with the dairy farming activities, consequently its performance decreases. Further, attendance to any assignments outside the farm implies the dairy attendant is left unsupervised which could lead to decreased labour productivity, and consequently reduced efficiency.

Short courses in business education to dairy farmers had no effect in milk production efficiency among farms in the study area. There was no difference between the dairy farmers who attended and those who did not attend business courses, with regard to both the technical and cost efficiencies. The *a priori* expectation on business management courses is that they would unlock the participants' potential, enabling them to diagnose problems affecting the performance of dairy farming. Studies by Wubeneh and Ehui (2006), and Owuor and Ouma (2009) found business management information playing some role in decreasing management errors. It is expected that viewing any venture as a business could lead to seeking for information on how best to

carry it out. Poor dairy farming management leads to lower milk yields relative to potential. Low production implies low income, preventing investment in good feeds and animal health (EADD, 2008). Dairy farmers had opportunities for joining groups where short courses on agri-business could be offered under the existing public extension programmes in the study area, but only about a fifth of them attended.

There are several probable reasons why business courses to farmers did not significantly contribute to dairy farming efficiency. The period of attendance was short making it hard for the trainers to cover enough material. Extension service providers basically trained in agricultural sciences were facilitated by government supported programmes for short entrepreneurship and agribusiness courses, after when they trained farmers under 'common interest (enterprises) groups'. Probably they were not good enough.

5.2 Technical Efficiency Estimates of Dairy Farms

The technical efficiency of a farm is defined in terms of the ratio of the observed output to the corresponding frontier output, conditioned on the level of inputs used by the farm; technical inefficiency being the amount by which the level of production by the farm is less than the frontier output. Dairy farms in the study area achieved an average efficiency of 83.7% implying that in the short-run, there is scope for increasing technical efficiency in milk production by about 16.3% in the study area. This could in part be achieved by motivating the farmers through policy changes that are geared towards reducing dairy input costs and making milk prices predictable (inflation-corrected). Other

studies on technical efficiencies on dairy farming which reported almost equal mean efficiency levels include; Cabrera *et al.* (2009), Alemdar (2010), Saravanakumar and Jain (2007), Edirisinghe *et al.* (2007), and Binici *et al.* (2006).

The findings of this study showed that an opportunity to increase milk yields through increased use of the current inputs exists. Yields would more than double if all the inputs in use at the moment were to be proportionately doubled, as indicated by the total output elasticity of 2.11. The implication of this finding is that dairy farmers could benefit from the economies of scale linked to increasing returns, even with the current number of mature cows.

5.3 Cost Efficiency Estimates of Dairy Farms

There was discrepancy between each farm and its best practice cost, with farms operating at about 4.4% higher costs. This was due to both the technical and allocative inefficiencies. This implies that an opportunity of lowering the current costs by the same margin exists among the dairy farms in Embu and Meru Counties, on condition that they operate on their efficient frontiers. Lucila *et al.* (2005) found smallholder dairy farms in six provinces of Northeast Thailand being 26% above the frontier costs. They recommended proper herd management with the view to maintaining an optimal milking cows-herd size ratio, coupled with yield-enhancing technologies to enhance cost efficiency. Feed technology options that could potentially reduce costs while maintaining yield levels were also recommended. William and Juan (1985) through an evaluation of farms by herd size groups, showed the

average measure of cost efficiency to range from 170 to 180 percent. Kavoi *et al.* (2010) found smallholder dairy farmers in the transitional zones of Machakos and Makueni Districts of Kenya to range from 0.01 - 81.11, with a mean of 27.45%. Road infrastructure, extension and credit facilities were found to significantly reduce cost inefficiency.

On average, this study's finding is that the farmers in Embu and Meru Counties have relatively high efficiency levels in terms of cost management. The costs of roughage feeds and labour were the two main areas that could be addressed to decrease the total costs. It must be mentioned that the status of the national economy and the economic policies under implementation contribute to the total cost of dairy farming through input prices. A farmer to a large extent is unfortunately a price-taker when procuring inputs as well as when selling his farm products. He does not have the opportunity to set prices of his products. The implication of this finding is that farmers in the study area can do very little to reduce the cost of milk production, through improvement in cost efficiency.

5.4 The Contribution of Farm Efficiencies in Reducing the Cost of Milk Production

Microeconomic theory states that the objective of a firm is to utilize given inputs to produce the maximum output and to minimize the production costs at the given outputs in order to maximize profits. In order to achieve this objective, a farmer must be familiar with the expenses associated with the farming business (Mkhabela, 2011).

Table 5.1: A Schedule of Annual Milk Production and Consumption from Selected African Countries

Country	Production (Billion Lts)	Per capita consumption (Kg)	Remarks
Angola	0.195	25.4	A gross importer
DRC Congo	0.005	1.9	Importer
Madagascar	0.536	28.6	Importer
Mauritius	-	120	Milk is imported
Mozambique	0.0688	5.7	It was higher earlier
Namibia	0.0205	5.7	A drop from 9.1
South Africa	3	-	Self-sufficient
Swaziland	0.0071	4.7	Importer
Zimbabwe	0.248	14	Importer
Kenya	3	76.7	Self-sufficient
Uganda	1.4	50	Importer
Tanzania	1.15	39	Importer

Source: FAOSTAT and Dairy Mail Africa, 2009

This study found the cost of producing a kilogram of milk in Embu and Meru Counties being US\$ 0.43 (US\$ 1=KES 85). This cost was much higher than the costs in many other countries. According to the FAOSTAT and IFCN (2008), the following were some of the costs of producing a kilogram of milk in other countries; Uganda (US\$ 0.26), Pakistan (US\$ 0.1), Vietnam (US\$ 0.15), Bosnia and Herzegovina (US\$ 0.3), and Argentina, Brazil, and New Zealand (varies between US\$ 0.07 to 0.17). This finding indicates that Kenya is one of the most expensive milk producers, an implication of how uncompetitive its product is in the market.

Kenya's per capita milk consumption is about 76.7 kg (FAO, 2007) against the recommended 200 by the WHO. The country is within a region where both milk production and per capita consumptions are relatively low (table 5.1). This implies that Kenyan dairy farmers have an opportunity for producing and

offering milk for sale within the country and the region. The big concern is on the product's price competitiveness against other countries offering a similar product or products competing for the same market.

There is a need for making smallholder dairy production more competitive because it is a powerful tool for raising nutrition levels and improving the livelihoods of rural people (FAO, 2010). This study's finding contradicts Staal *et al.* (2008) which suggest that Kenya's smallholder dairy producers are generally competitive. This scenario was different at the time of this study, when the cost of milk production was higher than its market price.

Kenya's 3.5 million dairy cattle are more than any other country's herd in Africa, being more than the combined total of the rest of Eastern and Southern Africa, including South Africa (RoK, 2008). Several factors, which include the presence of significant dairy cattle populations, the historical importance of milk in the diets of most Kenyan communities and a suitable climate for dairy cattle, contribute to the observed status in Kenya (Thorpe *et al.*, 2000). Kenya is self-sufficient in milk production based on the current effective demand (RoK, 2008).

Kenya is however, a relatively small-sized country with most of its national herd being hosted in about 20% (approximate 120,000 Km²) of its land mass. Upton (2000) indicated that the average agricultural land size in Kenya is relatively small, at about half that of the other Sub-Saharan countries. This implies that Kenya has no more opportunity of increasing milk production

through increases in herd sizes. Its ability to defend its national milk market as well as penetrate the open markets in the neighbouring countries will depend on optimized per cow yields, and reduced production costs.

At the moment, the dairy herds in Embu and Meru Counties are bigger than the owned land sizes can hold. The milk yield per cow relative to its potential is low (9.3 kg) and the cost per kilogram (Ksh. 37.4) relative to the costs by other countries' producers is high. The implication of this finding is that Kenyans cannot access milk produced in their country, it cannot be accessed by its neighbours and that a possibility exists that in case the countries within the EAC and COMESA trade blocks increase their outputs, they can easily access the Kenyan milk market rendering the local producers jobless. Loss of local market could mean more than just jobs. Food, incomes, manure for soil fertility, among other cattle benefits would be at stake.

Smallholder dairy farming is faced with many challenges, with some being at the farm level and others beyond the farmers' control. The farms' average technical efficiency was 16.3% below, and the average cost efficiency was 4.4% above, their respective best practice frontiers (sections 4.2.4 and 4.3.6). An increase in these efficiencies to their optimal levels would decrease the cost of milk production (from Ksh. 36.7 to 29.3) and consequently increase demand. This would imply expansion of local milk market. At the same time, an opportunity of developing an export market through increased access would arise.

Policy actions taken concurrently with the farmers' improvement in efficiency would make dairy farming robust. According to Schantz (2006) and Skunmun and Chantalakhana (2000), animal feed is the largest cost in milk production and it is therefore important to optimize production through its cost efficient use (Roche and Newman, 2008). Feeds contributed the highest proportion of the total cost in the study area. Any approach to obtain cheaper sources of roughage feed is important to dairy farming. This study found about 60% of the farmers owning a maximum of 2 acres of land where mixed crop-livestock farming was practiced. This finding echoes Upton's (2000), that the average agricultural land size in Kenya is relatively small. About 47% of land size is in fragments. The herd size averaged 4 animals against a recommendation of one acre per cow. Although the total annual maintenance costs per cow decreases along with an increase in the number of cows in a herd (Marek *et al*, 2007), the land size is a limiting factor in Kenya. The cost and quality of concentrate feed was prohibitive. These high costs were attributable to expensive imported raw materials, unstable Kenyan shilling (currency), high cost of energy and poor road transport. To address both the milk production costs and its quality, favourable government policies are critical.

The importance of making smallholder dairy farming more competitive cannot be overemphasized because it is a powerful tool for reducing poverty. The continued liberalization of world trade and the accelerating international competition for markets, require both farmers to consider the competitiveness

of their production systems (Roche and Newman, 2008). According to Kennedy *et al.* (1997), competitiveness is the ability to profitably create and deliver value (e.g. milk) through cost leadership. This definition implies that competitiveness is directly related to factors that influence both the cost and demand structure of a firm. Smallholder dairy farming in Kenya is practiced by people of low incomes, in an environment of farm inefficiency, unpredictable input and milk prices and a liberalized economy. Milk production at the farm level is limited by mainly the small land sizes (low roughage outputs) followed by generally high input costs. Farmers depend on rain-fed plants relying on unpredictable rainfall.

Pitts and Lagnevik (1998) describes a competitive industry as one that possesses the sustained ability to profitably gain and maintain market share in domestic and/or foreign market. Competitiveness is determined by the productivity with which a nation uses its human, capital, and natural resources. This study found the herd sizes being unsustainably big relative to the land resource, leading to inability in utilizing the genetic potential of the kept breeds. A trend of increasing the number of dairy farms, decreasing land size per farm and a decreasing number of livestock extensionists was observed. Farmers complained of high costs, low quality and underweight concentrate feeds.

Buckley *et al.* (1988) identified a useful distinction between three different measures of competitiveness, namely: Competitive Performance, Competitive Potential and the Competitive Process. Competitive Performance is the

measurement of indicators of competitiveness of specific firms, sectors or countries. Although no studies on cost and technical efficiencies were found on dairy farms within the Eastern African region save for Ethiopia (technical efficiency), the competitive performance of dairy farms may not be significantly different. However in terms of cost leadership, this study established that farmers in the study area (Kenya) were not competitive.

Cost leadership is a strategy which seeks to improve efficiency and control costs throughout the organization's supply chain. It is pursued by firms which strive to be the lowest cost producers in an industry, through approaches such as economics of scale of production, learning curve effects, tight cost control, and cost minimization in all the possible areas (Porter, 1998). They compete with each other in areas such as process technology, raw material input costs and capacity utilization (Picot and Scheuble, 2000). Competitiveness in the market place for homogenous commodities such as milk is largely determined by costs of production. Although process competitiveness is critical in milk production, an increase in dairy farm land size and improved per cow yields are the most important factors. Kenya has unutilized competitive potential based on its favourable climatic conditions, a long history of dairy farming, and the currently large national herd size.

CHAPTER SIX:

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

This study sought to evaluate the efficiency of dairy farms in Embu and Meru counties of Kenya. A descriptive survey research design was employed in the collection of data among randomly sampled dairy farms using semi-structured questionnaires. This data was supplemented with information collected from the dairy industry stakeholders using pre-written interview schedules. Data was collected largely on the amount of milk produced and its farm level price, total and milking herd sizes, breed, amounts of roughage, concentrate and mineral supplements provided, amount of labour employed, size of land owned and whether the farmer owned a chaff-cutter or not. Data on the prices of feeds and labour were also collected. The other data collected included the formal education of the farmer, age and experience in dairy farming, extension service availability, and membership to an agricultural-activity related group and on whether the farmer had attended any business or livestock husbandry courses.

Data were analyzed using the SPSS computer software package to obtain descriptive statistics that were used in characterizing the farms and their owners. Parametric stochastic frontier methodology of Aigner *et al.* (1977) was used in estimating the technical and cost efficiencies. To estimate the technical efficiency of the dairy farms, a Cobb-Douglas functional form was

imposed and estimated, while in measuring the cost efficiency of the same farms, the translog functional form was imposed on the data and estimated. In the estimation of cost efficiency, a dairy farmer's observed total cost was modeled to deviate from the cost-efficient frontier due to random noise and possibly cost inefficiency. The Frontier 4.1c (Coelli, 1996) and STATA econometric softwares were used in the estimations and in testing for heteroscedasticity, respectively.

Results revealed that the dairy cattle herds averaged 3.93 animals with those milking averaging 1.56, a proportion of about 40%, against the suggested optimal ratio of 70-75 percent of the herd (Skunmun and Chantalakhana, 2000). Farmers kept large breeds with 89% of them constituting of Friesian, Ayrshire and their crosses. A large proportion of their feeds originated from outside the farm because the owned lands averaged only two acres, where various crop varieties were grown and different livestock species reared. About 47% of the owned land was in fragments averaging 3.3 km away from the dairy farm. The cows were only offered an average of 52.2 kg of roughage against a requirement of about 100 kg and 2.2 kg/cow/day concentrate. A cow was supplied with about 1.1 kg of mineral supplements per month against a requirement of about 3 kg. It was only about 23.7% of the farmers who owned chaff-cutters. The dairy animals were mainly zero-grazed (>96%), with the farmer employing labour at an average of 2.2 hours/cow/day against a recommendation of about 1.6. Individual cow yield averaged about 9.3 kg/day while the average yield by a milking herd was 15 kg.

It was revealed that dairy farmers were literate (99%), experienced in dairy farming (over 95% with more than 5 years) and many (56%) aged between 36 and 55 years. About one third of the farmers; were members of agricultural-activities related groups, had received livestock extension services and had attended short animal husbandry courses. It was only about one fifth who had attended a business course. Results revealed that all the farmer characteristics had no statistical relationship with either dairy farm technical or cost efficiency.

Results showed farm milk yield was limited by the number of milking cows and the quantities of roughage, concentrate and mineral supplements availed. It was shown that any further employment of labour, would lead to a decline in milk outputs. The roughages and labour were the main factors in the cost of milk production. Although increased use of roughages did not show any economies of scale, further analysis revealed that roughage and labour substituted one another to lower the cost of milk production.

Results on efficiencies indicated that on average, farmers were operating at an average of 16.3 and 4.4% below their technical and cost efficient frontiers, respectively. About 38% of the farmers operated above the 90% technical efficiency level, and their mean farm milk yield averaged 11.6 kg. About 12% of the farmers operated below 70% technical efficiency level, and their average yield was 3.3 kg. All the farms operated above 85% cost efficiency level. A positive correlation was shown to exist between the achieved technical efficiency and the farm revenues, but none with the cost efficiency.

Calculations based on mathematical proportions showed that combined, optimized technical and cost efficiencies could lower the cost of milk production by about 20%, from an average of Ksh. 36.7 to 29.2. However, this potential value still remained above the observed farm level price of milk per kilogram, at Ksh. 24.4.

6.2 Conclusions

This study evaluated the efficiency of dairy cow farms in Embu and Meru counties of Kenya. Concerns regarding dairy farming efficiency had arisen after an observation of a sustained low per cow milk yield and its high per unit cost, despite many studies and consequent recommendations. Individual dairy farms and their owners were characterized and their technical and cost efficiencies estimated. The observed efficiencies were related to their potential best practice levels to determine the extent to which the cost of milk production could reduce if those efficiencies were optimized.

The findings of the study, pointed out that the region has potential for milk production based on the existing large number and type of dairy breeds, farmer experience and a growing large human population that could offer market for milk. Dairy farming continued being an important farm activity in the region. However, the sampled farms lacked enough land to grow fodder, a basic requirement in dairy farming. Buying of roughage from outside the farm raised the cost of dairy farming and limiting its use. Although the contribution of land to milk yields was statistically insignificant, contradicting the surveyed literature, the amount of roughage available in the farm was its proxy. Prices

offered for milk at the farm gate level were not motivating, considering the high costs of its production.

It was revealed that the dairy farms were small-sized and practiced mixed crop-livestock farming where large breeds were overstocked and underfed. Although this was not a new finding, the levels were. Land sub-division had reached its lowest levels that expensive alternative sources of roughage were sought, which exaggerated the cost of milk production. Results indicated that the region had the smallest land sizes compared to other regions in the country (Musalia *et al*, 2007 and Lukuyu *et al*, 2011). The extent of land fragmentation and the distance between each plot and its effect on the amount of labour employed had not yet been documented. The level of dairy cow underfeeding (roughage, concentrate and mineral supplements) at about 50% had a direct influence on milk yields, where the simple average was about 9.3 kg which was about half of the potential. This level of production was however, higher than the national average of about 6 kg. The possible reason for this higher performance could be because the study region lies on the high rainfall potential areas of the country, while the national average includes results from all the regions that include the marginal zones.

The indication of the dairy breed as being insignificant in milk production was unexpected, and contradicted other studies such Staal *et al*. (2008). Further, contrary to past recommendations on the need to continue on dairy farming intensification and upgrading to larger breeds, this study's finding was that such actions were untenable. This was in part due to the uncontrolled

increase of concurrent land sub-division and new smallholder dairy farm start-ups, leading to increased operational costs, and consequently increased costs of the produced milk.

An opportunity for increasing milk yields through increased number of dairy cows, feeds and mineral supplements was established. It was also revealed that the sum of the partial output elasticities with respect to all inputs was 2.11, pointing out that a proportional increase in all the factors of production could lead to a more than proportionate increase in milk yields. This further indicated that dairy farmers could benefit from economies of scale linked to increasing returns to boost production. However, this opportunity could be lost because the land sizes available were quite limiting.

The findings of the study were that roughages and labour were the main factors in the cost of milk production. Further analysis revealed that their increased use had no economies of scale. However, it was shown that roughage and labour substituted one another to lower the cost of milk production, an aspect that could offer some reprieve. Both roughages and the number of milking cows were shown to limit milk yields in the farm. Additionally, a positive and significant relationship was shown to exist between technical efficiency and farm milk revenues. These findings point out the significance of sourcing for plentiful and cheap roughages by consolidating and increasing the land sizes for herbage development.

The technical efficiency of 83.7% by the dairy farms was a common finding in the surveyed literature (chapter two), but the 95.6% mean cost efficiency was exceptionally high. It was revealed that farms scoring high technical efficiencies had much higher average milk yield than those operating at lower efficiency levels. Optimization of both technical and cost efficiencies could lower the cost of milk production by about 20%. However, the price of milk at the farm level would still remain lower. This indicated that farm efficiency optimization could only be part of a wider array of approaches to lower the cost of milk production. Results of this study raise serious questions about the sustainability of the sub-sector, if the current trend of smallholder start-ups and price of inputs are not addressed.

6.3 Recommendations

This study was planned to characterize the dairy cow farms, estimate their technical and cost efficiencies and then relate the estimated efficiencies, each with its potential optimal with a view to determining the extent to which the cost of milk production could reduce. On the basis of the findings, several recommendations were made.

Contrary to past messages to farmers on the need to practice mixed crop-livestock farming endeavoring food security, results of this study show a need for a policy reverse with regard to this subject. Farmers require specializing in either crop or dairy farming based on their preference; household farm size has decreased over time due to continued sub-division. Those choosing to continue on dairy farming require shifting from the large to smaller breeds

such as Jersey and Guernsey. Additionally, policy makers require coming up with incentives to motivate farmers to specialize. Legal mechanisms should be put in place to ensure continued trend of sub-dividing the agricultural land is minimized in the short-term and that in the long-run, a structural shift in land ownership/use takes place, such that individual lands increase with the view to having larger and more productive herds. This would ensure that milk yield is no longer limited by the number of cows, nutrition and its cost.

Researchers require establishing the least-cost combination ratio for roughage and labour, an action that would lower the cost of milk production. Dairy farmers require addressing general dairy farming inefficiencies in part by raising the current milking cows-herd size ratio from the current 40 percent to the suggested ratio of 70-75 percent (Skunmun and Chantalakhana (1999), and further, ensure cows receive enough cheap roughage.

This study showed that milk production and its cost in the country is faced with several challenges part of which include decreased household land size, operational inefficiencies and high input costs. It is recommended that future studies cover wider regions and that they are repeated over time to show performance trends, particularly on land size per household, yield per cow and cost of production. The Kenyan population will continue seeking for affordable milk, irrespective of its source. A national source would offer the much needed food, incomes and employment.

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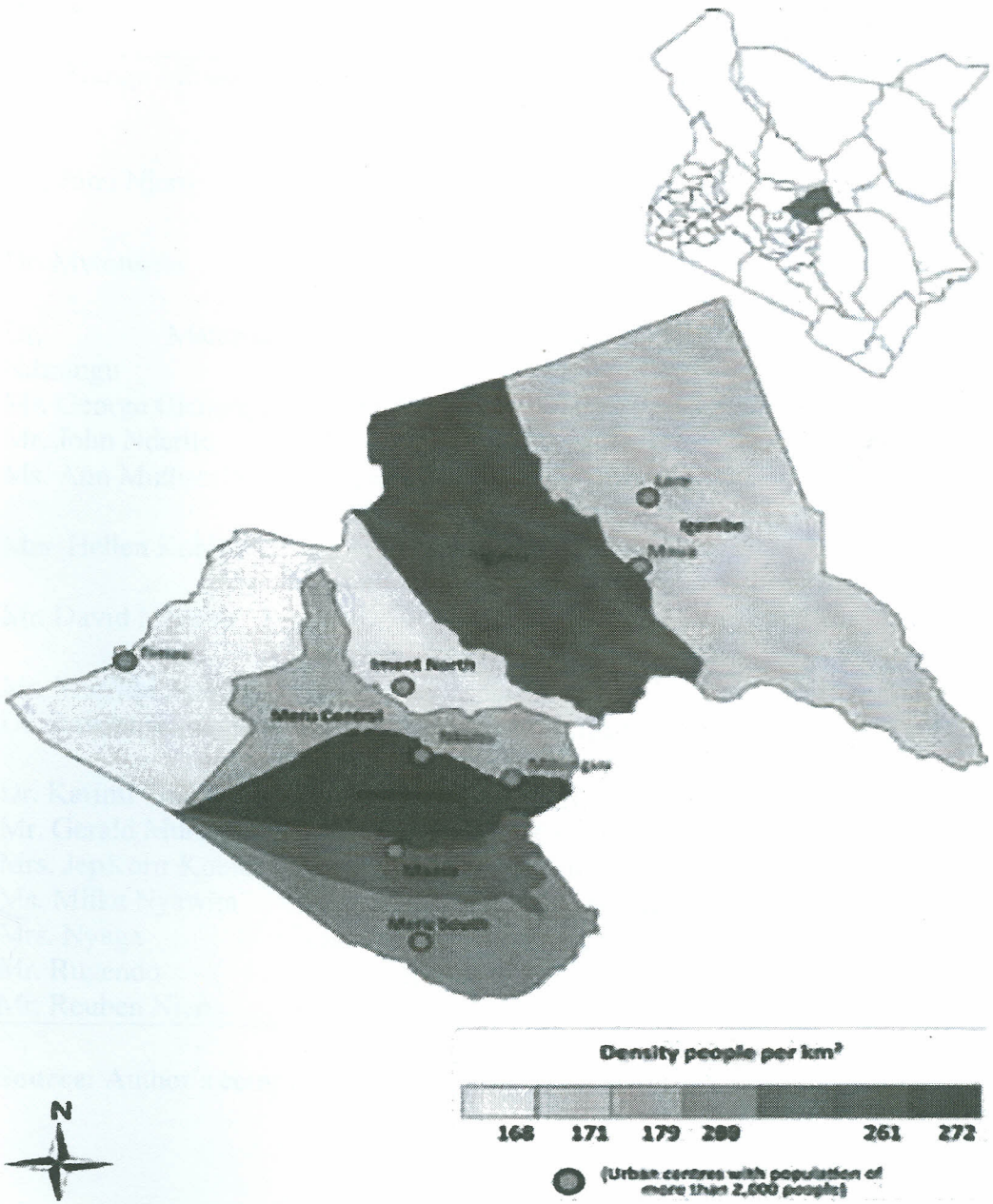
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Appendix 2: A Map of Meru County



Source: Kenya Open Data (2012)

Appendix 3: List of Interviewees/Stakeholders

Name	Job Title/ Workplace	Date of Interview
Mr. Riungu Mbwiria	District Livestock Production Officer (DLPO), Igembe South District, Maua	5 th May, 2010
Mr. John Njeru	Deputy DLPO Embu East, Runyenjes	27 th April, 2010
Dr. Mwangela	District Veterinary Officer (DVO), Igembe South District, Maua	7 th May, 2010
Dr. Mahinda Ndirangu	DVO, Embu East District, Runyenjes	28 th April, 2010
Mr. George Gichungu	DLPO, Embu West District, Embu	4 th May, 2010
Mr. John Nderitu	NKCC manager, Runyenjes	12 th May, 2010
Ms. Ann Muthamia	District Development Officer, Embu East District	5 th August, 2010
Mrs. Hellen Kobia	Kenya Bureau of Statistics, Meru County	7 th May, 2010
Mr. David Mbaabu	Ministry of Agriculture (MOA), Igembe South District	3 rd June, 2010
Mr. Muriithi Imwere	MoA, Embu East	5 th June, 2010
Dr. Runyenje	Private Veterinary surgeon, Embu East, Runyenjes	18 th June, 2010
Dr. Karimi Thiakunu	Private Veterinary Surgeon, Maua	6 th July, 2010
Mr. Gerald Muriithi	WAMA Agro Vet/ Chemist, Maua	6 th July, 2010
Mrs. JepKorir Kobia	Athiru Agro Vet, Igembe	5 th May, 2010
Ms. Milka Nyawira	Manager Kianjai Agro vet, Meru	7 th June, 2010
Mrs. Nyaga	Kagaari Agro Vet Shop, Embu	14 th May, 2010
Mr. Rugendo	Chandi Agro Vet, Runyenjes	17 th May, 2010
Mr. Reuben Njeru	Highway Agro-Vet Shop	14 th May, 2010

Source: Author's compilation, 2012

Appendix 4: Reliability tests

			Both Embu E and Igembe S	Embu E	Igembe S
		Item			
White test	Homoscedasticity test	Chi ²	60.04	52.62	39.00
		df	53	53	38
		p-value	0.2359	0.4890	0.4246
Multicollinearity test for the milk production inputs	Variance Inflation Factor (VIF)	minmnth	1.51	1.42	2.44
		labour	1.48	1.39	2.35
		cfedcow	1.44	1.34	2.08
		breed	1.42	1.32	2.01
		techlgy	1.26	1.28	1.95
		roghagef	1.19	1.23	1.54
		herds	1.15	1.18	1.34
		milkinghs	1.13	1.12	1.31
		tland	1.12	1.08	1.21
		Mean VIF	1.30	1.26	1.80
	Durbin-Watson statistic	Statistic	1.81	1.97	2.44
Proportion of variation in milk yield explained by the inputs	Coefficient of determination	of R ² statistic	0.78	0.60	.81
Milk production model fit	ANOVA	F-Value	49.45	14.40	13.63
		Significance	0.000	0.000	0.000

Appendix 5: A Summary of Maximum Likelihood Estimates of the Cobb-Douglas Production Frontiers and Inefficiency Models for Dairy Farms in Embu and Meru Counties, Kenya

Variable	Whole Study Area TE			Embu East TE			Igembe South TE		
	Coefficient	Standard-Error	t-ratio	Coefficient	Standard-Error	t-ratio	Coefficient	Standard-Error	t-ratio
Constant	-20.31	0.29	-0.01	-0.22	0.33	-0.68	-1.44	0.86	-0.18
Herd Size	0.06	0.10	0.51	0.09	0.13	0.69	-0.20	0.72	-0.28
Milking Herd Size	0.76	0.11	6.85***	0.07	0.12	5.70***	1.09	0.32	3.43***
Breed	0.05	0.08	0.58	0.07	0.10	0.74	-0.29	0.22	-1.33
Roughage Feeds	0.51	0.17	3.02***	0.64	0.20	3.18***	1.18	0.52	2.25**
Concentrate Feeds	0.59	0.09	6.4***	0.59	0.10	6.18***	0.44	0.24	1.79*
Mineral Supplements	0.28	0.07	4.00***	0.21	0.07	2.78***	0.81	0.39	2.11**
Labour	-0.19	0.09	-2.14	-0.20	0.11	-1.77	-0.03	0.28	-0.09
Land Size	0.07	0.09	0.84	0.09	0.10	0.87	-0.08	0.45	-0.17
Chaff-cutter	-0.03	0.04	-0.78	-0.01	0.05	-0.22	-0.04	0.37	-0.10
Inefficiency model									
Intercept	-3.25	6.12	-0.53	-9.53	10.39	-0.92	1.14	5.0	0.23
Education Level	-3.05	4.22	-0.72	0.34	0.87	0.39	-1.83	4.84	-0.38
Farmer Age	-0.17	2.57	-0.66	3.64	4.31	0.84	0.03	3.20	0.01
Farmer Experience	-0.45	0.93	-0.49	0.80	0.89	0.89	-1.33	1.63	-0.82
Extension Service	-0.86	1.01	-0.86	0.05	0.25	0.18	-0.38	2.17	-0.17
Group Membership	1.71	2.27	0.75	0.42	0.49	0.86	0.50	0.85	0.59
Business Course	-2.26	3.33	-0.68	0.48	0.56	0.84	-0.77	0.76	-1.02
Variance Parameters									
σ^2	1.32	1.94	0.68	1.03	1.04	0.99	0.05	0.11	0.50
γ	0.98	0.02	54.38	0.98	0.02	5.50	0.28	0.95	0.30

Mean TE 83.7
(%)

86.7

92.0

*, ** and *** significant at 10, 5 and 1 percent significance levels, respectively.

Source: Own computation

Appendix 6: Relationships among Dairy Farm Characteristics, Costs, Revenues, Gross Margins and Efficiency Estimates

Number Milking	Yield Per Cow	Total Yield (Kg)	Milk Price/Kg	Milk Revenues	Total Variable Cost	Gross Margin	TE Estimate	CE Estimate
1	6	6	23	138	447.28	-309.3	60.3	90.9
2	12	23	25	575	531.71	43.29	87	93.2
1	8	8	20	160	286.81	-126.8	91.3	97.4
1	7.5	7.5	23	172.5	306.24	-133.7	89.6	91.6
1	4	4	23	92	280.72	-188.7	78.3	95.3
2	6	12	22	264	492.29	-228.3	83.4	93.7
2	5	10	25	250	192.34	57.66	93	98.6
1	16	16	20	320	217.81	102.2	93.8	94.6
1	9.5	9.5	22	209	227.48	-18.48	94.7	96.7
2	11	22	22	484	380.58	103.4	91.4	97.3
2	2	4.5	25	112.5	343.72	-231.2	73.4	98.9
3	9	27	21	567	793	-226	80.7	88.9
1	18	18	21	378	435.94	-57.96	90.4	90.9
1	10	10	24	240	352.73	-112.7	91.1	93.4
2	9	18	21	378	501.28	-123.3	86.8	95.3
1	2.5	2.5	22	55	166.14	-111.1	59.2	91.3
1	5	5	21	105	226.2	-131.2	87.5	97.4
1	3	3	25	75	133.16	-58.16	81.1	96.9
3	20	20	20	400	749.58	-349.6	72.3	87
1	8	8	21	168	407.44	-239.4	87.7	95
1	18	18	21	378	755.15	-377.2	93.6	97.9
1	5	5	21	105	210.24	-105.2	76.4	94.9
1	7	7	20	140	193.81	-53.81	90.7	98.6
1	11	11	20	220	680.01	-459.4	96.1	99.5
1	7	7	20	140	408.62	-268.6	71.3	94.9
1	14	14	20	280	339.2	-59.2	90.9	91.3
1	10	10	20	200	236.62	-36.62	90.2	95.8
1	17	17	19	323	1205.9	-882.9	84.2	90.6
3	7	21	20	420	619.29	-199.3	93.2	95.3
2	15	30	25	750	729.28	20.72	88.7	94.2
1	10	10	20	200	700.62	-500.6	84.7	98.1
1	8	8	20	160	573.51	-413.5	74.5	96.3
1	14	28	20	560	346.81	213.2	96.9	95.4
2	8	16	22	352	928.28	-576.3	80.8	90
1	12	12	20	240	314.85	-74.85	90.1	94.3
1	29	29	20	580	725.71	-145.7	91.5	86
2	7.5	15	20	300	588.58	-288.6	86.1	96.2
1	14	14	20	280	205.26	75.26	89.2	89.4
1	5	5	19	95	458.53	-363.5	67.9	96.2
1	7	7	16	112	449.03	-337.0	71.9	94.3
1	10	10	20	200	227.48	-27.48	92.6	96
1	4	4	20	80	444.77	-364.8	74.2	90.7

1	8	8	20	160	482.86	-322.9	78.1	94.2
1	24	24	30	720	987.52	-267.5	89.7	96.9
3	9	27	30	810	698.77	111.2	91.4	96.8
1	25	25	22	550	482.86	67.14	94	96.5
2	12	24	22	528	616.34	-88.34	92.5	98
1	8	8	20	160	395.58	-235.4	88.3	96.9
1	25	25	20	500	361.1	138.9	96.6	98.9
1	24	24	20	480	1068.1	-588.1	89.8	92.9
1	10	10	20	200	622.39	-422.4	86.9	98
1	10	10	17	170	325.86	-155.9	88.3	98.3
1	15	15	20	300	735.1	-435.1	92.3	98.6
1	8	8	20	160	406.1	-246.1	85.3	97.4
1	5	5	20	100	368.44	-268.4	76.1	95.5
2	16	32	19	608	847.78	-239.8	90.6	99.4
2	10	20	18	360	562.05	-202.1	91.2	96.9
2	16.5	33	18	594	660.38	-66.38	94	92.6
1	14	14	16	224	497.77	-273.8	90.8	98.3
4	13.5	54	19	1026	1074.1	-48.14	93	95.1
2	6.5	13	17	221	574.72	-353.7	88.2	92.2
3	13	40	18	720	997.72	-277.7	88.3	94.8
0		0		0	318.7	-318.7	56.1	91.5
2	13	26	22	572	722.97	-151.0	93.8	93.1
2	10.5	21	20	420	797.49	-377.5	89.1	98.9
2	12.5	25	20	500	695.42	-195.4	85.7	94.7
1	5	5	19	95	439.68	-344.7	81	96.1
1	6	6	16	96	378.13	-282.1	87.5	94.7
2	2.5	5	18	90	599.93	-509.9	74.5	92
2	5.5	11	17	187	659.82	-472.8	93.5	98
1	12	12	18	216	468.34	-252.3	90.7	98.8
1	7	7	17	119	420.01	-301.0	88.8	92.2
1	10	10	18	180	374.81	-494.8	92.3	98.2
2	14.5	29	18.5	536.5	827.52	-291.0	86.8	94.8
1	8	8	23	184	638.44	-454.4	88.2	98
2	7	14	18	252	408.77	-156.8	90	92.8
1	5	5	20	100	377.97	-278.0	93.1	96.2
1	2	2	20	40	322.72	-282.7	57.4	96.7
1	4	4	20	80	143.31	-63.31	87.7	98.4
1	8	8	20	160	171.14	-21.14	91.1	97.9
2	4.5	9	16	144	297.2	-153.2	93.7	95.6
2	6.5	13	20	260	548.51	-288.5	85.6	96.8
2	7	14	24	336	414.96	-78.96	93.5	98.2
2	8.5	17	15	255	603.61	-348.6	88.3	91.8
2	4	8	24	192	477.97	-286.0	86.6	96.6
1	8	1	19	19	286	-267	37.2	88.2
3	4	12	20	240	899.01	-659.0	78	97.7
1	5	5	20	100	287.97	-188.0	92	92.8
1	4	4	20	80	225.03	-145.0	88.7	91.6
1	3	6	19	114	275.53	-181.5	92.5	95.7
0		0		0	145.77	-155.8	58.7	96.9

1	8	8	20	160	238	-78	92.1	94.9
1	10	10	20	200	210.77	-10.77	96	97.9
3	4	19	20	380	735.92	-355.9	94.3	98.1
1	5	5	20	100	275.44	-175.4	88.7	95.8
2	3.5	7	20	140	340.05	-200.1	81.3	96.4
1	5	5	40	200	270.38	-70.38	81.6	98.3
1	19	19	30	570	289.86	280.1	94.4	98.3
2	7	14	30	420	909.62	-489.6	77.6	98.5
2	2	4	25	100	428.44	-328.4	71.9	99.1
4	7.5	30	30	900	963.23	-63.23	81.3	94.4
4	7	28	30	840	930.82	-90.82	87.6	97.4
2	5.5	11	30	330	431.38	-101.4	94.3	96.4
0		0		0	182.2	-182.2	47.4	99.1
1	10	10	40	400	276.24	123.8	91.3	97.6
1	1	1	30	30	458.96	-429.0	49.2	96
0		0		0	282.38	-282.4	41.5	97.7
2	7	14	30	420	422.24	-2.24	88.5	94.9
3	5.7	17	30	510	916.34	-406.3	78.7	98.3
1	7	7	40	280	601.1	-321.1	88.8	99
1	2	2	35	70	433.2	-363.2	64.4	98
1	6	6	35	210	682.77	-482.8	89.7	98.4
4	11	33	40	1320	1520.8	-200.8	64.6	98.5
3	9.3	28	40	1120	1277.2	-157.2	92.2	95.3
3	7.6	23	35	805	912.21	-107.2	87.8	95.5
2	12.5	25	35	875	1001.2	-126.2	92.6	90.9
2	17	34	35	1190	761.38	482.6	94.8	99
1	10	10	38	380	517.86	-137.9	79.4	94.1
3	12	36	38	1368	1196.5	171.5	89.3	96.9
1	5	5	38	190	332.2	-142.2	76.3	95.1
1	12	12	38	456	409.53	46.7	85.8	92.6
2	5	10	35	350	709.2	-359.2	85.1	98.4
1	2	2	35	70	376.4	-306.4	66	96.3
1	5	5	40	200	414.16	-214.2	80	95.7
1	0	0		0	342.01	-342.0	53.3	97.6
5	12	60	32	1920	2111.9	-191.9	84.5	99.4
4	17	68	35	2380	1348.5	1031.	93	97.2
1	5	5	40	200	149.53	50.47	93.8	99.4
1	5	5	32	160	661.61	-501.6	88.1	94.4
1	2	2	40	80	262.48	-182.5	49	89.7
3	14	42	40	1680	1250.6	429.4	92.1	95.8
2	14	28	40	1120	1206.5	-86.51	88.5	93.8
0		0			181.77	-181.8	54.1	98.5
3	10	30	40	1200	1687.6	-487.6	79.1	97.7
1	15	15	35	525	316.6	208.4	94.5	90.9

Source: Field Survey Results, 2012.

Appendix 7: Livestock kept and crops grown in Embu East and Igembe South Districts

Livestock species	Remarks
Dairy cattle	Kept in both Districts
Local Zebus	Kept mainly in lower of parts of Igembe and proportionately only a few in Embu East
Indigenous Goats	“
Dairy Goats	Mainly German Alpines in Embu and Toggenburgs in Igembe (Meru region)
Indigenous Sheep	Common in Igembe
Exotic Sheep	Not many in both Districts
Indigenous Poultry	Common in both Districts (mainly chicken)
Layer Birds	“
Rabbits	Common in Embu and Emerging in Meru
Crops	
Miraa (<i>Catha edulis</i>)	Main source of income in Igembe and emerging in Embu
Tea bushes	Common in both Districts
Coffee trees	“
Banana crop	“
Macadamia trees	“
Maize	“
Beans	“
Fodder crops	
Napier	Common in the two Districts
<u>Calliandra Spp.</u>	“
<u>Luceana Spp.</u>	“

Source: Ministry of Livestock Development and Ministry of Agriculture, Embu East and Igembe South (Annual Reports, 2009).

Appendix 8: Summary Statistics for the farm inputs, costs, outputs and milk price

Item Description	Continuous Variable Simple Average
Average total daily dairy farming cost (Ksh)/herd	551.1
Average milk yield per farm per day (Kg)	15.0
Average household roughage feeds cost per day (Ksh.)	295.8
Average household cost of mineral supplements per day (Ksh.)	19.9
Average cost of dairy farming labour per day (Ksh.)	148.9
Average cost of concentrate feed (Ksh.)/day	86.5
Other important information and data	
Average price of milk (Ksh.)	24.4
Average revenue (Ksh.)	366
Average herd size	3.93 \approx 4
Average milking herd size	1.56 \approx 2
Average cost of producing a kilogram of milk (Ksh.)	36.74
Average gross margin (Ksh)	-185.1
Average gross margin per kilogram milk (Ksh.)	-12.2

Source: Field survey results, 2012