DETERMINANTS OF PROFIT EFFICIENCY OF CAMEL MILK TRADERS IN FIVE COUNTIES IN NORTHERN KENYA

NJOROGE JOSIAH MATHU

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DECLARATION

This thesis is my original work and has not been submitted for an award of a degree in any other university.

Signature...... . Date...07 December, 2022................

Njoroge Josiah Mathu

Approval:

This thesis has been submitted with our approval as university supervisors:

Signature..... .... Date...07 December, 2022.......................

Dr. Patrick Irungu

Department of Agricultural Economics

University of Nairobi

Signature..... ...... Date...07 December, 2022..................

Dr. Cecilia Ritho

Department of Agricultural Economics

University of Nairobi

Signature... ………….......... Date…07 December, 2022....................

Dr. Nadhem Mtimet

Agricultural Economists

International Fund for Agricultural Development

DEDICATION

I would like to dedicate this thesis to my loving parents Mr. Peter Mathu and Mrs. Magaret Mathu, my siblings, uncles and aunts for their tireless encouragement, provision, love, and prayers in the course of my study.

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ABSTRACT

Camel milk is a major source of both revenue and nutrition for pastoral communities in Northern Kenya. However, despite the existence of significant trade in camel milk in the region, the estimation of traders' profit efficiency has received little attention, perhaps in furtherance of the longstanding historical neglect of socio-economic research on camel milk. To address this gap, this study used a cross-sectional dataset of 933 camel milk traders collected in Garissa, Isiolo, Marsabit, Turkana, and Wajir counties in Northern Kenya to assess their profit efficiency and identify its drivers using a stochastic translog profit frontier, and to determine spatial profit efficiency gap across the five counties using the meta-frontier framework. The study found that women dominated the camel milk trade in Northern Kenya at a ratio of 4.6:1. In addition none of the five counties was fully profit efficient; in fact, the average profit efficiency was only 43% suggesting that 57% of the profit was lost to technical inefficiencies in the marketing system and traders' idiosyncracies. Nevertheless, Isiolo and Wajir counties emerged as the best, with 78% and 71% profit efficiency scores, respectively. Being female, traders' milk selling experience, participation in milk handling training, and value addition significantly reduced the profit inefficiency, while the distance to markets had the opposite effect. Accordingly, the study recommends increased investment in value addition in camel milk, the establishment of trader milk handling safety and hygiene training programs, and the development of road and market infrastructure to improve the profit efficiency of camel milk traders in Northern Kenya for enhanced welfare.

Keywords: Profit efficiency. Camel milk traders. Stochastic translog profit frontier

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AE	Allocative efficiency
ANOVA	Analysis of variance
ASAL	Arid and semi-arid lands
CD	Cobb Douglas
CES	Constant elasticity of substitution
CIDP	County Integrated Development Plan
DEA	Data envelopment analysis
DF	Degree of freedom
FAO	Food and Agriculture Organization of the United Nations
GFSS	Global Food Security Strategies
ILRI	International Livestock Research Institute
KNBS	Kenya National Bureau of Statistics
KSh	Kenya shillings
OLS	Ordinary least squares
PE	Profit efficiency
PEGR	Profit efficiency gap ratio
SE	Standard errors
SDG	Sustainable development goal
SFA	Stochastic frontier analysis
SSA	Sub-Saharan Africa
TE	Technical efficiency
VMP	Value of marginal product

CHAPTER ONE: INTRODUCTION

1.1 Background

Camels flourish well in desert and arid regions of the world (Oselu *et al.,* 2022). They possess various adaptations which make them more resilient to harsh environments than other livestock species. Their long legs raise their bodies further away from the hot ground to lessen overheating (Tibary & El Allali, 2020). They can minimize sweating, thus conserving water by adjusting their body temperature to 34 to 40°C (Habte *et al.,* 2021). Camels have large padded feet that support their weights in the sand. According to the Food and Agriculture Organization of the United Nations (FAO, 2022), the current global population of camels is estimated at 39 million.

Camel milk is still the most important source of nutrition among the desert population in Asian and African countries (Benmeziane–Derradji, 2021). It is said to have medicinal properties and is predominantly consumed by pastoral communities in arid and semi-arid lands (ASAL) in Asia, the Middle East, and Africa (Zibaee, 2015; Ogolla *et al.,* 2017). Rasheed (2017) notes that vitamins and minerals, especially vitamin B and vitamin C are essential elements found in camel milk. In addition, camel milk is helpful in ASAL where the supply of green vegetables and fruits is limited (Sumaira *et al.,* 2020).

Gizachew *et al*. (2014) on the other hand, observed a high insulin content that is useful in the treatment of type 1 or type 2 diabetes. Countries in sub-Saharan Africa (SSA) keep camels predominantly for milk, blood, and meat production and transport (Opoola *et al.,* 2019). Camel milk contributes about 8% of the total milk production in SSA countries (FAO, 2022). Camels are used as multifunctional animals in Eastern Africa, where they are kept for the production of milk, blood, hides, meat, provision of transport, barter trade, and social-cultural functions (Dokata *et al.,* 2014). Their dung is also used to construct houses for pastoralists. In Kenya, camels are primarily found in northern, and coastal regions where they are kept for milk, meat, hides, and draught power (Oselu *et al.*, 2022). Kenya has the third largest camel herd in Africa (Hughes & Anderson, 2020), estimated at 4.72 million, after Somalia and Sudan (FAO, 2019). About 80% of camels are found in North-Eastern Kenya with Mandera County having the largest population of 1.83 million (Kenya National Bureau Statistics [KNBS], 2019).

Kenya is the world's largest producer of camel milk, with a production of 1.2 million tons (FAO, 2022). Camel milk accounts for about 10% of Kenya's total milk production (Kaindi, 2018). The pastoral households in Kenya rely on camel milk sales with the amount of milk depending on the family's economic and social needs (Elhadi *et al.*, 2015). The camel milk value chain in northern Kenya has a dual character, i.e., milk from pastoral areas is informally marketed through a chain of middlemen to hawkers and vendors in tertiary markets such as Nairobi (Eastleigh), Nakuru, Mombasa, and Kisumu (Isako & Kimindu, 2019).

The informal camel milk value chain is characterized by the low quality of milk leading to high postharvest losses. Camel milk is also formally marketed through dairy cooperatives and commercial processors like Ngamia milk suppliers and Vital Camel Milk Limited in Nanyuki, Isiolo camel milk cooperative, and Anolei Women's camel milk cooperative, where the milk is pasteurized, packaged, and distributed to distant outlets such as Nairobi, Mombasa, and Nakuru (Muloi *et al.*, 2018). Processed products such as yogurt, camel cheese, and butter are sold in regional and international markets (Gitonga, 2017). According to Kaindi (2018), about 55% of camel milk produced in Kenya goes to waste due to poor handling and transportation, and a lack of storage facilities. The other constraints that affect the performance of the informal camel milk market include poor organization of traders, weak financial management skills, and inadequate physical infrastructure and institutional support (Blackmore *et al.*, 2015).

According to the theory of the firm, business operators seek to maximize their profits by employing scarce resources in production (Derbertin, 1986). Accordingly, camel milk traders, like any other business operators, invest in camel milk marketing because of the profit motive. According to Awais *et al.* (2016), the profit motive incentivizes business operators to take risk investing in a business. It also incentivizes businesses to invest in research, technology, and innovation (Leone, 1986). Accordingly, the profit motive promotes efficiency of the enterprise so that the investor is constantly seeking new ways to efficiently produce goods and services for consumers (ibid). Therefore, understanding the profit efficiency of camel milk traders is essential in identifying potential areas of improvement to enable traders to optimize the use of scarce resources in pursuit of their profit motive in their camel milk business. This study is an attempt in this regard. This study used primary data collected by the International Livestock Research Institute (ILRI) in five counties in northern Kenya, i.e., Turkana, Wajir, Marsabit, Isiolo, and Garissa, in a large study that assessed the microbial quality and safety of camel milk and associated products along the value chain of dromedary camel in northern Kenya. The motivation for this study was to provide insights and solutions into how camel traders' profit inefficiency could be enhanced for improved social welfare.

1.2 Statement of the Research Problem

Among the inhabitants in northern Kenya, camel milk plays a crucial role in their livelihood. The potential for camel milk to create more employment and wealth as well as improve the livelihood of the pastoralist communities in northern Kenya has been enormous (Noor *et al.,* 2013). Previous economic studies on camel milk have mainly focused on the acceptability of the milk and its products. For example, Odongo *et al.* (2017) studied practices and knowledge of food hygiene and safety among camel milk handlers in the pastoral camel value chain in Isiolo County, Kenya.

The camel milk handlers were found to have a low understanding of postharvest-handling losses which reduced their returns. On the other hand, Wayua *et al.* (2012) assessed the postharvest handling, preservation, and processing practices along the camel milk value chain in the then Isiolo District, and established that milk spoilage was the primary cause of low profit accrued by the milk traders because the milk was marketed in an unhygienic environment. Anderson *et al.* (2012) examined the commodification of camel milk in Isiolo and noted that inadequate regulation of the camel milk business led to an increase in milk spoilage. Muloi *et al.* (2018) conducted a value chain analysis and sanitary risk of camel milk systems supplying Nairobi city and discovered a high gap in hygiene practices, especially at the farm gate and market level which affected the income of the traders.

Other researchers have identified declining profits from the camel milk industry. For example, Elhadi & Wasonga (2015) reported that 55% of camel milk goes to wastage leading to a reduction in the income of the traders. The camel milk handlers in northern Kenya have been reported to have a low understanding of postharvest-handling losses, which reduces their returns (Kaindi, 2018). Milk spillage and spoilage have been noted to be the primary causes of low profit accrued by camel milk traders because the milk was marketed in an unhygienic environment (Elhadi *et al.*, 2015). Camel milk marketing in northern Kenya is constrained by a lack of road and transportation facilities, the absence of training programs on milk safety and hygiene, an inadequate supply of cooling facilities, and the absence of organized marketing channels. These factors have reduced their efficiency leading to traders earning low returns from their business.

Based on the review of previous studies, little attention has been paid to camel milk traders' profit efficiency in northern Kenya, perhaps in furtherance of the longstanding historical neglect of socio-economic research on camel milk. Hence, this study is pioneering in its examination of profit efficiency and its determinants among camel milk traders in northern Kenya. Understanding the profit efficiency of camel milk traders will aid in designing interventions aimed at improving the marketing and operational efficiency of camel milk traders for optimal profit and enhanced welfare.

1.3 Objectives of the Study

The overall objective of this study was to examine the profit efficiency of camel milk traders in five counties of northern Kenya. The specific objectives for the study were to:

1. Assess the profit efficiency of camel milk traders in northern Kenya.
2. Evaluate the factors influencing the profit efficiency of camel milk traders in northern Kenya.
3. Determine the spatial variation in profit efficiency among camel milk traders in the five counties of northern Kenya.

1.4 Hypotheses Tested

The following hypotheses were tested in this study:

1. That the camel milk traders in northern Kenya are not profit efficient.

2. That social economic and institutional factors have no effect on the profit efficiency of camel milk traders in northern Kenya.

3. That there is no spatial variation in profit efficiency of camel milk traders in the five counties of northern Kenya.

1.5 Justification of the Study

This study aligns with the National Food and Nutrition Security policy, which states that increasing the awareness of camel milk and marketing camel milk is critical in ensuring food accessibility and availability. The study aligns with the Global Food Security Strategies (GFSS) Kenya country plan which emphasizes addressing challenges affecting the quality of camel milk and its marketing channels to increase food accessibility and availability to all Kenyans. This study is also in line with Kenya' vision 2030, the national Big four Agenda, and the County Integrated Development Plan (CIDP), which support the establishment of an efficient, sustainable, and competitive camel milk sector that promotes the safety and quality of camel milk being consumed at the household, county, and national level.

The results of this study will enhance the camel milk traders' efficiency, thus improving the distribution of better quality camel milk to consumers and optimizing the profit margins of camel milk dealers. This will increase their net income and reduce their income poverty. In effect, this will contribute to the first two sustainable development goals (SDG) of zero hunger and poverty alleviation. In addition, the study will provide policymakers with information on factors influencing the profit efficiency of camel milk traders, thus guiding them in designing relevant policies that will increase such efficiency for higher profit and social welfare.

Other stakeholders who could use the results of this study include non-governmental organizations who will use the information to formulate efficiency-enhancing programs in the camel milk value chain. Camel milk traders who will use these results will understand what factors reduce their profit efficiency. County extension officers will use the information to develop interventions aimed at increasing traders’ profit efficiency. This study contributes to the literature on profit efficiency in a pastoral setting that is currently relatively thin.

1.6 Organization of this Thesis

This thesis is organized in paper format. Chapter I presents the detailed background of the study, statement of the research problem, objectives of the study, hypotheses tested, and justification of the study while chapter 2 presents a review of the literature on profit efficiency and its theoretical underpinnings and conceptual framework. Chapter 3 presents the first paper entitled ‘‘Are camel milk traders in Northern Kenya profit efficient? Evidence from a stochastic translog profit frontier” while chapter 4 consists of the second paper entitled ‘‘A meta-frontier analysis of profit efficiency of camel milk traders in northern Kenya’’. Chapter 5 closes the thesis with a general discussion, conclusions, and recommendations.

CHAPTER TWO: LITERATURE REVIEW

2.1 Profit Efficency Concept

The term ‘‘profit efficiency’’ comprises two words that require to be unpacked. According to Nariswari & Nugraha (2020), ‘‘profit’’ refers to money gained in a trade or business after paying the costs associated with producing a good or service. ‘‘Efficiency’’ on the other hand is the ability to attain the optimal level of performance with the least amount of input to obtain the highest amount of output (Farrell, 1957). Hence, ‘‘profit efficiency’’ refers to the capability of a firm to attain the maximum potential profit given the level of fixed factors and prices faced by the firm (Cherchye *et al.,* 2016).

Profit efficiency is expressed as a ratio of predicted actual profit to the expected maximum profit for a best practice adopted by a firm (Sadiq *et al.*, 2016). Ansah *et al.* (2014) note that if a firm fails to operate on the profit frontier, it is considered to be profit inefficient. Otherwise, it is profit efficient, and it can earn the maximum allowable profit from available resources. According to Sahoo *et al.* (2014), it is derived from a profit function where the prices of input and output are considered exogenous. As such, it permits the consideration of revenues that can be attained through varying both inputs and outputs (Aiello & Bonanno, 2018).

Profit efficiency accounts for any errors arising from both the output and input sides of a given production process. Mawa *et al.* (2014) argue that the concept of profit efficiency is more comprehensive than cost efficiency because it considers the effect of the choice of a particular vector of production on both cost and revenue. Thus, profit efficiency is key in estimating the overall performance of the firm because it collects any errors arising from both inputs and outputs. Estimation of profit efficiency is important because it provides information suitable for the firm whose principal behavioral objective is profit maximization (Pilar *et al.*, 2018).

2.2 Review of Theoretical Literature

2.2.1 Theories Underpinning the Concept of Profit Efficiency

Profit efficiency is anchored on the neoclassical theory of the firm which holds that under perfect market conditions, the overall objective of a firm is to maximize profit by maximizing the gap between revenue and cost. The firm's problem is to make the difference between its total revenue and total cost as large as possible through the use or pursuit of efficient strategies. For instance, selecting the best input-output combinations such that the output bundle yields the greatest potential revenue from the corresponding input bundle.

At the same time, the selected input bundle yields the corresponding bundle at minimum cost and optimal distribution of scarce resources given their respective prices and production technology (Onubuogu *et al.,* 2014). The adoption of efficient strategies not only enables a firm to reduce its unit variable costs but also its fixed costs (Ray & Das, 2010). At the same time, increasing the adoption of cost-reducing technologies lead to the maximization of profit (Dawar, 2014). Therefore, efficiency determines how a firm manages its scarce resources to maximize its profits (Bandiera *et al.,* 2015). As such, it allows a firm to minimize the wastage of its resources but utilize them in a productive manner (Elhendy & Alkahtani, 2013).

Farrell (1957) distinguishes two types of efficiency; i.e., technical and allocative efficiency. Technical efficiency (TE) is achieved when a firm produces the highest output for a given technology and the combination of inputs (Chikobola, 2016). As such, a firm is considered technically inefficient when its actual and observed output is less than the maximum possible output (Fan, 2000). Alrafadi *et al.* (2016) define allocative efficiency (AE) as the ability of the firm to optimally use the input combination given their respective price and production technology.

Accordingly, allocative efficiency is achieved when the firm's marginal value product (MVP) is equal to its marginal factor cost under competitive market conditions (Elhendy & Alkahtani, 2013). Fitzpatrick & McQuinn (2008) argue that profit efficiency can be defined as the overall efficiency of the firm, such that in case a firm is efficient in terms of its profits, that means it is efficient in terms of both its cost and scale of production. According to Aparicio *et al.* (2015), a firm may be profit inefficient despite being technically efficient because it failed to select the correct input combination.Inefficiency practices such as poor prioritization of the output to produce, ignorance on the use of technologies that reduce the cost of production, and poor distribution of resources (Mgbenka *et al.*, 2016).

Farmal *et al.* (2006) argued a firm will be able to maximize its output level given the input bundles or minimize input bundle of production given the level of output (Farmal *et al.*, 2006). Thus, inefficient practices increase the cost of production of goods which, in turn, affects the realization of profit by the firm. For inefficient allocation of resources will reduce the ability of the farm to make profit by inducing losses within the firm. Thus, the presence of technical and allocative inefficiencies lower the firm's profit. According to Kumbhakar (2001), a firm maximizes its profit subject to a production technology by equating VMP to the optimal input price:

$$\mathrm{p}f_j(.) = w_j \tag{2.1}$$

where p is the output price, $f\,(.)$ is the production function, and w_j is the optimal input price. Solving this first-order condition via Hoteling's lemma yields the factor demand and the output supply functions, as shown in equation 2.2 and 2.3.

$$dy/dx = -x_j(w, p) \tag{2.2}$$

$$dy/dy = y\,(w, p) \tag{2.3}$$

where x_j is the vector of input, w is the input price, and y is the output (Askar & Al-Khedhairi, 2020). According to Kumbhakar *et al.* (2015), substituting equation the optimal demand and output supply functions given by equations 2.2 and 2.3 respectively into the definition of profit (total revenue minus total variable cost) gives the following ‘‘efficient’’ profit function:

$$\pi^* = p \,. y\,(w,p) - \,w.x(w,p\,) \qquad (2.4)$$

where π^* is the profit for a fully efficient firm what one could call ‘‘ profit efficiency’’.

In the presence of technical and allocative inefficiency then the first-order condition of profit maximization in equation (2.1) can be expressed as:

$$\mathrm{p}f_j(.)e^{\mu} = \theta_j w_j \qquad (2.5)$$

where $e^{\mu}\ is$ output-oriented technical inefficiency, θ_i is the allocative inefficiency parameter. Solving this first-order condition via Hoteling’s lemma yields the factor demand and the output supply functions, as shown in equations 2.6 and 2.7.

$$dy/dx = -x_j(w,p,\mu,\theta) \qquad (2.6)$$

$$dy/dy = \,y\,(w,p,\mu,\theta) \qquad (2.7)$$

By substituting the optimal input demand and output supply functions given by equation 2.6 and 2.7, respectively, into the definition of profit (total revenue minus total variable cost) gives the following ‘‘inefficient’’ profit function (Kumbhakar, 2001):

$$\pi^* = p \,. y\,(w,p,\mu,\theta) - \,w.x(w,p,\mu,\theta) = \,\pi^* = (w,p,\mu,\theta) \qquad (2.8)$$

Han & Kim (2018) argue that profit efficiency can be decomposed to reflect the sources of technical inefficiency and allocative inefficiency since they tend to lower the profit of the firm. In addition, Ali *et al.* (1994) argued that within the profit function, the concepts of technical and allocative efficiencies are combined while any errors arising from production decisions are interpreted as lowering the firm’s profit. The neoclassical theory of the firm will aid in explaining the nature of camel milk traders in northern Kenya including its structure, existence, and relationship to the market. Thus, the theory influences the decision of traders in terms of allocating scarce resources, price adjustment, and a combination of inputs to use.

2.2.2 Methods Used to Operationalize the Concept of Profit Efficiency

Both parametric and non-parametric techniques are widely used in measuring profit efficiency. Balcerzak *et al.* (2017) note that the choice of the use of parametric and non-parametric methods relies on the objective of the researcher. According to Syarifa *et al.* (2019), a non-parametric method that is widely used to analyze profit efficiency is the Data Envelopment Analysis (DEA). DEA uses linear programming to develop a piece-wise frontier that envelopes the observations of all firms and computes efficiency scores by estimating how far an observation is situated from the envelope (Nguyen *et al.,* 2016 and Khezrimotlagh & Chen, 2018). As such, a functional form is not needed to explicitly specify the underlying profit function (Charnes *et al.,* 1985).

According to Ghasemi *et al.* (2020), the key benefit of using DEA is that it considers multiple inputs and outputs simultaneously, using different units of measurement. This makes it easy to analyze the efficiency of the firm because prior aggregation of outputs is not compulsory (Atici & Podinovski, 2015). The main disadvantage of using the non-parametric approach is that it is difficult to conduct statistical tests of the results as it does not account for the random statistic noise and measurement error (Chen *et al.,* 2015). For this reason, the current study did not use the DEA.

Besides its inability to test the obtained hypotheses its use of a two-step procedure where the estimated efficiency scores obtained in the first stage are regressed on predictors hypothesized to influence profit efficiency in the second step leading to inefficient parameter estimate (Johnson & Kuosmanen, 2012). The parametric approach uses a precise functional form to specify the underlying profit relationship linking the output to an input bundle (Kumbhakar *et al.,* 2015).

Adding a composite error component to deterministic stochastic profit frontier which uses the stochastic frontier analysis (SFA) of Aigner *et al.* (1977) and Meeusen & Van den Broeck (1977). The key advantage of SFA over the DEA is that it considers measurement errors and statistical noise in the data (i.e., factors outside the control of the firm, such as price volatility and shocks) (Bidzakin *et al.,* 2014, cited in Chikobola, 2016). In addition, with SFA, it is possible to estimate standard errors, which is not possible with DEA (Iqbal Ali & Lerme, 1997). The main limitation of the parametric method is that it requires the specification of a functional form of the profit frontier (Wongnaa *et al.,* 2019). This implies that the predicted efficiencies might be biased if the functional form is wrongly specified (Giannakas *et al.*, 2003).

Different functional forms including Cobb-Douglas (CD), quadratic, translog, generalized Leontief, and constant elasticity substitution (CES) have been used in previous studies to estimate the profit efficiency (e.g., see Kutlu *et al.* (2020) for a review). Both Cobb Douglas and translog profit functions have been frequently used in empirical work to estimate profit efficiency and the factors influencing it (e.g., see Sadiq *et al.* (2016) for a review). The choice of which functional forms to use depends on the satisfaction of the relationship between the predictor and explanatory variables (Giannakas *et al.,* 2003). Regardless of the functional form chosen, the estimation of the profit efficiency and the factor influencing is ideally achieved in a single step (Battesse & Coelli, (1995).

2.3 Review of Empirical Literature

Kumari *et al*. (2020) used a normalized translog profit function to estimate the profit efficiency of women dairy farmers in the Begusari District of Bihar, India. The specification of translog was preferred due to its flexibility over other functional forms such as the CD (Abdulai & Huffman, 2000; Rahman, 2003). They adopted the generalized likelihood ratio test to account for the suitability of using a flexible translog profit function and testing for the existence of inefficiency in the profit function. They found that the age of the dairy farmer (woman), her experience, herd size, training, and herd composition were the main significant determinants of profit inefficiency. According to Ferrara & Vidoli (2017), the critical setback of the translog functional form is the problem of insufficient degrees of freedom due to the presence of interaction terms and it is exposure to multicollinearity.

This can be corrected through centering or standardization methods (Wang *et al.*, 1995). Akintunde *et al.* (2020) applied a CD stochastic frontier technique to assess the profit efficiency of egg producers in southwestern Nigeria. The authors found that the profit efficiency of the producers was statistically improved by access to extension services, livestock insurance, stock size, and biosecurity services. The efficiency score together with the factors explaining inefficiency was estimated in a single-step procedure. Adnan *et al.* (2021) used the translog-based stochastic frontier profit function method to examine the profit efficiency of maize producers and the factors influencing it in Bangladesh. The findings showed that maize producers were 71% profit efficient. Factors such as age, producer education level, extension experience, and non-farm income were the main significant determinants of profit inefficiency.

Hansen *et al.* (2019) used the CD stochastic frontier profit function to examine how dairy farmers can become more profit efficient in Norway. The study found beef quantity, organic farming, low age of first calving, and automatic milking system significantly influenced the farmer's profit. However, this study used panel data to assess the revenue efficiency of dairy farmers. Wongnaa *et al.* (2019) applied a translog stochastic frontier profit function approach to evaluate the profit efficiency of maize farmers in Ghana. They found the average profit efficiency of the maize farmer was 48.4%. In addition, access to good roads, agricultural extension officers, credit as well as maize farmers' gender and level of education influenced profit efficiency.

Mawa *et al*. (2014) employed the CD stochastic frontier profit function to assess dairy farmers' profit efficiency in the Rift valley and Central province in Kenya. They found the average profit efficiency of a dairy farmer was 68%. In addition, farmers' age and access to extension services decreased profit efficiency while the cost of fodders increase profit efficiency.

2.4 Conceptual Framework

Grounded on the theory of the firm, the principal objective of the trader is to maximize profits. However, traders do not consistently achieve maximum profit because of technical and allocative inefficiencies and random statistical noise. Both technical and allocative inefficiencies might be due to poor management skills while random statistical noise arises from factors beyond the control of the decision-maker. Figure 2.1 illustrates how different factors interrelate to determine a trader's decision-making process for his/her milk enterprise; these decisions eventually influence a trader's profit efficiency.

The combination of production, market, and institutional factors and the trader's characteristics influence the trader's decision-making in terms of how to allocate resources, selecting the best capital investment, and selecting the desired management practices which will effectively reduce losses. For example, an increase in the costs of production, such as wages, transportation costs, and the cost of hiring cooling facilities, might limit the scale of the milk enterprise because the trader might be forced to borrow money inexpensively, thus, making the enterprise unmanageable. For instance, an increase in the price of milk transporting containers might affect the quality of milk since traders might opt to use poor means of transporting the milk leading to a high wastage of milk.

Investment in purchasing milk processing handling, quality testing, and transportation equipment is likely to improve the efficiency of milk traders because it reduces postharvest losses along the milk supply chain. On the other hand, institutional factors such as participation in training programs, access to credit, and extension services enhance the trader's capacity to adopt improved technologies such as freezers and aluminum cans (Tingirtu, 2019). The adoption of modern technologies improves the safety and quality of milk, thus reducing postharvest losses and improving the profit efficiency of milk enterprises. Market factors such as distance to the market impact the choice of mode of transport used by the milk traders. Besides, long-distance increases transportation costs since it adds to the cost of distributing the product.

Value addition tends to reduce losses related to poor milk handling practices such as spillage and adulteration. In addition, adding value to milk by the production of yogurt, cheese, butter, and milkshake will enable traders to charge a higher price for their products, thus, making more profits. Thus, value addition improves the efficiency of traders by minimizing postharvest losses. Milk traders' socioeconomic factors such as age, gender, and experience play a critical role in influencing milk enterprise management decisions. For example, a trader's age determines their determination while engaging in milk marketing activities.

More youthful milk traders, albeit with less experience, might be bound to be energetic and learn and adopt new technologies in the milk enterprise (Nakanwagi & Hyuha, 2015). Milk traders with more experience in the milk enterprise can identify the best practices needed in the management of the business best on experience. The attainment of technical efficiency depends on the trader's management decision, such as the type of milk containers used for storage and transportation, the mode of transport and the choice of the method of preservation, the labor required to assist in the collection and delivery of milk, and how value addition and training traders improve milk quality and handling practices.

These factors largely influence the safety and quality of milk, therefore technical efficiency is an important aspect for milk enterprise to thrive. The allocative efficiency depends on the trader's management decisions like the distribution of labor to maximize customer advantage. Besides, management decisions are also associated with labor costs, the cost of buying milk, and the cost of delivering milk to the consumer which might affect the quality of milk, thus affecting allocative efficiency since the customers will not be satisfied. The arrows in Figure 2.1 show the direction of influence.

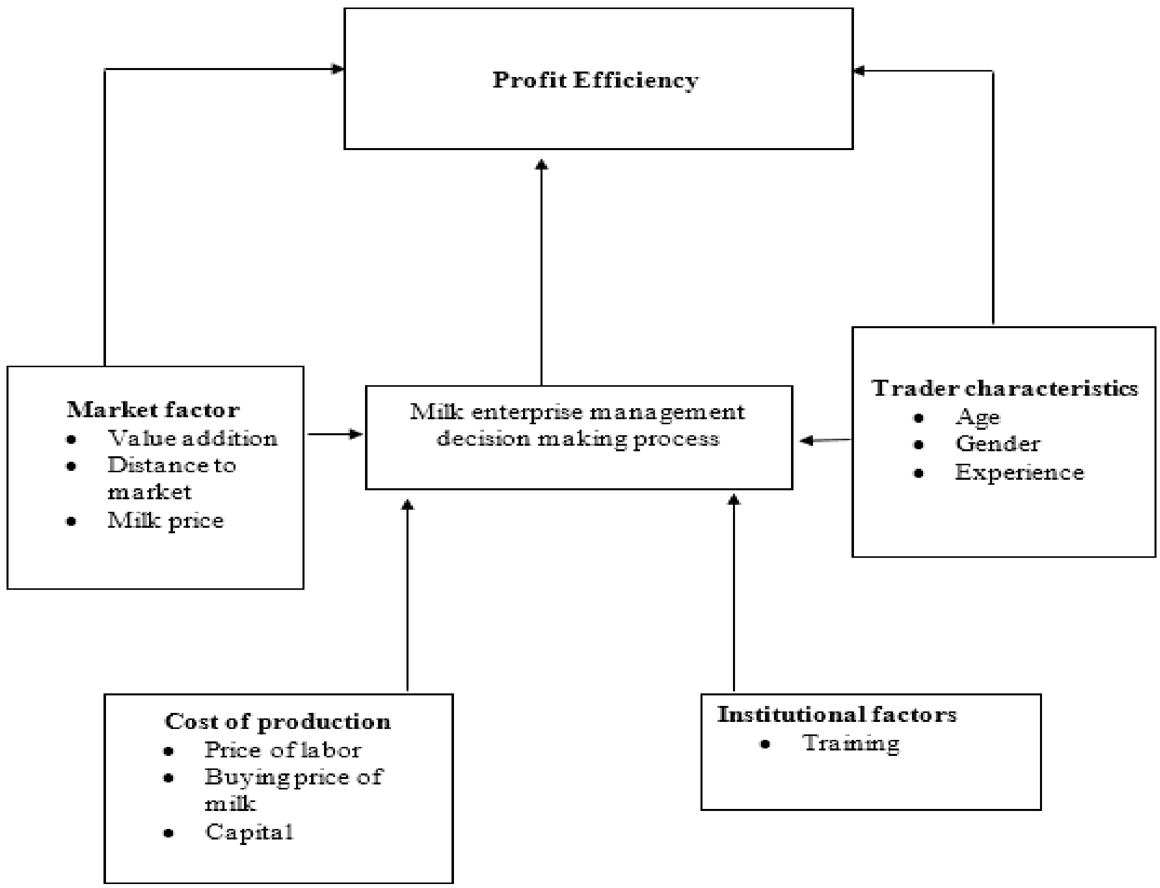


Figure 2.1: Conceptualization of the determinants of profit efficiency of milk traders

Source: Author's own conceptualization

2.5 Summary

The literature reviewed in this chapter reveals that the dominant theoretical basis of this study is the neoclassical theory of the firm. The main parametric method used in estimating profit efficiency is the stochastic frontier analysis. It is widely used because it considers measurement errors and statistical noise in the data. The most prominent empirical approaches used to estimate profit efficiency are the translog and Cobb-Douglas profit efficiency frontiers. Virtually no economic studies have examined the profit efficiency of camel milk traders in Northern Kenya. Most previous research on camel milk marketing research has concentrated mainly on its microbial composition, its role in pastoral livelihood, its acceptability, the contribution of camel milk to the economy, and post-harvest milk preservation and processing practices. The business case for camel milk has largely been ignored and hence this study is motivated to fill this gap.

CHAPTER THREE: ARE CAMEL MILK TRADERS IN NORTHERN KENYA PROFIT EFFICIENT? EVIDENCE FROM A STOCHASTIC TRANSLOG PROFIT FRONTIER

Abstract

Camel enterprises in Kenya are an essential source of livelihood, especially among pastoral communities in Northern Kenya. However, there is a growing concern about declining profits from the camel milk industry. Despite its high demand in the market, the estimation of the profit efficiency of camel milk traders has received little attention, perhaps in keeping with the general lack of economic research on camel milk. This study used primary cross-section data to assess the profit efficiency of camel milk traders and its determinants in five counties of Northern Kenya using a stochastic translog profit frontier. The study found an average profit efficiency of 43%, implying that 57% of the profit was lost because of technical inefficiency in managing the milk venture. Further, the study found that the price of labor led to a decline in profit as it increased the cost of running the milk business. The profit efficiency of camel milk traders was positively influenced by the trader's milk selling experience, being female, having participated in previous training on milk handling and quality control, and value addition in milk. Distance to market was negatively associated with profit efficiency from delays in milk collection and reduced traders' access to training offered in towns. Accordingly, the study recommends increased investment in value addition in camel milk, the establishment of trader milk handling safety and hygiene training programs, and the development of road and market infrastructure to improve the profit efficiency of camel milk traders in Northern Kenya for enhanced welfare.

3.1 Introduction

Desert camels are highly endowed with the capacity to yield quality milk in some of the hottest and most unfriendly surroundings worldwide (Abri & Faye, 2019). In addition, camels are adapted to harsh desert conditions both biologically and morphologically (Tibary & El Allali, 2020). Kenya had 4.7 million camels in 2019 (Oselu *et al.,* 2022), the fifth largest population in the world (FAO, 2019). About 80% of these camels are found in northern Kenya with Mandera County leading (Oselu *et al.,* 2022). In 2019 Kenya was recognized as the leading producer of camel milk worldwide with a production of 1,165,210 tons (FAO, 2019).

Camel milk and its related products have been recognized as an indispensable source of livelihood for pastoral communities (Kebede *et al.,* 2013). Milk is a handy remedy during periods of severe drought due to climate change and is therefore critical to the survival of pastoral communities (Wambua, 2019). Apart from guaranteeing household food security, camel milk marketing creates jobs, alleviates poverty, and enables households to diversify their income sources (Mwaura *et al.,* 2015). Elhadi & Wasonga (2015) indicated that the sales of camel milk accounts for 35% to 40% of household income in some communities, especially during dry seasons.

The marketing of camel milk and its related products is undertaken through three main channels the shortest of which is direct sales from producers to consumers and retailers such as milk bars and restaurants (Isako & Kimindu, 2019). The second channel is where traders transport fresh milk to urban towns that house county headquarters, Nanyuki and Nairobi. The third channel involves selling fresh milk to processors such as Vital Camel Milk Limited in Nanyuki and Nuug Camel Milk Products Limited based in Nairobi (Muloi *et al.,* 2018). The processor then sells the value-added milk (e.g., yogurt, cheese, butter) to nearby towns such as Nakuru, Nyeri, and Meru.

Camel milk traders in Northern Kenya are constrained by high post-harvest losses associated with poor handling practices, inadequate information on the camel milk market, milk prices, and insufficient supply of cost-effective post-harvest handling technologies to increase the shelf life of milk (Odongo *et al.,* 2016). In addition, milk suppliers are unable to deliver milk on time due to harsh climatic conditions which lead to milk spoilage in transit. Considerable efforts have been made to address these constraints through the establishment of training programs on milk quality and safety, improving production innovation, and information packages, however, there has been a great challenge in sustaining these initiatives (Wayua *et al.,* 2012).

Previous studies on camel milk have focused on its microbial composition, its role in pastoral livelihood, its acceptability, and postharvest milk handling and preservation (Akweya *et al.,* 2012; Noor *et al.,* 2013; Odongo *et al.,* 2017). Therefore, there is a need to examine the profit efficiency of camel milk traders to improve their welfare by minimizing their managerial inefficiencies. Further, understanding the profit efficiency of camel milk traders is important in identifying potential areas of improvement to enable traders to optimize the use of scarce resources in pursuit of the profitability of the camel milk business. In addition, identifying factors influencing the profit efficiency of camel milk traders will enable policymakers and other practitioners to formulate policies and strategies aimed at improving the camel milk dairy sector which has long been neglected by both policy and economic research.

3.2 Literature Review

A firm is less efficient as a result of either failing to distribute goods and services as per the request of the consumers (allocative inefficiency) or to achieve the maximum possible output given the combination of input and technology (technical inefficiency) (Kumbhakar *et al.,* 2014). Since technical and allocative efficiency reduces profit, profit efficiency can be decomposed to reflect the source of each inefficiency (Han & Kim, 2018).

Doing so guides the development of solutions to reducing inefficiency. According to Sadiq *et al. (*2016), profit inefficiency for a firm is the difference between the maximum possible profit achievable relative to the one achieved. As opposed to a production function, the profit function combines both technical and allocative concepts in one profit function, and any errors in the management decisions are interpreted as lower profits (Ali *et al.*, 1994). Various functional forms have been utilized by different researchers to estimate firm efficiency including Cobb Douglas (CD), translog, generalized Leontief, and quadratic (Farmal *et al.*, 2006). However, most studies employ the Cobb Douglas and translog profit frontier because of their ease of estimation and tractability of results (Kuboja *et al.*, 2017). For example, in profit efficiency studies focusing on milk marketing, Nganga *et al.* (2010), Mawa *et al.* (2014), and Acharya *et al.* (2021) used the Cobb Douglas profit frontier in Kenya and India, respectively.

Nganga *et al.* (2010) and Mawa *et al.* (2014) reported an average profit efficiency of dairy farmers of 60% and 68%, respectively, while Acharya *et al*'s an average profit efficiency between 2% and 92%. On the other hand, Mwalongo (2018) and Kumari *et al.* (2020) used a translog profit frontier to evaluate the profit efficiency of dairy farmers in Malawi, Tanzania and India, respectively. The average profit efficiency reported varied from 8% and 99% (Mwalongo, 2018). A casual examination of two sets of results revelas that the profit efficiency estimation from the Cobb Douglas specification is slighter higher than that from a translog, perhaps because it is not susceptible to multicollinearity (Sanusi, (2015). This difference suggests that the choice of the functional form matter and if ignored could lead to biased results that have no use in policy design.

The choice of which functional forms to use depends on the satisfaction of the relationship between the predictor and explanatory variables (Giannakas *et al.*, 2003). The Cobb-Douglas and translog are widely used functional forms because of their prior empirical evidence. The review of these studies concerning the use of the functional form has shown that the choice of appropriate function is very important. This means that misspecification of the functional form might lead to the production of biased and inaccurate estimators, thus, posing a severe challenge to policy prescription (Giannakas *et al.*, 2003).

3.3 Materials and Methods

3. 3.1 Theoretical framework

From a theory of the firm perspective, profit efficiency is referred to as the firm's ability to achieve the maximum potential profit, given input and output prices, and the level of fixed factors used. According to Debertin (1986), a profit-maximizing firm equates its value marginal product (VMP) to optimal input price, i.e.

$$p.MPP_{x_i}.e^{\mu} = \theta_i w_i \quad (3.1)$$

where, p is output price, MPP_{x_i} is the marginal physical product of the i th input, e^{μ} is output-oriented technical inefficiency, θ_i is the allocative inefficiency parameter, and w_i is an input price vector. The output-oriented technical inefficiency gives the amount by which the first-order condition of the profit maximization problem eliminates part of output technical inefficiency if equation (3.1) fails to hold (Kumbhakar, 2001). Following Kumbhakar (1987) and assuming a homogeneous technology across firms, the firm's problem is to maximize profit subject to the existing technology variable, and fixed inputs. Thus, the profit function is defined as follows:

$$\text{Maximize } (\pi) = pye^{\mu} - wx \text{ Subject to } h(y, x, z, \mu, \theta) = 0 \quad (3.2)$$

where π is profit, pe^{μ} is the output price associated with technical inefficiency, y is the output, x is the input, h represents current technology, z is a vector for fixed inputs, and μ is technical inefficiency. Applying Hoteling's lemma on equation (3.2) yields input (equation 3.3) and output supply (equation 3.4) functions, respectively (Lau & Yotopoulos, 1971; Schmidt & Lovell, 1979):

$$X^* = -X(pe^{\mu}, w, z, \theta) \quad (3.3)$$

$$Y^* = y(pe^{\mu}, w, z, \theta) \quad (3.4)$$

Substituting equations (3.3) and (3.4) into the objective profit function in equation (3.2) yields the actual profit function (π^a), which is the maximum profit that a firm can attain given output price (pe^{μ}), input price (w), availability of fixed factor (z), and technology $h(.)$ (Kumbhakar *et al.*, 2015):

$$\pi^a = pe^{\mu}.y(w,z) - wx(w,z) = \pi(w,z,pe^{\mu},\theta) \quad (3.5)$$

Based on equation (3.5), the profit frontier can be expressed as:

$$\pi(w,z,pe^{\mu},\theta) = \pi(w,z,pe^{\mu},\theta)|_{\mu=0} \quad (3.6)$$

The following equation can also be established from equation (3.5) due to monotonicity attribute of profit function, i.e., because $pe^{\mu} \leq p$ and $\pi(w,z,pe^{\mu},\theta) \leq \pi(w,z,p)$ (Kumbhakar *et al.*, 2015)

$$\pi^a = \pi(w,z,pe^{\mu},\theta) = \pi(,z,pe^{\mu}).h(w,z,pe^{\mu},\theta) \quad (3.7)$$

or,

$$ln\,\pi^a = ln\pi(w,z,pe^{\mu},\theta) + lnh(w,z,pe^{\mu},\theta) \quad (3.8)$$

Equation (3.8) shows that the natural logarithm of actual profit ($ln\,\pi^a$) can be decomposed into a profit frontier $\ln\pi(w,z,pe^{\mu},\theta)$ and profit technical inefficiency component $lnh(w,z,pe^{\mu},\theta) \leq 0$. (Kumbhakar *et al.*, 2015).

3.3.2 Specification of Empirical Model

The choice of appropriate functional form between translog and Cobb Douglas that best fits the data was done using the likelihood rati test. This involves the calculation of λ, the likelihood ratio using the following formula (Moreira, 2003):

$$\lambda = -2(l_R - l_U) \quad (3.9)$$

where l_R was the likelihood function of the Cobb Douglas model (reflecting the null hypothesis) while l_U was the likelihood function of a translog model or the alternative hypothesis. The test showed that the translog functional form was more suitable for the data (Chi-square value of 21.77 and p-value of 0.004). Therefore, the following translog model is specified as:

$$\ln(\pi_j{}') = \alpha_0 + \sum_{i=1}^{3} \alpha_i lnp_{ij} + 0.5 \sum_{i=1}^{3} \alpha_{ii} (lnp_{ij})^2 + \sum_{i=1}^{3} \sum_{k=2}^{3} \alpha_{ik} lnp_{ij} lnp_{jk} + (v_j - \mu_j) \tag{3.10}$$

where ln is the natural logarithm, π' is the normalized gross margin calculated for the $j\ th$ camel milk trader. It was calculated as total revenue minus variable costs. This subtraction gave 82 traders who made losses. Following Haung *et al.* (2017) the losses were treated as a censored sample where the logged gross margin in equation (3.10) was equated to an arbitrarily small value just greater than zero, which acted as the breakeven point or threshold. Therefore, the entire dataset consisted of 82 censored observations with a negative gross margin and 788 observations with a positive gross margin.

The main reason for censoring traders with negative gross margins was to avoid loss of data and information leading to the potential of distortion of the dependent variable. In equation 3.10, p_{ij} represents the price of inputs used by the j th trader (i= k=1, 2, 3) such that p_1 is the price of hired labor (including opportunity cost for family labor) normalized by selling price of milk (KShs/Litre), p_2 is the buying price of milk (KShs /Litre) normalized by the selling price of camel milk (KShs /Litre), and p_3 is the amount of capital used by the camel milk trades calculated as the present value of the total replacement cost of milk processing and milk handling, milk quality verification, and transportation equipment per month (Hanrahan *et al.*, 2018).

The cost of milk handling equipment, milk quality check equipment was estimated based on replacement cost at present value. $\alpha_0, \alpha_i, \alpha_{ii}$, and α_{ik} are the model parameters to be estimated. v_j is the statistical disturbance error term assumed as independent, identical, and distributed normally with an average of zero and a constant variance two-sided random error (Aigner *et al.*, 1977), and μ_j is inefficiency error term assumed to be identically and independently distributed such that μ_j is expressed by a positive truncation of the normal distribution. v_j and μ_j are also assumed to be independent to each other.

The milk traders in this study were small scale and therefore, they made consumption, production, and labor supply decision simultaneously. Accordingly, the estimation of allocative inefficiency was inappropriate (Barrett, 1997). According to Battesse & Coelli (1995), the μ_j in equation (3.10) can be expressed as:

$$\mu_j = \beta_0 + \sum_{d=1}^{n} \beta_d Q_{dj} + \vartheta \tag{3.11}$$

where β_0 is constant , β_d are the coefficients to be estimated, Q_{dj} are the factors hypothesized to contribute to inefficiency, ϑ is truncated random variable. Thus, the normalized gross margin in equation (3.10) was estimated in single-step incorporating technical inefficiency in equation (3.11). The log-likelihood function of equation (3.10) is given by:

$$\ln L = \sum_{j=1}^{N} \{- \frac{1}{2} \ln (2\pi) - \ln \sigma^2 - \ln\Phi\left(\frac{\mu}{\sigma^2\sqrt{\gamma}}\right) + \ln\Phi\left[\frac{(1-\gamma)\ \mu - f\gamma\epsilon_j}{\{\sigma^2\gamma\ (1-\gamma)\}^{\frac{1}{2}}}\right] - \frac{1}{2}\ (\frac{\epsilon_i + f\mu}{\sigma^2})^2\} \tag{3.12}$$

where L is the log-likelihood, σ^2 is the total variance of the model $({\sigma^2}_v + {\sigma^2}_\mu)$, where ${\sigma^2}_v$ denotes the random errors variance, ${\sigma^2}_\mu$ represents the profit inefficiency component, $\Phi(\ )$ is the cumulative distribution function of the standard normal distribution, f is the functional form, $\epsilon_j = (y_j - X_j\beta)$ whereby y_i is the gross margin for ith trader, X_j are the explanatory variables, β is the parameter to be estimated, and γ is gamma ($^{\sigma^2\mu}/_{\sigma^2}$), which is the ratio of firm-specific efficiency effects to the total output variance with a range of zero and one (Bidzakin *et al.*, 2014). A value of γ equal to zero indicates that the deviation from the frontier results from random statistical noise; in contrast, a value of γ close to one implies that the deviations from the frontier arise from inefficiency alone (Kumbhakar *et al.*, 2015). To estimate profit inefficiency (μ_j) for each observation, Jondrow *et al.* (1982) suggest the conditional mean of μ_j given ε_j is determined as the estimate of profit inefficiency for every observation.

$$E(\mu_j|\varepsilon_j) \tag{3.13}$$

where E denotes expectation operator (Kumbhakar *et al.*, 1989). Therefore, each camel milk trader is assigned a profit efficiency index based on the value estimated of μ_j (Hansen *et al.*, 2019)

$$PE_j = e^{-E(\mu_j|\varepsilon_j)} \tag{3.14}$$

where PE_j is the profit efficiency for the jth trader and lies between zero and one. It also has a negative association with the level of profit inefficiency. The description of explanatory variables in equation 3.10 and 3.11 and their hypothesized signs are presented in Table 3.1 below.

Table 3.1: Description of explanatory variables in equations 3.10 and 3.11 and their hypothesized signs

Variables	Description	Unit of measurement	Expected sign
Normalized gross margin model (Equation 3.10)			
p_1	Buying price of milk (KShs/L)	Continuous	-
p_2	Wage of hired labor and family labor in man-days (KShs/L)	Continuous	-
p_3	Value of fixed capital (KShs)	Continuous	+
Inefficiency model (Equation 3.11)			
Q_1	Age in years of trader	Continuous	+
Q_2	Number of years in the milk enterprise	Continuous	-
Q_3	Traders who attended training on milk handling and control	Dummy (1 = Yes, 0 = No)	-
Q_4	Distance to the nearest market (km)	Continuous	+
Q_5	Traders who added value to their milk	Dummy (1 = Yes, 0 = No)	-
Q_6	Sex of milk traders	Dummy (1 = Male, 0 = Female)	-

Note: All normalized variables were normalized by dividing by the selling price of milk.

3.4 Description of Variables used in Efficiency Analysis

Several socio-demographic variables have been hypothesized differently by many authors on how they influence traders' profit efficiency. The preference of the explanatory variables utilized in this study was based on the empirical literature, the researcher's knowledge of the contextual setting, theory, and data availability. The motivation for their addition and likely influence on profit efficiency estimation are outlined below:

3.4.1 Trader characteristics

The age of camel milk traders is a significant factor in milk enterprise management and is measured in years. It determines the ability to contribute to business activities.

More youthful traders, albeit with less experience, might be bound to be energetic and learn and adopt new technologies in the business (Nakanwagi & Hyuha, 2015). Hence, they may be more efficient than older traders who are more conservative to the traditional way; thus, they tend to be reluctant to embrace new technologies. According to Tijani *et al.* (2006), the dairy farmer's age decreases profit efficiency as a result of high production costs related to elderly farmers. The hired labor services were preferred, which resulted in the profit efficiency of farmers declining. Elderly farmers have a high propensity of applying modern technologies in preference for traditional methods, making them less efficient.

Ansah *et al.* (2014) hypothesized that farmers' age positively influences profit efficiency in Ghana. Nganga *et al.* (2010) found that dairy farmers who had more years in the milk business attained higher efficiency levels in Meru-South District in Kenya. Thus, supporting the classical economic hypothesis, which perceives that specialization is a key determinant of proficiency. Nganga *et al.* (2010) further observed that farmers who have spent several years in the dairy enterprise were more efficient since they had learned over time to minimize their production costs.

Sadiq *et al.* (2016) and Rahman (2003) found that traders in Nigeria and Kenya, respectively, were more profit efficient because they had more experience participating in the dairy farming enterprise. The trader gender variable is measured as a dummy, whereby it takes one if male and zeroes if a female was incorporated in the model to investigate the association between profit efficiency and gender. Also, Bocher & Simtowe (2017) hypothesized that male-headed households are more proficient in asset utilization than females. It was established by Akite *et al.* (2022) that there was a direct and significant association between profit efficiency and the male gender farmers in Uganda.

3.4.2 Institutional factors

Participation in training on milk handling and control programs is measured as a dummy variable, whereby it takes one if a trader participated in the training and zeroes if traders did not participate in the training. It was incorporated into the model to investigate the association between profit efficiency and participation in training on milk handling and control. It is a channel for the dispersion of innovations to the trader and is required to lessen management inefficiency. Sadiq *et al*. (2016) hypothesized that access to training services has a positive relationship with profit efficiency, and therefore it was incorporated into the study.

Dairy farmers were technically efficient due to participating in the training program (training on improved dairy husbandry practices and financial management skills), which improved their income levels. Training programs provided farmers with new knowledge about input utilization, risk aversion, storage, preservation methods, final output marketing, technology adoption, and saving aspects (Ahmed & Geta, 2013). The high proportion of farmers in training implied that they would have comprehensive marketing information and ideas about improved production techniques, making them more productive and efficient (Tsue *et al.,* 2012). Therefore, participation in training programs is hypothesized to have a positive relationship with profit efficiency.

3.4.3 Marketing factors

The distance covered by traders to the market is measured in kilometers. It was used as a proxy for transaction costs. Mwalongo (2018) noted that dairy farmers closer to the market were profiting more than those far from the market. Besides, long-distance increases transportation costs since it added to the total charge of the dairy farmers in accessing and distributing inputs to the points of sale.

Long-distance reduces access to marketing and production technology, especially for those who reside in remote areas. Thus, they become less profit-efficient (Bocher &Simtowe, 2017). The distance to the market might affect traders' access to information and modern innovation, thus influencing their efficiency level. It is hypothesized to have a positive relationship with profit efficiency. Value addition is measured as a dummy, which equals 1 for those traders that added value to their milk and zero otherwise. Through value addition, traders can increase their profit margins; thus, it was hypothesized to influence profit efficiency positively.

3.4.4 Costs of Production

As per Khan *et al.* (2021), the profit efficiency of farmers was improved by the association between higher output prices and extension services. Lower producers' costs and higher prices of the producers in the informal channel cause families to trade informally, thus reducing the amount of milk available to processing plants. Profit efficiency among dairy farmers was reduced through the application of hired labor than those who favored household labor since the gross margin levels were still higher. Farmers who depended entirely on household labor did not incur any labor costs; therefore, their unit gross margins remained high and were more profitable (Tsue *et al.,* 2012).

Dairy farmers are price takers. With price volatility resulting from seasonality and geography, milk production can be more profitable if they produced with reduced costs of inputs and assured milk demand (Kurwijila *et al.,* 1995). Furthermore, the vital criteria for improving milk production were to reduce input costs such as labor, feed, and transportation costs to allow effective use of available resources rather than optimize animal production. Capital was the single most expensive item that dairy farmers had to invest in; hence, an increase in capital investment would improve milk profits since dairy farmers would take more caution in using resources (Iruria *et al.,* 2009).

3.5 Data Collection

The study utilized cross-section data extracted from a survey conducted by the International Livestock Research Institute (ILRI) in Wajir, Turkana, Isiolo, Garissa, and Marsabit counties in northern Kenya to examine the microbial quality and safety of camel milk and associated products along the value chain of camel milk (Figure 3.1). Northern Kenya is semi-arid and prone to rainfall variability and more frequent droughts (Watson *et al.*, 2016). Accordingly, over 80% of households rely on nomadic pastoralism for their livelihoods (FAO, 2014). The predominant livestock species in Northern Kenya are; cattle, sheep, goats, and camels (Omwenga *et al.,* 2019*)*.

The region is characterized by high poverty and malnourishment rate, poor social (such as schools, and hospitals), and economic (such as markets, and banks) in part due to historical neglect and marginalization by public policy (Odongo *et al.*, 2017). The five counties had a total population of approximately 3,227,379 in 2019 (KNBS, 2019). A sampling transect technique was employed to collect the primary data from camel milk traders who sold camel milk and its products in market centers during the study. The study took the main road network passing through the main markets across the camel-keeping areas in each study County.

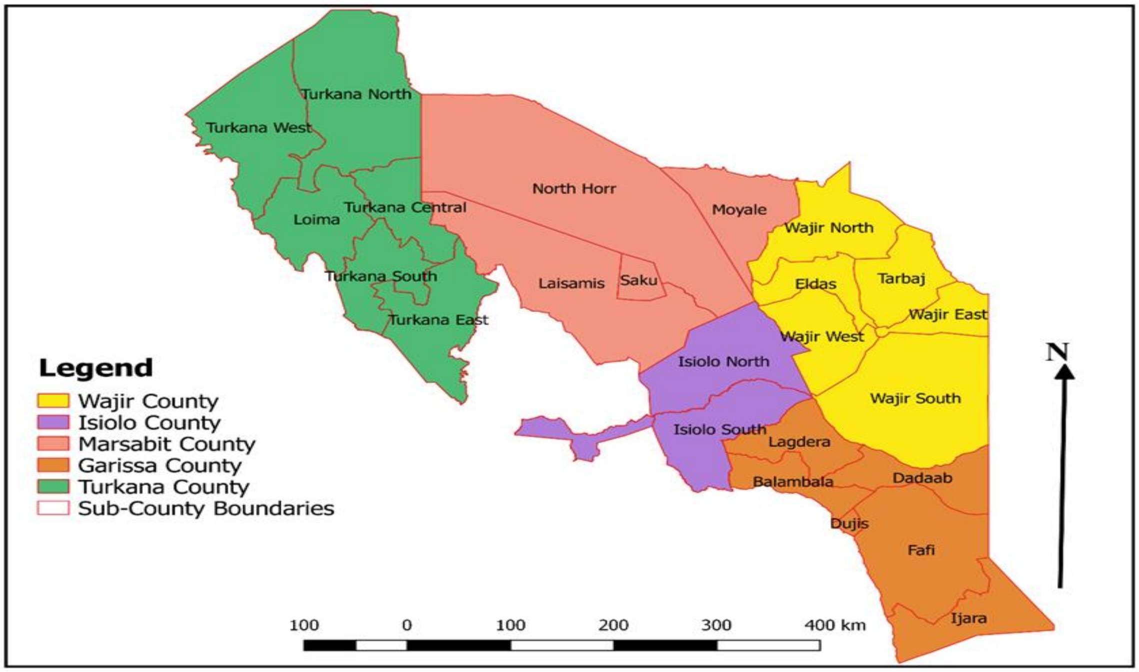


Figure 3.1: Location of study area

Source: ILRI (Geographical Information System Unit)

The main markets were Kangatosa, Lodwar, Kerio, Lokichar, and Kakuma markets (in Turkana County), Oldonyiro, Merti, Eskut, Isiolo markets (in Isiolo County), Bute, Habaswain, and Wajir market (in Wajir County), Merille, Ilaut, Jirime, and Moyale (in Marbsabit County), Masalani, Balambala, Modogashe, and Garissa market (in Garissa County). Due to the lack of a proper sampling frame, a snowball sampling approach was used to identify camel milk traders in these markets. A total of 933 traders distributed as 12 (Kangatosa), 20 (Lodwar), 20 (Kerio), 53 (Lokichar), 52 (Kakuma), 40 (Oldonyiro), 35 (Merti), 60 (Eskut), 60 (Isiolo town), 70 (Bute), 60 (Habaswain), 60 (Wajir town), 50 (Merille), 20 (Ilaut), 60 (Jirime), 66 (Moyale), 50 (Masalani), 47 (Balambala), 48 (Modogashe), and 50 (Garissa town).

The number of traders by County was: 157 (Turkana), 190 (Wajir), 195 (Garissa), 195 (Isiolo), and 196 (Marsabit). The traders were interviewed by trained enumerators using semi-structured questionnaires that captured trades' demographic information, the quantity of milk procured and sold, the buying and selling price of milk, amount of labor employed by the traders, cost of capital equipment (quality check, transportation, and handling equipment) and intermediate cost (e.g., of electricity, water and rent). The collected data was then entered into a census and survey processing software for cleaning. 63 milk traders had incomplete responses on data cleaning and were removed from the analysis. Thus, the study retained a sample of 870 milk traders. STATA version 16 was used for estimation.

3.6 Test for Stochastic Profit Frontier Model Specification

Various null hypothesis tests were conducted to assess the suitability and significance of the employed stochastic profit frontier model by adopting the generalized likelihood ratio statistic. The critical values for this kind of test were attained from the Table of Kodde and Palm (1986). The first hypothesis aims to test functional form choice where the null hypothesis was that Cobb Douglas functional form was a better representative of the profit frontier function ($H_o : \beta_{ij} = 0$). The likelihood ratio test rejected the null hypothesis (Chi-square = 21.77, $p < 0.05$, df = 6) suggesting that the translog functional form better fitted the data as opposed to Cobb Douglas functional form. The second hypothesis was that profit inefficiency was not present among the milk traders ($H_o : \gamma = 0$). The likelihood ratio test rejected the null hypothesis (Chi-square = 39.22, $p < 0.05$, df = 6) suggesting that the stochastic profit function was appropriate for the data. It also implied that there was some profit inefficiency in the camel milk business in northern Kenya. The third hypothesis is that the coefficients in square and cross-terms were not statistically different from zero $(H_O : \alpha_{ij} = 0)$. The likelihood ratio test rejected the null hypothesis (Chi-square = 152.85, $p < 0.05$, df = 9) implying that the coefficients in square and cross-terms are statistically different from zero. The fourth hypothesis was that the explanatory variables identified in the inefficiency model were simultaneously equal to zero ($H_o : \delta_1 = \delta_2 = \delta_3 = \cdots = \delta_n = 0$). The likelihood ratio test rejected the null hypothesis (Chi-square = 25.79, $p < 0.05$, df = 7) indicating that variables related to the inefficiency effect model were jointly different from zero. Finally, the last hypothesis being tested was that the half-normal distribution of the inefficiency terms was a better representation of the data, given the general truncated normal distribution ($H_o : \delta_0 = \delta_1 = \delta_2 = \delta_3 = \cdots = \delta_n = 0$). The likelihood ratio test rejected the null hypothesis (Chi-square = 25.79, $p < 0.05$, df = 7) indicating that the truncated normal distribution that was assumed by the data was appropriate for the distribution of the inefficiency term.

3.7 Results and Discussion

3.7.1 Traders' Socio-demographic Characteristics

Table 3.2, presents the summary statistics of camel milk traders' socio-demographic characteristics. 82% of all milk traders were female, with Wajir County having the highest percentage. This suggests that women dominated camel milk marketing across the five counties, contrary to expectations. Traditionally, pastoral women do not have any formal control over the decision on herding and livestock disposal, thereby playing a subordinate role in livestock marketing (Badejo *et al.*, 2017). However, recent development activities largely by non-governmental organizations have empowered most pastoralist women to participate in livestock marketing (Odongo *et al.*, 2017). The women milk traders in the study sample were organized into self-help groups such as the Anolei camel milk cooperative, Tawakal (in Isiolo County), and Deffee (in Wajir County).

These trader groups offered their members marketing information, cooling facilities, training, and bargaining power over their milk price. All the milk traders were relatively young, with an average age of 38 years; 59% of the traders were less than the overall mean age of 38 years. The traders' age was not statistically different across the five counties (ANOVA F-value = 3.14; p-value = 0.392). Their experience in milk trading was low but statistically different across the counties (ANOVA F-value =17.25; p-value = 0.000). Turkey's post hoc test was used to separate the means across the five counties.

Traders from Wajir County had the most experience, while those from Turkana County had the least. This could be attributed to the differences in market access between the two counties. The average distance covered by traders to the market from their homes was around 34km and was statistically different across the five counties (ANOVA F-value= 67.14; p-value = 0.000), with traders from Garissa County covering the longest distance. Distance to the market has implications on profit efficiency because it tends to increase input prices due to transactions (Mphafi *et al.,* 2019). Counties in Northern Kenya generally have widely dispersed markets due to low population density (Watson *et al.,* 2016).

Table 3.2: Means of camel milk trader's socio-demographic characteristic in Northern Kenya

Variables	Garissa	Marsabit	Isiolo	Turkana	Wajir	Pooled	P-value
Gender Male (%)	13	24	15	33	7	18	0.000
Gender Female (%)	87	76	85	67	93	82	0.000
Age (Years)	39	40	38	39	38	39	0.392
Experience (Years)	6	7	8	5	9	7	0.000

3.7.2 Camel Milk Marketing

On average, each trader bought and sold 42 and 25 liters of milk daily (Table 3.3). The average postharvest loss of milk per day was relatively high at 21L (or 50% of milk purchases) per day. The traders from Garissa County recorded the highest postharvest loss, while those from Turkana County recorded the least. The variation in the postharvest loss was perhaps due to variation in management practices adopted in each county. For example, Ogolla *et al.* (2017) observed that setting up colling facilities and use of aluminum cans for milk transportation led to the disparity of postharvest loss among milk traders in Isiolo County.

The initial average capital invested by each trader was KShs 1,395, which is rather small. The low capital requirement is important for pastoral women traders because they usually lack access to capital due to a general lack of suitable sources (banks are non-existent in marginal areas) and collateral as well as institutional inhibition (Mulema *et al.*, 2017; Roba *et al.*, 2019). Traders sourced capital from selling livestock (mainly sheep and goats) and gifts and loans from friends and kin. Pastoral women generally have no access to large ruminants. However, most own small ruminants (sheep, goats, and shoats) which they sell either individually or as a group (Alemayehu *et al.*, 2015). The cost of labor was as highest in Marsabit County and was statistically different across the five counties (ANOVA F-value = 37.55; p-value = 0.000). Overall the mean gross margin earned by each milk trader was KShs 180,559 per month and was statistically different across the five counties (F-value =82.67; p-value=0.001).

Table 3.3: Means of variables in camel milk marketing in the five counties in Northern Kenya

Variables	Garissa	Marasabit	Isiolo	Turkana	Wajir	Pooled	P-value
Amount of milk purchased (L/Day)	24	28	27	19	22	42	0.000
Amount of milk sold (L/Day)	22	20	21	14	19	25	0.000
Postharvest losses (L/Day)	2	8	6	5	3	17	0.000
Gross margin (KShs)	63,496	265,211	428,798	31,141	40,622	180,559	0.001
Cost of labor	274	280	254	179	267	255	0.000
Capital	1,602	820	1,823	539	2,036	1,395	0.000
Selling price (KShs/L)	94	77	80	82	62	64	0.000
Buying price (KShs/L)	76	51	41	70	55	57	0.000
Number of suppliers	6	3	4	2	8	4	0.000
Training No (%)	78	74	66	82	71	74	0.004
Training Yes (%)	22	26	34	17	28	26	0.004
Add value No %	67	82	46	86	79	75	0.000
Add value Yes %	33	18	54	14	21	25	0.000

Traders from Isiolo County had the highest gross margin, while those of Turkana had the least. The disparity in the gross margin seems to correlate with the level of market development. Studies show that Isiolo milk market is more developed than those of other counties followed by Marsabit, Garissa, Wajir, and Turkana in that order (Oselu *et al.,* 2022). Nevertheless, long distance to markets that indicates remoteness and the attendant problem of insecurity could also explain the disparity in the gross margin among the five counties. Despite the traders having previously received training on safety and quality, most (74%) had not received any training on milk quality and control, with Turkana County reporting the highest proportion (38%), followed by Garissa and Marsabit counties.

Turkana County had the highest percentage of untrained milk traders, perhaps due to a lack of trainers and training programs related to milk handling and hygiene. An examination of Turkana County Integrated Development Plan (2018-2022) reveals that inadequate infrastructure and poor road networks have affected access to training programs. Contrary to expectation, most (75%) milk traders did not add value to their milk. The level of value addition in milk in marginal areas is lagging due to a weak institutional framework, poor capacity in value addition, and poor road and market infrastructure (Roba *et al.*, 2019).

Among the 25% who added value to their milk, 10% sold fermented milk in Turkana County, followed by Garissa County at 9% (Figure 3.2). On the other hand, own-processed yogurt was mostly sold in Marsabit and Isiolo Counties (10%), while milkshake was largely sold in Wajir County (11%). The low percentage of those who added value to their milk implies that they attain more profit from consumers that are willing more for different products (De Graaf *et al.,* 2016).

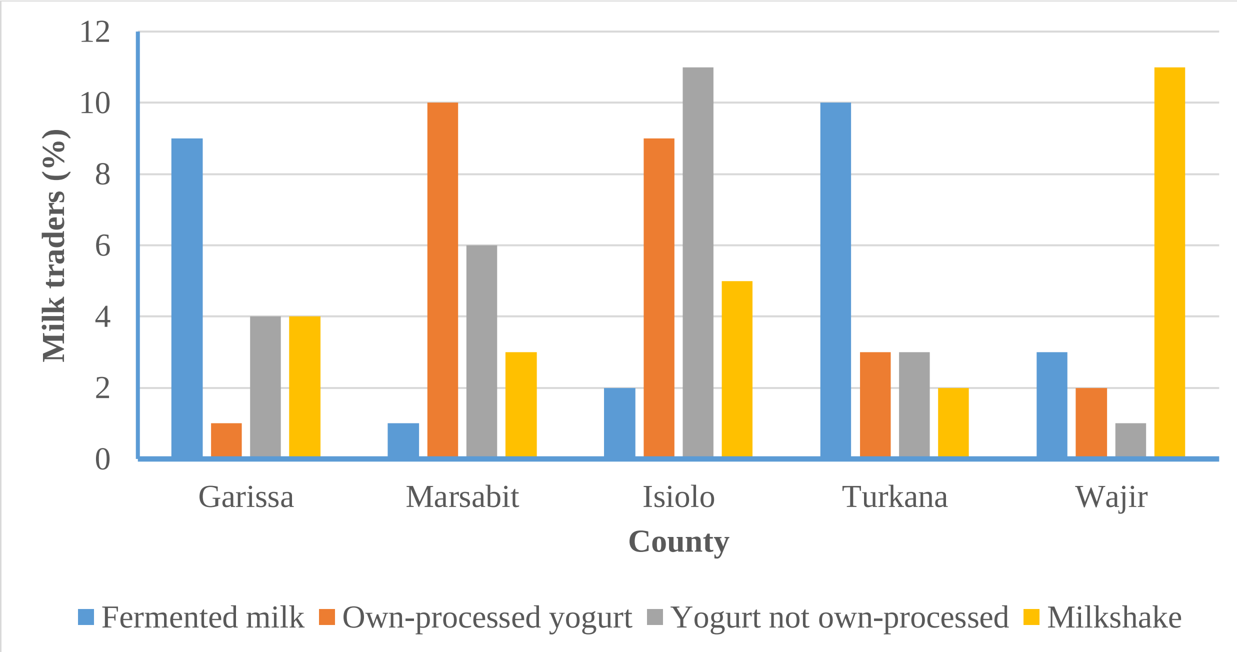


Figure 3. 2: Value added products sold by milk traders in five counties of Northern Kenya

3.7.3 Maximum Likelihood Estimates of Stochastic Profit Frontier

Table 3.4 below presents the maximum likelihood estimates of the stochastic frontier translog primal system. The positive sign of sigma-u and sigma-v provide evidence of the appropriateness of model fit, specification, and distribution assumptions. Lambda (λ) from the pooled data was statistically significant (p-values<0.05). It shows that the discrepancy in actual profit comes from the difference in milk traders' practices as opposed to random variability. In addition, the negative sign on input price variables is consistent with theoretical expectations. The coefficient of the price of labor in Turkana County was not statistically significant. The reason could be that it contributed less to profit because most traders from this region depended mainly on unpaid family labor, which made labor wage not a constraint in the operation of the milk business.

Table 3.4: Maximum likelihood estimates of the stochastic translog profit frontier

Variables	Garissa	Marsabit	Isiolo	Turkana	Wajir	Pooled
Translog profit function						
Constant	11.33 (0.47)**	9.67 (0.49)**	10.76 (0.50)**	11.07 (0.76)**	9.72 (0.59)**	11.43 (0.20)**
lnlabor	-0.66 (0.22)**	-0.54 (0.17)**	-0.52 (0.04)**	-0.58 (0.43)	-0.02 (0.01)**	-0.74 (0.07)**
lnbuyingprice	-0.12 (0.17)**	-0.15 (0.35)**	-0.11 (0.12)**	-0.10 (0.18)**	-0.09 (0.05)*	-0.06 (0.09)*
lncapital	0.06 (0.07)**	0.16 (0.08)	0.13 (0.33)**	0.44 (0.39)*	0.28 (0.17)	0.10 (0.04)**
lnlabor2	0.07 (0.01)***	-0.70 (0.56)**	0.30 (0.24)*	0.05 (0.01)	-0.11 (0.09)	-0.03 (0.29)
lnbuyingprice2	-0.47(0.53)	-0.84 (0.62)	0.10 (0.15)	0.06 (0.01)	-0.38 (0.24)	0.04 (0.03)
lncapital2	0.06 (0.02)**	0.01 (0.09)***	-0.02 (0.11)	0.01 (0.02)	-0.02 (0.01)	-0.05 (0.03)*
lnlaborxlnbuyingprice	0.41 (0.26)	0.45 (0.39)**	-0.19 (0.29)	-0.01 (0.01)	0.32 (0.22)	-0.03 (0.04)
lnlaborxlncapital	0.07 (0.10)	0.04 (0.09)	0.09 (0.03)***	0.12 (0.09)**	0.07 (0.01)	0.08 (0.29)**
lnbuyingpricexlncapital	-0.07 (0.07)	-0.03 (0.12)	0.21 (0.17)	-0.01 (0.06)***	-0.18 (0.12)*	0.07 (0.02)
Inefficiency model						
Age (Years)	-0.11 (0.10)	-0.08 (0.02)***	0.08 (0.06)	-0.09 (0.01)*	-0.45 (0.29)	0.02 (0.01)
Experience (Years)	-1.13 (0.22)*	0.22 (0.66)	-0.02 (0.01)**	0.02 (0.01)	-0.12 (0.24)**	-0.10 (0.04)**
Gender (2=Female)	0.23 (0.18)	0.04 (0.01)	-0.17 (0.11)***	-0.16 (0.24)	-0.26 (0.13)**	-2.19 (0.85)**
Training (Yes=1)	-2.29 (0.50)**	-0.38 (0.13)**	-1.24 (0.17)**	-0.57 (0.24)**	0.25 (0.19)	-1.37 (0.27)**
Distance (km)	-0.10 (0.07)	0.11 (0.06)**	-0.01 (0.01)	0.04 (0.01)**	0.13 (0.28)*	0.14 (0.04)**
Value addition (Yes=1)	-1.28 (0.09)**	0.03 (0.01)	-0.42 (0.23)	-0.57 (0.34)**	1.23 (0.45)	-1.25 (0.69)*
Constant	-3.51 (0.49)	-2.63 (0.34)	1.83 (0.57)**	4.94 (0.52)**	2.97 (0.73)	1.34 (0.59)**
Variance parameters						
usigma_cons	0.51 (0.88)	-0.53 (0.42)**	-0.53 (0.38)	0.63 (0.11)**	-1.82 (0.67)*	2.34 (0.34)**
vsigma_cons	-0.31 (0.13)**	-0.07 (0.12)	-0.10 (0.47)**	-0.25 (0.14)	-0.34 (0.13)**	-0.29 (0.10)**
Sigma-u	1.29 (0.57)**	0.63 (0.35)**	0.76 (0.15)**	1.37 (0.08)**	1.40 (0.21)*	2.91 (0.48)**
Sigma-v	0.86 (0.06)**	0.96 (0.06)**	0.60 (0.14)	0.79 (0.52)**	0.84 (0.05)**	0.87 (0.04)**
Lambda	1.50 (0.61)**	0.64 (0.29)**	1.27 (0.27)**	1.09 (0.67)**	0.47 (0.24)*	3.36 (0.38)**
Wald's chi2(9)	85.26**	46.08**	58.61**	28.06**	34.88**	158.90**
Pro>chi2	0.0000	0.0004	0.0000	0.0009	0.0001	0.0000
Log-likelihood	-281.53	-268.84	-262.45	-269.23	-246.37	-1580.44

Note: ***, ** and * denote 1%, 5%, and 10% levels of significance, respectively. The standard errors (SE) are the figures in parentheses.

The coefficient of cost of capital in Marsabit and Wajir counties was insignificant. The possible reason could be that they rely on debt capital to finance their business. Thus it had a very smaller contribution to the profit of the enterprise. The squared term of the buying price of milk across the five counties had an indeterminate influence on the trader's profit. The implication implies that the additional rate of the buying price of milk failed to improve the profit level due to the restriction of the lower purchasing power of the consumers in these regions. From Table 3.4, most of the interactive terms (complimentary effects) were statistically insignificant.

This suggests that when they are jointly used, they have lesser contribution due to technology constraints in Northern Kenya. The elasticity of profit with respect to input price was calculated as the percentage change of profit divided by the percentage change in the input price. *Ceteris paribus*, a 1% rise in the price of labor would lower the gross margin by 22% (Table 3.5), suggesting that an increase in labor cost, especially the use of hired labor, tends to reduce the gross margin of traders. This result corroborates the findings of Acharya *et al.* (2021), who reported an inverse relationship between the wage rate and profit efficiency of peri-urban milk producers in Odish, India.

Table 3.5: Estimated profit elasticities from the stochastic translog profit frontier

Variable	**Coefficient**	**Standard Error**
Price of labor	-0.22	0.01**
The buying price	-0.12	0.07**
Capital	0.10	0.10**

Note: ***, ** and * denotes 1%, 5%, and 10% levels of significance, respectively.

Accordingly, the own price elasticity of milk was negative, as expected from theory, indicating the fulfillment of the non-increasing input price property of the profit function. Thus suggesting that a 1% increase in the buying price of milk would lower the gross margin by 2%, holding other factors constant. On the other hand, a 1% increase in the cost of capital would increase traders' gross margins by 10% *ceteris paribus*, implying that the optimal utilization of capital per the need of the business would increase the gross margin. The findings support Bahta & Baker (2015) and Haloho *et al.* (2013), who established a positive association between dairy cattle farmers' profit and capital inputs in Botswana and Indonesia, respectively. The price elasticity of milk was not statistically significant, perhaps due to the low purchasing power of the consumers.

3.7.4: Profit Efficiency Scores for Camel Milk Traders in Northern Kenya

The average profit efficiency for the five counties was rather low at 43% (Table 3.6), implying that 57% of profit could have been lost to significant inefficiencies along the milk value chain, including poor market development, poor infrastructure, insecurity, and low purchasing power. As expected, the average profit efficiency scores varied by County, with Isiolo County being the most profit-efficient. This means that traders from Isiolo County used efficient techniques in managing their businesses. This could be because the camel milk market is better developed in the County, with traders accessing Nanyuki and Nairobi markets that pay better prices than other counties.

As indicated earlier, camel milk traders in Isiolo County are organized into self-help marketing cooperatives such as Anolei and Tawalal marketing groups. Besides, Isiolo County has a booming camel milk enterprise in its own right and a network of value-adding milk processors (Muloi *et al.*, 2018). Traders in Wajir County had the second highest score of 71%, implying that traders from this County have adopted better management practices, such as the wide use of automated teller machines that have improved their efficiency. This could be possible due to the Deffee marketing group offering milk handling training to traders.

Table 3.6: Summary statistics of profit efficiency scores of camel milk traders in Northern Kenya

County	n	Mean	Std. Error	Minimum	Maximum
Isiolo	186	78%	0.014	3%	99%
Wajir	182	71%	0.010	1%	90%
Marsabit	184	65%	0.020	2%	97%
Garissa	178	58%	0.012	1%	93%
Turkana	140	38%	0.012	4%	89%
Pooled	870	43%	0.001	1%	99%

Marsabit County had the third largest score of 68%. This could be attributed to the frequent exchange visit between dairy cooperatives between Marsabit and Isiolo, where traders were being trained on value addition on milk and milk handling hygiene practices. Turkana County had the least profit efficiency score of only 38%. The possible reason would be due to the fragile security of the County that scares away investors, poor market development, information asymmetry on milk prices, and poor infrastructure with impassable roads, especially during rainy seasons.

3.7.5 Factors Influencing Profit Efficiency of Camel Milk Traders in Northern Kenya

The pooled results of the inefficiency model in Table 3.4 reveals that year of milk selling experience, having participated in previous training on milk handling and quality control, being female, and adding value to milk products significantly reduced traders' profit inefficiency. Past research shows that more experienced traders can adopt the best milk management practices through a continuous learning process, which enables them to efficiently utilize their inputs (Masuku *et al.*, 2014; Kumari *et al.,* 2020; Acharya *et al.* 2021).

Similarly, participation in training programs enhances traders' management skills because they can acquire knowledge of new practices, thus, giving them a clear understanding of efficiency practices to improve their profits. For example, Muloi *et al.* (2018) and Masuku *et al.* (2014) found that traders who participate in training, such as milk quality and hygiene handling of milk at the farm in Kenya and Eswatini, respectively. Being a female trader reduced profit inefficiency. This could be attributed to the fact that in Nothern Kenya, they were the pioneers of the camel milk trade; thus, there has more selling experience than their counterparts.

They also have more understanding of the better milk management practices that reduce inefficiency that they had learned from their long experience in milk marketing. Adding value to milk reduces postharvest losses through increased shelf-life. In addition, value-added products are often sold at a higher price than fresh milk, contributing to higher profit efficiency. Yegon *et al.* (2016) found that investment in value addition improved the profit margin of dairy farmers in Kericho and Bomet counties in Kenya.

Likewise, Sardaro *et al.* (2017) observed that developing differentiated dairy products increased the farmers' profits in Southern Italy. On the other hand, distance to market was negatively associated with profit efficiency due to increased time and transportation costs, which undermined milk quality and traders' gross margin. Mwalongo (2018) and Hansen *et al.* (2021) found that long-distance to the market is inversely related to profit efficiency in Njombe in Tanzania and Norway, respectively.

3.8 Conclusions and Recommendations

The study sought to assess the profit efficiency of camel milk traders and the factors influencing it in Northern Kenya. The study found that women dominate camel milk marketing in Northern Kenya at a ratio of 4.6:1, contrary to expectations in predominant pastoralist communities. In addition, traders; profit efficiency was rather low at only 43% on average. This suggests that 57% of profit could have been lost to significant inefficiencies along the milk value chain, including poor market development, weak infrastructure, insecurity, and low purchasing power. Nevertheless, Isiolo and Wajir counties emerged the best with profit efficiency scores of 78% and 71%, respectively.

Distance to market was negatively associated with profit efficiency, suggesting that long-distance delayed milk collection and trader's access to training offered in towns. Accordingly, providing traders training, for example, through extension services by public health officers, could enhance traders' milk managerial skills to improve their efficiency levels. On the other hand, reducing the distance to the market by creating market linkage and road infrastructure development could go a long way to reducing postharvest losses, thus improving the profits efficiency of camel milk traders in Northern Kenya for enhanced sustenance and welfare. Further research should focus on camel milk value chain actors and their governance. This would provide information on how equitable the value chain is as well as how much power each actor possesses in influencing decisions such as the setting of buying and selling price of camel milk for policy redress.

CHAPTER FOUR: A META-FRONTIER ANALYSIS OF PROFIT EFFICIENCY OF CAMEL MILK TRADERS IN NORTHERN KENYA

Abstract

Inter-regional disparities in resource endowment define the upper limit of production possibilities as well as the level of market development in each region, which supports Krugman's (1991) hypothesis of new economic geography. Understanding how geography influences the profit efficiency of business enterprises is key in designing appropriate interventions that are geared towards reducing regional economic imbalance to promote equity and social inclusiveness. This study employed a two-step stochastic translog profit meta-frontier to compare the profit efficiency of 870 camel milk traders in five counties in Northern Kenya. To provide evidence on the role of geography in the distribution of the profit efficiency of business enterprises. In addition, the study estimated the profit efficiency gap ratios to assess the difference between the meta-profit efficiency and the county-specific profit efficiency. The study found that none of the five counties lay on the profit meta-frontier with estimated profit efficiency gap ratios of 0.87, 0.84, 0.74, 0.73, and 0.66 for Isiolo, Marsabit, Wajir, Garissa, and Turkana, respectively. This suggests that geography matters in the distribution of profit efficiency of camel milk enterprises in Northern Kenya. It also reveals none of the milk traders in all five counties was profit efficient. In addition, traders in each of the five counties employed different technologies in their milk business, perhaps dictated by geographical access and availability. The consideration of geographical differences among the five counties when designing interventions aimed at increasing camel milk traders' profit efficiency; one size does not fit all. Therefore, the study recommends the development of a platform for sharing information on relevant managerial skills in milk enterprises between counties, for example, inter-county exchange visits could reduce the profit efficiency gap among camel milk

traders in the five counties.

4.1 Introduction

Kenya is the world's largest producer of camel milk with a production of 1.2 million tons annually (FAO, 2022). The population of camels in Kenya is estimated at 4.7 million (FAO, 2019), with about 80% of camels located in the North-Eastern region of Kenya (Kenya National Bureau Statistics [KNBS], 2019). Like in other arid countries, camels in Kenya play a multi-purpose role in terms of milk, meat, hides, and dung production as well as in income generation, racing, tourism, transportation, and in social and cultural functions (Dokata *et al.,* 2014).

In Kenya, camel milk contributes up to 50% of pastoralists' total nutrient intake thereby playing a vital role in ensuring household food security in a harsh and arid environment that is devoid of alternative livelihood options (Wayua *et al.,* 2012). Camel milk is also sold in major market centers that litter the landscape (Machan *et al.,* 2022). In Kenya, the camel milk trade has significantly evolved from a small-scale business being carried out in local villages to its current status comprising various market actors that supply milk to urban towns including Kenya's capital city of Nairobi (Muloi *et al.,* 2018). Even then, most of the demand for camel milk in urban areas is largely driven by the Somali community with a few other urban consumers taking up camel milk due to its alleged nutritional and medicinal value (Mahamed *et al.,* 2015).

The increase in demand for camel milk in urban centers has forced milk traders to find a way to familiarize themselves with the camel milk supply chain, which has changed the pattern of milk production and supply (Alonso *et al.,* 2018). For example, the production of value-added products such as yogurt, cheese, butter, and milkshake (Ogolla *et al.,* 2017). According to Isako & Kimindu (2019), the increase in population growth and rural-urban migration has increased the demand for camel milk in both rural market centers and towns.

Muloi *et al.* (2018) noted the main milk traders are camel keepers, female traders, and processing companies such as Vital Camel Milk Limited in Nanyuki and Nuug Camel Milk Products Limited in Nairobi which exports 5% of their product to regional and international markets. These traders face a myriad of challenges including inadequate milk suppliers, impassible roads during rainy seasons, high postharvest losses, lack of knowledge of hygiene and quality check, inadequate supply of cooling facilities, and long distance to market (Mwangi *et al.,* 2016). Camel milk marketing and production constraints include a lack of clean water for washing containers, the widespread use of cycled oil plastic jerry cans with limiting openings, and long-distance transport with high temperatures (Noor *et al.,* 2013).

Understanding how geography influences the profit efficiency of business enterprises is key in designing appropriate interventions that are geared towards reducing regional economic imbalance to promote equity and social inclusiveness. The geographical location of a business matters in terms of the adoption of new technologies aimed at reducing the inefficiency of the enterprises (Degl'Innocenti *et al*., 2017). Although several studies have been undertaken on camel milk marketing, there is virtually no study on the comparison of profit efficiency of camel milk traders across counties in northern Kenya, perhaps economics research on the camel is still in its infancy. Yet understanding the differences in profit efficiency gap across the counties is imperative for developing interventions aimed at improving the camel milk industry in Northern Kenya. It would also encourage traders to adopt modern technologies that would improve their profit efficiency.

The study adopted a two-step stochastic meta-frontier profit approach to systematically examine the differences in profit efficiency in five counties in Northern Kenya. This approach has been used by researchers to compare efficiencies for firms operating under different technologies because it allows the profit efficiency gap to be distinguished from profit inefficiency and it assumes firms operate under a common frontier (e.g., see Tasila Konja *et al.* (2019 for review).

The rest of the paper is structured as follows: Section 4.2 presents the methods used in the study comprising an overview of the stochastic meta-frontier approach, empirical model, and data sources while section 4.3 presents the results and discussion. The conclusions and recommendations of the study are presented in section 4.4.

4.2 Methods and data

4.2.1 Theoretical framework

This study is anchored on the neoclassical theory of the firm which holds that under perfect market conditions, the overall objective of a firm is to maximize profit by maximizing the gap between revenue and cost (Ali *et al.*, 1994). Ultimately, the firm's problem is to maximize make the difference between its total revenue and total cost through the use or pursuit of efficient strategies, such as selecting the best input-output combinations that either minimize costs or maximize revenue (Colman & Young, 1989).

The term efficiency involves a reduction in the quantity of inputs required to produce a given level of output or producing more output using the same level of inputs (Kumbhakar *et al.*, 2020). Based on the theory of the firm ‘‘profit efficiency’’ refers to the capability of a firm to attain the maximum possible profit given the level of fixed factors and prices faced by the firm (Cherchye *et al.*, 2016).

According to Debertin (1986), a profit-maximizing firm equates its value marginal product (VMP) to optimal input prices, i.e.

$$p.MPP_{x_i}.e^{\mu} = \theta_i w_i \quad (4.1)$$

where, p is output price, MPP_{x_i} is the marginal physical product of the i^{th} input, e^{μ} is output-oriented technical inefficiency, θ_i is the allocative inefficiency parameter, and w_i is an input price vector. The output-oriented technical inefficiency gives the amount by which the first-order condition of the profit maximization problem eliminates part of output technical inefficiency if equation (4.1) fails to hold (Kumbhakar, 2001). Following Kumbhakar (1987) and assuming a homogeneous technology across firms, the firm's problem is to maximize profit subject to the existing technology variable, and fixed inputs. Thus, the profit function is defined as follows:

$$\text{Maximize } (\pi) = pye^{\mu} - wx \text{ Subject to } h(y, x, z, \mu, \theta) = 0 \quad (4.2)$$

where π is profit, pe^{μ} is the output price associated with technical inefficiency, y is the output, w is a vector for prices for the input prices, x is the input, h represents current technology, z is a vector for fixed inputs, and μ is technical inefficiency. Applying Hoteling's lemma on equation (4.2) yields input demand (equation 4.3) and output supply (equation 4.4) functions, respectively (Lau & Yotopoulos, 1971; Schmidt & Lovell, 1979):

$$X^* = -\mathrm{X}(pe^{\mu}, w, z, \theta) \quad (4.3)$$

$$Y^* = \mathrm{y}(pe^{\mu}, w, z, \theta) \quad (4.4)$$

Substituting equations (4.3) and (4.4) into the objective profit function in equation (4.2) yields the actual profit function (π^a), which is the maximum profit that a firm can attain given output price (pe^{μ}), input price (w), availability of fixed factor (z), and technology $h(.)$ (Kumbhakar *et al.*, 2015).

$$\pi^a = pe^{\mu}.y(w,z) - wx(w,z) = \pi(w, z, pe^{\mu}, \theta) \quad (4.5)$$

Based on equation (4.5) profit frontier can be expressed as:

$$\pi(w,z,pe^{\mu},\theta) = \pi(w,z,pe^{\mu},\theta)|_{\mu=0} \quad (4.6)$$

The following equation can also be established from equation (4.5) due to monotonicity attribute of profit function, i.e., because $pe^{\mu} \leq p$ and $\pi(w,z,pe^{\mu},\theta) \leq \pi(w,z,p)$ (Kumbhakar *et al.*, 2015):

$$\pi^{a} = \pi(w,z,pe^{\mu},\theta) = \pi(,z,pe^{\mu}).h(w,z,pe^{\mu},\theta) \quad (4.7)$$

or,

$$ln\,\pi^{a} = ln\pi(w,z,pe^{\mu},\theta) + lnh(w,z,pe^{\mu},\theta) \quad (4.8)$$

Equation (4.8) shows that the natural logarithm of actual profit $(ln\,\pi^{a})$ can be decomposed into a profit frontier $\mathrm{l}n\pi(w,z,pe^{\mu},\theta)$ and profit technical inefficiency component $lnh(w,z,pe^{\mu},\theta) \leq 0$. (Kumbhakar *et al.*, 2015).

4.2.2 The Stochastic Meta-frontier

According to Battesse & Rao (2002), a stochastic meta-frontier function is an envelope of all individual stochastic frontiers for distinct groups under consideration and is widely used to compare efficiencies for firms operating under different technologies. The use of a stochastic meta-frontier framework allows the researchers to test the hypothesis that firms under consideration have access to similar technology (Lau & Yotopoulos, 1989). Thus, the rejection of the null hypothesis would imply that the presence of any efficiency difference between groups could be due to the presence of X-inefficiency factors such as selective rationality, incomplete labor contracts, and difference in group interest (Leibenstein, 1978).

The stochastic meta-frontier approach permits the estimation of profit efficiency gap ratios

(PEGR) that show how far or close the group-specific profit frontier is relative to the best possible profit meta-frontier (Villano & Mehrabi Boshrabadi, 2010). This way the stochastic meta-frontier approach yields a reliable comparison of profit efficiency between groups thereby minimizing biases. Following Battesse *et al.* (2004), the stochastic profit frontier model is given as:

$$\pi_i = f(p_i, \beta_i)e^{V_i - U_i} \tag{4.9}$$

where π_i is the vector of gross margin for the i th trader, defined as total revenue minus total variable costs, i represents the camel milk traders, $f(.)$ is a deterministic kernel, p_i is the input price paid by the i th trader, β_i are unknown parameters to be estimated, V_i is the statistical disturbance error term assumed to be identically and independently distributed with zero mean and constant variance while U_i is the profit inefficiency error term assumed to be identically and independently distributed as half normal truncation around zero (Aigner *et al.*, 1977). In addition, both V_i and U_i are assumed to be independent to each other.

Equation (4.9) is employed to estimate the profit efficiency of each trader, with that the assumption that all traders use similar management practices and/or they operated in the same region (Orea & Kumbhakar, 2004). Such an assumption ignores the possibility of the occurrence of efficiency differences thereby clouding the actual difference to profit efficiency. Therefore, assuming j distinct groups and following Abid & Goaied (2015), a group-differentiated stochastic frontier is expressed as:

$$\pi_i^j = f^j(p_i^j, \beta_i^j)e^{V_i^j - U_i^j} \equiv e^{p_j\beta^j + V_i^j - U_i^j} \quad \forall_i = 1,2,\ldots,\text{n and } j = 1,2,\ldots,5 \tag{4.10}$$

where π_i is the vector of gross margin for the ith trader in the j th group (j =1,2,…,5) representing Wajir, Marsabit, Turkana, Isiolo and Garissa counties. p_i^j are vector for price price paid i th trader in the j th group . β_i^j are unknown parameters to be estimated for the i th trader in the j th group.

As mentioned above, U_i denotes non-negative unobservable random error associated with the i th trader's profit inefficiency, with G_i^j representing factors hypothesized to influencing profit inefficiency (Battesse *et al.*, 2004). To estimate profit inefficiency (U_i^j) for each observation, Jondrow *et al.* (1982) suggest the conditional mean of U_i^j given ε_i^j is determined as the estimate of profit inefficiency for every observation. That is

$$E(U_i^j|\varepsilon_i^j) \tag{4.11}$$

Therefore, each camel milk trader in each group is assigned profit efficiency index based on the value estimated of U_i^j, such that (Hansen *et al.*, 2019):

$$PE_i^j = e^{-E(U_i^j|\varepsilon_i^j)} \tag{4.12}$$

where PE_i^j is the profit efficiency for the i th trader in the j th group and lies between zero and one. It also haa a negative association with the level of profit inefficiency. Meta-frontier is a function that envelopes each group's specific frontier, thus considered an envelope curve over the profit frontier of individual groups (Battese *et al.*, 2004). Therefore, following Haung *et al.* (2014) the stochastic meta-frontier function represented by MM^* (Figure 4.1), envelops all the profit frontiers of the j group and is expressed as:

$$\pi_i^M = f^M(p_i, \beta^M) \equiv e^{p_i \beta^M} \tag{4.13}$$

where β^M represents vector for the meta-frontier function such that

$$p_i\beta^M \geq p_i\beta^j \tag{4.14}$$

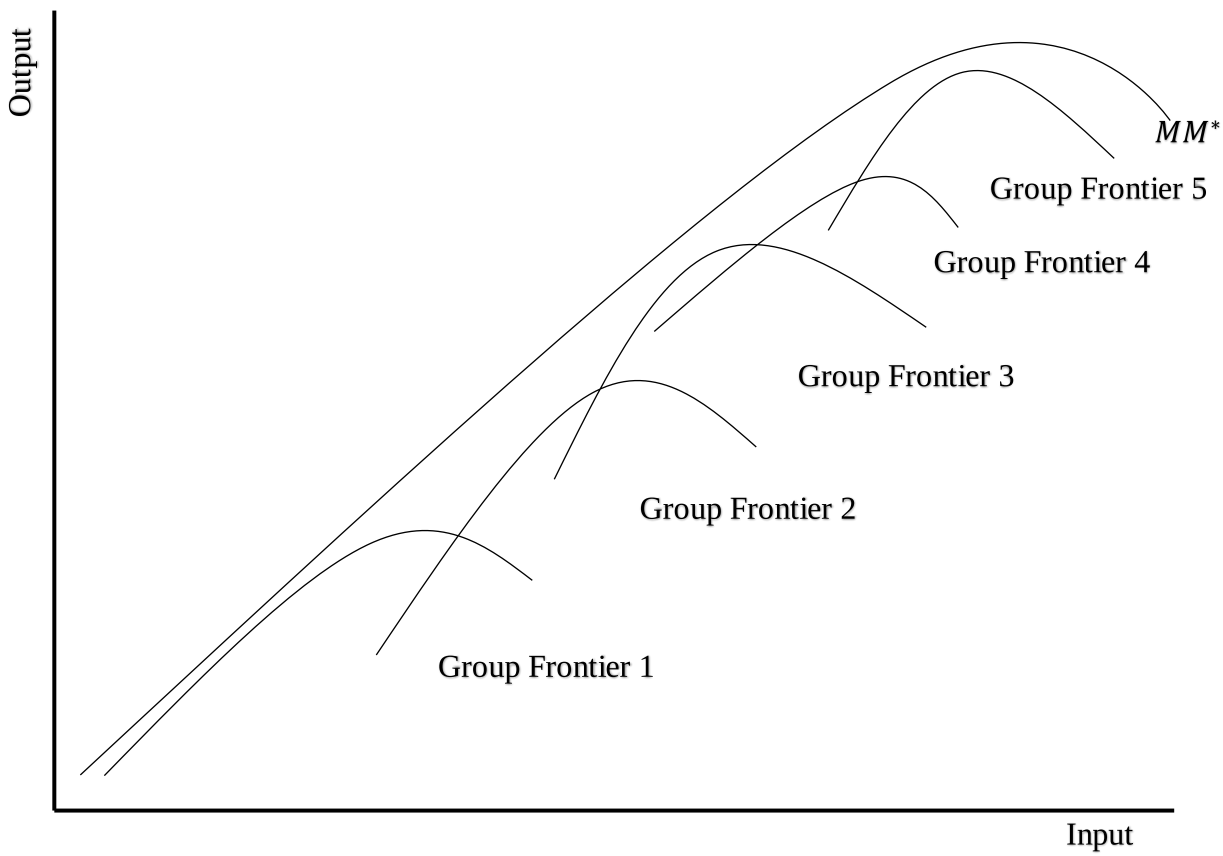


Figure 4. 1: An illustration of a profit meta-frontier

Source: Adopted from Battesse *et al.* (2004)

Following Abid & Goaied (2017) the profit efficiency of the i th trader defined by the stochastic profit function for the i th trader frontier model for the j th group in equation (4.10), is stated in terms of the profit meta-frontier in equation (4.13) as:

$$PE_i^M = e^{-U_i^j} X \frac{e^{p_i \beta^j}}{e^{p_i \beta^M}} X e^{p_i \beta^{j} + V_i^j} \tag{4.15}$$

where PE_i^M is the profit efficiency for the i th trader in the j th group and all other symbols are as previously defined. The first term on the right hand side of equation (4.15) gives the conventional element of profit efficiency, which measures the deviation of the current profit of the group members for the group-specific frontier (Haung *et al.*, 2014).

$$PE_i^j = \frac{e^{p_i\beta^j + V_i^j - U_i^j}}{e^{p_i\beta^M + V_i^j}} = e^{-U_i^j} \tag{4.16}$$

The second term in equation (4.15) is the profit efficiency gap ratio (PEGR) which measures the deviation of the group's profit efficiency from the profit meta-frontier and ranges between zero and one (Chen *et al.*, 2020).

$$PEGR_i^j = \frac{e^{p_i\beta^j}}{e^{p_i\beta^M}} \tag{4.17}$$

The profit efficiency for the trader relative to the meta-frontier adjusted for the corresponding random error is given as (Abid & Goaied, 2017):

$$PE_i^M = PE_i^j \; X \; PEGR_i^j \tag{4.18}$$

Equation (4.18) indicates that the profit efficiency relative to meta-frontier function is the product of the profit efficiency relative to the stochastic frontier for the given group and the profit efficiency gap ratio (Haung *et al.*, 2014).

4.2.3 Empirical Estimation

The estimation of the profit meta-frontier involved two-step (Battesse *et al.*, 2014). The first step was the estimation of the group-specific stochastic frontier and the second step was the estimation of the profit meta-frontier. The choice was made on the functional form of the deterministic kernel (Equation 4.5) between the Cobb Douglas and translog profit functional forms that are widely used in the literature (Asravor *et al.*, 2019). The likelihood ratio test supported the use of translog functional form (Chi-square = 21.77 and p value < 0.05). Therefore, following Bocher & Simtowe

(2017) the translog profit frontier was specified as:

$$\ln\left(\pi_i{}^j\right) = \beta_0^j + \sum_{k=1}^{3} \beta_k^j lnp_{ik}^j + 0.5 \sum_{k=1}^{3} \beta_{kk}^j \, (lnp_{ik}^j)^2 + \sum_{k=1}^{3} \sum\nolimits_{l=2}^{3} \beta_{kl}^j \, lnp_{ik}^j lnp_{il}^j + (V_i^j - U_i^j)$$

(4.19)

where $\pi_i{}^j$ is the normalized gross margin for the i th trader in the j th group (j =1,2,…,5) representing Wajir, Marsabit, Turkana, Isiolo and Garissa counties. p_{ik}^j is a vector of k input price (i.e. cost of labor, the buying price of milk) paid by the i th trader in the j th group. As before, βs are the unknown parameters to be estimated. $V_i{}^j$ and $U_i{}^j$ are the stochastic random noise and profit ineffecient term, respectively. The model of profit inefficiency is therefore expressed as:

$$U_i{}^j = \delta_0 + \textstyle\sum_{k=1}^{3} \delta_k \; G_{ik}{}^j \qquad (4.20)$$

where $U_i{}^j$ is the stochastic frontier component of profit inefficiency, δs are the unknown parameters to be estimated, and Gs represent the vectors of the characteristics of traders hypothesized to influence profit inefficiency. The variables incorporated in the model in equation (4.20) comprise the age of trader, the experience of traders, distance to the nearest market, gender of traders, traders who add value to their milk and traders who attended training on milk quality and control.

$$U_i{}^j = \delta_0 + \delta_1^j G_1^j + \delta_2^j G_2^j + \delta_3^j G_3^j + \delta_4^j G_4^j + \delta_5^j G_5^j + \delta_6^j G_6^j \qquad (4.21)$$

where δs are the unknown parameters to be estimated, G_1^j parameter to be estimated for age of camel milk trader in j th group, G_2^j parameter to be estimated for milk selling experience of camel milk trader in j th group, G_3^j parameter to be estimated for traders who particiepated in the training on milk quality and control in j th group, G_4^j parameter to be estimated for distance covered by traders to the market in j th group, G_5^j parameter to be estimated for traders who add value to their milk in j th group, G_6^j parameter to be estimated for gender of camel milk trader in j th group. Table 4.1 presents the description of explanatory variables included in equation 4.19 and 4.21 and their hypothesized signs.

Table 4.1: Description of explanatory variables in equations 4.19 and 4.21 and their hypothesized signs

Variables	Description	Unit of measurement	Expected sign
Normalized gross margin model (Equation 4.19)			
p_1	Buying price of milk	Continuous	-
p_2	Wage of hired labor and family labor in man-days (Ksh)	Continuous	-
p_3	Value of fixed capital (Ksh)	Continuous	+
Inefficiency model (Equation 4.21)			
G_1	Age in years of trader	Continuous	+
G_2	Number of years in the milk enterprise	Continuous	-
G_3	Traders who attended training on milk handling and control	Dummy (1 = Yes, 0 = No)	-
G_4	Distance to the nearest market in kilometers	Continuous	+
G_5	Traders who added value to their milk	Dummy (1 = Yes, 0 = No)	-
G_6	Sex of milk traders	Dummy (1 = Male, 0 = Female)	-

4.2.4 Tests for Model Specification

The five hypotheses were tested in this study to validate the models shown in eqution (4.19) and (4.21). These were that: (i) The coefficients of the square values and the interaction terms in the translog were equal to zero because they are not important (ii) There were no inefficiency effects (iii) The profit efficiencies of traders operating in different countries were not statistically different

(iv) The variables included in the inefficiency effect model have no effect on the level of profit efficiency (v) The variables included in the inefficiency effect model have no effect on the level of meta-profit efficiency. The generalized likelihood ratio statistic was used to test the null hypothesis and the critical values for this kind of test were attained from the Table of Kodde & Palm (1986). For the first hypothesis, the likelihood ratio test rejected the null hypothesis (Chi-square = 12.58; $p < 0.05$; $df = 9$) suggesting that the coefficients for the squared value in the translog stochastic profit function were not equal to zero, thus they were very important. This test also justified the use of translog as opposed to the Cobb-Douglas profit function. For the second hypothesis, the likelihood ratio test on the pooled data also rejected the null hypothesis (Chi-square = 16.92, $p < 0.05$, $df = 6$) indicating that the stochastic profit function appropriately represented the data.

It also implied some profit inefficiency in the camel milk business in Northern Kenya. For the third hypothesis, the likelihood ratio test rejected the null hypothesis of no efficiency gap between counties (Chi-square = 7105.16; $p < 0.05$; $df = 45$) implying that the comparison of profit efficiency across the five counties under the meta-frontier was appropriate. For the fourth hypothesis, the likelihood ratio test rejested the null hypothesis (Chi-square = 58.78, $p < 0.05$, $df = 7$) suggesting that variables present in the inefficiency model have a collectively significant contribution to explaining inefficiency. Finally, for the last hypothesis the likelihood ratio failed to rejected the null hypothesis (Chi-square = 10.78, $p > 0.05$, $df = 7$) suggesting that variables present in the inefficiency model for the meta-frontier model have no collectively significant contribution in explaining inefficiency. Thus, these variables were excluded while estimating meta-frontier.

4.2.5 Data Sources

The study utilized cross-sectional data extracted from a survey conducted by the International Livestock Research Institute (ILRI) in Wajir, Turkana, Isiolo, Garissa, and Marsabit counties in Northern Kenya. Occupying almost half of the country, Northern Kenya is an ASAL with high rainfall variability and is prone to frequent droughts (Watson *et al.*, 2016). Accordingly, over 80% of households rely on nomadic pastoralism for their livelihoods (FAO, 2014). The region is characterized by high poverty and malnourishment rates, poor social (such as schools and hospitals), and economic (such as markets and banks) amenities in part due to historical neglect and marginalization by public policy (Odongo *et al.*, 2017).

Under these circumstances, the camel plays a critical role in pastoral household food security by providing milk, meat, blood, and occasional income when the animal or its product is sold. The five counties had a total population of 3,227,379 in 2019 (KNBS, 2019). A sampling transect technique was employed to collect primary data from camel milk traders who sold camel milk and its products in market centers during the study (i.e., between February and April 2019). The transect was mapped along the main road network passing through the main markets across the camel-keeping areas in each study county.

The main markets were Kangatosa, Lodwar, Kerio, Lokichar, and Kakuma markets (in Turkana County), Oldonyiro, Merti, Eskut, Isiolo market (in Isiolo County), Bute, Habaswain, and Wajir market (in Wajir County), Merille, Ilaut, Jirime, and Moyale (in Marbsabit County), Masalani, Balambala, Modogashe, and Garissa market (in Garissa County). Due to the lack of a proper sampling frame, a snowball sampling approach was used to identify camel milk traders in these markets. A total of 933 traders distributed as 12 (Kangatosa), 20 (Lodwar), 20 (Kerio), 53 (Lokichar), 52 (Kakuma), 40 (Oldonyiro), 35 (Merti), 60 (Eskut), 60 (Isiolo town), 70 (Bute), 60

(Habaswain), 60 (Wajir town), 50 (Merille), 20 (Ilaut), 60 (Jirime), 66 (Moyale), 50 (Masalani), 47 (Balambala), 48 (Modogashe), and 50 (Garissa town). The number of traders by County was: 157 (Turkana), 190 (Wajir), 195 (Garissa), 195 (Isiolo), and 196 in Marsabit. The traders were interviewed by trained enumerators using semi-structured questionnaires that captured traders' socio-demographic information, the quantity of milk procured and sold, buying and selling price of milk, amount of labor employed by the traders, cost of capital equipment such as quality check, transportation, and handling equipment and intermediate cost including electricity, water, and rent bills. The collected data were entered into a census and survey processing software for cleaning. Sixty-three milk traders had incomplete responses and were removed from the analysis. Thus, the study retained a sample of 870 milk traders. STATA version 16 was used for empirical estimation.

4.3 Results and Discussion

4.3.1 Descriptive Statistics

Table 4.2 shows substantial variation in the means of gross margin and factor prices across the five counties (ANOVA F-value = 82.01 and $p < 0.05$). The fact that the average gross margins were positive in all counties suggests that the camel milk enterprise was profitable in the study area. Isiolo County recorded the highest average gross margin followed by Marsabit County. Turkana County had the least probably because of the limited supply of processing facilities, lack of organized market channels, and poor milk handling practices that affect the quality of their milk (Isako & Kimindu, 2019). Isiolo County recorded the highest due to its proximity to the Nairobi terminal market where there is high demand for camel milk (Oselu *et al.*, 2022). With regards to factor price, Marsabit County recorded the highest average daily labor cost while Turkana had the least.

The average buying price of milk per liter was highest in Turkana County and least in Isiolo. The reason is that there is an oversupply of milk in Isiolo since it also received an additional supply of milk from neighboring counties such as Marsabit, Garissa, and Wajir (Muloi *et al.,* 2018). The variation in relative prices in inputs among regions offered firms a useful incentive to trade on the opposite side (Chen *et al.,* 2020). On the other hand, the average capital outlay was highest in Wajir County and least in Turkana. Turkana County recorded the least capital outlay perhaps due to the poor access to credit facilities in the region that discourages traders from investing more in the milk enterprise (CIDP, 2018-2022). The wide variation of factor prices in the five counties means the milk traders in those regions have been offered an essential incentive to trade on the opposite side (Chen *et al*., 2020).

As shown in Table 4.3, The trader's age was not statistically different across the five counties (ANOVA F-value= 3.14; p-value = 0.392). Traders from Isiolo and Wajir counties have the most youth traders. Traders from Wajir County were the most experienced traders while traders from Turkana County were the least. This could perhaps be attributed to the differences in market access between the two counties. Traders from Garissa covered the longest distance to the market with an average of 31km while those for Marsabit covered the shortest. Distance to the market implies profit efficiency because it tends to increase input prices due to high transactions and affects access to credit facilities that are usually found in markets (Mphafi *et al.*, 2019).

Table 4.2: Summary statistics of variables used in the county-specific profit frontier and meta-frontier

County	Variables	Mean	S.E	Minimum	Maximum
	Gross margin (KShs)	63,496	2246.6	21,262	555,727
Garissa	Cost of labour (Kshs)	274	3.0	50	500
	Buying price (KShs/L)	76	2.1	20	175
	Capital (KShs)	1,602	11.1	100	7,700
	Gross margin (KShs)	265,211	31,733.6	-823	440,647
Marsabit	Cost of labour	280	5.1	50	600
	Buying price (KShs/L)	51	1.7	200	175
	Capital (KShs)	820	92.8	100	7,700
	Gross margin (KShs)	428,798	40,082.2	-601	471,937
Isiolo	Cost of labour (Kshs)	254	6.0	100	600
	Buying price (KShs/L)	41	1.6	15	175
	Capital (KShs)	1,823	128.1	100	8,470
	Gross margin (KShs)	31,141	8,152.2	-1575	896,217
Turkana	Cost of labour (Kshs)	179	3.2	50	250
	Buying price (KShs/L)	82	2.2	20	175
	Capital (KShs)	539	56.5	100	6130
	Gross margin (KShs)	40,622	5,666.3	-750	371,711
Wajir	Cost of labour (Kshs)	267	5.7	50	350
	Buying price (KShs/L)	55	1.9	25	150
	Capital (KShs)	2,036	125.9	100	8,850

Note: S.E is the standard error

Wajir County had the highest percentage (93) of female traders across the five counties suggesting that females dominated camel milk marketing in Wajir County, contrary to expectation. Women in pastoral communities have been empowered to participate in the trade of camel milk along streets and in the market which has improved their income status (Gitonga, 2017).

Marsabit and Garissa counties had the highest number of male traders. The sex of traders across the five counties was statistically different (ANOVA F-value= 13.57 and p-value < 0.05). Turkana County reported the highest proportion (31%) of untrained milk traders followed by Garissa and Marsabit Counties (Table 4.3). Turkana County had the highest percentage of untrained milk traders perhaps as a result of a lack of training programs in the County. Training programs provided farmers with new knowledge about input utilization, risk aversion, storage, preservation methods, final output marketing, technology adoption, and saving aspects (Ahmed & Geta, 2013). Marsabit County had the highest percentage of traders who add value to their milk and was followed by Isiolo County, thus, they sold processed products such as yogurt, fermented milk, and milkshake.

Table 4.3: Summary statistics of variables used in the county-specific inefficincy model

Variables	Garissa	Marsabit	Isiolo	Turkana	Wajir	F-statistic	P-values
Age	39	40	38	39	38	1.03	0.039
Experience	6	7	8	5	9	17.25	0.000
Distance	31	22	26	30	25	67.15	0.000
Sex Male (%)	13	24	15	33	7	18	0.000
Sex female (%)	87	76	85	67	93	82	0.000
Training No (%)	78	74	66	82	71	74	0.004
Training Yes (%)	22	26	34	17	28	26	0.004
Add value No %	67	82	46	86	79	75	0.000
Add value Yes %	33	18	54	14	21	18	0.000

4.3.2 County-specific Profit Frontiers and Meta-frontier Estimates

Table 4.4 presents the maximum likelihood estimates of the translog stochastic profit function parameters for the five counties and the meta-frontier. The positive sign of sigma squared across the five counties and meta-frontier indicated the model's goodness of fit and the correctness of the specified distributional assumption since the inefficiency effects were random and stochastic.

Table 4.4: Maximum likelihood estimates for parameters of the stochastic profit frontiers and meta-frontier

Variables	Garissa		Marsabit		Isiolo		Turkana		Wajir		Meta	
	Coeff	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**	**Coeff**	**SE**
Constant	11.33	0.47**	9.67	0.49**	10.76	0.56**	11.07	0.66**	9.72	0.59**	12.43	0.56**
Lnbuyprice	-0.12	0.17**	-0.15	0.35**	-0.11	0.012**	-0.10	0.18**	-0.09	0.05*	-0.24	0.12**
Lnlabor	-0.66	O.22**	-0.54	0.17**	-0.52	0.36**	-0.58	0.43	-0.02	0.01**	-0.42	0.31
Lncapital	0.06	0.07**	0.16	0.08	0.13	0.33*	0.44	0.39**	0.28	0.17	0.09	0.12**
lnbuyprice2	-0.47	0.53	-0.84	0.62	0.10	0.15	0.06	0.01	-0.38	0.24	0.11	0.03
lnlabor2	0.07	0.01***	-0.70	0.56**	0.30	0.24*	0.05	0.01	-0.11	0.09	0.42	0.22
lncapital2	0.06	0.02**	0.01	0.09	-0.02	0.11	0.01	0.09	-0.02	0.01	-0.22	0.14
lnlaborxlnbuyprice	0.41	0.26	0.45	0.22**	-0.19	0.03***	-0.01	0.02	0.32	0.22	0.07	0.21
lnlaborxlncapital	0.07	0.10	0.04	0.09	0.09	0.04	0.12	0.09	0.07	0.01	0.08	0.13
lncapitalxlnbuyprice	-0.07	0.11	-0.03	0.12	0.21	0.17	-0.01	0.06	-0.18	0.12*	0.23	0.12
Inefficiency model												
Age (Years)	-0.11	0.14	-0.08	0.02**	0.08	0.06	-0.09	0.01*	-0.45	0.29		
Experience (Years)	-1.13	0.22*	0.22	0.16	-0.02	0.01**	0.02	0.01	0.12	0.24***		
Female trader	0.23	0.18	0.04	0.01	-0.17	0.11***	-0.16	0.24	-0.26	0.13**		
Training (Yes=1)	-2.29	0.50**	-0.38	0.13**	-1.24	0.17**	-0.57	0.24**	0.26	0.19		
Distance (km)	-0.10	0.07	0.11	0.06**	-0.01	0.01	0.04	0.01**	0.13	0.28		
Add value (Yes=1)	-1.28	0.09**	0.03	0.01	-0.42	0.23	-0.57	0.34**	1.23	0.45		
Constant	3.51	0.49	-2.63	0.34	1.83	0.57**	4.94	0.52**	2.97	0.73		
Variance parameters												
Sigma square	0.83	0.06**	0.65	0.11**	0.66	0.13**	0.78	0.43**	0.59	0.21*	0.77	0.26**
Gamma	0.70	0.03**	0.52	0.16**	0.55	0.24**	0.67	0.38**	0.84	0.03	0.62	0.18**
Lambda	1.50	0.61**	0.64	0.29**	1.27	0.27**	1.09	0.67**	0.47	0.41*	1.32	0.67**
Wald's chi2(9)	85.26**		46.08**		58.61**		28.06**		34.88**		226.08**	
Prob>chi2	0.0000		0.0004		0.0000		0.0009		0.0001		0.0000	
Log-likelihood	-281.53		-268.84		-262.45		-269.23		-246.37		-1674.39	
No of observation	178		184		186		140		182		870	

Note:. Coeff denotes coefficient. SE denotes standard errors. *** , **, * denote statistical significance at 1%, 5%, and 10%, respectively.

The relatively high sigma squared values for Garissa, Turkana, and Isiolo counties suggest that the model explained more than 66% of the variation in profit efficiency across the five counties. Wajir County has a low sigma squared value of only 0.59 suggesting that the compose error term weekly dominated the measurement error (Mawa *et al.,* 2014). The value of lambda from the five counties and meta-frontier was statistically significant at 5% implying that the discrepancy in actual profit comes from the difference in milk traders' practices as opposed to random variability.

The value of gamma across the five counties and in the meta-frontier was statistically different from zero ($p < 0.05$) suggesting that the inefficiency effect in the stochastic models was stochastic. Thus, proving further evidence of the goodness of fit of the used stochastic model. According to Bocher & Simtowe (2017), a zero value of gamma means that ordinary least square methods are the best estimator because of the absence of inefficiency. The result in Table 4.4 revealed that the milk traders in Garissa, Marsabit, Isiolo, Turkana, and Wajir had Wald chi-square statistics of 82.26, 46.08, 58.61, 28.06, and 34.88, respectively. They were also significant at 5% level. Thus, implying that the stochastic models were conjointly significant at 5% level. Because all variables in the stochastic profit frontier were normalized using their geometric means their first-order coefficients can be interpreted as partial elasticity (Coelli *et al.,* 2005).

Accordingly, the own price elasticity of milk was negative as expected from theory, indicating the fulfillment of the non-increasing input price property of the profit function (Lau, 2019). The estimated elasticity of profit with respect to the price of labor was negative and statistically significant across the five counties and the meta-frontier while that of capital was positive and statistically significant in Garissa, Marsabit, Isiolo, Wajir, and the meta-frontier.

These findings support those of Mawa *et al.* (2014) and Mwalongo (2018), who reported that an increase in the cost of labor decreases the profit level of dairy farmers in the Rift valley and Central provinces (Kenya) and Njombe (Tanzania), respectively. The positive relationship between capital and profit was likely to occur because investment in the use of modern preservation techniques (use of cooler facilities) would minimize milk spoilage, hence increasing trader's profit through the reduction of postharvest losses. This finding supports the results of Iruria *et al.* (2009) that an increase in capital investment improved the profit margins of smallholder dairy farmers in western Kenya.

According to Tanko (2015), higher capital investment reduces investors' inefficiency as they tend to be more cautious to reduce investment risk. According to Abdulai & Huffman (2000), the challenge of the functional form of translog is that the interaction parameters had no economic significance. The squared value of the price of labor was positive and significant in Garissa and Isiolo while negative and significant in Marsabit County. This means an additional increase in the price of labor will increase the profit of traders in Garissa and Isiolo counties while a decrease in Marsabit County. This is contrary to the findings of Mujuru *et al.* (2022) who found that the squared value of the cost of labor had an indeterminate influence on profit. The squared value of the cost capital was positive and significant in Garissa County suggesting an additional increase in the cost of capital will increase the profit of the traders.

4.3.3 Profit Efficiency and the Profit Efficiency Gap Ratio

Table 4.5 presents the summary statistics estimates for profit efficiency, profit efficiency gap ratio, and profit efficiency of the meta-frontier. The Welch ANOVA test reveals that the profit efficiency scores are based on the stochastic frontier profit function (PE) with Isiolo County being the highest followed by Wajir and Marsabit counties in that order. This means that the null hypothesis of the profit efficiency across the five counties was not different and was rejected (F-values = 22.35 and p-values = 0.002). However, none of the counties lay on the profit fully suggesting that all milk traders were profit inefficient. The results could be attributed to differences in management techniques adopted by traders and economic and infrastructure development in a particular county. This indicates that in the short run, trader's profit would increase with improvement in the milk supply chain management practices as well as the reduction of hired labor and increase in the cost of capital in the five counties.

The cost capital was the single most expensive item that dairy farmers had to invest in; hence, an increase in capital investment would improve milk profits since dairy farmers would take more caution in using resources (Iruria *et al.,* 2009). The mean PEGRs for the five counties were statistically different from each other (F-values of 23.97 and p-values of 0.000) indicating profit gaps were evident among traders across the counties. However, the maximum PEGRs in each County suggested that there was potential to overcome inefficiency by adopting better practices.

In general, higher PEGRs suggest a smaller profit gap between the County frontier and meta-frontier. The results further demonstrated that there was a difference in the management of milk enterprise across the counties as measured by the PEGRs. According to Asante *et al.* (2017), bridging the profit inefficiency gap would require addressing the relative inefficiency in the milk enterprise through strategies such as training traders on milk hygiene practices and improvement of rural road infrastructure.

Table 4.5: Summary statistics of profit efficiency and profit efficiency gap ratios for camel milk trader in five counties in Northern Kenya

County	Mean	Std. Error	Minimum	Maximum
Profit efficiency based on the stochastic frontier profit function (PE)				
Isiolo	0.78	0.013	0.03	0.99
Wajir	0.71	0.010	0.01	0.90
Marsabit	0.65	0.020	0.02	0.97
Garissa	0.58	0.012	0.01	0.93
Turkana	0.38	0.012	0.04	0.89
Profit efficiency gap ratio (PEGR)				
Isiolo	0.87	0.025	0.74	1.00
Marsabit	0.84	0.028	0.80	1.00
Wajir	0.74	0.029	0.24	1.00
Garissa	0.73	0.034	0.64	1.00
Turkana	0.66	0.025	0.19	1.00
Profit efficiency based on meta-frontier (PE^*)				
Isiolo	0.70	0.010	0.08	0.96
Marsabit	0.61	0.020	0.04	0.96
Wajir	0.52	0.009	0.006	0.62
Garissa	0.45	0.017	0.009	0.59
Turkana	0.31	0.012	0.008	0.78

Isiolo County had the highest PEGRs perhaps because of its highly commercialized camel milk value chain that has outlets in major towns and the city of Nairobi. In addition, the County has well-established cooperatives which occasionally provide training and financial services to milk traders (Elhadi *et al.*, 2015). Although milk traders in Turkana County have a high potential to increase their profit efficiency, the presence of poor marketing channels and market infrastructure, and limited access to training programs would still render them inefficient (CIDP, 2018-2022).

The lower section of Table 4.5 presents the average profit efficiency based on meta-frontier (PE^*) where Isiolo led the pack at 70% while Turkana County had the least. This justifies that in northern Kenya Isiolo County is more profit efficient while Turkana County is least efficient. Notably, none of the five counties lay on the meta-frontier implying that all the traders were profit inefficient. Accordingly, Isiolo, Marsabit, Wajir, Garissa, and Turkan would need to increase investment in value addition, establish training programs, increase investment in value addition, improvement in roads and market infrastructure, and improve access to information on milk handling and storage, respectively to lie on the meta-frontier.

Moreira & Bravo-Ureta (2010) argued that adopting better milk handling techniques and practices from other regions to local conditions could increase the profit efficiency scores from the regional frontier to the meta-frontier. It can be observed from Table 4.5 that the average profit efficiencies to meta-frontier were lower than those obtained relative to individual counties' frontiers. These findings support Battesse *et al*. (2004) and O'Donnell *et al.* (2008) such that using profit efficiency for comparison across the five counties to individual county frontiers would be misleading.

4.4 Conclusions and Recommendations

The key objective of this study was to compare the profit efficiency among camel milk traders in five counties in Northern Kenya. The study employed the meta-frontier framework to test the null hypothesis that the camel milk traders in Northern Kenya were equally profit-efficient, which was rejected by the Welch ANOVA test. Although based on the profit meta-frontier Isiolo County performed better than others, none of the counties was fully efficient suggesting all traders were profit inefficient. In addition, the study estimated the proximity of County frontiers to the meta-frontier using the profit efficiency gap ratios and found significantly different ratios.

This suggests bridging the profit inefficiency gap would require addressing the relative inefficiency in the milk enterprise through strategies such as training traders on milk hygiene practices, improvement of rural road infrastructure, and increasing investment in local research to generate modern milk preservation technologies that would improve the efficiency of traders. Notably, none of the five counties lay on the meta-frontier suggesting all the traders were profit inefficient. Isiolo County outdid the other while Turkana County performed the worst suggesting that its traders were either using managerial skills inferior to Isiolo County or constrained by a lack of markets and supporting rural infrastructure. As such, traders in Turkana County would benefit the most if such constraints were addressed to enable them to achieve maximal profit. Further studies should focus on the determinant of the profit efficiency gap since none of the five counties lay on the meta-frontier.

CHAPTER FIVE: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General Discussion

The main objective of this study was to examine the profit efficiency of camel milk traders in five counties of Northern Kenya. The motivation for this study is to provide insights and solutions for profit inefficiency of camel milk traders in Northern Kenya. The specific objectives were to assess the profit efficiency of camel milk traders, to investigate factors influencing the profit efficiency of camel milk traders, and to assess the spatial profit efficiency gap among camel milk traders in the five counties of Northern Kenya. The study utilized cross-section data extracted from a survey conducted by the International Livestock Research Institute in Wajir, Turkana, Isiolo, Garissa, and Marsabit counties in northern Kenya to examine the microbial quality and safety of camel milk and associated products along the value chain of camel milk.

A sampling transect technique was employed to collect the primary data from camel milk traders who sold camel milk and its products in market centers during the study. The study took the main road network passing through the main markets across the camel-keeping areas in each study County. A snowball sampling approach was used to identify camel milk traders in those markets. This gave a total of 933 traders distributed as 157 (Turkana), 190 (Wajir), 195 (Garissa), 195 (Isiolo), and 196 (Marsabit) that were interviewed using a questionnaire.

The collected data was then entered into a census and survey processing software for cleaning. On data cleaning 63 milk traders had incomplete responses and were therefore removed from the analysis; the study retained a sample of 870. Descriptive statistics were computed to characterize both the milk traders and their enterprises. A stochastic translog profit frontier was then used to assess the profit efficiency of the camel milk traders together with factors affecting it.

At 83%, the milk enterprise was dominated by females most of whom were relatively young with an average age of 38 years. On average, the milk traders had a low trading experience. On average, traders sold 25 liters of camel milk per day to rural consumers in rural and urban towns such as Nairobi, Nakuru, and processing companies like Vital Camel Milk Limited. 25% of the traders added value to their milk in the form of milkshakes, yogurt, and fermented milk. The average gross margin was KShs 180,559 with Isiolo County being the highest and Turkana County the least.

The positive gross margin in all five counties suggests camel milk trade is a profitable enterprise that traders generated income from the sales of camel milk. Lack of knowledge of milk hygiene and safety, inadequate physical infrastructure, and institutional support were the major constraints that hindered the exploitation of the camel milk enterprise. The estimated translog stochastic profit frontier indicated that the traders' profit efficiency level ranged between 1 and 99% with a mean profit efficiency level of 43%. Isiolo County was the best while Turkana County was the poorest.

The low-profit efficiency in all five counties could be attributed to poor handling and transportation of milk, lack of cooling facilities, inadequate physical infrastructure and institutional support, low participation in training programs related milk hygiene practices and value addition. This suggests there is a big room for improvement if these constraints are addressed. The elasticities of cost of labor and buying price of milk with respect to profit showed that a unit increase in the labor cost and buying price of milk would reduce profit by 22% and 12%, repectively, *ceteris paribus.* On the other hand, a unit increase in the cost of capital would increase profit by 10% *ceteris paribus.* This finding emphasizes the importance of hired workers and the cost of capital in improving the profit of the camel milk trade.

Among the determinants of profit efficiency, trader's milk selling experience, his/her gender, participation in milk quality and control training, and value addition significantly increased the trader's profit efficiency. Long distances to the market reduced profit efficiency. This means that traders who were closer to the market were more efficient. This might be attributed to the fact that traders who are closer to market centers have the advantage of easy and timely access to essential inputs, *ceteris paribus*. distance covered by the trader to the market, and traders who add value to their milk significantly influence the observed profit efficiency of the camel milk trader.

To assess the spatial profit efficiency gap among camel milk traders in the five counties of Northern Kenya, a stochastic translog meta-frontier was fitted into the data. Notably, none of the five counties lay on the meta-frontier suggesting all the traders were profit inefficient. Isiolo County outdid the others while Turkana County performed the worst. The estimated profit efficiency gap ratios were 0.66, 0.73, 0.74, 0.84, and 0.87 for Turkana, Garissa, Wajir, Marsabit, and Isiolo, respectively, indicating wide differences in profit efficiencies among the five counties. Accordingly, the null hypothesis of the five counties having the same profit efficiency could not be sustained.

5.2 Conclusions

The main conclusion drawn from the findings is the camel milk enterprise in northern Kenya is a profitable business. Its further development would help to reduce the endemic poverty and food insecurity in the five counties, particularly among the pastoral communities that rely on livestock as their sole source of livelihood. Further traders in Isiolo County were more profit-efficient than those in all the other counties suggesting that the development of a platform for sharing information on relevant managerial skills in milk enterprises between counties, for example, through inter-county exchange visits could reduce the profit efficiency gap among camel milk traders in the five counties. The results further suggest that there is a huge potential for improving the profit efficiency of camel milk traders by addressing the causes of technical and allocative inefficiencies. Technical inefficiencies can be addressed by creating cooperative societies that would increase access to dairy equipment such as aluminum cans and freezers while value addition and training traders on how to improve milk quality and handling practices could resolve allocative inefficiencies. The study found that traders who added value to their milk were more profit efficient than those who did not add value.

5.3 Recommendations

Based on the results of this study, the following reccomendations are made:

1. There is a need to provide regular training programs on milk handling, safety, and hygiene to camel actors in the camel milk value chain to effectively minimize postharvest losses and increase their profit efficiency. This could be achieved by collaborating with public health officers and Kenya Camel Association.

2. Both county and national governments should invest more in training camel traders on value addition to increase the commercialization of the camel milk sectors. This could be done by working closely with camel milk trades cooperatives and self-help groups where camel milk traders are members.

3. The study found that distance to the market reduces the profit efficiency of milk traders. Accordingly, there is a need for the county government to work with the national government to

improve road and market infrastructure to enhance camel milk trading activities. This will reduce the time to deliver milk to consumers, especially those located in urban towns and cities such as Nairobi, Kisumu, and Nakuru. In addition, building better roads would improve the accessibility of training programs and markets for traders.

4. The analysis reported in this study did not consider all the actors operating in the camel milk value chain. Therefore, further research should focus on camel milk value chain actors and their governance. This would provide information on how equitable the value chain is as well as how much power each actor possesses in influencing decisions such as the setting of buying and selling price of camel milk for policy redress.

REFERENCES

Abdulai, A. and Huffman, W. (2000). Structural adjustment and economic efficiency of Rice Farmers in Northern Ghana. *Economic Development and Cultural Change* 48(3), 504-519.

Abid, I., & Goaied, M. (2017). A meta-frontier assessment of bank efficiency in Middle East and North Africa countries. *International Journal of Productivity and Performance Management*, 66(2), 266-296.

Abri, M. A. A., & Faye, B. (2019). Genetic improvement in dromedary camels: challenges and opportunities. *Frontiers in Genetics*, 12(10), 167-192.

Acharya, K. K., Malhotra, R., Sendhil, R., & Kumari, B. (2021). Profit efficiency among peri-urban dairy farms in Odisha: an application of the stochastic frontier function. *Agricultural Economics Research Review*, *34*(2), 207-215.

Adnan, K. M., Sarker, S. A., Tama, R. A. Z., & Pooja, P. (2021). Profit efficiency and influencing factors for the inefficiency of maize production in Bangladesh. *Journal of Agriculture and Food Research*, volume 5, Article ID 100161. https://doi.org/10.1016/j.jafr.2021.100161.

Ahmed, J. H., & Geta, E. (2013). Analysis of farm households' technical efficiency in production of smallholder farmers: the case of Girawa District, Ethiopia. *Journal of Agriculture and Environmental Science*, *13*(12), 1615-1621.

Aiello, F., & Bonanno, G. (2018). On the sources of heterogeneity in banking efficiency literature. *Journal of Economic Surveys*, *32*(1), 194-225.

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*(1), 21-37

Akintunde, O. K., Agboola, T. O., & Alabi, B. O. (2020). Assessment of Effect of Biosecurity Level on Profit Efficiency in Poultry Egg Production in Southwestern, Nigeria. *Nigerian*

Journal of Animal Science, *22*(1), 208-224.

Akite, I., Okello, D. M., Kasharu, A., & Mugonola, B. (2022). Estimation of profit efficiency of smallholder rice farmers in Uganda: A stochastic frontier approach. *Journal of Agriculture and Food Research*, 8, 1–8. https://doi.org/10.1016/j.jafr.2022.100315.

Akweya, B. A., Gitao, C. G., & Okoth, M. W. (2012). The acceptability of camel milk and milk products from north eastern province in some urban areas of Kenya. *African Journal of Food Science*, *6*(19), 465-473.

Alemayehu, G., Hailu, B., & Seid, N. (2015). Quality Constraints in the Market Chains for Export of Small Ruminants from Afar Pastoral and Agro-Pastoral Areas. *Animal and Veterinary Sciences*, *3*(2), 51-57.

Ali, F., Ashok, P & Mir, S. 1994. Measurement of Profit Efficiency using Behavioural and Stochastic Frontier Approaches. *Applied Economics.* 26(2), 181-188.

Alonso, S., Muunda, E., Ahlberg, S., Blackmore, E., & Grace, D. (2018). Beyond food safety: Socio-economic effects of training informal dairy vendors in Kenya. *Global Food Security*, *18*, 86-92.

Alrafadi, K. M., Yusuf, M. M., & Kamaruddin, B. H. (2016). Measuring efficiency in banks: a brief survey on non–parametric technique (data envelopment analysis). *International Journal of Business, Economics and Management*, *3*(5), 52-68.

Anderson, D. M., Elliott, H., Kochore, H. H., & Lochery, E. (2012). Camel herders, middlewomen, and urban milk bars: the commodification of camel milk in Kenya. *Journal of Eastern African Studies*, *6*(3), 383-404.

Ansah, I. G. K., Oduro, H., & Osae, A. L. (2014). A comparative analysis of profit efficiency in maize and cowpea production in the ejura sekyedumase district of the ashanti region, ghana. *Research in Applied Economics*, *6*(4), 106.

Aparicio, J., Borras, F., Pastor, J. T., & Vidal, F. (2015). Measuring and decomposing firm′ s revenue and cost efficiency: The Russell measures revisited. *International Journal of Production Economics*, *165*, 19-28.

Asante, B. O., Villano, R. A., & Battese, G. E. (2017). Integrated crop-livestock managem practices, technical efficiency and technology ratios in extensive small-ruminant systems in Ghana. *Livestock Science*, *201*, 58-69.

Askar, S. S., & Al-Khedhairi, A. (2020). Dynamic investigations in a duopoly game with price competition based on relative profit and profit maximization. *Journal of Computational and Applied Mathematics*, *367*(0377-0427), p. 112464. https://doi.org/10.1016/j.cam.2019.112464.

Asravor, J., Wiredu, A. N., Siddig, K., & Onumah, E. E. (2019). Evaluating the environmental-technology gaps of rice farms in distinct agro-ecological zones of Ghana. *Sustainability*, *11*(7), 2072-2093.

Atici, K. B., & Podinovski, V. V. (2015). Using data envelopment analysis for the assessment of technical efficiency of units with different specialisations: An application to agriculture. *Omega*, 54(3), 72-83. https://doi.org/10.1016/j.omega.2015.01.015

Awais, M., Laber, M. F., Rasheed, N., & Khursheed, A. (2016). Impact of financial literacy and investment experience on risk tolerance and investment decisions: Empirical evidence from Pakistan. *International Journal of Economics and Financial Issues*, *6*(1), 73-79.

Badejo, A. F., Majekodunmi, A. O., Kingsley, P., Smith, J., & Welburn, S. C. (2017). The impact of self-help groups on pastoral women's empowerment and agency: A study in Nigeria. *Pastoralism*, *7*(1), 1-12.

Bahta, S., & Baker, D. (2015). Determinants of profit efficiency among smallholder beef producers in Botswana. *International Food and Agribusiness Management Review*, *18*(1030-2016-83051), 107-130.

Balcerzak, A. P., Kliestik, T., Streimikiene, D., & Smrcka, L. (2017). Non-parametric approach to measuring the efficiency of banking sectors in European Union Countries. *Acta Polytechnica Hungarica*, *14*(7), 51-70.

Bandiera, O., Guiso, L., Prat, A., & Sadun, R. (2015). Matching firms, managers, and incentives. *Journal of Labor Economics*, *33*(3), 623-681.

Barrett, C. B. (1997). How credible are estimates of peasant allocative scale, or scope efficiency? A commentary. *Journal of International Development*, *9*(2), 221-229.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, *20*(2), 325-332.

Battese, G. E., & Rao, D. P. (2002). Technology gap, efficiency, and a stochastic metafrontier function. *International Journal of Business and Economics*, *1*(2), 87.

Battese, G. E., Rao, D. P., & O'Donnell, C. J. (2004). A meta-frontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies. *Journal of Productivity Analysis*, *21*(1), 91-103

Benmeziane–Derradji, F. (2021). Evaluation of camel milk: gross composition a scientific overview. *Tropical Animal Health and Production*, *53*(2), 1-15.

Bidzakin, J.K., Fialor, S.C., and Asuming-Brempong, D. (2014). Small Scale Maize Production in Northern Ghana: Stochastic Profit Frontier Analysis. *Journal of Agricultural and Biological Science*, 9(2),76-83.

Blackmore, E., Alonso, S., & Grace, D. (2015). Legitimizing informal markets: a case study of the dairy sector in Kenya. *IIED Brief* (2015). https://cgspace.cgiar.org/handle/10568/68871. Accessed: May 18, 2019.

Bocher, T. F., & Simtowe, F. P. (2017). Profit efficiency analysis among groundnut farmers from Malawi. *Journal of Development and Agricultural Economics*. 9(10), 278-288.

Charnes, A., Cooper, W. W., Golany, B., Seiford, L., & Stutz, J. (1985). Foundations of data envelopment analysis for Pareto-Koopmans efficient empirical production functions. *Journal of Econometrics*, *30*(1-2), 91-107.

Chen, C. M., Delmas, M. A., & Lieberman, M. B. (2015). Production frontier methodologies and efficiency as a performance measure in strategic management research. *Strategic Management Journal*, *36*(1), 19-36.

Chen, X., Fu, T. T., Juo, J. C., & Yu, M. M. (2020). A comparative analysis of profit inefficiency and productivity convergence between Taiwanese and Chinese banks. *BRQ Business Research Quarterly*, *23*(3), 193-202.

Cherchye, L., De Rock, B., & Walheer, B. (2016). Multi-output profit efficiency and directional distance functions. *Omega*, 61(0305-0483), 100-109. https://doi.org/10.1016/j.omega.2015.07.010.

Chikobola, M. M. (2016). Profit efficiency of groundnut production: Evidence from Eastern Province of Zambia. *Journal of Economics and Sustainable Development*, *7*(8), 147-153.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An Introduction to Efficiency and Productivity Analysis*. springer science & business media.

Colman, D., & Young, T. (1989). *Principles of agricultural economics: markets and prices in less developed countries*. Cambridge University Press. Cambridge.

County Intergrated Development Plan (CIDP). 2018-2022. Second Turkana County Integrated

Development Plan 2018–2022. Turkana County Government. https://repository.kippra.or.ke/bitstream/handle/123456789/2832/Turkana_CIDP_2018-2022. Accessed: April 22, 2022.

Dawar, V. (2014). Agency theory, capital structure and firm performance: some Indian evidence. *Managerial Finance*. 4(12), 1190-1206. https://doi.org/10.1108/MF-10-2013-0275. Accessed: April, 23, 2020.

Debertin, D.L. (1986). Agricultural production economics, Macmillan Publishing Company. New York.

Degl'Innocenti, M., Matousek, R., Sevic, Z., & Tzeremes, N. G. (2017). Bank efficiency and financial centres: Does geographical location matter? *Journal of International Financial Markets, Institutions and Money*, 46(9), 188-198.

De Graaf, S., Van Loo, E. J., Bijttebier, J., Vanhonacker, F., Lauwers, L., Tuyttens, F. A., & Verbeke, W. (2016). Determinants of consumer intention to purchase animal-friendly milk. *Journal of Dairy Science*, 99(10), 8304-8313.

Dokata, M. D. Maitho, T & Rugendo, C. (2014). *Factors Influencing Camel Milk Production in Central Division of Isiolo District: A case of Three Camel Milk Women Self-help Groups in Isiolo County, Kenya*. Unpublished PhD Thesis University of Nairobi. https://scholar.google.com/scholar?hl=en&as_sdt=2005&sciodt=0%2C5. Accessed. June, 23, 2019.

Elhadi, Y. A., Nyariki, D. M., & Wasonga, O. V. (2015). Role of camel milk in pastoral livelihoods in Kenya: contribution to household diet and income. *Pastoralism*, *5*(1), 8.

Elhadi, Y. A., & Wasonga, O. V. (2015). Economic and nutritional contribution of camel milk in Northern Kenya. *A Field Study in Isiolo County*. IIED Country Report. IIED, London.

https://www.iied.org/10125iied. Accessed, April 14, 2020.

Elhendy, A. M., & Alkahtani, S. H. (2013). The resource use efficiency of conventional and organic date farms in Saudi Arabia: A data envelopment analysis approach. *Journal of Animal and Plant Sciences, 23*(2), 596-602.

Fan, S. (2000). Technological change, technical and allocative efficiency in Chinese agriculture: The case of rice production in Jiangsu. *Journal of International Development: The Journal of the Development Studies Association*, *12*(1), 1-12.

Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of Royal Statistical Society*, 120(3): 253-290.

Farmal, A., Ashok, P & Mir, S. (2006). Measurement of Profit Efficiency using Behavioural and Stochastic Frontier Approaches. *Applied Economics.* 26(2), 181-188.

Ferrara, G., & Vidoli, F. (2017). Semiparametric stochastic frontier models: A generalized additive model approach. *European Journal of Operational Research*, *258*(2), 761-777.

Fitzpatrick, T., & McQuinn, K. (2008). Measuring bank profit efficiency. *Applied Financial Economics*, *18*(1), 1-8.

Food and Agriculture Organization (FAO) .(2014). Africa Sustainable Livestock 2050: Country Brief Kenya. *Agricultural Outlook.* Accessed: July 13, 2019.

Food and Agriculture Organization of the United Nations (FAO) .(2019). Gateway to dairy production and products: http://www.fao.org/dairy-production-products/production/dairy-animals/camels/en/. Accessed: July 13, 2019.

Food and Agriculture Organization of the United Nations (FAO) .(2022). Gateway to dairy production and products: http://www.fao.org/dairy-production-products/production/dairy-animals/camels/en/. Accessed: April 22, 2022.

Fullerton, R. R., Kennedy, F. A., & Widener, S. K. (2014). Lean manufacturing and firm performance: The incremental contribution of lean management accounting practices. *Journal of Operations Management*, *32*(7-8), 414-428.

Ghasemi, S., Aghsami, A., & Rabbani, M. (2020). Data envelopment analysis for estimate efficiency and ranking operating rooms: a case study. *Int J Res Ind Eng*, *10*(1), 67-86.

Giannakas, K., Tran, K. C., & Tzouvelekas, V. (2003). On the choice of functional form in stochastic frontier modeling. *Empirical Economics*, *28*(1), 75-100.

Gitonga, P.N. (2017). Camel Milk Value Chain Analysis and Feasibility Study_Wajir County, Kenya. https://www.researchgate.net/publication/319459144. Accessed: April 22, 2022.

Gizachew, A., Teha, J., Birhanu, T., & Nekemte, E. (2014). Review on medicinal and nutritional values of camel milk. *Nature and Science*, *12*(12), 35-41.

Habte, M., Eshetu, M., Maryo, M., Andualem, D., Legesse, A., & Admassu, B. (2021). The influence of weather conditions on body temperature, milk composition and yields of the free-ranging dromedary camels in Southeastern rangelands of Ethiopia. *Cogent Food & Agriculture*, *7*(1), 923-932.

Haloho, R. D., Santoso, S. I., Marzuki, S., Roessali, W., & Setiadi, A. (2013). Profit function analysis of dairy cattle farming in Getasan and West Ungaran Districts, Semarang Regency. *Journal of the Indonesian Tropical Animal Agriculture*, *38*(2), 116-122.

Han, Y., & Kim, M. H. (2018). The estimation of profit efficiency. *Applied Economics Letters*, *25*(15), 1066-1070.

Hanrahan, L., McHugh, N., Hennessy, T., Moran, B., Kearney, R., Wallace, M., & Shalloo, L. (2018). Factors associated with profitability in pasture-based systems of milk production. *Journal of Dairy Science*, *101*(6), 5474-5485.

Hansen, B. G., Moland, K., & Lenning, M. I. (2019). How can dairy farmers become more revenue efficient? Efficiency drivers on dairy farms. *International Journal of Agricultural Management*, *8*(2), 65-73.

Huang, T. H., Chiang, D. L., & Lin, C. I. (2017). A new approach to estimating a profit frontier using the censored stochastic frontier model. *The North American Journal of Economics and Finance*, *39*, 68-77.

Huang, C. J., Huang, T. H., & Liu, N. H. (2014). A new approach to estimating the meta-frontier production function based on a stochastic frontier framework. *Journal of Productivity Analysis*, *42*(3), 241-254.

Hughes, E. C., & Anderson, N. E. (2020). Zoonotic pathogens of dromedary camels in Kenya: a systematised review. *Veterinary Sciences*, *7*(3), 103-128.

Iqbal Ali, A., & Lerme, C. S. (1997). Comparative advantage and disadvantage in DEA. *Annals of Operations Research*, *73(4)*, 215-232.

Iruria, O. D., Odhiambo, D. M., & Mairura, M. O. (2009). Economics evaluation of relative profitability in small hold dairy farms in western Kenya. *Journal of Development and Agricultural Economics*, *1*(2), 049-054.

Isako, T & Kimindu, V .(2019). Camel Milk Value Chain in Kenya: A Review. *Journal of Markeeting and Consumer Research*. Vol. 58.2019. DOI**:** 10.7176/JMCR/58-06.

Jondrow, J., Lovell, C. K., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics*, *19*(2-3), 233-238.

Johnson, A. L., & Kuosmanen, T. (2012). One-stage and two-stage DEA estimation of the effects of contextual variables. *European Journal of Operational Research*, *220*(2), 559-570.

Kaindi, D. W. M. (2018). Improving camel milk quality and safety for higher incomes for pastoralists. *AgriFoSe2030/ILRI Policy Brief*. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q. Accessed: April 12, 2022.

Kebede, S., Animut, G., & Zemedu, L. (2013). The contribution of camel milk to pastoralist livelihoods in Ethiopia An economic assessment in Somali Regional State. *IIED Country Report, IIED, London*. *http://pubs. iied. org/10122IIED.* Accessed: June 22, 2020.

Kenya National Bureau of Statistics (KNBS). (2019). Population and Housing Census Survey. Nairobi. Ministry of Finance and Planning. Goverment Printer. Nairobi.

Khan, M. A., Roll, K. H., & Guttormsen, A. (2021). Profit efficiency of Pangas (Pangasius hypophthalmus) pond fish farming in Bangladesh–The effect of farm size. *Aquaculture*, *539*(5), 662-679.

Khezrimotlagh, D., & Chen, Y. (2018). Data envelopment analysis. In *Decision Making and Performance Evaluation Using Data Envelopment Analysis* (pp. 217-234). Springer, Cham.

Kodde, D. A., & Palm, F. C. (1986). Wald criteria for jointly testing equality and inequality restrictions. *Econometrica: Journal of the Econometric Society*, 12(7), 1243-1248.

Kuboja, N. M., Isinika, A. C., & Kilima, F. T. M. (2017). Determinants of economic efficiency among small-scale beekeepers in Tabora and Katavi regions, Tanzania: a stochastic profit frontier approach. *Development Studies Research*, *4*(1), 1-8.

Kutlu, L., Liu, S., & Sickles, R. C. (2020). Cost, revenue, and profit function estimates. *Handbook of Production Economics*, 6(3), 1-39.

Kumari, B., Chandel, B. S., Malhotra, R., Kumari, T., & La, P. (2020). Profit efficiency of women dairy farmers in Begusarai District of Bihar. *Indian Journal of Economics and*

Development, *16*(2), 472-476.

Kumbhakar, S. C. (1987). The specification of technical and allocative inefficiency in stochastic production and profit frontiers. *Journal of Econometrics*, *34*(3), 335-348.

Kumbhakar, S. C. 2001. Estimation of profit functions when profit is not maximum. *American Journal of Agricultural Economics, 83*(1), 1-19.

Kumbhakar, S. C., Biswas, B., & Bailey, D. (1989). A study of economic efficiency of Utah dairy farmers: a system approach. *The Review of Economics and Statistics*, 71(4), 595-604.

Kumbhakar, S. C., Lien, G., & Hardaker, J. B. (2014). Technical efficiency in competing panel data models: a study of Norwegian grain farming. *Journal of Productivity Analysis*, *41*(2), 321-337.

Kumbhakar, S. C., Parmeter, C. F., & Zelenyuk, V. (2020). Stochastic frontier analysis: Foundations and advances I. *Handbook of Production Economics*, 1-40. DOI: https://doi.org/10.1007/978-981-10-3450-3_9-2.

Kumbhakar, S. C., Wang, H., & Horncastle, A. P. (2015). *A Practitioner's Guide to Stochastic Frontier Analysis using Stata*. Cambridge University Press.

Kurwijila, R. L., Mdoe, N. S. Y., Nyange, D. N., Auerbock, R. M. and Malya, H. N. (1995). *Assessment* of *fresh Milk and Milk Products Market and Consumption in Dar es Salaam.* Austro Project Association, Dar es Salaam, Tanzania. 51pp. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q. Accessed: July, 12, 2021.

Lau, I. J. and Yotopolous, P.A. (1971). A test for a relative and application to Indian agriculture. *American Economic Review* ,61(5), 94-109.

Lau, L. J., & Yotopoulos, P. A. (1989). The meta-production function approach to technological change in world agriculture. *Journal of development economics*, *31*(2), 241-269.

Leibenstein, H. (1978). X-inefficiency Exists: Reply to an Exorcist. *The American Economic Review*, 68(1), 203-211.

Leone, R. A. (1986). *Who Profits: Winners, Losers and Government Regulation.* Basic Books, New York.

Machan, S., Agwata, J., & Oguge, N. (2022). Aspects of the sustainability of the camel milk value chain and its regulatory framework in Isiolo County, Northern Kenya. *Journal of Agriculture, Food Systems, and Community Development*, *11*(2), 1-18.

Mahamed, A., Haji, A., Beriso, K., & Gebeyew, K. (2015). Smallholder Camel Milk Production Performance in Jigjiga district, Somali Regional State, Eastern Ethiopia. *Journal of Veterinary Science and Technology*, *6*(23), 6-13.

Masuku, B. B., Masuku, M. B., & Belete, A. (2014). Economic efficiency of smallholder dairy farmers in Swaziland: An application of the profit function. *Journal of Agricultural Studies*, *2*(2), 132-146.

Mawa, L. I., Kavoi, M. M., Baltenweck, I., & Poole, J. (2014). Profit efficiency of dairy farmers in Kenya: An application to smallholder farmers in Rift Valley and Central Province. *Journal of Development and Agricultural Economics*, *6*(11), 455-465.

Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, 19(9),435-444.

Mgbenka, R. N., Mbah, E. N., & Ezeano, C. I. (2016). A review of smallholder farming in Nigeria: Need for transformation. *International Journal of Agricultural Extension and Rural Development Studies*, *3*(2), 43-54.

Moreira, M. J. (2003). A conditional likelihood ratio test for structural models. *Econometrica*, *71*(4), 1027-1048.

Moreira, V. H., & Bravo-Ureta, B. E. (2010). Technical efficiency and metatechnology ratios for dairy farms in three southern cone countries: a stochastic meta-frontier model. *Journal of Productivity Analysis*, *33*(1), 33-45.

Mphafi, K., Oyekale, A. S., & Ndou, P. (2019). Effect of enterprise development support program on market participation and profit efficiency of indigenous vegetable production in South Africa. *Appl. Ecol. Env. Res*, *17*, 6853-6864.

Mujuru, N. M., Obi, A., Mishi, S., & Mdoda, L. (2022). Profit efficiency in family-owned crop farms in Eastern Cape Province of South Africa: a translog profit function approach. *Agriculture & Food Security*, *11*(1), 1-9.

Mulema, A. A., Farnworth, C. R., & Colverson, K. E. (2017). Gender-based constraints and opportunities to women's participation in the small ruminant value chain in Ethiopia: A community capitals analysis. *Community Development*, *48*(3), 351-369.

Muloi, D., Alarcon, P., Ombui, J., Ngeiywa, K. J., Abdullahi, B., Muinde, P., & Fèvre, E. M. (2018). Value chain analysis and sanitary risks of the camel milk system supplying Nairobi city, Kenya. *Preventive Veterinary Medicine*, *159(13)*, 203-210.

Mwalongo, S. S. (2018). *Determinants of Profit Efficiency among Small Scale Dairy cattle Farmers in Njombe district*. *Unpublished PhD* Doctoral dissertation, Sokoine University of Agriculture, Tanzania. https://www.suaire.sua.ac.tz/handle/123456789/2964. Accessed: May, 13, 2021.

Mwangi, L. W., Matofari, J. W., Muliro, P. S., & Bebe, B. O. (2016). Hygienic assessment of spontaneously fermented raw camel milk (suusa) along the informal value chain in Kenya. *International Journal of Food Contamination*, *3*(1), 1-9.

Mwaura, M. W., Wasonga, O. V., Elhadi, Y. A., & Ngugi, R. K. (2015). Economic contribution of the camel milk trade in Isiolo Town, Kenya. *London: IIED*. https://d1wqtxts1xzle7.cloudfront.net/46436357/Economic_contribution_of_the_camel_milk_20160613-25733. Accessed: July 09, 2019.

Nakanwagi, T. T., & Hyuha, T. S. (2015). Technical Efficiency of Milk Producers in Cattle Corridor of Uganda: Kiboga District Case. *Modern Economy*, *6*(07), 846-871.

Nariswari, T. N., & Nugraha, N. M. (2020). Profit growth: impact of net profit margin, gross profit margin and total assests turnover. *International Journal of Finance & Banking Studies (2147-4486)*, *9*(4), 87-96.

Nganga, S. K., Kungu, J., De Ridder, N., & Herrero, M. 2010. Profit efficiency among Kenyan smallholders milk producers: A case study of Meru-South district, Kenya. *African Journal of Agricultural Research*, *5*(5), 332-337.

Nguyen, H. O., Nguyen, H. V., Chang, Y. T., Chin, A. T., & Tongzon, J. (2016). Measuring port efficiency using bootstrapped DEA: the case of Vietnamese ports. *Maritime Policy & Management*, *43*(5), 644-659.

Noor, I. M., Guliye, A. Y., Tariq, M., & Bebe, B. O. (2013). Assessment of camel and camel milk marketing practices in an emerging peri-urban production system in Isiolo County, Kenya. *Pastoralism: Research, Policy and Practice*, *3*(1), 28-53.

Nwachukwu, I. N., & Onyenweaku, C. (2007). Economic efficiency of Fadama Telfairia production in Imo State Nigeria: A Translog profit function approach. *Journal of Agricultural Research and Policies*, 4(2), 87-93.

Odongo, N. O., Lamuka, P. O., Matofari, J. W., & Abong, G. O. (2016). Risk factors associated with the post-harvest loss of milk along camel milk value chain in Isiolo County, Kenya. *African Journal of Agricultural Research*, *11*(8), 674-682.

Odongo, N. O., Matofari, J. W., Lamuka, P. O., & Abey, K. A. (2017). Knowledge and practices of food hygiene and safety among camel milk handlers in the pastoral camel value chain in Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, *17*(1), 11803-11821.

O'Donnell, C. J., Rao, D. P., & Battese, G. E. (2008). Meta-frontier frameworks for the study of firm-level efficiencies and technology ratios. *Empirical Economics*, *34*(2), 231-255.

Ogolla, J. A., Dede, C., Okoth, M. W., Hensel, O., & Sturm, B. (2017). Strategies and technologies for camel milk preservation and utilization of non-marketed milk in arid and semi-arid areas. *East African Agricultural and Forestry Journal*, *82*(2-4), 144-167.

Omwenga, I., Aboge, G. O., Mitema, E. S., Obiero, G., Ngaywa, C., Ngwili, N., & Bett, B. (2019). Staphylococcus aureus enterotoxin genes detected in milk from various livestock species in northern pastoral region of Kenya. *Food Control*, *103*, 126-132.

Onubuogu, G. C., Esiobu, N. S., Nwosu, C. S., & Okereke, C. N. (2014). Resource use efficiency of smallholder cassava farmers in Owerri Agricultural zone, Imo State, Nigeria. *Scholarly Journal of Agricultural Science*, *7*(8), 142-152.

Opoola, O., Mrode, R., Banos, G., Ojango, J., Banga, C., Simm, G., & Chagunda, M. G. G. (2019). Current situations of animal data recording, dairy improvement infrastructure, human capacity and strategic issues affecting dairy production in sub-Saharan Africa. *Tropical animal health and production*, *51*(6), 1699-1705.

Orea L & Kumbhakar SC. (2004). Efficiency measurement using a latent class stochastic frontier model. *Empirical Economics* 29(1): 169–83.

Oselu, S., Ebere, R., & Arimi, J. M. (2022). Camels, Camel Milk, and Camel Milk Product Situation in Kenya in Relation to the World. *International Journal of Food*

Science, (2022), Article ID 1237423. https://doi.org/10.1155/2022/1237423.

Pilar, P. G., Marta, A. P., & Antonio, A. (2018). Profit efficiency and its determinants in small and medium-sized enterprises in Spain. *BRQ Business Research Quarterly*, *21*(4), 238-250.

Rahman, S. (2003). Profit efficiency among Bangladeshi rice farmers. *Food policy*, *28*(5-6), 487-503.

Ray, S. C., & Das, A. (2010). Distribution of cost and profit efficiency: Evidence from Indian banking. *European Journal of Operational Research*, *201*(1), 297-307.

Rasheed, Z. (2017). Medicinal values of bioactive constituents of camel milk: A concise report. *International Journal of Health Sciences*, *11*(5), 1-24.

Roba, G. M., Lelea, M. A., Hensel, O., & Kaufmann, B. (2019). Elusive profits: understanding economic performance of local traders in the pastoral small ruminant value chain in Northern Kenya. *Nomadic Peoples*, *23*(1), 78-105.

Sadiq, M. S., Singh, I. P., Suleiman, A., Isah, M. A., Umar, M. S., Maude, M. A., & Sallawu, H. (2016). Profit Efficiency and Profit Progress among Small Scale Fish Farmers in Niger State, Nigeria: MLE Econometric Profit Frontier Function Approach. *International Journal of Aquaculture*, 5(45), 1-12.

Sahoo, B. K., Mehdiloozad, M., & Tone, K. (2014). Cost, revenue and profit efficiency measurement in DEA: A directional distance function approach. *European Journal of Operational Research*, *237*(3), 921-931.

Sardaro, R., Pieragostini, E., Rubino, G., & Petazzi, F. (2017). Impact of Mycobacterium avium subspecies paratuberculosis on profit efficiency in semi-extensive dairy sheep and goat farms of Apulia, southern Italy. *Preventive Veterinary Medicine, 136(0167-5877),* 56-64.

Schmidt, P., & Lovell, C. K. (1979). Estimating technical and allocative inefficiency relative to stochastic production and cost frontiers. *Journal of Econometrics*, *9*(3), 343-366.

Sumaira, A. M. S., Solangi, G. A., Anwar, I., & Kalwar, Q. (2020). Composition and Beneficial Impact of Camel Milk on Human Health. *Punjab University Journal of Zoology*, *35*(2), 179-189.

Sanusi, S. M. (2015). Profit efficiency of Egusi melon (Colocynthis citrullus var. lanatus) production in Bida local government area of Niger State, Nigeria. *Indian J Econ Dev*, *11(2)*, 543-552.

Syarifa, L. F., Shamsudin, M. N., Radam, A., Latif, I. A., & Haris, U. (2019). Non-Parametric Approach towards Smallholders Rubber Production Efficiency: A Two-Stage Data Envelopment Analysis (DEA). *Journal of Asian Scientific Research*, *9*(2), 10-19.

Tanko, L. (2015). Determinants of profit inefficiency among small scale yam farmers in Nasarawa state, Nigeria: a stochastic Translog profit function approach. *Journal of Emerging Trends in Economics and Management Sciences*, *6*(7), 244-251.

Tasila Konja, D., Mabe, F. N., & Oteng-Frimpong, R. (2019). Profitability and profit efficiency of certified groundnut seed and conventional groundnut production in Northern Ghana: A comparative analysis. *Cogent Economics & Finance*, *7*(1), 163-175.

Tibary, A., & El Allali, K. .(2020). Dromedary camel: A model of heat resistant livestock animal. *Theriogenology*, *154(0093-6916)*, 203-211.

Tijani, A. A., Alimi, T., & Adesiyan, A. T. (2006). Profit efficiency among Nigerian poultry egg farmers: a case study of aiyedoto farm settlement, Nigeria. *Research Journal of Agricultural Biological Sciences*, *2*(6), 256-261.

Tingirtu, G. T. (2019). Promoting female leaders in Somali Region, Ethiopia: An entrepreneurship approach. *International Journal of Sociology and Anthropology*, *11*(2), 18-26.

Tsue, P. T., Lawal, W. L., & Ayuba, V. O. (2012). Profit efficiency among catfish farmers in Benue State, Nigeria. *African Journal of Food, Agriculture, Nutrition and Development*, *12*(6). 457-482.

Villano, R., & Mehrabi Boshrabadi, H. (2010). When is metafrontier analysis appropriate? An example of varietal differences in pistachio production in Iran. *Journal of Agricultural Science and Technology*, *12*(4), 379-389.

Wambua, B. N. (2019). Analysis of the Current and Potential Future Climate Hazards and their Impacts on Livelihoods and Adaptation Strategies in Arid and Semiarid Lands. *Asian Journal of Agriculture and Food Sciences*, *7*(4). 2567-2592.

Wang, Z., Dean, T., & Kowalski, B. R. (1995). Additive background correction in multivariate instrument standardization. *Analytical Chemistry*, *67*(14), 2379-2385.

Watson, E. E., Kochore, H. H., & Dabasso, B. H. (2016). Camels and climate resilience: adaptation in northern Kenya. *Human Ecology*, *44*(6), 701-713.

Wayua, F. O., Okoth, M. W., & Wangoh, J., (2012). Survey of post-harvest handling, preservation and processing practices along the camel milk chain in Isiolo district, Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, *12(7*, 1684-5374,

Wongnaa, C. A., Awunyo-Vitor, D., Mensah, A., & Adams, F. (2019). Profit efficiency among maize farmers and implications for poverty alleviation and food security in Ghana. *Scientific African*, *6(2468-2276)*, e00206.

Zibaee, S. (2015). Nutritional and therapeutic characteristics of camel milk in children: a Systematic review. *Electronic Physicians*, 7(7), 1523.

Yegon, M., Omunyin, M., Bii, F., & Ruto, J. (2016). observations on dairy dattle production related to land holding, Value Addition and Marketing of Milk in Kericho and Bomet Counties of

Kenya. *International Journal of Livestock Research.* 6 (1), 68-77.

APPENDICES

Appendix I: Questionnaire

ASSESSMENT OF THE MICROBIAL QUALITY AND SAFETY OF CAMEL MILK AND PRODUCTS AND ECONOMIC LOSSES ALONG THE DROMEDARY MILK VALUE CHAIN IN NORTHERN KENYA

SECTION A : QUESTIONNAIRE IDENTIFICATION

Sample/Questionnaire Code ______________________
Date of interview: (dd/mm/yy) [______ / _____ / _______]
Name of enumerator __________________________________
Name of respondent ____Mobile Phone No.
____
Type of milk Seller [___] (Code)
County ________________ Sub-County _______________Trading Centre/Road_________________
GIS co-ordinates: E________________ N__________________________

Codes
Type of milk seller
1=Seller of Own Milk, 2=Aggregator (Wholesaler) 3=Milk vendor (Retailer) 4=Others (specify)______________ ______________

SECTION B: BACKGROUND INFORMATION

A. Background for camel milk trader

Type of business	Name of owner of business (if respondent is not the owner)	Gender of owner of business (M/F)	Age of owner of business	Years the owner has been in business
[_____]	________________________	[___]	[___] years	[___] years

Type of business
1= Mobile trader (bicycle), 2= Mobile trader (*Bodaboda*), 3= Mobile trader (Matatu/Bus), 4= Shop/Kiosk, 5 = Milk-bar, 6= Selling own milk, 7=Others (specify)_____________________________

SECTION C: INFORMATION ON MILK PROCUREMENT, HANDLING AND SALE

Qi). Milk procurement and handling

Source area (Name)	Source type	Number of suppliers	Average amount per supplier per Day (Liters)	Organization of collection	Amount procured yesterday (liters)	Purchase price (KES/Liter)	Quality control measures before receiving milk	Type of milk containers used by suppliers?
i.	[______]			[____]			[___][___][___]	[___] [___]
ii.	[______]			[____]			[___][___][___]	[___] [___]
iii.	[______]			[____]			[___][___][___]	[___] [___]
iv.	[______]			[____]			[___][___][___]	[___] [___]
v.	[______]			[____]			[___][___][___]	[___] [___]
vi.	[______]			[____]			[___][___][___]	[___] [___]
vii.	[______]			[____]			[___][___][___]	[___] [___]

CODES

Source type	Organization of collection	Quality control measures by trader	Type of milk cans
1 = Own Camels	1=Producers deliver to collection point	1= None	1=Metal cans
2 = Individual camel keeper	2=Traders deliver to collection point	2= Odour test	2=Plastic cans
3 = Self-help group	3=Producers deliver to collection premises	3= Visual check	3=Traditional guard
4 = Private processor	4=Traders deliver to collection premises	4= Tasting	4=Others (specify)_________
5 = Dairy co-op. Society	5=Buyer collects at a group/co-op collection point	5= Lactometer	
6 = Traders/hawkers	6=Buyer collects from producer's homesteads	6= Alcohol test	
7 = Others (specify)_____	7=Group/co-op deliver to trader's premises	7= Boiling	
	8=Others (specify)_____________________	8= Others (Specify)_______	

Qii). Milk procurement and handling (cont'd)

Method(s) of preservation	Mode of cleaning containers by trader	Sales area	Distance to the resale area (km)	Mode of transport to sales area	Time between collection/ Milking until sale (Hours)	Do you process milk? (Y/N)	What products does the market agent make
[___][___]	[___][___]		[___]	[_________]			[_______________]]

Method of milk preservation	Mode of cleaning milk containers	Mode of transport	Major sales products
1= Not treated	1 = With cold water alone	1=On foot	1= Maziwa Lala Mala/ "*Susa*"
2= Boiling	2 = With hot water alone	2=Draught animals/cart	2=Yoghurt, own processed
3= Refrigerating/chilling	3 = With cold water and soap	3=Bicycle	3=Yoghurt, not own processed
4= Cold water bath	4 = With hot water and soap	4=*Boda boda*	4=Milk shake
5= Antibiotics added	5 = Cold water, scrubbing with soap solution	5=Open public service vehicles	7=Others (specify) ______
6= Hydrogen peroxide	6 = Hot water, scrubbing with soap solution	6=Closed public service vehicles	
7=Smoking/Traditional fumigation using hot/burning wood/charcoal	7=Smoking/Traditional fumigation using hot/burning wood/charcoal	7=Open private vehicle	
8= Other additives / preservation method (specify) ______	8=Others (Specify) _____	8=Closed private vehicle	
		9=Others (specify) __________	

B2. Camel milk and milk product sales and spoilage

Type of camel milk product sold	Unit of sale	Selling price (KSH)	Amount usually sold per day	Average Amount left-over daily		Fate of left-over milk/milk product	Amount of milk/milk product spoilt daily		Fate of milk/milk product spoilt daily	Selling price of spoilt milk (KES /the specified unit of measure)
				Unit of measure	Total number of units		Unit of measure	Total number of units		
Fresh milk	[___]									
	[___]						[____]		[____]	
	[___]									
Mala/Lala/Susa	[___]									
	[___]						[____]		[____]	
	[___]									
Others (specify)	[___]									
	[___]						[____]		[____]	
	[___]									
	[___]									

Codes

Major sales products	Unit of Sale/measure	Fate of leftover milk	L. Fate of spoilt milk and milk products
1=Raw fresh milk	1=Liter	1=Thrown away	1=Thrown away
2=Mala/Lala/Susa	2=Kg	2=Used by family	2= Given to animals
3=Yoghurt, own processed	3=Treetop bottle(750ml)	3=Un-boiled, naturally fermented and used by family	3=Sold at a low price (salvage price)
4=Yoghurt, not own processed	4=Soda bottle (300ml)	4=Un-boiled, naturally fermented and used and sold	4=Others (specify)______________________
5=Milk shake	5=Small cup (350ml)	5=Boiled, naturally fermented	
6=Cream	6=Large cup (500ml)		
	7=Others (specify)		

7=Ice cream 8=Others (specify) ______________________	______________	and used and sold 6=Given to animals 7=Processed into Mala (cultured) 8=Refrigerated and sold 9=Others (specify) _______________	

SECTION D. PERCEPTIONS ABOUT THE CAUSES OF CAMEL MILK SPOILAGE

C.1. What are the three (3) most important causes of camel milk spoilage as perceived by camel milk sellers?

1____

2____

3____

C2. What are the three (3) most important product attributes or concerns about the safety of camel milk by customers?

1____

2____

3____

SECTION E: TRAINING ON MILK HANDLING AND QUALITY CONTROL

D1. Have you received any training on hygienic milk handling and quality control? [_____] 1=Yes, 0=No

D2. If Yes, give details

Duration of Training	Where was the training received?	Practices learnt at the training	New practices used after training	New practices learnt and planned to be used	Any other topic (s) you need to learn	Reasons for not using new practices learnt, if any

______ days;	________________	[___][___][___]	[___][___][___]	[___][___][___]		[___][___]

CODES

New Practices learnt = None = Odour test = Visual check = Tasting	= Lactometer = Alcohol test = Boiling = Hygienic handling of milk at the farm = Others (Specify)________________________________	B. Reasons for not using practices learnt 1 = Not necessary 2 = Lack of money 3 = Other (specify) ____________________

SECTION F: LABOUR FORCE

D1. How many of the workers do you engage? How much do you pay them including other benefits?

	Number	Daily wage	Other benefits
Men			
Women			

SECTION G: COSTS

CAPITAL EQUIPMENTS

		Number	% share of daily use in dairy activity	Estimated replacement cost at present
Handling equipment	Aluminium cans			
	Jerricans			
	Crates			
	Freezers			
	Jikos			
	Sufurias			
	Cooling tanks			
	Scoops			

	Sealers				
	Funnels				
	Stirrer				
	Others (specify) ________				
Quality check equipment	Lactometer				
	Alcohol gun				
	Thermometer				
	Others (Specify)________________				
Transportation equipment	Bicycles				
	Motorbike				
	Draught animals				
	Carts				
	Pickup/Van/Truck				
Furnishings (furnishers – tables, chairs	i.				
	ii.				
	iii.				
	iv.				

INTERMEDIATE COSTS

Item		Unit	Price/unit (KES)	Number of units per month	Total expenditure/month
Utilities	Rent for premises				
	Electricity				
	Water				
Milk processing agents	Inoculants				
	Sugar				
	Food colouring				
	Fuel (charcoal, firewood, kerosene)				

Others	Soaps and detergents				
	Stationery				
	Repairs and maintenance				

OTHER EXPENSES

Licence fees ______________ KES/year

Contingency protection fee (police, council askaris, KDB inspectors, harassment) ___________KES/month

SECTION H. CONSTRAINTS

F.1 Give some three constraints to the camel milk business (starting with the most important as number 1) and your suggestions of solutions

Constraint	Suggested of solution
1	
2	
3	
4	

SECTION I: OBSERVATION CHECKLIST/GUIDE

What is the ambient temperatures at the time of the interview?...............................

What containers are being used by the interviewee to carry the milk/product? (Please explain your response and take photo) – link photos to questionnaire code

Traditional guard/calabash ☐ Jerric ☐ Alluminium cans ☐

Where is the milk selling point/place (Please explain your response and take photo)

Out in the open in the sur ☐ Open but under some sh ☐ Inside a milk bar/building ☐

i)Type of milk measuring gadget ....

NOTE: Use a measuring cylinder to determine the equivalent of the used measuring gadget in liters

What is the price fresh of milk and product at the time of the interview (KES)

Fresh camel milk.........................Camel milk product (Specify)...

What is the level of observable cleanliness – attributes of cleaniliness and code the attributes – very clean, dirty, moderately clean etc. / hygiene (Please explain your obserbations and take photo)

Very dirty ☐ Moderate ☐ Very clean ☐

Other (Specify) ☐ ....

What is the level of observable cleanliness of the containers (Please explain your observations and take photo)

Very dirt ☐ Moderate ☐ Very clean ☐

Other (Specify) ☐ ....

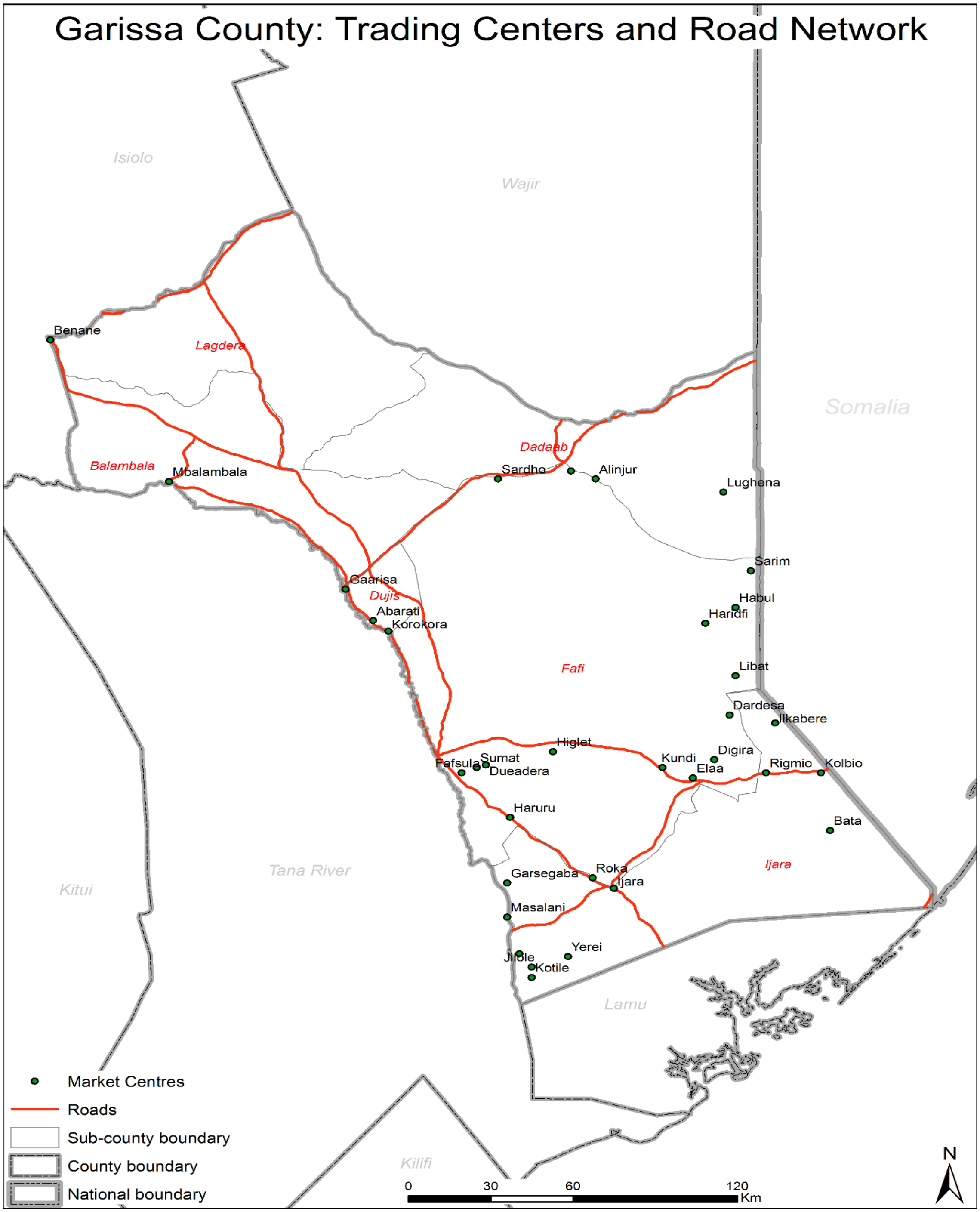
NOTE:
If possible swab some empty traditional container(s). Additionally, buy some jerricans for opening them up and swabbing the hidden points inside the jerricans (at the handles etc.) (Please explain your observations and take photo)
Thank you so much for participating. We hope to use your responses to help screen milk to reduce disease.

Appendix II: Isiolo County map showing camel population distribution

Areas	**Estimated population**	
Gotu	15,000	15,000
Kachuru	3,200	5,000
Barambate	2,300	
Kulamawe	3,000	
Boji	1,500	
Kinna-Rapsu	5,000	5,000
Oldonyiro-Kipsing-Longopito	10,000	10,000
Shaab-Lombolio-Kubi foni-Ngare mara	5,000	5,000
Malka daka, Biliqo, Bulesa	5,000	5,000
Merti	5,000	5,000
Garbatulla	5,000	5,000

Key: 1: 5,000 (one image=5,000 heads of camel)
NOTE: Camel population estimate at 2014 according to department of livestock was 45,309 *(***Source**:** Department of livestock annual report 2014 and Isiolo County livestock strategy 2015-2020)*. *******The population estimate for 2014 was arrived at using compound formulae for livestock population projections = (P (1+r) n). The value for each livestock unit was calculated using the national assumed mean value. Where P = base year census livestock population (2009), r = projection rate, and n = number of years. Annual percentage increase for camel was at 3%. Therefore, estimate for 2017 with annual percentage increase of 3% + influx from other counties.
Source of Information: - *Department of livestock Production and marketing, Key camel producers, Chiefs and Camel milk transporters).*

Appendix III: Trading Centers and Road Network in Garissa County



Appendix IV: Camel poplation distribution in Wajir County