

**ECONOMIC DETERMINANTS OF DAIRY COW MILK PRODUCTION
AMONG SMALL-SCALE FARMERS IN MARAKWET EAST SUB-COUNTY,
ELGEYO-MARAKWET COUNTY, KENYA**

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KENYA**

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has never been presented for the award of an academic degree in any other university and should not be copied, or reproduced in any format without written authority from the author and/or University of Eldoret.

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DEDICATION

This thesis is dedicated to my beloved wife, Beatrice, for her moral and financial support, self-sacrifice, and determination. I dedicate this work also to my children, Joy, Lynn, Don, and Tracy, my parents, and my siblings for their invaluable support during my research period.

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ABSTRACT

Dairy farming remains a major economic backbone in Kenya, contributing food and income to the households of many small-scale farmers. In Marakwet East Sub-County, however, annual milk production has plateaued at approximately 25 metric tonnes of milk despite concerted improvement efforts in recent decades. The average milk production per cow per day between 2016 and 2021 was 5.52-5.75 liters against a national potential of 10-12 liters per day achievable under optimal dairy farming conditions. This study's specific objectives were to determine socio-economic, technological, farm production, and institutional factors influencing dairy cow milk production among small-scale dairy farmers in Marakwet East Sub-County. Production and resource allocation theories guided the study while descriptive and cross-sectional research designs were adopted. Primary data was collected using a questionnaire from 230 small-scale dairy farmers through purposive, stratified, and systematic random sampling techniques. Secondary data was collected from existing records. Multiple Linear regression model and Cobb-Douglas production functions (double log-linear form) were used to analyze data. Descriptive results revealed that the mean age of the small-scale dairy farmers was 47 years, owned on average 3.3 acres of land, with 16.8 years of farming experience, and earning an average annual farmer income of KShs. 91,938. Multiple linear regression results revealed that a unit increase in the level of education, family/household size, farmer's experience, and total farmer's income positively affected dairy cow milk production by 60.2%, 109.1%, 131.1%, and 112.2%, respectively. Technological factors like artificial Insemination, deworming services, high-yielding fodder/pasture, improved feeds, and improved dairy breeds positively affected milk production by 69%, 68.4%, 183.4%, 178% and 167.2% respectively. Further, results revealed that a unit increase in the type of land tenure system, access to extension services and credit facilities, and membership in farmer organizations had a positive influence on milk production by 45%, 172.4%, 190.4% and 105.6%, respectively. Cobb-Douglas production function results revealed that a unit increase in farm size, capital, type of dairy breed, farming system, access to veterinary services, and quality feeds positively influenced milk production by 21.51%, 82.37%, 46.23%, 89.97%, 82.60% and 108.23%, respectively. To enhance dairy milk production, the study recommends strategies that encourage farmers to direct their resources toward securing high-quality feeds and improving their farming systems, promoting interventions and activities geared towards the adoption of technologies that improve milk production, such as access to credit facilities, subsidies, or micro financing programs to boost farmers' capital, and enhance veterinary care and education. Additionally, policymakers should encourage the adoption of high-yielding breeds through subsidies and breeding programs. There is need to improve access to quality feeds, farming system, and capital to boost milk production.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFC	Agricultural Finance Cooperation
AI	Artificial insemination
ANOVA	Analysis of Variance
ASAL	Arid and Semi-Arid Land
ASDSP	Agriculture Sector Development Support Programme
BMT	Billion Metric Ton
CIDP	County Integrated Development Pan
COMESA	Common Market for Eastern and Southern Africa
DFID	Department for International Development
DMI	Dry Matter Intake
EAAPP	East Africa Agriculture Productivity Programme
EADD	East Africa Dairy Development
ECM	Energy Corrected Milk
EMC	Elgeyo Marakwet County
EU	European Union
FAO	Food and Agriculture Organization
FCS	Farmers' Cooperative Society
GDP	Gross Domestic Product
GM	Gross Margin
GOK	Government of Kenya
ICT	Information and Communication Technology
IFAD	International Fund for Agricultural Development
IFCN	International Farm Comparison Network
ILRI	International Livestock Research Institute
KALRO	Kenya Agricultural and Livestock Research Organization
KCSAP	Kenya Climate Smart Agriculture Project
KDB	Kenya Dairy Board
KDP	Kenya Dairy Project
KDSCP	Kenya Dairy Sector Competitiveness Programme
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KNBS	Kenya National Bureau of Statistics
KSH	Kenya Shillings
MDG	Millennium Development Goals

MFI	Monetary and Financial Institutions
MLR	Multiple Linear Regression
MMT	Million Metric Tons
MOLD	Ministry of Livestock Development
MSR	Mixed Silage Rations
NACOSTI	National Commission for Science, Technology and Innovation
NKCC	New Kenya Cooperative Creameries
PA	Per Annum
SDCP	Small-scale Dairy Commercialization Programme
SDG	Sustainable Development Goal
SMP	Skimmed Milk Product
SPSS	Statistical Package for Social Sciences
SRA	Strategy for Revitalization of Agriculture
SSA	Sub-Saharan Africa
SSMV	Small Scale Milk Vendors
TMR	Total Mixed Rations
TSP	Total-Factor Productivity
UK	United Kingdom
USA	United States of America
USAID	United States Agency for International Development
USMCA	United States-Mexico-Canada Agreement
VIF	Variance Inflation Factor

OPERATIONAL DEFINITION OF TERMS

- Dairy Breed** Specific breeds of cattle that have been systematically selected for the primary purpose of producing milk.
- Improved dairy breeds** Breeds of dairy cattle that have been genetically enhanced to have desirable traits such as higher milk yield, greater resistance to diseases, and better adaptation to local conditions
- Dairy cows:** These are cows bred to produce milk, which can be consumed, sold, or from which dairy products can be made.
- Dairy “Cow milk”** Liquid produced by dairy cows, comprising approximately 4.8% lactose, 3% protein (80% of which is casein), 3–4% fat, and essential nutrients such as calcium, phosphorus, and various vitamins
- Dairy Sector:** This refers to an area of the economy or an industry in which the dairy business operates to produce, market, consume, and/or process raw milk. In the study area, the dairy sector refers to the production of milk from dairy cows for consumption, marketing, or processing into other milk products.
- Farm input factors:** These are resources that are used in farm production, such as chemicals, equipment, feed, seed, and energy. For this study, the farm input factors were access to capital, access to clean water, access to extension services, access to feeds/grazing, access to grazing lands, access to information, accessibility of markets, availability and quality of information, availability of

adequate infrastructure, availability of credit, cost of production, dairy breed types, extension support, and land tenure system.

Milk production: In this study, milk production is the activity of producing and handling milk on a dairy farm, but does not include activities such as transporting, pasteurizing, or homogenizing milk or making butter, cheese, ice cream, or other dairy products.

Small-scale farmers: These are farmers keeping dairy cows with a herd of less than 10 cattle on land sizes that range from 1 to 6 acres. Therefore, in this study, farmers with a herd of less than ten dairy cattle, irrespective of the breeds and producing milk (lactating) were considered to be small-scale dairy farmers.

Economic factors: These are factors that can affect and influence an individual's financial status.

Socio-economic factors: These are social factors of the dairy farmers e.g. age, marital status, sex, education level, income, and occupation, among others, that in one way or the other affect productivity.

Technological factors: This refers to the ways new practices and equipment can affect businesses or production systems. These factors create new tools, machinery, skills, or information and thereby create new products and market opportunities. In this study, technology was considered as practices such as artificial insemination, emerging vaccination methods, milk storage facilities, feeding facilities, Hay/silage technology, new technologies for information exchange, and milk processing technologies.

Institutional factors: Refers to the organizational structures, policies, and support systems that influence and shape dairy cow milk production, including access to extension services, farmer cooperatives, supportive policies, and market linkages. These factors play a role in facilitating or constraining the development and success of dairy farming activities.

Market linkages: Refers to the connections and relationships established by dairy farmers with various market actors, including milk processors, wholesalers, retailers, and consumers. Strong market linkages facilitate the efficient and profitable sale of dairy products, while also providing access to market information and opportunities for value addition.

Extension services: Refers to the provision of advisory, educational, and technical support to dairy farmers by extension agents or agricultural experts. Extension services aim to improve farmers' knowledge and skills, promote best practices, and enhance the adoption of new technologies and innovations in dairy cow milk production.

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter presents the background, statement of the problem, objectives, hypotheses, significance, justification, scope, limitations, and assumptions of the study.

1.2 Background Information of the Study

The Livestock sector plays an important role in the provision of food and income to farmers and households, as well as in improving the structure and fertility of the soil (Bowles *et al.*, 2019; Hoque *et al.*, 2022; Liu *et al.*, 2023). As a result, the livestock sector is one of the fastest-growing segments of the agricultural economy worldwide (Beck *et al.*, 2023). At the global level, the value of the livestock sector to the growth of national economies between 2016 to 2021 was 42% and 22% of total agricultural output in developed and developing nations, respectively (Pandey and Upadhyay, 2022). Approximately 987 million or about 28% of the 3.42 billion of the world's poor depend on livestock production for food and income (Haldar *et al.*, 2022).

The dairy industry dominates the livestock sector in several countries (Grelet *et al.*, 2021; Bojovic & McGregor, 2023) due to the rapid increase in demand for milk, which stood at 105-110 g/capita/day against a supply of 51.4 g/capita/day in 2020 (Radwan *et al.*, 2020; Henschion *et al.*, 2021). In 2015, the dairy sector produced 497 million metric tons (MMT) of cow milk worldwide; by 2021, that figure rose to around 844 MMT (Miller *et al.*, 2022) against a demand of about 1.64 billion metric tons (BMT) (Mickiewicz and Volkava, 2022).

Demand for milk will likely continue to increase globally by about 3.5% annually, with milk production growth expected to be slightly above 2% annually (Smith *et al.*, 2022).

Worldwide, 843 MMT of milk is produced per year (Bhat *et al.*, 2022). In countries such as the United States of America, Western European countries, Russia, the United Kingdom, China, India, and the Scandinavian countries dairy farming is done on a large scale and it is highly mechanized (Duan *et al.*, 2022; Owusu-Apenten and Vieira, 2022). This is reflected in the milk production by 2020 which was dominated by India (187.95 MMT), the European Union (143.9 MMT), USA (102.4 MMT), Pakistan (45.78 MMT), China (35.6 MMT), Brazil (34.7 MMT), Russia (30.6 MMT), and United Kingdom (21.4 MMT) (FAO, 2022). Other top 12 milk-producing countries include New Zealand (21.39 MMT), Mexico (12.4 MMT), Argentina (10.5 MMT), Ukraine (10.2 MMT), and Australia (9.29 MMT). Among these 12 countries, only India and China rank among developing countries, and production is quite high due to the large population in those countries.

Approximately 150-230 million households around the globe are engaged in raw cow milk production (Van Heerden, 2019; Budiman and Alta, 2022). Among these, over 80% of the raw milk volume produced globally comes from small-scale dairy cattle production systems (Feyissa *et al.*, 2023; Rowe *et al.*, 2023). Small-scale dairy farmers are estimated at 700 to 950 million (10 to 12%) of the world population (Lema *et al.*, 2023). On average, these small-scale farmers rear two milking cows producing about 11 liters per day (Dallago *et al.*, 2021).

The dairy sector is responsible for producing milk and other processed milk products, which are important sources of nutrition and livelihoods for millions of people across the world (Rodriguez, 2020; Miller *et al.*, 2022). Most dairy products are consumed in the form of fresh unprocessed milk, freshly processed milk, or only slightly processed (i.e., pasteurized or fermented) and their share in world consumption is expected to increase over the next decade (Campbell and Marshall, 2016). The majority of the world's milk comes from cows (81%), buffalo (14%), goats (4%), and about 1% of the milk is derived from combined goats, sheep and camel (Bittante *et al.*, 2022; Pandey and Upadhyay, 2022). Caution is, however, required when studies of milk production are being undertaken since statistics of milk production from buffalo are very rare and the international conventions do not allow for the world trade of wild animal products, including milk. Therefore, most of the available studies on milk production come from cow milk, with some statistics from the arid areas emphasizing milk from camels. For this study, milk will refer to cow milk.

The global per capita consumption of milk in 2022 was between 105 to 110 g/capita/day (Smith *et al.*, 2022b). However, more milk is expected to be consumed over the medium term, thus increasing the overall, global per capita consumption to 219 g/capita/day by 2031 in high-income countries and 175 g/capita/day and 145 g/capita/day in low-middle income and low-income countries, respectively (Henchion *et al.*, 2021; Headey, 2023). The key drivers for the increasing milk overall and per capita milk consumption are intricately linked to higher demands for milk in India, China, Pakistan, and Africa, where population growth is increasing tremendously (Mishra *et al.*, 2021). In low and middle-income countries, fresh dairy products comprise over 70% of the average per capita dairy

consumption (milk solids), while consumers in high-income countries tend toward processed products (Rodriguez, 2020).

The Asian Continent produces over 50% of the global milk production, which stood at 400 MMT in 2021, up 2.9% year-on-year, principally driven by increases in India, China, Pakistan, Uzbekistan, Kazakhstan, and Japan (Bekhit *et al.*, 2022). Over 50% of milk production in the Asian Continent came from India (210 MMT) due to the favourable climate, the genetic potential of dairy cattle, fodder availability and expanded milk collection (Kumar *et al.*, 2023). In China, increased investment in large-scale farms, higher quality genetics and vertically integrated production systems, which led to an increase in dairy cattle and productivity, underpinned a 7% expansion in milk output in 2021 (Jia and Chen, 2023). In Pakistan, the increased number of dairy cattle improved milk production by 3.2% while the modernization of farms facilitated milk production expansions in Kazakhstan and Uzbekistan (Robinson, 2020). In Japan, government subsidies and dairy herd expansion led to a 2.1% increase in output in 2021 (Kitano *et al.*, 2022).

In the European Union (EU), milk production reached 143.9 million tons, a slight decrease (-0.4%) from 2020, mainly due to declines in Ukraine and France (Bórawski *et al.*, 2022). Milk output in the EU is expected to grow more slowly than the global average at 0.5% annually, due to policies aimed at sustainable milk production and pasture-based systems. In the EU, increased production accelerated the decline in dairy cattle numbers, which significantly reduced milk deliveries (Bórawski *et al.*, 2022).

In North America, milk output reached nearly 112 MMT in 2021. In the United States, milk output rose by 1.3%, reaching 102.4 MMT, driven by high dairy cow numbers until mid-2021 (Henderson *et al.*, 2023). In Canada, milk output increased by 1.7%, reflecting a rebound in dairy cattle numbers to a 15-year high due to increased farm gate milk prices (Matson *et al.*, 2021). The continent has some of the highest average yields per cow, as the share of grass-based production is low, and feeding is focused on high yields from specialized dairy herds (Sebastianski *et al.*, 2022). As domestic demand is projected to remain stronger for milk and milk products, the United States will mostly export skim milk powder (SMP), while Canadian exports of SMP are capped under the United States-Mexico-Canada Agreement (USMCA) (Dufour and Hurdle, 2022).

In Oceania, following a 1.1% expansion in 2020, milk output decreased marginally (0.2%) in 2021, reaching 31 MMT (Mickiewicz and Volkava, 2022). In Australia, poor rainy conditions and increased input costs of fertilizer and energy, combined with the skilled labour shortage, led to a decline in milk production by 0.8% in 2021 (Rezitis and Rokopanos, 2019). In New Zealand, milk output increased by a meager 0.1% in 2021, principally due to cold and wet spring conditions that prevailed towards the end of 2020 and several supply-side constraints, including increased input costs, labour shortages, and relatively tight producer margins (Edwards, 2019). Although the share of New Zealand in world milk production is currently only 2.5%, it is the most export-oriented country (Gardner *et al.*, 2020). Milk output growth has been very modest in recent years, and it is projected to grow at 0.4% p.a. over the next decade. The main constraining factors for

growth are land availability and increasing environmental restrictions, but a shift to a more feed-based production is not likely.

Dairy production in Africa plays a central role in the region's economic and sustainable development (Mutembei, 2022). The industry has been growing gradually, where traditional systems have dominated milk production for several years and still supply considerable amounts of milk today, accounting for above 90% of the dairy ruminant population in Sub-Saharan Africa (Monica, 2022). The total volume of milk in the continent stood at about 13.67 MMT to 14.92 MMT from 2006 through 2010, which continued with surges to over 46.62 MMT in 2022 (Mishra *et al.*, 2021; Wu *et al.*, 2022). These values represent only about 5% of the world's milk production. In 2022, quintet African countries led by Kenya (4.92 MMT), Sudan (4.59 MMT), Egypt (4.47 MMT), South Africa (3.75 MMT), South Sudan (3.26 MMT), Algeria (3.06 MMT) and Ethiopia (2.77 MMT), accounted for over 70% of the total milk production from small-scale dairy farming (Merem *et al.*, 2022). The second-tier class of African Nations led by Somalia (2.15 MMT), Mali (2.12 MMT), Morocco (1.78 MMT), Uganda (1.73 MMT), and Tanzania (1.64 MMT) accounted for 20% of milk production, which exceeded the combined total for the remaining 42 African countries (FAO, 2022).

Eastern Africa is the leading milk-producing region in Africa, representing 51% of the continent's milk output. The region holds 50% of Africa's cattle, about 300 million head (Headey, 2023). The dairy sector is one of the fastest-growing agricultural sub-sectors in Eastern African countries, which has generated significant economic returns, employment

opportunities, and dairy value chains (Merem *et al.*, 2022). In Eastern Africa, Kenya's dairy farming sub-sector, followed by Uganda and Tanzania, is the most vibrant, and it has the highest milk per capita availability (Adeyanju *et al.*, 2023).

Milk production grew steadily in East Africa in the 1980s and 1990s. The pace of growth has since accelerated following recent high rates of income growth and urbanization, representing 51% of the continent's milk output (Paul *et al.*, 2020). Estimates indicate that by 2021, East Africa will produce about 23.4 MMT of milk from about 300 million herds of dairy heads (Headey, 2023). The dairy sector is one of the fastest-growing agricultural sub-sectors in Eastern African countries, where annual rates of milk production increased from the 1990s to 2022, were 4.1% in Kenya, 3.1% in Ethiopia, 2.6% in Uganda, and 2.2% in Tanzania (Merem *et al.*, 2022). One reason for such high growth in milk production is high domestic production from the increasing intensification of dairy farming, as well as increased consumption (Brandt *et al.*, 2020).

Dairy farming has a significant contribution to Kenya's economy (Nyokabi, 2023). Kenya has one of the largest dairy industries in sub-Saharan Africa with an improved cattle herd larger than all of the rest of Eastern and Southern Africa (Habermann *et al.*, 2022; Nyokabi, 2023). Dairy farming is the single largest sub-sector of agriculture in Kenya, contributing 14% of Agricultural GDP and 3.5% of total GDP (FAO, 2022). Dairy milk production in Kenya, among small-scale farmers, stood at 510.5 million litres (4.92 MMT) in the year 2021, up from 491.6 million liters (4.75 MMT) in 2016 (FAO, 2022; King'ori, 2022). Currently, the sector is experiencing one of the highest growth rates of 3 to 4% annually.

Small-scale dairy farmers dominate the sector (80%) with about 1.8 million farmers involved in the production of milk (Koech, 2023). These dairy farmers have a farm size of about 3–5 acres, keeping 2–5 cows which produce about 5L of milk per day (Mwanga *et al.*, 2019). In addition, the sector produced 4.92 MMT in the year 2021 (FAO, 2022; King'ori, 2022), which makes it the highest producer of milk in sub-Saharan Africa. Moreover, the demand for milk and milk products in Kenya is among the highest in developing countries (King'ori, 2022; Headey, 2023). It has 1.8 million small-scale farmers who produce over 80% of the domestic milk and sell raw milk directly to consumers (King'ori, 2022). Most of the dairy farming is done in the populated regions of Central and the Rift Valley regions (Nabiswa, 2023). The success of dairy production on small scales is also a result of the presence of a significant dairy cattle population, the importance of milk for most Kenyan communities, a suitable climate, and an enabling policy and institutional environment (Wairimu *et al.*, 2022; Siele *et al.*, 2023).

Many small-scale farmers in Kenya own less than 5 acres of land and hence practice semi-intensive dairy farming where they do either open grazing with zebu cattle where cattle are herded on their own or other people's farms or communal lands; with crossbred cows which involves the use of cultivated pastures with some minerals and concentrates stall feeding; semi zero-grazing where animals are confined in an enclosure for part of the day and released to pasture for the rest of the day where they are supplemented with concentrates; and full zero grazing with stall feeding programmes (Bosire *et al.*, 2019; Basu and Galiè, 2021). The widespread dairy milk production of dairy cattle in the country was stimulated by several interacting factors such as the conducive policy and institutional

environments provided by successive governments; the presence of significant dairy populations (owned by settler farmers); a sub-tropical geography suitable for dairy cattle; and small-scale communities who kept cattle and who had milk as an important part of their diet (Mburu *et al.*, 2007; Chagunda *et al.*, 2016).

Small-scale dairy farming plays a pivotal role in Kenya's agricultural landscape, serving as a cornerstone of both milk production and rural livelihoods (Siele *et al.*, 2023). These small-scale farmers are the unsung heroes of the dairy industry, collectively owning approximately 80% of the nation's dairy cattle. This segment of the industry is responsible for an impressive 56% of Kenya's total milk output, and it supplies an astonishing 80% of the milk that flows into the Kenyan market (KDB, 2023).

According to Herrero *et al.* (2010), small-scale dairy farmers in Kenya typically yield milk ranging from 5 to 50 litres per cow per day, and their herds typically consist of 5 to 10 cows each. These small-scale dairy farmers make up a substantial portion of Kenya's livestock population, constituting roughly 27% of the total livestock numbers. This population of cattle in Kenya comprises 14.1 million indigenous cattle and 3.4 million exotic cattle, which adds up to 17.5 million cattle in total (KNBS, 2019).

Small-scale dairy farmers in Kenya typically prefer breeds such as Friesian, Ayrshire, Jersey, Guernsey, and their crosses. The choice of these breeds provides the flexibility to accommodate variations in milk production capabilities and genetic resilience within the sector (Kirea, 2023). Given its enormous economic contribution, the small-scale dairy farming sector in Kenya is nothing short of remarkable. In 2022, this sector contributed an

estimated 4.6 billion litres of milk to the nation's annual production. This substantial contribution extends well beyond the numbers, as it provides livelihoods to approximately 1.8 million Kenyan households. The dairy industry contributes significantly to the national GDP, with 4.5% coming from the dairy value chain. Given the prevalence of small-scale dairy farming, a substantial portion of this economic contribution can be attributed to their efforts (KDB, 2023).

Kenya stands out regionally and even globally with its remarkably high milk consumption. According to a report by Wamaitha (2022), the average milk consumption per person per year in Kenya stands at an impressive 120 litres. This figure is notably higher than the milk consumption in other East African countries, surpassing it by more than fivefold. This underscores the pivotal role of dairy products in the Kenyan diet and the sector's importance in ensuring food security and nutrition for the population.

Within Kenya's vibrant dairy sector, numerous opportunities await those willing to explore and innovate. One of the most promising avenues is value addition. The dairy industry has untapped potential to diversify its product portfolio by venturing into the production of processed dairy items, including cheese, yoghurt, and other value-added offerings. This expansion can unlock new revenue streams, bolster the sector's profitability, and cater to evolving consumer preferences for dairy products (Blackmore *et al.*, 2022).

Despite the crucial role these small-scale dairy farmers play in the sector, they are characterized by lower productivity than anticipated. In Kenya, the dairy sector in general

faces several challenges, including disease outbreaks and erratic climate patterns. Disease control within the dairy sector is an ongoing concern. Diseases such as mastitis and tick-borne illnesses can wreak havoc on cattle's health and milk production. Disease outbreaks have the potential to lead to significant production losses, posing a significant threat to small-scale dairy farmers' stability and profitability. Robust disease control measures and access to veterinary services are indispensable in mitigating these risks (Wetende *et al.*, 2018).

Elgeyo-Marakwet County, situated adjacent to Uasin Gishu County, boasts a burgeoning dairy sector within Kenya. This region benefits from favourable agro-climatic conditions, making it conducive to the advancement of dairy farming livelihoods (Kiome *et al.*, 2021). As of 2021, Elgeyo-Marakwet County (EMC) exhibited a noteworthy dairy milk production output, contributing an average of 180,000 litres or 180.0 metric tons of milk (Kiome *et al.*, 2021). This translates to approximately 0.35% of Kenya's total milk production (Kiome *et al.*, 2021; Murkomen, 2019).

The county's dairy production achievement can be attributed to various interventions initiated by the county government. These interventions encompass a spectrum of initiatives, including artificial insemination, heifer distribution programs, improved extension services, and enhanced disease surveillance and control. The county's commitment to implementing these strategies has significantly impacted the dairy subsector, fostering growth and sustainability (CIDP, 2018-2022). Artificial insemination, for instance, plays a pivotal role in enhancing the genetic quality of the dairy cattle

population (Murkomen, 2019). The county has introduced superior genetics into the local herds through AI, which improves milk yields per cow, contributing to increased overall production (ASDSP, 2020; CIDP, 2018-2022). ASDP (2020) records that the county, in its ambition to increase the milk production value chain, has introduced heifer distribution programs. Moreover, heifer distribution programs facilitate the acquisition of young, productive female cattle, ensuring a continuous supply of high-yielding cows to farmers. This, in turn, bolsters milk production capacity at the household level (ASDSP, 2020).

Improved extension services are fundamental in disseminating knowledge and best practices among dairy farmers (Murkomen, 2019). The County Government collaborates with various state and non-state organizations to provide extension services. These partners include the Agriculture Sector Development Support Programme (ASDSP), Egerton University, Kenya Agriculture and Livestock Research Organization (KALRO), Heifer International, Kenya Climate Smart Agriculture Project (KCSAP), and East Africa Agriculture Productivity Project (EAAPP), among others (CIDP, 2018-2022). These services provide farmers with valuable insights into modern dairy farming techniques, nutrition, and healthcare for their cattle. By equipping farmers with up-to-date information and expertise, the county promotes optimal dairy farming practices.

The dairy cattle population trends for Elgeyo-Marakwet County from 2016 to 2022 revealed a steady increase, as shown in Table 1.1. In 2016, the county recorded 194,433 dairy cattle, which grew to 210,534 in 2020 and further increased to 216,280 dairy cows in

the year 2022 (Elgeyo-Marakwet County Department of Livestock & Fisheries Annual Report, 2022).

Table 1.1: Elgeyo Marakwet County Dairy Cattle Population Trend

Sub-County	Year						
	2016	2017	2018	2019	2020	2021	2022
Keiyo South	97,682	102,719	103,451	104,950	106,834	109,136	110,570
Keiyo North	31,258	32,150	32,998	33,157	33,989	34,011	34,100
Marakwet West	43,943	44,254	44,818	45,124	45,005	25,030	46,200
Marakwet East	21,550	22,465	23,590	23,978	24,706	25,030	25,410
County Total	194,433	201,588	204,857	207,209	210,534	214,039	216,280

Source: Livestock Annual Report, Department of Livestock and Fisheries, Elgeyo Marakwet County (2022)

Accompanying the upward rise in dairy cattle population, was an upward increase in milk production in the county as shown in Table 1.2. In 2016, the county produced a total of 89,158 metric tonnes of milk, which increased to 145,845 metric tonnes in 2020 and by 2022, the number further increased to 180,122 metric tonnes (Elgeyo Marakwet County Department of Livestock & Fisheries Annual Report, 2022).

Table 1.2: Elgeyo Marakwet County Dairy Cattle Milk Production Trend (metric tonnes)

Sub-County	Year						
	2016	2017	2018	2019	2020	2021	2022
Keiyo South	44,797	47,045	58,967	62,970	74,677	81,852	92,085
Keiyo North	14,332	14,725	18,809	19,894	23,758	25,508	28,399
Marakwet West	20,148	20,268	25,546	27,074	31,458	34,397	38,476
Marakwet East	9,881	10,289	13,446	14,387	17,269	18,773	21,162
County Total	89,158	94,344	116,768	124,325	145,845	160,529	180,122

Source: Elgeyo Marakwet County Department of Livestock & Fisheries Report (2022)

However, despite the positive increase in the dairy cattle population from 2016 to 2022 (Table 1.1), the dairy sector in Elgeyo Marakwet County had a large disparity in milk production by the year 2022 among the various Sub-Countries, as shown in Table 1.2. According to the Elgeyo Marakwet County Department of Livestock & Fisheries Annual Report (2022), Keiyo South Sub-County had the largest number of dairy cows (110,570) and produced 92,085 metric tonnes of milk. This was followed by Marakwet West (46,200 dairy cattle) and Marakwet East (25,410 dairy cattle), which produced 38,476 and 21,162 metric tonnes of milk, respectively. Therefore, among the four Sub-counties, Marakwet East had the lowest total milk production among the small-scale dairy farmers in the county. This discrepancy raised questions regarding the efficiency and productivity of dairy farming in the Sub-County.

The dairy subsector in Marakwet East Sub-County continues to develop and significantly contributes to the Sub-County economy, food security, and household incomes. It is a

primary economic activity employing thousands of the population and producing quality milk for high-quality consumption (CIDP, 2022).

According to the Elgeyo Marakwet County Integrated Development Plan (CIDP 2018-2022), dairy cattle production in the sub-county emerged as a critical player in the local economy, food security, and household employment opportunities for a substantial portion of the population. Dairy cow milk production is predominantly done in the highlands and marginally along the escarpment areas of the sub-county. Some of the County's significant interventions include extension services, purchase of heifers, provision of subsidized Artificial Insemination (AI), purchase of Boma Rhodes seeds, installation of one milk cooler for Kapsitotwo Cooperative Society (FCS) in Kapyego Ward, and ongoing construction of Sambirir farmers' cooperative society. Additionally, the sub-sector significantly contributes to the availability of high-quality milk for consumption, renowned for its superior nutritional value (Murkomen, 2019). Dairy products, such as milk, play a vital role in enhancing the nutritional quality of the local diet, providing essential proteins and nutrients to the populace (Nabuko *et al.*, 2020).

The dairy sub-sector in Marakwet East Sub-County, according to the Marakwet East Sub-County Department of Livestock Production Annual Report (2022), showed that dairy cattle population trends from 2016 to 2022 in the sub-county were on a steady increase, as shown in Table 1.3. In 2016, the Sub County had 21550 dairy cattle, which grew to 24706 in 2020 and further increased to 25,410 dairy cows by 2022.

Table 1.3: Marakwet East Sub-County Dairy Cattle Population Trend

Ward	Year						
	2016	2017	2018	2019	2020	2021	2022
Kapyego	4,932	5,219	5,316	5,542	5,827	6,078	6,324
Sambirir	4,225	4,360	4,684	4,390	4,185	4,502	4,575
Endo	5,143	5,410	5,913	6,390	5,836	6,175	6,084
Embobut/Embolot	7,250	7,476	7,677	7,656	7,858	8,275	8,427
TOTAL	21,550	22,465	23,590	23,978	24,706	25,030	25,410

Source: Marakwet East Sub-County Department of Livestock Production Annual Report (2022)

Accompanying this rise in dairy cattle population was an upward increase in milk production. In 2016, the Sub-County produced a total of 9881 metric tonnes of milk, which increased to 17269 metric tonnes in 2020 and further increased to 21162 metric tonnes in 2022, as shown in Table 1.4.

Table 1.4: Marakwet East Sub-County Dairy Cattle Milk Production Trend (Metric Tonnes)

Ward	Year						
	2016	2017	2018	2019	2020	2021	2022
Kapyego	2635	2421	2831	3597	3754	4693	6172
Sambirir	1317	2421	2831	3597	4505	4693	3527
Endo	2635	3026	3538	3597	4505	3911	4409
Embobut/Embolot	3294	2421	4246	3597	4505	5475	7054
TOTAL	9,881	10,289	13,446	14,387	17,269	18,773	21,162

Source: Marakwet East Sub-County Department of Livestock Production Annual Report (2022)

Despite the marginal increase in dairy cattle population and milk production in Marakwet East Sub-County, the average per capita dairy cow milk production is low at only 5.52-5.75 liters per cow per day against a potential of 10-12 liters per cow per day achievable under optimal dairy farming conditions (Muthoni *et al.*, 2017). The Sub County's low per capita milk production per cow per day raised pertinent questions about the factors that could be contributing to this disparity and the strategies needed to enhance milk production in the sub-county. According to the County Director of Livestock Production (William Bore), 2022, Marakwet East has the potential to become a significant player in the national and global dairy market, provided that the necessary steps are taken to improve milk quality in the sub-county.

However, the low per capita milk production per cow per day in the dairy sub-sector in the study area had been plagued by many factors. Among the factors that have contributed to the low milk production in the study area are low farm gate milk prices received by small-scale dairy cattle farmers that range from Ksh 24 to 28 per litre which is lower than the set minimum farm gate milk price range of between Ksh 35 and 37 per liter as recommended by the Kenya Dairy Board. This discourages the farmers, who decry manipulation and opt for other alternatives (KDB, 2023). Besides, excerpts from one of the trainings that were done in Marakwet East Sub County, "Barnaba Chepkok, in 2022", decried the use of substandard feeds, particularly milled maize stovers that have very low nutrient content, and also the use of rotten maize that harbours aflatoxins. While the population of dairy cattle had grown steadily in Marakwet East Sub-County, the gap between average milk production per cow per day and the national average suggested there was room for

improvement in enhancing the productivity of dairy cows. The sub-county's dairy sector has the potential to generate growth. Although the average dairy cow milk production per cow per day was known, the sector's maximizing milk production potential has not been realized. The average milk production per cow per day is of particular interest for this study. Therefore, this study aimed to determine the economic factors that influence dairy cow milk production among small-scale farmers in Marakwet East Sub-County. The findings of this study will provide key dairy cow milk production insights and opportunities to the small-scale dairy cattle farmers and other stakeholders in the study area.

1.3 Statement of the Problem

In Kenya, there are approximately 625,590 small-scale dairy farmers who collectively produce an annual milk volume of 4.92 million metric tons (MMT). This impressive output translates to an average of 10 liters of milk per cow per day (Dudych *et al.*, 2022). Notably, around 40% of this milk is retained for household consumption, underlining the dual significance of dairy as both a source of income for rural households and a crucial component of household nutrition. In Elgeyo Marakwet County, dairy production has emerged as a critical player in the local economy, food security, and household employment opportunities for a substantial portion of the population (CIDP 2018). However, despite the improvement in dairy cow milk production over the years in Marakwet East Sub-County, the average per capita dairy cow milk production is alarmingly low, ranging from 5.52 to 5.75 litres per cow per day. That production rate falls significantly short of the national potential yield of 10 to 12 litres per cow per day achievable under optimal dairy farming conditions (Muthoni *et al.*, 2017; Kamau, 2019). Coupled with the low milk production

below production potential, small-scale dairy cattle farmers in the study area also received very low farm gate milk prices of about Kenya Shillings (KSh) 24 to 28 per litre in the year 2022. That was lower than the set minimum farm gate milk price range of between Ksh 35 and 37 per litre, as recommended by the Kenya Dairy Board (KDB, 2022). Therefore, it indicated a negative economic factor in the study area that could have contributed to the low level of dairy cow milk production among small-scale dairy cattle farmers. Likewise, the sub-optimal milk production level represented a significant challenge for small-scale dairy farmers. Therefore, to bridge the knowledge gap between the existing state and the ideal scenario, this study explored the underlying factors contributing to the discrepancy by assessing the economic factors affecting dairy cow milk production among small-scale farmers in Marakwet East Sub-County.

1.4 Objectives of the study

1.4.1 General Objective

The general objective of this study was to examine the economic determinants of dairy cow milk production among small-scale farmers in Marakwet East Sub-County in Elgeyo Marakwet County, Kenya.

1.4.2 Specific Objectives

- (i) To determine the influence of socio-economic factors on dairy cow milk production among small-scale farmers in Marakwet East Sub-County.
- (ii) To determine the effect of technological factors on dairy cow milk production among small-scale farmers in Marakwet East Sub-County.

- (iii) To determine the effect of farm production factors on dairy cow milk production among small-scale farmers in Marakwet East Sub-County.
- (iv) To analyse the effect of institutional factors on dairy cow milk production among small-scale farmers in Marakwet East Sub-County

1.5 Research Hypotheses

- H₀₁:** Socio-economic factors have no effect on dairy cow milk production among small-scale farmers in Marakwet East Sub-County
- H₀₂:** Technological factors have no effect on dairy cow milk production among small-scale farmers in Marakwet East Sub-County
- H₀₃:** Farm production factors have no effect on dairy cow milk production among small-scale farmers in Marakwet East Sub-County
- H₀₄:** Institutional factors have no effect on dairy cow milk production among small-scale farmers in Marakwet East Sub-County

1.6 Significance of the Study

The findings of this study are expected to contribute significantly to the existing body of knowledge on the economic factors influencing dairy cow milk production in Kenya, with particular emphasis on Marakwet East Sub-County. By generating localized insights, the study provides valuable reference material for researchers undertaking similar studies in the field of agricultural economics and rural development.

Moreover, the study offers practical implications for policy-makers, key stakeholders in the dairy industry, and the Elgeyo-Marakwet County government. The results can guide

evidence-based decision-making in the formulation and implementation of policies aimed at improving the economic viability of small-scale dairy farming. Understanding the role and impact of economic factors is crucial in developing strategies that can enhance milk production and support rural livelihoods.

The study also seeks to inform relevant government ministries, development agencies, NGOs, and private sector actors, enabling them to revise and redesign livestock development programs and policies. This can foster an enabling environment for increased milk production and sustainability in the small-scale dairy sector. Importantly, the study responds to the pressing need for policy-relevant research by examining how economic factors can be leveraged to benefit small-scale dairy farmers. It underscores the role of the livestock sector in improving food security, rural incomes and overall economic development.

In addition, the study highlights opportunities for integrating technological innovations to improve milk production. The study identifies key growth areas within the local dairy value chain, including the demand for high-quality feeds, improved breeding techniques and high-yielding pasture. Ultimately, if the identified economic constraints are adequately addressed, the study's outcomes may contribute to improved milk yields, enhanced farmer incomes, and better household nutrition, not only in Marakwet East Sub-County but also in similar agro-ecological zones across the country. This, in turn, supports Kenya's broader agricultural development and poverty reduction goals.

1.7 Scope of the Study

The study focused mainly on the analysis of economic determinants (socio-economic, technological, farm production, and institutional) influencing dairy cow milk production among small-scale dairy farmers in Marakwet East Sub-County, particularly those small-scale dairy farmers with relevant data from the 2016 to 2022 seasons.

1.8 Limitations of the Study

Firstly, the study covered all four wards of the study area with a sample of 230 small-scale dairy farmers. Secondly, the terrain of some parts of the study area was rough, which posed a major logistical challenge. Thirdly, the unwillingness of some small-scale dairy farmers to provide accurate, full, personal and timely information. However, this challenge was expected and overcome by maintaining anonymity and strict confidentiality during data collection and assurance of the respondents that the issue was treated with utmost secrecy. Lastly, the information on which the research depended was purely voluntary, which was therefore not fully verifiable.

1.9 Assumptions of the Study

The successful execution of this research hinged upon several key assumptions that underpinned its methodology and findings. Firstly, it was assumed that all respondents approached for participation provided candid, truthful, complete, and sincere responses to the questions presented in the research questionnaire. This presumption was vital to ensure the reliability and authenticity of the data collected. Secondly, the study assumed that weather conditions would remain favourable throughout the data collection period. This assumption was essential as adverse weather could potentially disrupt the research

activities, affecting both the quality and timeliness of data collection. Thirdly, the study assumed that the targeted respondents were available and accessible during the designated data collection period. Their availability was paramount for ensuring a comprehensive and representative dataset, which was crucial for drawing meaningful conclusions. Lastly, it was acknowledged that within the complex dairy farming ecosystem, various factors not under the study's direct focus would exert significant influences on the observed outcomes. Nevertheless, this research assumed that these non-selected factors interacted with and impacted the results within the scope of the study. These assumptions served as the foundational framework upon which this research was constructed. While every effort was made to uphold these assumptions, the study remained cognizant of potential deviations or limitations, and these were transparently acknowledged and addressed in the final research findings.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter presents a literature review of dairy production, as well as a review of literature on economic factors such as socio-economic, farm production, technological, and institutional factors affecting dairy milk production. The chapter also presents the literature review of empirical models, theoretical framework, conceptual framework and knowledge gap.

2.2 Review of Relevant Literature

2.2.1 Review of Socio-Economic Factors in Dairy Cow Milk Production

Socio-economic factors have a significant influence on the productivity and profitability of dairy cow milk production, particularly among small-scale farmers. In Marakwet East Sub-County, this review delves into the impact of various socio-economic factors on dairy cow milk production. These factors include age, gender, marital status, family size, education level, occupation, income level, land size, and years of experience. Each of these socio-economic factors interacts with and contributes to the complex landscape of dairy cow milk production among small-scale farmers.

Age is a significant socio-economic factor with a significant bearing on dairy cow milk production. Older farmers often possess extensive experience and knowledge accrued over years of engagement in dairy farming. This wealth of experience translates into better strategies for managing cow health, nutrition, and reproduction, ultimately positively

impacting milk production. Studies conducted by Omosa *et al.* (2018) and Njuki *et al.* (2017) have consistently indicated that older farmers in Kenya tend to exhibit greater proficiency in dairy farming practices. Moreover, research conducted in Gwagwalada, Abuja, Nigeria, by Ifeoma *et al.* (2021), in Ethiopia's Amhara and Oromia National Regional States by Dehinenet *et al.* (2014), and in Ndola, Zambia, by Mumba (2022) and Kiwanuka-Lubinda *et al.*, (2021) has corroborated the association between the age of the household head and increased milk production. Similar findings have been observed in Zimbabwe, particularly in Mashonaland and Manicaland Provinces, as reported by Kim *et al.*, (2023), and in Northern Ghana by Abdul-Rahaman and Abdulai (2018). Studies in Cameroon by Awazi *et al.*, (2020) and in Rwanda by Habumugisha *et al.* (2018) have also lent support to this trend. Additionally, a study in Uganda by Ahikiriza *et al.*, (2021) found analogous results.

The relationship between age and other factors, such as education and access to extension services, emerges as crucial. Older farmers with higher levels of education and exposure to modern farming techniques tend to achieve higher milk yields (Gitau, 2013). Experience empowers them to make informed decisions regarding breeding, feeding, and disease control. However, research by Maina (2018) has unveiled the role of older farmers in contributing to technical inefficiencies within the milk production process. While experience is invaluable, it can also lead to certain inefficiencies. Studies by Gitau (2013) and Maina (2018) align in highlighting that age-related factors may be linked to suboptimal herd management, outdated milking techniques, or inadequate disease control measures. These inefficiencies may result from factors like limited access to training and resources,

resistance to change, or reduced physical capacity associated with aging. Nevertheless, it is crucial to recognize that age alone may not be a singular predictor of milk production. The ability of older farmers to achieve higher milk yields is intricately connected with their access to resources and support services. Therefore, interventions and policies aimed at enhancing dairy cow milk production must consider age within the broader context of farmers' knowledge, experience, and access to resources.

Gender is another fundamental socio-economic factor profoundly affecting dairy cow milk production, particularly in the context of small-scale farming. Gender disparities within the dairy farming sector encompass access to resources, decision-making authority, and opportunities. These disparities often limit women's participation and, consequently, hinder productivity. Research by Waithaka *et al.*, (2022) in Kenya has unveiled numerous challenges faced by women in dairy farming, including limited access to land, credit facilities, and extension services. These challenges culminate in lower milk production compared to male farmers. Moreover, gender-based inequalities extend to control over income and resource allocation decisions, further influencing productivity.

Marital status is another important socio-economic factor that can exert a substantial influence on dairy cow milk production among small-scale farmers. Marriage often confers certain advantages that can positively affect milk production outcomes. Research by Wekesa *et al.* (2018) in Kenya has shed light on how married farmers benefit from increased labour availability within their households. The division of labour among family members facilitates more efficient management of dairy farming activities, encompassing feeding, milking, and animal care. This enhanced labour availability can contribute

significantly to higher milk production levels. Additionally, marital status can also impact access to extension services and credit facilities. Kahi *et al.*, (2018) have noted that married farmers tend to have a higher likelihood of accessing extension services, thereby acquiring valuable knowledge to enhance their dairy farming practices. Moreover, being married may enhance farmers' creditworthiness, simplifying their access to financial resources for investments in dairy infrastructure, animal health, and improved genetics. Nonetheless, it is essential to recognize that the relationship between marital status and milk production is intricate and may vary depending on cultural and socio-economic contexts. The division of labour and increased resource access associated with marriage can positively influence milk production among small-scale farmers. However, the ability to balance family demands with those of the dairy enterprise is pivotal in determining the net impact of marital status on milk production.

Family size constitutes another socio-economic factor with implications for dairy cow milk production among small-scale farmers. The size of a farmer's family directly affects both labour availability and resource allocation within the household, thereby influencing milk production outcomes. Larger family sizes often translate to a readily available source of labour for dairy farming activities. This increased labour availability enables efficient task execution, including feeding, milking, and cleaning, ultimately contributing to higher milk production. However, it is crucial to acknowledge that larger family sizes may also result in augmented household expenses. As the family size grows, the financial burden associated with providing for household needs, education, and healthcare escalates. This may limit the resources available for investment in dairy farming inputs such as improved

genetics, high-quality feed, and veterinary services, which can subsequently affect milk production. Thus, the relationship between family size and milk production is multifaceted, and the net effect may hinge on specific circumstances and the farmer's capacity to navigate the demands of both family and dairy farming.

Education level is a significant socio-economic factor with a substantial influence on dairy cow milk production among small-scale farmers. A wealth of research consistently highlights that higher education levels are associated with improved milk production outcomes. Farmers with advanced education have access to superior information and knowledge concerning modern dairy farming practices. This knowledge empowers them to adopt advanced techniques for feeding, breeding, and disease control, thereby enhancing milk production. Furthermore, education plays a pivotal role in bolstering farmers' decision-making processes and problem-solving skills. Farmers with higher educational attainment are better equipped to analyse market trends, identify opportunities, and make informed decisions regarding investments in their dairy enterprises. This strategic approach contributes to increased productivity and profitability. Moreover, higher education levels facilitate access to extension services and training programs, where farmers can acquire specialized knowledge in dairy farming. The study by Kimani *et al.* (2021) in Meru County, Kenya, accentuates that farmers with higher education levels had superior access to extension services, which positively influenced their milk production outcomes. Therefore, education emerges as a critical determinant in dairy cow milk production, enabling farmers to make more informed decisions, adopt modern practices, and access essential resources and support services.

Occupation is another socio-economic factor that influences dairy cow milk production. The nature of a farmer's occupation, particularly whether it entails full-time farming or engagement in multiple occupations, can significantly impact their capacity to allocate time and resources to dairy farming. Full-time dairy farming often leads to higher milk production compared to concurrent involvement in various occupations. Farmers dedicated exclusively to dairy farming can prioritize and focus on optimizing their dairy enterprises, including aspects such as animal nutrition, health management, and reproductive strategies. Conversely, farmers juggling multiple occupations may contend with time constraints and limited availability for dairy farming activities. Divided attention and time commitments to other occupations may hinder their ability to implement optimal farming practices and invest sufficient effort into dairy cow milk production.

Years of experience represent a crucial socio-economic factor that shapes dairy cow milk production outcomes. Accumulated knowledge, skills, and expertise derived from years of practical engagement in dairy farming equip farmers to achieve improved productivity. Experience contributes to a deeper understanding of the intricacies of dairy farming. As showcased in the research conducted by Alem *et al.*, (2019), and Kimani *et al.*, (2021), farmers with more extensive experience in dairy farming attain higher milk yields compared to those with fewer years of involvement. This underscores the pivotal role of experience in enhancing milk production.

Income level stands as an important socio-economic factor significantly influencing dairy cow milk production among small-scale farmers. Adequate income serves as a linchpin for accessing and maintaining the requisite resources for prosperous dairy farming. Farmers with higher income levels possess greater financial capacity to invest in enhanced dairy infrastructure, procure high-quality feeds, and access veterinary services. This empowers them to provide superior nutrition and healthcare for their cows, ultimately leading to higher milk production. Research by Nyamwaro *et al.*, (2020) and Maina *et al.*, (2021) in Kenya attests to the positive correlation between income levels and milk production among small-scale dairy farmers. Moreover, a higher income level facilitates the adoption of technologies and innovations that enhance efficiency and productivity in milk production. Financially well-endowed farmers can embrace automated milking systems, cooling equipment, and other modern technologies that improve milk quality and augment production capacity.

Land size emerges as another socio-economic factor capable of influencing dairy cow milk production among small-scale farmers. The availability and adequacy of land resources directly dictate the ability to cultivate forage crops, establish grazing paddocks, and provide ample space for animals. Farmers with larger land sizes gain the advantage of cultivating a diverse array of forage crops, such as maize silage or Napier grass, essential for fulfilling the nutritional requirements of dairy cows. Furthermore, adequate grazing land supports rotational grazing systems that optimize available forage utilization and afford pastures sufficient time to regenerate. Research by Mengistu *et al.*, (2017) in Ethiopia and Wambui *et al.*, (2021) in Kenya consistently demonstrates that farmers with larger land sizes tend

to achieve higher milk yields compared to those with smaller land holdings. However, it is imperative to recognize that factors such as land quality, soil fertility, and effective land management practices are also instrumental. Access to adequate land resources serves as the foundation for thriving dairy farming, allowing farmers to implement sustainable production systems. To support small-scale farmers grappling with limited land resources, interventions can prioritize efficient land use practices. These may include implementing silage production systems, adopting zero-grazing methods, and exploring innovative approaches to maximize productivity within prevailing land constraints.

2.1.2 Review of Technological Factors in Dairy Cow Milk Production

This section provides a literature review of the technological factors identified in the conceptual framework for analysing dairy cow milk production among small-scale farmers. The following technological variables were examined: access to technology, artificial insemination, vaccination, deworming, milk storage facility, feeding facilities, hay/silage technology, improved dairy breeds, information technologies, and milking machines.

A study by Girma *et al.* (2018), conducted in Ethiopia, demonstrated the transformative potential of AI in dairy farming. AI has significantly improved the reproductive performance and milk yield of dairy cows, resulting in higher conception rates and more efficient calving intervals (Girma *et al.*, 2018; Mekuriaw *et al.*, 2016). Moreover, AI introduced superior genetics to dairy herds, enhancing their milk-producing potential (Mrode *et al.*, 2017). The research by Sölkner *et al.*, (2020) in Kenya emphasized that AI

not only fosters genetic progress but also increases income generation for farmers, highlighting its multifaceted advantages. AI's relevance in small-scale dairy farming contexts was underscored by Tesfaye *et al.*, (2015) and Onyango *et al.*, (2023).

Deworming, as proposed by Abdi and Ayana, (2017) is fundamental in dairy farming. Cows subjected to systematic and routine deworming outperform their counterparts, with significantly increased milk yields. Deworming reduces the parasite load within cows, preventing nutrient absorption and feed utilization issues. Regular deworming, as advocated by Waweru *et al.*, (2019), leads to higher milk yields. Martinez *et al.*, (2020) demonstrated the global significance of deworming in unlocking dairy cow productivity. Njoroge *et al.*, (2021) in Kenya explored the economic benefits of deworming practices, fortifying the economic foundations of dairy farming. Patel *et al.*, (2019) in India corroborated the global consensus on the significance of deworming.

2.1.3 Review of Farm Production Factors in Dairy Cow Milk Production

Farm production factors play a crucial role in dairy cow milk production among small-scale farmers. This section reviews the existing literature on various farm production factors and their impact on milk production outcomes.

Feed quality and nutrition are vital for milk production in dairy cows. Gitau *et al.*, (2018) in Kenya emphasized the importance of balanced diets in meeting cows' physiological demands, resulting in increased milk production, improved reproduction, and reduced metabolic disorders. High-quality forage, such as Napier grass or alfalfa, was found to

enhance milk yields (Capstaff and Miller, 2018 and; Crovetto *et al.*, 2019). A study in Tanzania by Ferreira *et al.*, (2022) demonstrated that scientifically formulated rations, notably mixed ration silage (MRS) provide animals with a diet formulation that presents a higher increase in both milk volume and composition. In South Asia, Rahman *et al.*, (2021) in Bangladesh showed that combining local forage with supplemented concentrates improved milk production economically. In India, Singh *et al.*, (2018) found that tailored rations for lactating cows led to superior milk production.

Breeding and genetics play a pivotal role in milk production. Kemboi *et al.*, (2019) highlighted the importance of advanced genetics, like artificial insemination, in Kenya. Genotype by environment interaction was noted by Haile *et al.* (2002), emphasizing the need to consider environmental factors in breeding decisions. Selective breeding and genomic technologies were suggested to enhance genetics (Gibson & Glasscock, 2016). Sexed semen was also found to contribute to improved milk yields (Shahin *et al.*, 2018), with economic benefits from genetic improvement (Mrode & Ojango, 2018).

Farm size and herd management practices are interconnected. Maina *et al.*, (2020) in Kenya found a positive correlation between larger farm sizes and increased milk production. Smith and Johnson (2018) emphasized proactive herd management practices. Rahman *et al.*, (2021) in Bangladesh highlighted the role of mentorship in enhancing dairy production. Besides, financial resources and investments play a pivotal role. Nyangaga *et al.*, (2020) found that access to capital can enhance milk production. Johnson and Brown (2019) noted the catalytic impact of technology-driven investments. Ongom *et al.*, (2018) in Uganda

emphasized how access to credit facilities galvanizes dairy farming. Mwaura *et al.*, (2017) in Tanzania showed how financial education empowers farmers.

2.1.4 Review of Institutional Factors in Dairy Cow Milk Production

This section provides a comprehensive literature review of the institutional factors that influence dairy cow milk production among small-scale farmers. The following institutional factors were examined: Access to extension services, credit from MFI, membership in farmer groups or cooperative society, communication services, marketing services, milk markets and market information.

Research from various countries highlights the significance of access to extension services in improving milk production. Studies in Uganda (Kugonza *et al.*, 2017) and Kenya (Wanyoike *et al.*, 2019) emphasize how extension services enhance knowledge dissemination and skill development, leading to increased milk yields.

Extension services also improve animal health management, feeding strategies, and reproductive techniques, as seen in Uganda (Kugonza *et al.*, 2017). In Ethiopia (Yenesew *et al.*, 2020), access to extension services is linked to better disease control and disease prevention practices, contributing to elevated milk production. Moreover, extension services facilitate the adoption of sustainable and eco-friendly farming practices and improved feeding practices (Chikagwa-Malunga *et al.*, 2015), ultimately increasing milk production.

Participation in dairy cooperatives has a significant positive impact on milk production. Studies in various regions show that cooperative members report higher milk yields and greater market opportunities (Muthoni *et al.*, 2019). Cooperatives enable collective investments in critical aspects of the dairy value chain, such as milk collection, processing, and marketing. This collective action amplifies bargaining power, access to premium prices, and profitability for farmers. Cooperatives also provide essential knowledge and skills through extension services and training programs, enhancing modern dairy farming practices (Muriuki *et al.*, 2017). Additionally, cooperatives facilitate access to credit, enabling investments in dairy infrastructure and improved feeding practices (Kamugisha *et al.*, 2018).

Market linkages are crucial for milk production. Farmers with robust market linkages, especially formal dairy markets, report higher milk yields and increased profitability. These linkages enable timely milk sales, minimizing losses and incentivizing farmers to enhance milk quality and production. Access to diversified market channels empowers farmers to tap into new consumer bases, boosting milk production and income. Market linkages also facilitate regular sales, reduce milk wastage, and encourage investment in improving milk production (Haile *et al.*, 2019).

Credit access is a catalyst for milk production. Farmers with access to credit facilities can invest in essential dairy infrastructure, high-yielding breeds, and modern farming technologies (Kariuki *et al.*, 2019). Credit resources enable the timely procurement of necessary inputs, leading to enhanced dairy farm performance. Access to credit fosters an

environment conducive to dairy enterprise growth, resulting in higher milk production, improved livelihoods, and economic stability (Tembo *et al.*, 2016).

Access to communication services, such as mobile phones and the internet, enhances knowledge, market connectivity, and farm management, contributing to increased milk production (Wambui *et al.*, 2017). Farmers can access timely information, seek veterinary advice, and connect with buyers, leading to improved cow health and milk yields. ICT interventions enhance knowledge and awareness among farmers, resulting in higher milk production (Mbilinyi *et al.*, 2018). Access to extension services, participation in cooperative societies, supportive policies, market linkages, credit access, social capital, and communication services all play crucial roles in improving milk production among small-scale dairy farmers. These factors contribute to enhanced knowledge, better farming practices, increased access to resources, and greater market opportunities, ultimately leading to higher milk yields and improved livelihoods for farmers across different regions.

2.2 Review of Empirical Models

This study employed the Cobb–Douglas production function (double log-linear form) (Cobb & Douglas, 1928) and multiple linear regression (Wooldridge, 2016) in data analysis.

2.2.1 Review of Cobb-Douglas Production Function

The Cobb-Douglas production function serves as a fundamental economic tool for modelling the intricate relationship between production output and various production

inputs or factors. This model, which has proven its versatility, accommodates two or more variables representing inputs and effectively describes a firm's output (Douglas & Cobb, 1928). Typical factors considered in this model include labour (L) and capital (K). It functions not only to determine the optimal input ratios for efficient production but also to estimate technological advancements and their influence on production methods.

Initially crafted during the 1920s by economist Paul Douglas and mathematician Charles Cobb, this production function was primarily conceived to elucidate the connection between output quantity and two pivotal factors of production: physical capital (K) and labour (L). The core expression of this relationship is exemplified by Equation 2.1 below:

$$Q = AK^\alpha L^\beta \text{ where } \alpha + \beta = 1 \dots\dots\dots (2.1)$$

Where;

Q = Milk yield

K = Capital.

L = Labour.

α varies between 0 and 1, quantifying the sensitivity or elasticity of output concerning capital.

β is calculated as $1-\alpha$, which signifies the output elasticity concerning labour.

These two elasticity values, ' α ' and ' β ,' complement each other and sum up to 100%, portraying the proportional contributions of each factor to any output augmentation.

A = total-factor productivity (TFP). This value represents the ratio of output to total input, portraying the overall efficiency and quality of the production process.

As technological advancements occur and the skills and education levels of the workforce improve, businesses convert labour and capital into output more efficiently, indicating an increase in total-factor productivity over time. Importantly, the Cobb-Douglas formula extends easily to encompass more than two production factors. Each factor is multiplied successively, with its respective exponent needing to sum precisely to 1. For instance, a Cobb-Douglas model involving three factors, X_1 , X_2 , and X_3 , adopts the format below:

$$Q = AX_1^\alpha X_2^\beta X_3^\gamma, \alpha + \beta + \gamma = 1 \dots\dots\dots (2.2)$$

This functional form's application for measuring production is attributed to the contributions of mathematician Charles Cobb and economist Paul Douglas. They harnessed this model to discern the relative significance of two vital input factors, labour and capital, in manufacturing output within the United States from 1899 to 1922. Based on their analysis, Cobb and Douglas determined a value of 0.75 for α , which exceeds 1. This finding implies that labour accounted for three-quarters of the value of US manufacturing output, while capital contributed to the remaining quarter during the studied period. It is essential to note that Cobb and Douglas themselves acknowledged that their production function lacked robust theoretical foundations and should not be perceived as an absolute law of production (Douglas & Cobb, 1928). Instead, it serves as a statistical approximation of the observed relationships between production inputs and output. Nevertheless, the model's straightforward mathematical properties have captivated economists, establishing it as a cornerstone in microeconomic theory over the past century.

In reviewing the literature, the Cobb-Douglas production function has been extensively employed to investigate the input-output dynamics of various industries and sectors. Numerous studies across diverse fields have employed this model to uncover insights into production relationships, often yielding valuable findings that inform economic decisions and policy formulation. For instance, in agricultural economics, studies have utilized the Cobb-Douglas function to assess the contributions of various inputs like labour, capital, and land to crop or livestock production (Wang *et al.*, 2021). Such investigations have provided critical insights into the efficiency of resource allocation and the factors influencing agricultural productivity (Kibona *et al.*, 2023). Researchers have often adapted the model to specific contexts, incorporating region-specific variables to refine its applicability.

Bravo-Ureta *et al.*, (2020) investigated input-output associations by two-inputs using the Cobb-Douglas model. The study highlights the importance of understanding input-output relationships in agricultural production, a fundamental aspect that the Cobb-Douglas model captures. Similarly, Guo *et al.*, (2020) analyzed the spatiotemporal patterns and driving mechanisms of China's agricultural production efficiency from 2000 to 2015, emphasizing the significance of input efficiency in agricultural production. Their findings underscore the broader application of production functions in agricultural contexts.

2.2.2 Review of Multiple Linear Regression Model

By fitting a line to the observed data, regression models are used to describe relationships between variables (Nguyen *et al.*, 2020). One can estimate a dependent variable's change

as an independent variable or a set of independent variables change using regression. Multiple linear regression models are the most often used statistical method in data analysis, and they are the ideal econometric strategy to handle the continuous dependent variable. According to Adjei, (2019), it is a general statistical method for examining the relationship between a set of continuous dummy variables and a continuous dependent variable as shown in equation 2.3 below. It presumes that dependent variables and independent variables have a linear relationship in linear multiple regression.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_k X_k + \mu \dots\dots\dots (2.3)$$

Where;

Y = represents the dependent variable that is linearly related to k explanatory variables.

$\beta_1, \beta_2, \dots, \beta_k$ = Are the regression coefficients associated with X_1, X_2, \dots, X_k respectively.

μ = the random error term component reflecting the difference between the observed and fitted linear relationships. Such differences can be caused by numerous factors, such as the joint effect of those variables not included in the model, and random factors that cannot be accounted for in the model (Adjei, 2019).

Agutu, Ondiek, and Bebe (2020) evaluated the associations between intensification interventions and herd productivity in small-scale dairy farms in the Kenyan highlands using multiple linear regression. In this research, two regression models were used to explain milk yield and margin per liter with the indicators of ecological, genetic and socioeconomic interventions in the intensification of dairy production. The results from the research indicated that 58% of the variations in milk yield were explained by socioeconomic interventions like concentrate use, milk sales, and credit uptake, and genetic

intervention (insemination costs), without ecological intervention indicators was also noted. Research also indicates that almost half (45%) of the variations in margins per litre of milk were explained by concentrate use and socioeconomic milk sales, insemination costs under genetics and ecological intervention (manure recycling) indicators. The feasibility showed that a ten percent increase in concentrate feed would increase milk yield by 0.13% and reduce the margins earned by 0.09% per liter of milk. Shifting the focus to insemination, however, would marginally reduce milk yield and margins, while ten percent more milk sales would increase margins by 9.16%.

2.3 Theoretical Framework

This study adopted the Production Theory or the Theory of the firm and the Resource Allocation Theory.

2.3.1 Production Theory

Production, within an economic context, is the pivotal process of creating wealth, encompassing the activities resulting in the generation of goods and services to fulfil human desires (Antle and Capalbo, 2015). Ensuring food security has become an issue of key importance to countries with different degrees of economic development, while the agricultural sector plays a strategic role in improving food availability (Pawlak and Kołodziejczak, 2020). It's essential to distinguish production from mere manufacturing, as production involves the creation of utilities, aligning with Adam Smith's economic theory that views production as the conversion of inputs into outputs (Inoua & Smith, 2023). This process employs various resources to craft commodities suitable for exchange, making

production an economic endeavour that unfolds over both time and space due to its inherent flow nature. Production quantification typically revolves around measuring output rates over time, considering three fundamental aspects: the quantity of the commodity produced, the form of the goods created, and the temporal and spatial distribution of the commodity (Chase, 2023).

In the context of this study, the theory of production serves as a foundational framework for understanding how different factors of production, such as labour, capital, and technology, influence dairy cow milk production among small-scale farmers in Marakwet East Sub-County. It aids in unravelling the dynamics of milk production in both the short and long run, providing a lens through which to assess the impact of socio-economic, technological, farm production, and institutional factors on dairy cow milk production.

Mathematical expressions, like the production function, are critical tools in this regard. The production function, symbolically shown in Equation 2.4.

$$Q = f(L, K, N, E) \dots\dots\dots (2.4)$$

Here, the notation signifies:

Q = Quantity of output produced, which can encompass goods or services.

L = Labour input.

K = Capital input.

N = Land input.

E = Entrepreneurship input.

This equation allows us to model how these factors collectively influence dairy cow milk production. It forms the basis for analysing the impact of variables related to labour, capital, land, and entrepreneurship on milk output among small-scale farmers in the specified region.

The relevance of the Cobb-Douglas production function in the broader economic context is noteworthy. It enables an understanding of how inputs transform into outputs and how these transformations can be optimized (Wang *et al.*, 2021). By applying this production function to the context of dairy farming, we can express the farmer's milk production function as shown in Equation 2.5.

$$Y = f(x_1, x_2, \dots, x_n) \dots \dots \dots (2.5)$$

Where;

Y = Total milk output.

x = Vector of variables encompassing the physical units involved in the production process, such as land, labour, and capital.

2.3.2 Resource Allocation Theory

Resource allocation theory is a vital concept with diverse applications, spanning business management, economics, sociology, and financial theory. It involves the decision-making process where organizations distribute their production factors across various activities. This complex process considers economic, social, political, and technical factors, making it a subject of significant scholarly interest (Stads *et al.*, 2020).

In this study, resource allocation theory was applied to understand how limited resources in dairy farming, such as land, labour, capital, and entrepreneurial skills, are distributed to maximize milk production efficiency (Koutouzidou *et al.*, 2022). This involves making decisions about how to optimally allocate these resources to different aspects of dairy farming, including animal care, nutrition, disease control, and reproduction.

The study has explored how dairy farmers make resource allocation decisions, taking into account factors like age, gender, education, income, and family size. It has investigated whether certain socio-economic factors influence the allocation of resources and whether there are variations in resource allocation practices among small-scale farmers in the Marakwet East Sub-County. By applying resource allocation theory, the research aimed to uncover patterns and insights into how dairy farmers in this specific context make decisions regarding the allocation of their limited resources. This knowledge can inform strategies and interventions to enhance resource allocation practices, ultimately improving milk production outcomes among small-scale farmers in the region.

To analyse resource allocation in dairy farming, scholars often turn to production functions.

A common representation of this is the milk production function, as shown in Equation 2.6.

$$M = k * L^a * N^b * C^c * E^d \dots\dots\dots (2.6)$$

Where:

M = Represents the level of milk production.

L = Refers to the available land area for dairy farming.

N = Represents the labour force involved in dairy farming.

C = Includes the financial resources and equipment used in milk production.

E = Reflects the managerial skills and decision-making abilities of those operating the dairy farm.

k = A constant that encapsulates overall efficiency and technological advancements in milk production.

a , b , c , and d = are coefficients that signify the respective contributions of each factor to milk production.

This multifaceted theory of resource allocation provides a valuable framework for comprehending how dairy farmers optimize their use of inputs to enhance milk production, making it a pertinent subject of study within the agricultural domain (Mellaku and Sebsibe, 2022)

2.4 Conceptual Framework

A conceptual framework is a structural model that helps elucidate the intricate relationships among various attributes and variables. These variables are not isolated entities but rather interconnected, often exhibiting causative relationships that offer valuable insights into the core focus of the research (Mugenda & Mugenda, 2003). The conceptual framework, illustrated in Figure 2.1, shows a schematic representation of the perceived correlation on how the independent variables affect the dependent variable in the study. It shows the economic factors that affect dairy cow milk production among small-scale farmers in Marakwet East Sub-County. It was postulated that the independent variables such as socio-economic factors including age, gender, marital status, family size, education level,

occupation, years of experience, income level, land size, technological factors, and institutional factors directly have and positively influence the dairy cow milk production in the study area.

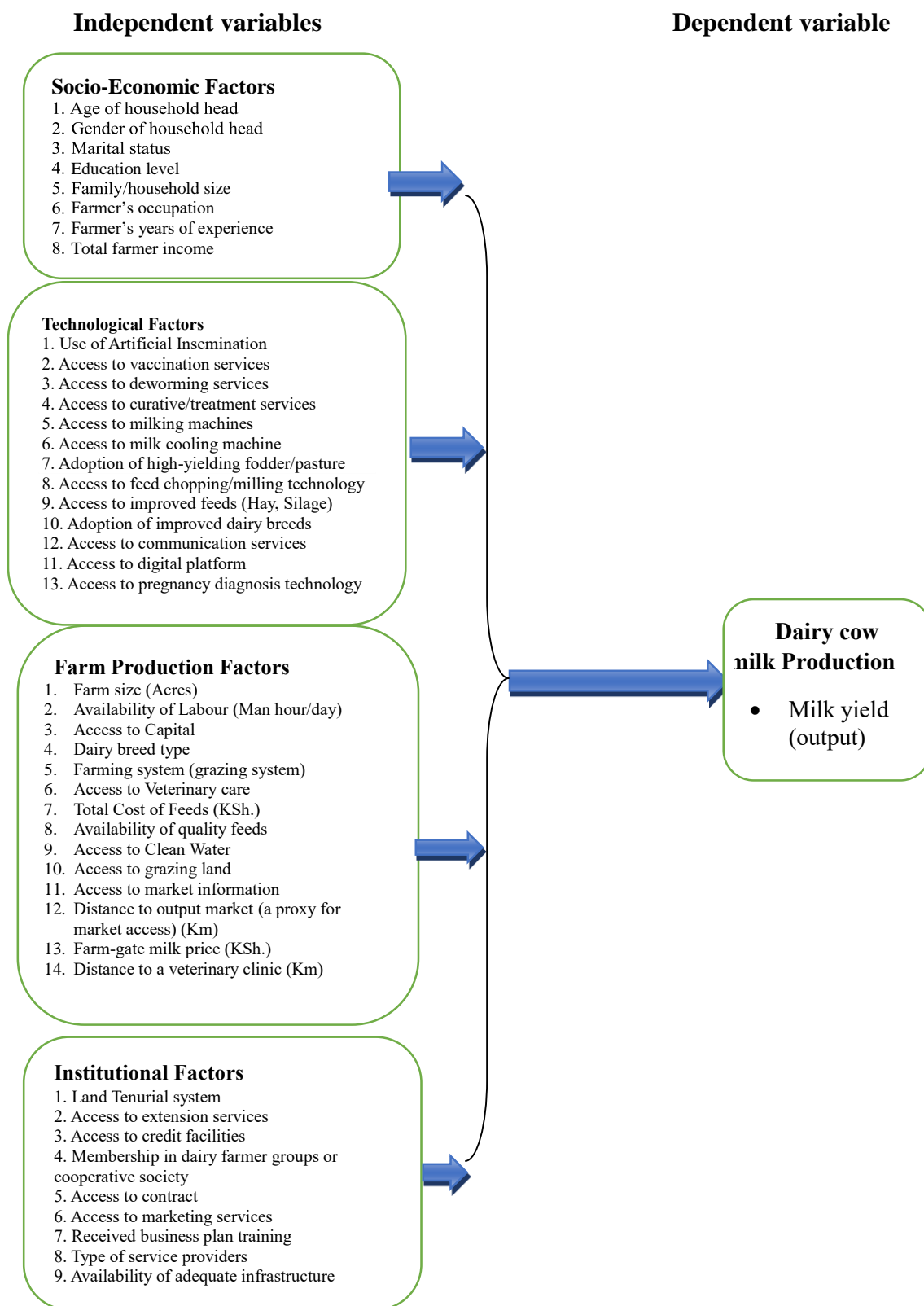


Figure 2.1: Conceptual Framework

Source: Author's conceptualization (2023)

2.5 The Identification of Knowledge Gaps

The literature reviewed in this chapter focused on dairy cow milk production among small-scale farmers. None of these studies emphasized how socio-economic factors, such as age, gender, education, and income, impact milk production. While previous studies have explored these variables, there is a lack of specific mechanisms explaining their impacts on dairy farming production. Additionally, the effectiveness and adoption of various technological interventions, such as artificial insemination, disease control measures, and feed rations, require further investigation. This entails empirical evidence of their actual impact, adoption rates among small-scale farmers, and potential barriers to implementation.

Understanding the role of institutional factors, including access to extension services, farmer cooperatives, policies, and market linkages, is essential. Investigating how these institutions facilitate knowledge transfer, resource allocation, and market access for small-scale dairy farmers can provide valuable insights. Identifying challenges and opportunities in utilizing institutional support can inform strategies to strengthen these systems and enhance milk production outcomes. Furthermore, integrating theoretical frameworks like production theory, social capital theory, and transaction cost theory offered a more comprehensive understanding of dairy cow milk production dynamics. This integration can reveal how these theories interact and influence outcomes, aiding in pinpointing areas for targeted interventions.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

This chapter presents the study area, research design, target population, sample size, sampling procedure, instruments of data collection, validity and reliability of instruments, data collection procedures, data analysis, and ethical considerations.

3.2 Study Area

The study area was Marakwet East Sub-County, which is one of the sub-counties of Elgeyo Marakwet County in the former Rift Valley Province (Figure 3.1). The Sub-County is located along the Kerio River Basin. It borders West Pokot County to the North, Baringo County to the East, Trans Nzoia County to the West, Uasin Gishu County, and Marakwet West Sub-County to the South (KNBS, 2019).

According to the KNBS (2019) Kenya Population and Housing Census, Marakwet East Sub-County has four wards, namely: Kapyego, Embobut/Embolot, Endo and Sambirir. It covers a total area of 784.3 (km²) (Kapyego 308.6 km², Embobut/Embolot 151.8 km², Endo 178.6 km² and Sambirir 145.3 km²). The Sub-County has approximately 97,041 people (Kapyego 21,268, Embobut/Embolot 19,794, Endo 28,905 and Sambirir 27,709).

The Sub-County is geographically diverse, comprising three distinct agro-ecological zones: highlands, escarpments, and the valley floor. The highlands account for 49% of Marakwet East Sub-County and encompass regions such as Kapyego, Chesoi, and

Embobut/Embolot (KNBS, 2019). These areas are characterized by favourable climatic conditions and are suitable for dairy cow rearing, sheep for wool production, as well as the cultivation of crops such as maize, peas, and beans. The escarpment covers approximately 11% of the sub-county area and is well-suited for the cultivation of crops like maize, millet, and sorghum. This region offers unique environmental conditions that support agricultural activities. The valley floor, constituting 40% of the sub-county area, represents the arid and semi-arid lands (Elgeyo Marakwet CIDP, 2018 -2022) with flat topography. The sandy soils and low and unreliable rainfall in this area make it challenging for traditional crop farming. However, it is suitable for the growth of drought-resistant crops such as fodder, fruits, millet, sorghum, groundnuts, and green grams. Livestock keeping, including zebu cattle, goats, sheep, and poultry, is also practiced in the open grazing areas. (Elgeyo Marakwet CIDP, 2018 - 2022). Marakwet East Sub-County is predominantly characterized by small-scale farmers, with an average landholding size of 1 to 6 acres, while a few large-scale farmers possess an average of 17.3 acres (GoK, 2013). Specific areas within the valley floor, such as Mogil, Chesongoch, and Tot, experience low and unreliable rainfall patterns, with intermittent dry spells occurring between April and August (GoK, 2015).

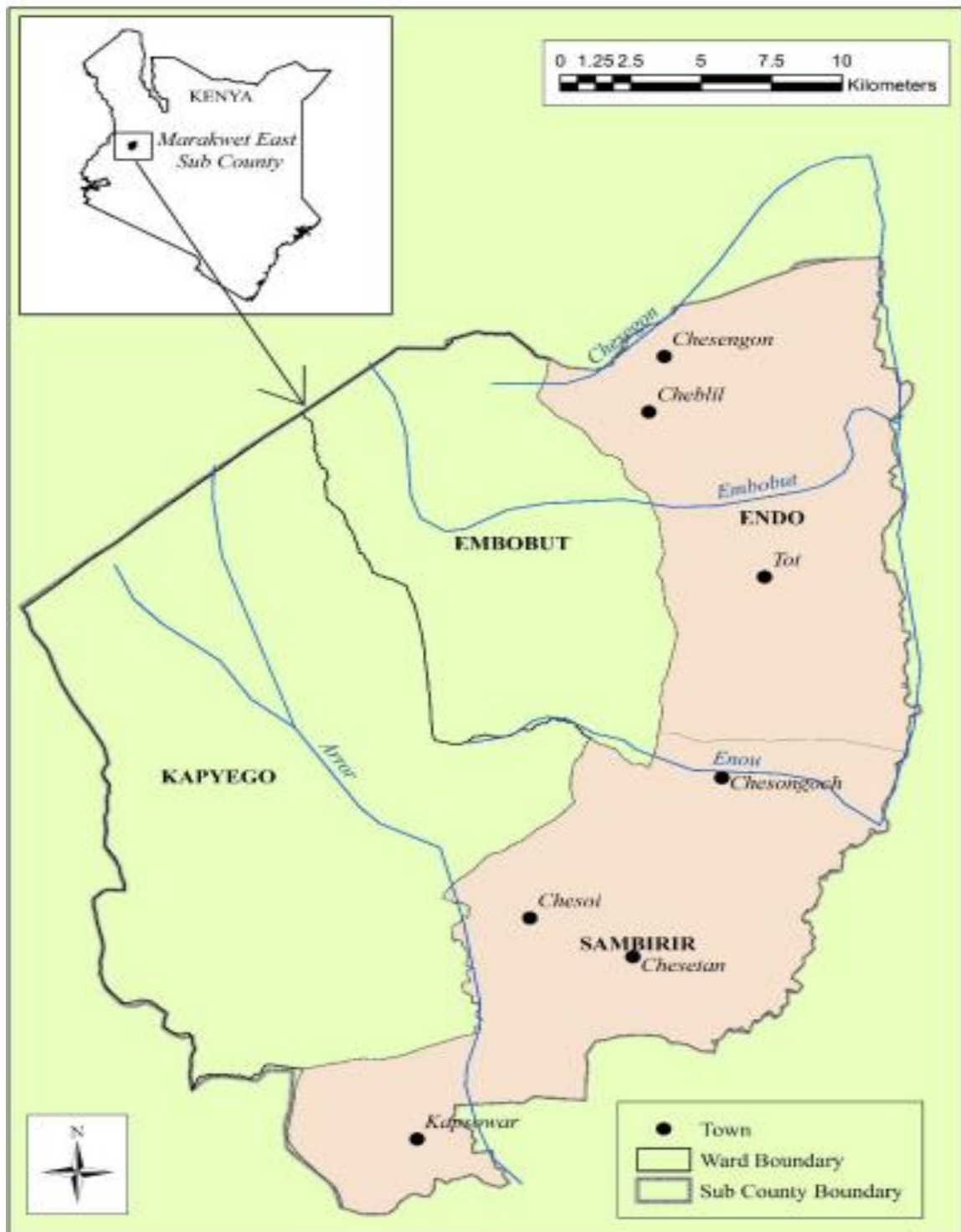


Figure 3.1: Map of Marakwet East Sub-County

Source: Murkomen (2019)

3.2.1 Biophysical Characteristics

Marakwet East sub-county is characterized by specific biophysical characteristics, including climate, physiology, vegetation, and water resources. These factors influence the agricultural practices and overall environment within the sub-county. The climate of the study area is characterized by an average annual rainfall ranging from 400 to 1000mm, with a reliability of approximately 30%. Rainfall is bimodal, with long rains occurring from May to August and short rains from September to early November. The area also experiences intermittent dry seasons. The average annual temperature ranges from 14°C to 24°C, with the period between December and March being the hottest and often marked by extended droughts (Chepkorir *et al.*, 2022).

Marakwet East sub-county is located along the basin of the Kerio River, with coordinates latitude 0 59°N and longitude 35°34' E. It sits at an altitude ranging from 800 to 1200 meters above sea level (GoK, 2005). The topography is characterized by river valleys, Cherangani hills, and volcanic rocks. The Cherangany Hills serve as a source of seasonal rivers in the sub-county (Murkomen, 2019).

The vegetation in the sub-county is diverse due to the presence of both arid and semi-arid areas as well as highlands with favourable rainfall. The highlands, particularly Embobot/Embolot Ward and Kapyego Ward, have significant forest cover, including plantations, indigenous forests, grasslands, and bushland. In arid and semi-arid areas, vegetation consists of woody shrubs, herbaceous plants, patchy grasslands, and riverine woody tree species. Dominant plant species include *Vachellia tortilis* and *Senegalia*

mellifera, which have adapted to limited moisture availability. The soils in the shrublands along the Kerio Valley range from silt loam to clay loam with low organic matter content (Chepkorir *et al.*, 2022).

3.2.2 Economic Activities

Farmers in the study area practice both livestock production and crop farming. The sub-county consists mostly of small-scale farmers who own land sizes that range from 1 to 6 acres (Elgeyo Marakwet CIDP, 2018-2022). There is a countable number of medium-scale farms with farm/land sizes of between 1 and 6 acres and large-scale farms that own more than 6 acres, which are very few in the sub-county. The main food crops produced in the study area are Irish potatoes, dairy, maize, beans, mangoes, avocados, cowpeas, green grams, sorghum, cassava, and finger millet. There are also cash crops such as pyrethrum, coffee, macadamia, and Napier grass. Livestock kept are dairy cows, local cattle, meat goats, dairy goats, poultry, and sheep. Livestock products include milk, beef, mutton, eggs, as well as hides and skins. Maize is the main food crop grown in the study area and a major staple food. Fruits grown include pawpaw, bananas, mangoes, oranges, lemons, and watermelons (Elgeyo Marakwet CIDP, 2018 -2022).

The highland of Marakwet East Sub-County that comprises Kapyego, Embobut/Embolot, and Upper Sambirir, also have dairy cows, sheep and chickens. The escarpment is a medium potential area that covers 11% of the sub-county and includes the hanging valley of Sambirir, Embobut/Embolot, and Endo wards are suitable for the cultivation of mangoes, sorghum, and finger millet and maize, with a few homesteads growing cassava

and bananas. The lowland valley floor is flat and comprises 40% of the sub-county area and is part of arid and semi-arid land (Murkomen, 2019), which covers Lower Sambirir and Endo is dry and soil supports the growth of staple and drought-resistant crops such as fodder, tomatoes, finger millet, sweet small-holder farmers, cassava, mangoes, sorghum, groundnuts, bananas and green grams. Livestock kept are zebu cattle, goat, sheep and poultry in free range. Most parts of the study area receive very low and unreliable rainfall with intermittent dry spells within months (Elgeyo Marakwet CIDP, 2018 -2022).

The agricultural programmes that are being implemented in Marakwet East Sub-County are the Agricultural Sector Development Support Programme (ASDSP), which promotes productivity enhancement for cow milk, Irish dairy and indigenous chicken value chains. Another programme implemented in the study area is the Kenya Climate Smart Agriculture Project (KCSAP), which promotes productivity enhancement for livestock production, cow milk, Irish dairy, indigenous chicken and Tomato value chains in Sambirir and Endo Wards (Elgeyo Marakwet CIDP, 2018 -2022).

3.3 Research Design

This study used descriptive and cross-sectional research designs. The descriptive research design provides a comprehensive description of the existing characteristics and conditions of small-scale dairy farmers in Marakwet East Sub-County. According to Bender (2020), descriptive design involves enquiring about different kinds of fact findings and then drawing conclusions about a targeted population by describing the data.

A cross-sectional research design provides data at a single point in time (Yilmaz, Gelaw, and Speelman, 2020). This provides a snapshot or a "cross-section" of the small-scale dairy farmers in the study area at a specific moment by allowing them to examine various variables and characteristics within that particular timeframe without studying changes over time. According to Cummings (2018), a cross-sectional research design, also known as a cross-sectional survey design, involves the collection of data at a single point in time from a sample of individuals or elements within a population.

3.4 Target Population

The target population encompassed all the small-scale dairy farmers residing in Marakwet East Sub-County. According to the Elgeyo-Marakwet Livestock and Fisheries Annual Report (2022), the total number of small-scale dairy farmers in Marakwet East Sub-County in 2022 was 8,364, and the dairy farmers' population distribution per ward is as shown in Table 3.1 below.

Table 3.1: Target Population of Small-scale Dairy Farmers per Ward

S. No	Ward	Target Population
1	Kapyego	2,108
2	Sambirir	1,419
3	Endo	2,028
4	Embobut/Embolot	2,809
Total		8,364

Source: Elgeyo-Marakwet Livestock and Fisheries Annual Report (2022)

3.5 Sample Size Determination

The sample size of a survey refers to the number of units selected from which data are gathered, which possesses relatively the same characteristics as those of the population (Rahman *et al.*, 2022). Larger samples reduce sampling errors but may be expensive, and small sample sizes may increase sampling bias and error variance (Kaplan, Chambers & Glasgow, 2014)

The sample size determination for the small-scale dairy farmers selected in the study area was based on the Nassiuma (2000) formula for calculating the minimum sample size required for this study. This formula contends that, in most surveys, a coefficient of variation in the range of $21\% \leq C \leq 30\%$ and a standard error in the range of $2\% \leq e \leq 5\%$ is acceptable. This study, therefore, used the coefficient of variation of 30% and a standard error of 2%. The higher limit for the coefficient of variation and standard error was selected to ensure low variability in the same and to minimize the error. The coefficient variation formula is presented as shown in Equation 3.1.

$$n = \frac{NC^2}{C^2 + (N-1)e^2} \dots\dots\dots (3.1)$$

Where: n = sample size

N= accessible population

C= Coefficient of Variance

e= standard error (error term)

To find the sample size for this study, the variable values were then fitted into Equation 3.1 as shown below:

$$n = \frac{8364 \times 0.3^2}{0.3^2 + (8364 - 1) \times 0.02^2} = 219$$

Therefore, from the above calculations, a total of 219 small-scale dairy farmers were the required sample size for this study. To take care of incomplete responses, this study added 5% (11) to the sample size to make 230 small-scale dairy farmers.

3.6 Sampling Procedure

Sampling involves a method of choosing a subset of a population that represents the characteristics of the entire population to collect information about the phenomenon of interest (Mweshi and Sakyi, 2020). Therefore, this study employed purposive sampling, stratified, and systematic random sampling techniques. Marakwet East Sub-County was selected as the study area because it is the least productive in terms of dairy cow milk production in Elgeyo Marakwet County. In the second stage, a stratified random sampling procedure was used to obtain the sample of small-scale dairy cow milk farmers in the whole Sub-County. This involved subdividing the small-scale dairy farmers into distinct subgroups or strata based on relevant characteristics (Hernandez, 2023). In this study, the four wards in Marakwet East Sub-County, namely Kapyego, Sambirir, Endo, and Embobot/Embolot, served as the strata. Thirdly, in each ward of the study area, a proportionate sample of small-scale dairy farmers was picked for the study, as shown in Table 3.2.

In the last stage, a systematic random sampling technique was used. This sampling involved selecting every n^{th} individual small-scale dairy farmer from the sampling frame or the list obtained from the sub-county Agricultural, Livestock, and Fisheries Office. This

technique ensures that each individual in the population has an equal chance of being selected (Mweshi & Sakyi, 2020),

Table 3.2: Proportionate Sample Distribution per Ward

Ward	Target Population	Proportion (Percent)	Sample Size
Kapyego	2,108	25.2%	58
Sambirir	1,419	17.0%	39
Endo	2,028	24.2%	56
Embobut/Embolot	2,809	33.6%	77
Total	8,364	100%	230

Source: Author's Computation from Marakwet East Sub-County Livestock and Fisheries Annual Report (2022).

3.7 Data Type and Sources

The data collected for this study relied on both primary and secondary data. The combination of primary and secondary data provided a comprehensive and robust dataset for the analysis and interpretation of the study findings. Primary data was collected directly from the 230 small-scale dairy cow farmers in all four Wards of Marakwet East Sub-County. This data provided specific information about the socio-economic factors, farm production factors, technological factors, and institutional factors related to dairy cow milk production.

Secondary data were obtained from existing sources such as government reports, research articles, and relevant publications from the Ministry of Livestock and Fisheries annual reports, published theses and economic journals, economic surveys, statistical abstracts,

conference reviews, books, magazines, national and county development and strategic plans, National Bureau of Statistics publications, desktop literature, and the internet sources. These sources provided additional information on the socio-economic context, existing policies and regulations, market trends, and other relevant data related to the study variables. The secondary data helped to complement and support the findings from the primary data.

3.8 Data Collection Instruments

In this study, primary data were collected directly from the small-scale dairy farmers using questionnaires, as shown in Appendix II. The questionnaire was administered to 230 small-scale dairy farmers. A research team of one researcher and nine trained assistants (enumerators) administered the questionnaire.

3.8.1 Validity of Instruments

Validity is defined as the accuracy and meaningfulness of inferences, based on the results of the research (Mochon and Schwartz, 2020). Simply, validity alludes to the accuracy and meaning of realities and proof, which are drawn from the research results. It is the extent to which results acquired from the investigation of the information represent the subject under study.

To establish the validity of the research instrument for this study, two measures were used. Firstly, the validity of the instruments was ensured through a comprehensive literature review and expert opinions (Sürücü and Maslakci, 2020). Secondly, in this study, validity

was achieved by discussion with the two university experts on the items in the instrument. The two experts have extensive experience in teaching and supervising postgraduate students. They were able to ascertain the validity by the clarity of wording and whether the respondents were able to interpret the questions. Similarly, suggestions were then incorporated into the final instruments.

3.8.2 Reliability of the Instruments

Reliability involves the degree to which the researcher can comfortably rely on the information collected for analysis from various data sources (Mellinger and Hanson, 2020). The questionnaire returned the same measurements when used at different times. The reliability of research instruments was crucial for obtaining consistent and dependable results in this study on economic factors influencing dairy cow milk production among small-scale farmers.

To ensure the reliability of the questionnaire, several measures were implemented. Firstly, internal consistency reliability is assessed using Cronbach's Alpha technique to measure the inter-item reliability of scales (Izah, Sylva, and Hait, 2023). According to Soares (2021), a pilot scope of between 1% and 10% is considered suitable. For this study, reliability was tested by pretesting the instrument with a sample of 23 (10% of the sample population) small-scale dairy cattle farmers in Marakwet West Sub-County of Elgeyo Marakwet County. Marakwet West Sub-County has similar characteristics to the study sample but was not part of the study. Data from the pilot study were analysed using

Cronbach's Alpha coefficient, mathematically expressed as shown in Equation 3.2 below.

A coefficient of 0.7 and above was deemed reliable.

$$\alpha = \frac{N\bar{c}}{v + (n-1)c} \dots\dots\dots (3.2)$$

Where α is the Cronbach's Alpha coefficient, \bar{c} is the average inter-item covariance among the items, \bar{v} is the average variance, and N is equal to the number of items/observations.

3.9 Data Collection Procedures

Before commencing data collection, a research permit was obtained from the National Commission for Science, Technology and Innovation (NACOSTI), as shown in Appendix IV, through an introductory letter from the Director, Board of Postgraduate Studies, University of Eldoret, as shown in Appendix III. The permit was then presented to obtain permissions from the Elgeyo Marakwet County Commissioner, as shown in Appendix V, the Ministry of Education, as shown in Appendix VI, and the Sub-County Agricultural, Livestock & Fisheries Officer to collect data from the selected dairy farmers. Subsequently, the researcher contacted and scheduled appointments with small-scale dairy cow farmers in Marakwet East Sub-County. Household heads served as the primary respondents during interviews, with spouses or knowledgeable individuals within the household being interviewed in cases where the household head is unavailable. These procedures were designed to facilitate legal, ethical, and efficient data collection while obtaining the necessary approvals and participant cooperation.

3.10 Data Analysis and Presentation

The initial data screening upon completion of the questionnaires was done by sorting, coding, and cleaning. The data sources were then numbered and coded using a coding frame in readiness for entry and analysis. The collected data were analysed using both descriptive and inferential statistics. Descriptive statistics were used to summarize the characteristics of the variables, including measures of central tendency (mean) and variability (standard deviation). Frequency distributions and percentages were used for categorical variables. Inferential analysis was done for each specific objective with the help of International Business Machine (IBM) Statistical Packages for Statistical package for Social Sciences (SPSS) version 28.0.1.1 software, as specified for each of the specific objectives as follows.

3.10.1 Estimates of Socio-Economic Factors on Dairy Cow Milk Production

To assess the effects of farm-specific socioeconomic factors affecting milk production among small-scale dairy farmers in Marakwet East Sub-County, Kenya, a multiple linear regression model was employed as shown in Equation 3.3 below. This model was suitable because it allowed us to analyse how various socio-economic variables jointly influence milk production. The use of multiple linear regression is also appropriate because it accommodates several independent variables simultaneously and helps identify the strength and direction of their relationships with the dependent variable.

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \epsilon_i \dots \dots \dots (3.3)$$

Where:

Y_i = Milk production (Milk yield)

X_1 = Age of household head

X_2 = Gender of household head

X_3 = Marital status

X_4 = Education level

X_5 = Family/household size

X_6 = Farmer's occupation

X_7 = Farmer's years of experience

X_8 = Total farm income

$\beta_1, \beta_2, \dots, \beta_8$ are the regression coefficients to be estimated.

ε = is the error term that is normally distributed with a mean of zero and constant variance of epsilon squared (ε^2), and included in the model to account for other factors that are not included in the model but affected the performance.

3.10.2 Estimates of Effects of Technological Factors on Dairy Cow Milk Production

To estimate the effects of technological factors on dairy cow milk production among small-scale farmers in Marakwet East Sub-County, a multiple regression model was used for data analysis as shown in Equation 3.4. This model helps us understand how various technological variables collectively influence milk production.

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \varepsilon_i \dots\dots\dots (3.4)$$

Where:

Y_i = milk production (Milk yield).

X_1 = Use of Artificial Insemination

X_2 = Access to vaccination services

X_3 = Access to deworming services

X_4 = Access to curative services

X_5 = Access to milking machines

X_6 = Access to milk cooling machine

X_7 = Adoption of high-yielding fodder/pasture

X_8 = Access to feed milling technology

X_9 = Access to improved feeds (Hay, Silage)

X_{10} = Adoption of improved dairy breeds

X_{11} = Access to communication services

X_{12} = Access to digital platform

X_{13} = Access to pregnancy diagnosis services

$\beta_1, \beta_2, \dots, \beta_{13}$ are the regression coefficients estimated.

ε = is the error term that is normally distributed with a mean of zero and constant variance of epsilon squared (ϵ^2), and included in the model to account for other factors that are not included in the model but affected the performance.

3.10.3 Estimates of Effects of Farm Production Factors on Dairy Cow Milk Production

To estimate the effects of farm production factors on dairy cow milk production among small-scale farmers in Marakwet East Sub-County, a Cobb-Douglas production function model (double log-linear form) as adopted from Douglas & Cobb (1928) was used, as

shown in Equation 3.5. This model is commonly used in agricultural economics to analyse production relationships and can capture the influence of multiple production inputs on milk production. Cobb-Douglas is a functional form of the production function used to represent the technical relationship between the amounts of two or more inputs (particularly physical capital and labour) and the amount of output that those inputs can produce. The model specification shown in Equation 3.5 is adopted from Meeusen *et al.*, (1977).

$$Y = AL^\beta K^\alpha \dots\dots\dots (3.5)$$

Where;

Y = annual gross margin in Kenya Shillings from milk production (the dependent variable is performance, which refers to the amount of money in profit realised by small-scale dairy cattle farmers from milk production, therefore measured in Annual GM) (Mawa, 2013)

L = Labour (in terms of man-hours/day),

K = Capital (in Ksh)

A = Total factor productivity

Where α and β are the output elasticities of labour and capital, respectively. These values are constants and determined by the available technology.

Taking on the logarithm on both sides of Equation 3.5, the function transforms to a double log-linear form as shown in Equation 3.6

$$\ln(Y_i) = \beta_0 + \beta_1 \ln(X_1) + \beta_2 \ln(X_2) + \beta_3 \ln(X_3) + \beta_4 \ln(X_4) + \beta_5 \ln(X_5) + \beta_6 \ln(X_6) + \beta_7 \ln(X_7) + \beta_8 \ln(X_8) + \beta_9 \ln(X_9) + \beta_{10} \ln(X_{10}) + \beta_{11} \ln(X_{11}) + \beta_{12} \ln(X_{12}) + \beta_{13} \ln(X_{13}) + \beta_{14} \ln(X_{14}) + \epsilon_i \dots\dots (3.6)$$

Where:

$Ln(Y_i)$ = The natural log for annual milk production in litres

LnY_i = Annual milk production in litres

LnX_1 = Farm size (Acres)

LnX_2 = Availability of labour (Man hour/day)

LnX_3 = Access to capital

LnX_4 = Dairy breed type

LnX_5 = Farming system (grazing system)

LnX_6 = Access to Veterinary care

LnX_7 = Total cost of feeds (Ksh)

LnX_8 = Availability of quality feeds

LnX_9 = Access to clean water

LnX_{10} = Access to grazing land

LnX_{11} = Access to market information

LnX_{12} = Distance to output market (Km) (a proxy for market access)

LnX_{13} = Farm-gate milk price (Ksh)

LnX_{14} = Distance to a veterinary clinic (Km)

$\beta_1, \beta_2, \dots, \beta_{14}$ are the regression coefficients estimated.

ε = is the error term that is normally distributed with a mean of zero and constant variance of epsilon squared (ε^2), and included in the model to account for other factors that were not included in the model but affected the performance.

3.10.4. Estimates of Effects of Institutional Factors on Dairy Cow Milk Production

To estimate the effects of institutional factors on dairy cow milk production among small-scale farmers in Marakwet East Sub-County, a multiple linear regression was used as shown in Equation 3.7. This model helps us understand how various institutional variables collectively influence milk production.

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \epsilon_i \dots \dots \dots (3.7)$$

Where:

Y_i = Milk production

X_1 = Land Tenure system

X_2 = Access to extension services

X_3 = Access to credit facilities

X_4 = Membership in farmer groups or cooperative society

X_5 = Access to contract

X_6 = Access to marketing services

X_7 = Received business plan training

X_8 = Type of service providers

X_8 = Availability of adequate infrastructure

X_9 = Availability of adequate infrastructure

$\beta_1, \beta_2, \dots, \beta_9$ are the regression coefficients estimated.

ϵ = is the error term that is normally distributed with a mean of zero and constant variance of epsilon squared (ϵ^2), and included in the model to account for other factors that were not included in the model but affect the performance.

3.11 Diagnostic Tests

Diagnostic tests were conducted on the regression results obtained from the analytical approach, specifically the SPSS output. These tests aimed to assess the assumptions underlying the chosen analytical model, which in this study was multiple linear regression using Ordinary Least Squares (Raihan *et al.*, 2023). The key assumptions that were tested include linearity, multicollinearity, normality, and homoscedasticity.

Multicollinearity, which refers to the correlation between independent variables, was assessed using the Variance Inflation Factor (VIF) in SPSS as shown in Equation 3.8 below. The VIF measures the extent to which the variance of an estimated regression coefficient is inflated due to multicollinearity. A VIF of 1 indicates no correlation, while values between 1 and 5 suggest a moderate correlation that does not require corrective measures. VIFs greater than 5 indicate severe multicollinearity, which can lead to unreliable coefficient estimates and questionable p-values (Bayman & Dexter, 2021).

$$VIF = \frac{1}{1 - R^2}$$

..... (3.8)

Additionally, diagnostic tests on model residuals were conducted to evaluate model adequacy. These tests provided information about the appropriateness of the model in explaining the observed data. SPSS provided various diagnostic tools to assess assumptions and identify any potential issues with the model. By conducting these diagnostic tests, the study ensured the validity and reliability of the regression analysis by addressing any violations of the underlying assumptions. This helps to ensure the accuracy and credibility of the findings (Pagan and Hall, 1983).

3.12 Definition, Measurement of Variables and Expected Signs

Table 3.3 shows the variables used in this study and their measurements. The positive sign (+) means that an increase in the variable causes an increase in the performance of small-scale dairy cattle farmers. In contrast, the negative sign (-) means an increase in the variable causes a decrease in the performance of small-scale dairy cattle production.

Table 3.3: Descriptions and Measurement of Variables

Variables	Description Unit	Expected sign	
Milk yield (output)	Continuous	+	
Dependent Variable			
Independent Variables			
Socio-Economic Factors in Dairy Cow Milk Production			
Age of household head	Continuous	Years	+
Gender of household head	Categorical	1 = male, 2 = female	+/-
Marital status	Categorical	1=Single [] 2=Married [] 3=Divorced [] 4=Widowed []	+/-
Education level	Categorical	1=None [], 2=Primary [], 3=Secondary [], 4= Tertiary[] 5=College [] 6=University []	+/-
Family/Household size	Continuous	Number of family members	+
Farmer's occupation	Categorical	1=Full-time farmer [] 2=Part-time farmer [] 3=Full-time employed [] 4=Part-time employed [] 5=other	+/-
Years of experience	Continuous	Years in dairying	+
Total farmer's income	Continuous	Total annual farm income in Ksh.	+
Technological Factors in Dairy Cow Milk Production			
Access to AI	Categorical	Uses Artificial Insemination: 1=Yes; 2=No	+/-
Access to vaccination services	Categorical	Access to vaccination services: 1=Yes; 2=No	+/-
Access to deworming services	Categorical	Access to deworming services: 1=Yes; 2=No	+/-
Access to curative services	Categorical	Access to curative services: 1=Yes; 2=No	+/-
Access to milking machines	Categorical	Access to milking machines: 1=Yes; 2=No	+/
Access to milk cooling facility	Categorical	Access to milk cooling facility: 1=Yes; 2=No	+/
Adoption of high-yielding pasture	Categorical	Adopted high-yielding fodder/pasture: 1=Yes; 2=No	+/
Access to feed chopping/milling	Categorical	Access to feed chopping/milling technology: 1=Yes; 2=No	+/-
Access to improved feeds	Categorical	Access to improved feeds: 1=Yes; 2=No	+/-
Adoption of improved dairy breeds	Categorical	Adoption of improved dairy breeds: 1=Yes; 2=No	+/-
Access to communication services	Categorical	Access to communication services: 1=Yes; 2=No	+/-
Access to a digital platform	Categorical	Access to digital platform: 1=Yes; 2=No	+/-
Farm Production Factors in Dairy Cow Milk Production			
Farm size (Acres)	Continuous	Total farm area in acres:	+
Availability of labour	Categorical	Has access to labour (man-hours/day): 1=Yes; 2=No	+/-
Access to capital	Categorical	Access to capital: 1=Yes; 2=No	+/-
Dairy breed type	Categorical	Type of dairy breed: 1 Friesian, 2 Ayrshire, 3 Cross-breeds; 4 Local breeds;	+/-

Farming system (Grazing system)	Categorical	Type of farming/grazing system: 1 Zero grazing; 2 Semi-zero grazing; 3 Free range; 4 Tethering	+/-
Access to veterinary care	Categorical	Access to veterinary services: 1=Yes; 2=No	+/-
Total cost of feeds (Ksh)	Continuous	Total cost of feeds in Ksh	+
Availability of quality feeds	Categorical	Availability of feeds: 1=Yes; 2=No	+/-
Availability of clean water	Categorical	Availability of clean water: 1=Yes; 2=No	+/-
Access to grazing land	Categorical	Access to grazing land: 1=Yes; 2=No	+/-
Access to market information	Categorical	Access to market information: 1=Yes; 2=No	+/-
Distance to market (market access)	Continuous	Distance to the market (Km) (a proxy for market access)	+
Farm-gate milk price (Ksh)	Continuous	Farm-gate Milk price per litre (Ksh)	+
Distance to a veterinary clinic(Km)	Continuous	Distance to a veterinary clinic	+
Institutional Factors in Dairy Cow Milk Production			
Land Tenure system	Categorical	Type of land tenure system: 1= Privately-owned; 2= Leased; 3= Family; 4= Communal; 5= State-owned	+/-
Access to extension services	Categorical	Access to extension services: 1=Yes; 2=No	+/-
Access to credit facilities	Categorical	Has access to credit from 1=Yes; 2=No	+/-
Membership in farmer groups	Categorical	Membership to farmer groups: 1=Yes; 2=No	+/-
Access to contract	Categorical	Access to contract: 1=Yes; 2=No	+/-
Access to marketing services	Categorical	Accessed marketing services: 1=Yes; 2=No	+/-
Received business plan training	Categorical	Received business plan training: 1=Yes; 2=No	+/-
Access to service providers	Categorical	Type of service providers: 1=Yes; 2=No	+/-
Availability of infrastructure	Categorical	Availability of adequate infrastructure: 1=Yes; 2=No	+/-

Source: Authors tabulation (2024)

3.13 Ethical Considerations

During the study in Marakwet East Sub-County, several ethical considerations were diligently observed to ensure the well-being of the participants and the integrity of the research. First and foremost, the confidentiality of the information provided by the respondents, including their details, was rigorously upheld. Respondents were made aware that their participation was solely for academic purposes, fostering trust and encouraging them to share information openly. To maintain academic integrity, every precaution was taken to prevent plagiarism throughout the research study, safeguarding intellectual property rights. All individuals involved in the research were treated with the utmost dignity and respect, adhering to ethical standards. Before thesis submission for examination, a comprehensive plagiarism check was conducted using recommended anti-plagiarism software, ensuring the originality of the work. A Certificate of Plagiarism Check for the thesis was obtained from the University of Eldoret, as shown in Appendix VII. These ethical measures were paramount in upholding the research's credibility and protecting the rights of all involved parties.

CHAPTER FOUR

RESULTS

4.1 Overview

This chapter presents the study's results. It includes the response rate, questionnaire reliability, descriptive analysis results, and the empirical analysis findings.

4.2 Response Rate and the Reliability of the Questionnaire

A sample size of 230 small-scale dairy farmer households was selected to participate in the study. From the sampled small-scale dairy farmer households, only a total of 196 questionnaires were duly filled out by the farmers and returned for data analysis.

4.3 Descriptive Analysis Results

This sub-section presents the descriptive results for economic factors affecting milk production among small-scale farmers in the Marakwet East Sub-County. A summary of statistics results on the continuous economic characteristics variables of small-scale dairy farmers is shown in Table 4.1.

Table 4.1: Summary Statistics Results for Continuous Variables of Small-Scale Dairy Farmers

Variable	Mean	Std.	Minimum	Maximum
Age of the household head (Years)	47.1	8	28	60
Family size (Number)	5.1	2	3	10
Farmer experience (Years)	16.8	8.1	3	30
Total farm income (Ksh.)	91,938	24,833	10,000	200,000
Farm size (Acres)	3.3	1.4	1.0	10.0
Distance to output market (Km) (a proxy for market access)	2.3	0.9	0.1	3.0

Source: Author's computation from Survey Data (2024)

Table 4.2: Summary Statistics Results for Categorical Variables of Small-Scale Dairy Farmers

Variable	Frequency	Percent
Gender		
Male	129	65.8
Female	67	34.2
Marital status		
Single	7	3.6
Married	177	90.3
Widowed	12	6.1
Level of education		
Primary	104	53.1
Secondary	83	42.3
College	9	4.6
Farmer occupation		
Full-time farmer	124	63.3
Part-time farmer	18	9.2
Fully employed	42	21.4
Trader	12	6.1
Land tenure system		
Private owned	42	21.4
Family owned	128	65.3
Community-owned	26	13.3
Access to credit		
Yes	58	29.6
No	138	70.4

Source: Author's computation from Survey Data (2024)

Results on the types of improved feeds in the study area are shown in Figure 4.1 of results.

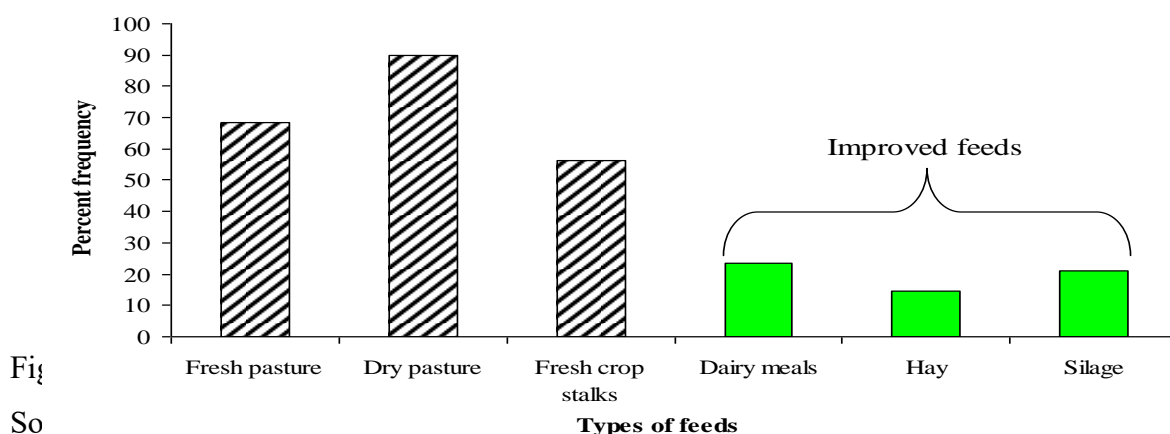


Table 4.3: Milk Production Statistics in Marakwet East Sub-County

Milk production	Mean	Std. Dev
Average annual milk production per household	2,925	211
Average annual milk production per cow	975	101
Average daily milk production per cow	4.5	0.4

Source: Author's computation from Survey Data (2024)

4.4 Diagnostic Test Results

The diagnostic results were tested for multicollinearity using tolerance and Variance Inflation Factors (VIF) as shown in Table 4.4 of the results. The results in Table 4.4 show that all the variables under study had a VIF ranging between 1.061 and 2.365 and also tolerance values ranging from 0.423 to 0.943, which show that there were no potential multicollinearity symptoms among the predictors and hence found to have no potential influence on the estimates from the model. These were the indicators that there was a low correlation among the variables under consideration.

Table 4.4: Estimates of Multicollinearity Statistics

Variable	Multicollinearity statistics	
	Tolerance	VIF
Age of the household head	0.739	1.354
Gender of the household head	0.677	1.477
Marital status	0.734	1.362
Levels of education	0.733	1.364
Family/Household size	0.631	1.585
Farmer's occupation	0.731	1.367
Farmer's experience	0.535	1.871
Total farmer income	0.631	1.584
Access to Artificial Insemination	0.690	1.450
Access to vaccination services	0.789	1.267
Access to deworming services	0.935	1.070
Access to curative services	0.729	1.372
Access to the milking facility	0.755	1.325
Access to milk cooling facilities	0.674	1.483
Adopted high-yielding fodder/pasture	0.705	1.419
Access to feed milling technology	0.766	1.305
Access to improved feeds (Hay, silage)	0.738	1.356
Adopted improved dairy breeds	0.695	1.438
Access to communication services	0.700	1.428
Access to a digital platform	0.626	1.598
Access to pregnancy diagnosis technology	0.508	1.967
Farm size (Acres)	0.498	2.007
Availability of labour (Man hour/day)	0.530	1.886
Access to capital	0.455	2.200
Dairy breed type	0.616	1.622
Farming system (Grazing system)	0.423	2.365
Access to veterinary care	0.578	1.731
Total cost of feeds (Ksh)	0.596	1.678
Availability of quality feeds	0.700	1.429
Availability of clean water	0.912	1.096
Access to grazing land	0.872	1.147
Access to market information	0.771	1.297
Distance to market (Km) (a proxy for market access)	0.661	1.513
Farm-gate milk price	0.764	1.308
Distance to a veterinary clinic (Km)	0.617	1.621
Land Tenure system	0.813	1.229
Access to extension services	0.935	1.069
Access to credit facilities	0.706	1.417
Membership in farmer groups or cooperative societies	0.551	1.817
Access to contract	0.830	1.205
Access to marketing services	0.727	1.376
Received business plan training	0.614	1.629
Access to service providers	0.727	1.375
Availability of adequate infrastructure	0.943	1.061

Source: Author's Computation from Survey Data (2024)

4.5 Econometric Analysis Results

To answer the four specific objectives of this study, econometric models were used to empirically analyse each objective separately. Multivariate linear regression model and Cobb-Douglas production function (double log-linear form) models were used to determine the factors influencing dairy cow milk production among small-scale farmers in the study area. The results are presented in the sub-sections that follow.

4.5.1 Estimates of Socio-Economic Factors on Dairy Cow Milk Production

The study's first objective sought to determine the socio-economic factors influencing dairy cow milk production among small-scale farmers in Marakwet East Sub-County, Kenya.

Table 4.5: Estimated Results on Effects of Socio-Economic Factors on Dairy Cow Milk Production

Regression Statistics					
Model summary					
Multiple R	0.894				
R Square	0.800				
Adjusted R Square	0.791				
Observations	196				
Standard Error	1.083				
ANOVA	SS	df	MS	F	P-value
Regression	877.925	8	109.741	93.414	<0.01
Residual	219.683	188	1.175		
Total	1,097.608	196			
	Unstandardized Coefficients		Standardized Coefficients	t Stat	P-value
	Beta	Std. Error	Beta		
(Constant)	4.899	0.666		7.356	0.000
Age of household head	0.009	0.011	0.033	0.871	0.385
Gender of household	0.212	0.198	0.043	1.069	0.286
Marital status	-0.107	0.173	-0.024	-0.617	0.538
Education level	0.602	0.088	0.270	7.054	0.000***
Family/household size	1.091	0.155	0.280	6.811	0.000***
Farmer's occupation	0.188	0.090	0.072	2.187	0.061
Farmer's experience	1.311	0.015	0.332	7.414	0.000***
Total farmer income	1.122	0.034	0.312	7.580	0.000***

Legend
 LR Chi² = 470.523
 Pseudo R² (Cox and Snell) = 0.785; Nagelkerke = 0.786
 Prob >Chi² = 0.000
 Log-likelihood = 1.439
 P-value ≤ 0.001 = ***
 P-value ≤ 0.01 = **
 P-value ≤ 0.05 = *

Source: Author's Computation from Survey Data (2024)

4.5.2 Estimates of Technological Factors on Dairy Cow Milk Production

The study's second objective sought to determine the technological factors influencing dairy cow milk production among small-scale farmers in Marakwet East Sub-County, Kenya. The estimated results on the effects of technological factors on dairy cow milk production are shown in Table 4.6 of results.

Table 4.6: Estimated Results on Effects of Technological Factors on Dairy Cow Milk**Production**

Regression Statistics						
Model summary						
Multiple R	0.857					
R Square	0.733					
Adjusted R Square	0.715					
Observations	196					
Standard Error	1.266					
ANOVA	SS	Df	MS	F	P-value	
Regression	805.805	13	61.985	38.661	<0.001	
Residual	291.803	183	1.603			
Total	1,097.608	196				
	Unstandardized Coefficients		Standardized Coefficients	t Stat	P-value	
	Beta	Std. Error	Beta			
(Constant)	2.222	0.149		14.934	0.000	
Use of Artificial	0.690	0.220	0.144	3.137	0.002***	
Access to vaccination	-0.046	0.232	-0.009	-0.200	0.842	
Access to deworming	0.684	0.208	0.130	3.285	0.001***	
Access to curative services	0.459	0.256	0.080	1.793	0.075	
Access to milking machines	-0.428	0.736	-0.026	-0.581	0.562	
Access to milk cooling	0.757	0.428	0.082	1.770	0.078	
Adoption of high-yielding	1.834	0.285	0.294	6.448	0.000***	
Access to feed milling	0.272	0.449	0.026	0.607	0.545	
Access to improved feeds	1.780	0.227	0.348	7.827	0.000***	
Adoption of improved dairy	1.672	0.264	0.290	6.324	0.000***	
Access to communication	-0.071	0.268	-0.012	-0.263	0.793	
Access to digital platform	0.687	0.497	0.067	1.383	0.168	
Access to pregnancy	0.502	0.429	0.063	1.170	0.243	
Legend						
LR Chi ² = 470.556						
Pseudo R ² (Cox and Snell) = 0.785; Nagelkerke = 0.786						
Prob >Chi ² = 0.000						
Log-likelihood = 2.431						
P-value ≤ 0.001 = ***						
P-value ≤ 0.01 = **						

Source: Author's Computation from Survey Data (2024)

4.5.3 Estimates of Farm Production Factors on Dairy Cow Milk Production

The third objective of the study sought to determine the farm production factors influencing dairy cow milk production among small-scale farmers in Marakwet East Sub-County, Kenya. The estimated results on the effects of farm production factors on dairy cow milk production are shown in Table 4.7.

Table 4.7: Estimated Results on Effects of Farm Production Factors on Dairy Cow Milk Production

Regression Statistics					
Model summary					
Multiple R	0.897				
R Square	0.804				
Adjusted R Square	0.789				
Observations	196				
Standard Error	3.1803				
ANOVA	SS	Df	MS	F	P-value
Regression	2022.4076	13	15560.10827	46.232	<0.001
Residual	612.37537	183	336.562504		
Total	2635.7829	196			
	Unstandardized Coefficients		Standardized Coefficients	t Stat	P-value
	Beta	Std.	Beta		
(Constant)	3.9924	0.9123		4.808	0.000
Farm size (Acres)	0.2151	0.0383	0.195	3.972	0.000***
Availability of labour	-0.0006	0.1903	0.036	0.737	0.462
Access to Capital	0.8237	0.1952	0.264	5.093	0.000***
Dairy breed type	0.4623	0.0924	0.228	5.029	0.000***
Farming system	0.8997	0.1858	0.279	5.120	0.000***
Access to veterinary	0.8260	0.3158	0.113	2.396	0.018*
Cost of feeds	0.0003	0.0001	0.157	1.458	0.0601
Access to quality feeds	1.0823	0.1854	0.154	3.963	0.000***
Access to clean drinking	0.0555	0.2180	0.025	0.673	0.502
Access to grazing land	0.0803	0.1661	0.036	0.932	0.352
Access to market	0.7375	0.3008	0.101	2.396	0.058
Distance to market for	-0.0255	0.0860	-0.021	-	0.638
Farm gate sales of milk	-0.0057	0.0147	-0.002	-	0.961
Distance to veterinary	0.0900	0.0441	0.084	1.840	0.067
Legend					
LR Chi ² = 243.434					
Pseudo R ² = (Cox and Snell) = 0.786; Nagelkerke = 0.792					
Prob >Chi ² = 178.56					
Log-likelihood = 3.153					
P-value ≤ 0.001 = ***					
P-value ≤ 0.01 = **					
P-value < 0.05 = *					

Source: Author's Computation from Survey Data, (2024)

4.5.4 Estimates of the Institutional Factors on Dairy Cow Milk Production

The fourth objective of the study sought to determine the institutional factors influencing dairy cow milk production among small-scale farmers in Marakwet East Sub-County, Kenya. The estimated results on the effects of the institutional factors influencing dairy cow milk production are shown in Table 4.8.

Table 4.8: Estimated Results on Effects of Institutional Factors on Dairy Cow Milk Production

Results in the current study					
Model summary					
Multiple R	0.798				
R Square	0.630				
Adjusted R Square	0.617				
Observations	196				
Standard Error	1.664				
ANOVA	SS	Df	MS	F	P-value
Regression	581.711	9	64.635	23.303	<0.001
Residual	515.898	187	2.774		
Total	1097.608	196			
	Unstandardized Coefficients		Standardized Coefficients	t Stat	P-value
	Beta	Std.	Beta		
(Constant)	1.219	0.415		2.939	0.004
Land tenure system	0.450	0.139	0.181	3.239	0.001***
Access to extension	1.724	0.433	0.234	3.978	0.000***
Access to credit	1.904	0.310	0.367	6.138	0.000***
Membership in farmer	1.056	0.387	0.185	2.725	0.007***
Access to milk contract	0.310	0.545	0.031	0.570	0.570
Access to marketing	0.247	0.301	0.048	0.818	0.414
Received business plan	-0.195	0.526	-0.024	-0.371	0.711
Access to service	-0.365	0.271	-0.070	-1.349	0.179
Availability of adequate infrastructure	0.039	0.276	0.095	0.767	0.4350
Legend					
LR Chi ² = 203.434					
Pseudo R ² = (Cox and Snell) = 0.756; Nagelkerke = 0.752					
Prob >Chi ² = 0.000					
Log-likelihood = 2.025					
P-value ≤ 0.001 = ***					
P-value ≤ 0.01 = **					
P-value ≤ 0.05 = *					

Source: Author's Computation from Survey Data, (2024)

CHAPTER FIVE

DISCUSSIONS

5.1 Overview

This chapter presents the study's discussions. It includes the response rate, questionnaire reliability, descriptive analysis results, and the empirical analysis findings.

5.2 Response Rate and the Reliability of the Questionnaire

A sample size of 230 small-scale dairy farmer households was selected to participate in the study. From the sampled small-scale dairy farmer households, only a total of 196 questionnaires were duly filled out by the farmers and returned for data analysis. The duly filled and returned questionnaires represented a response rate of 89.5%, and the overall return rate was suitable for data analysis. According to Mugenda (1999), a response rate of 50% is adequate for analysis and reporting; a rate of 60% is good, and a response rate of 70% and over is excellent. Therefore, for this study, the response rate of 89.5% was excellent for analysis and reporting.

Further, the study's findings show that the overall reliability of the questionnaire was 0.79, which suggests that the indicator instrument was reliable and good for data analysis. According to (Bujang *et al.*, 2024; Murphy *et al.*, 2017), a reliability value above 0.6 is adequate to accept the research instrument's internal consistency.

5.3 Descriptive Analysis Results

This sub-section presents the descriptive results for economic factors affecting milk production among small-scale farmers in the Marakwet East Sub-County. A summary of statistics results on the continuous economic characteristics variables of small-scale dairy farmers is shown in Table 4.1.

The results in Table 4.1 show that the mean age of the household head of the small-scale dairy farmers in the study area was 47 years, with a minimum of 28 years and a maximum of 60 years. The current finding may indicate that a higher proportion of farmers were old due to the possible migration of the youths to towns to look for better opportunities at the expense of livestock farming (Mueller *et al.*, 2020; Mussa, 2020). The high number of older farmers in the dairy industry production may also be related to the fact that land ownership is quite hard for young people to acquire (Hegde, 2019). The current results are in convergence with other study findings, such as those of Kirea (2023), who found that the mean age among livestock farmers in Tigania East Sub-County in Meru County was 46 years. Further, Abot (2020) found the mean ages of livestock farmers to be 44.8 years and 45.4 years in Kajiado and Makueni Counties, respectively. The current results also converge with the mean age of 46 years for ruminant farmers in Northern Ghana (Adams and Ohene-Yankyera, 2014), and 47 years for dairy farmers in Mekelle, South Africa (Elum *et al.*, 2017). The current findings on age also agree with the 45.6 years among urban livestock farmers in Nigeria (Asadu *et al.*, 2021) as well as 45 years of age among livestock farmers in the West Region of Cameroon (Oben *et al.*, 2024).

The result on family/household size indicates that there were 5 members in each family, where the minimum number was 3 and a maximum of 10 members. The number of members in the family is an important source of labour for the farms. Few members of the households therefore imply inadequate and unreliable farm labour supply thus negatively impacting milk production. The current result concurs with the provincial and national average family size of 5 members in Kenya (Kenya National Bureau of Statistics, 2019). This result also compares well with a study finding by Wanjala, (2023) that was conducted in Kiganjo Sub-location in Kiambu and found the mean size to be 5 members, a study of small-scale farmers in Western Kenya which reported 5 members per household (Musafiri *et al.*, 2022), as well as a study among dairy cattle farmers in Mbeere District of Eastern Kenya which had a household size of 5 members (Ikaal *et al.*, 2020). Elsewhere, the current study compares well with the mean number of 5 members among small-scale livestock farmers in Dodoma and Morogoro, located in Tanzania (Bundala *et al.*, 2020), as well as the mean age of 5 members among livestock farmers in three regions of Mayange in Rwanda, Mwandama in Malawi, and Ruhiira in Uganda (Hetherington *et al.*, 2017). Nevertheless, the current results of 5 members in a household are lower than the 12 household members reported among pastoral farmers adopting artificial insemination in Narok and Kajiado counties of Kenya (Khainga *et al.*, 2015). The current household size is also much lower than the 10 reported in a research study on pastoral households in Ghana (Nuvey *et al.*, 2020), and 11 household members were reported among herdsmen-farmers in conflict regions of Kogi State in Nigeria (Dimelu *et al.*, 2017).

From the results, the overall farmers' years of experience in livestock production in the study area were 16.8 years, which ranged from a minimum of 3 years to a maximum of 30 years. The current results suggest that the small-scale farmers had attained enough experience that positively influenced their levels of dairy production. The current results show similarity with studies of farmers' experience in other regions of Kenya. Such previous research studies include that of Job *et al.*, (2020), who found the mean years of farmers' experience to be 16.76 years for dairy farmers in Mosop Sub-County, Nandi County. The findings by Gregory, (2023) on adaptation strategies for enhancing sustainable smallholder dairy cattle productivity under the regime of climate change in Bungoma County, likewise show the mean years of farmers' experience in Bungoma County to be 16.8 years, while in Central Kenya, a study on factors influencing economic efficiency of milk production among small-scale dairy farms in Mukurweini, Nyeri County, the mean years of farmers' experience was 16.7 years (Maina *et al.*, 2020). The current years of farmer experience compare to the 16.8 years of communal livestock farmers in Ga-Matlala, Limpopo Province, South Africa (Monkwe *et al.*, 2023), 17 years of experience among farmers participating in traditional and modern livestock markets in the Republic of Benin (Akouegnonhou and Demirbaş, 2021), and 16.3 years of farmer experience of small-holder cattle farmers in South Kivu Province, Eastern Democratic Republic of Congo (Mugumaarhahama *et al.*, 2021). In contrast, the farmer experience in the current study was lower than the 24.8 years of farmer experience reported among small-scale dairy farmers in Western Kenya (Gregory, 2023).

The results for the mean annual farmer income of the small-scale dairy farmers were Kshs. 91,938, with a minimum of Kshs 10,000 and a maximum of Kshs. 200,000. Low mean annual farmer income makes many farmers remain vulnerable and experience shocks that have a significant impact on their households, since many lack appropriate coping strategies. Although it is often difficult to compare the income of farmers across different countries due to constant fluctuation of the rate of exchange, and cost of living, the current average income levels of Kshs. 91,938 translates to Kshs. 7660 (~\$60) per month in 2024 in the household and compares well with farmer income in several regions in Kenya such as the research findings by Otieno *et al.* (2021), who studied the welfare effect of small-scale livestock farmers and found that the income levels of small-scale livestock farmers were Kshs 91,000 in Nakuru. Similar findings to the current study were reported by Otieno, Muendo and Mbeche, (2020) on smallholder dairy production, motivations, perceptions and challenges in Nyandarua and Nakuru Counties. while studying the socio-economic dimensions of smallholder livestock management in Kenya and found that the mean household income was Kshs 87,540 in Kisii and Rachuonyo Districts. The current farmers' income levels were however, lower than in other studies done in Kenya where the income level among small-scale livestock farmers was Kshs 191,771 during a KIPPRA household survey (Karlyn, 2017), Kshs 132,000 among smallholder dairy farming in Nyandarua (Otieno *et al.*, 2021), Kshs 258,000 in Kangema, Murang'a County during a study of uptake of modern reproductive technologies in dairy cattle (Susan *et al.*, 2019).

The current study also compares well with the income of farmers in Tanzania during a study of smallholder farmers in Kenya, Zambia and Tanzania (Karlyn, 2017). The per

capita farmer income in the study area was estimated at Kshs 50 (\$0.40) per day, which is indeed low earning compared to a world recommended standard per capita of Kshs 700 (~\$5.50) a day for upper-middle-income countries, as well as Kshs 400 (~\$3.20) per day in the lower-middle-income countries that reported a mean per capita of Kshs 260 (~\$2) per day in a study on financial risk of smallholder dairy based on farm-scale at Malang district, Indonesia (Utami et al., 2023). The country's results confirm previous findings of low income among livestock farmers, including dairy farmers in Sub-Saharan Africa (Erdaw, 2023).

Results on farm sizes indicate that the small-scale dairy farmers owned an average of 3.3 acres of land. These are less than 5 acres and therefore indicate that farmers had small-sized farm sizes, and imply that dairy production can still be practiced in small sizes of land. The small land size may, however, have negative implications for pasture production. The current land sizes concur with land sizes in other studies, such as 3 acres among smallholder dairy farmers in Nakuru (Otieno *et al.*, 2021). The current farm sizes also compare well with other 3 acres among small-scale dairy farmers in Ethiopian central highlands (Bereda *et al.*, 2017), and 3 acres among small ruminant producers in Osun State, Nigeria (Fakoya and Oloruntoba, 2009). In Kenya, the current farm size was larger than that reported among small-scale farmers in Murang'a where farmers had 1.29 acres (Okello *et al.*, 2021). However, the current farm size is smaller than the 10 acres reported among farmers adopting artificial insemination in Kajiado and Makueni Counties (Abot, 2020). The current farm size was larger than the 1.2 acres among milk producers in Raya Kobo, North Eastern Ethiopia (Abegaz, 2022).

The study results also reveal that the average distance to the nearest output market was 2.3 km, with the nearest at 0.1 kilometres and the farthest at 3 kilometres. Long distances to the output market, coupled with poor road networks, limit milk transportation to markets. It is also likely to increase transportation costs and cause unnecessary delays, leading to milk contamination and spoilage. This implies that small-scale farmers are unable to deliver their milk to the market, thus increasing post-production losses. The current distance to the output market compares well with a study on the utilization of agricultural technologies among smallholder dairy farmers in Murang'a, where the distance to the output market of 2.12 km among in (Okello *et al.*, 2021). The current distance to the output market is generally shorter than in a study of Smallholder dairy farming characterisation, typologies and determinants in Nakuru and Nyandarua counties by Otieno *et al.*, (2021), which found that the distance to the output market was 4.5 km and 3.6 km in Nakuru and Nyandarua, respectively. The current distance to the output marker was also deemed shorter than in the study findings on the diversity in farm production and household diets among smallholders in Kenya and Tanzania, which found that the distance to the output market was 6.06 km in Tanzania and 3.8 km in Kenya (Kissoly *et al.*, 2020).

A summary of statistics results on the categorical socio-economic characteristics of small-scale dairy farmers in the study area is shown in Table 4.2.

A summary statistic results on the gender of the household head of the small-scale dairy farmers show that 65.8% were males while 34.2% were females. The results show that

smallholder dairy cattle farming in Marakwet East Sub-County is male-dominated, as more men are involved than women. This was not surprising since in African society, most of the households are headed by males who are in charge of the land and livestock resources. The result of the current study compares well with gender differences in Eastern and Western regions of Kenya where 77% of the households are male-headed compared to female-headed households (Maina *et al.*, 2020b). The current study also agrees with several other studies on the gender composition of the livestock farming communities in Sub-Saharan Africa. In Free State, South Africa, Nkonki-Mandleni *et al.*, (2019), found that males were 87.6% and females were 12.4% in a study on socioeconomic factors influencing livestock production among smallholder farmers. In three Regions of Northern Ghana, a study by Adams and Ohene-Yankyera, (2014) on socio-economic characteristics of subsistent small ruminant farmers found that males were 71.5% and females were 28.5%, which is almost in convergence with the current study finding.

Statistics results on marital status indicate that 90.3% of small-scale dairy cow milk-producing farmers were married, 6.1% were widowed, and 3.6% were single. The high number of married small-scale dairy farmers in Marakwet East Sub-County is not surprising since most of the household heads are mature and belong to the elderly category in a region where marriage is appreciated. Many African men aged above 26 years are often married. These results converge with others on the marital status of household heads in Africa. These include the study by Adisa and Adekunle (2010), who found that in North Central Nigeria, 69.9% were married, 14% were singles and the rest were widowed. A study by Cheruiyot and Otieno, (2017) on factors influencing milk production among

small-scale dairy farmers in Bomet County, Kenya, also found that 90% of the dairy farmers were married, which is in convergence with the current study findings. In the study by Nkonki-Mandleni *et al.*, (2019) on the socioeconomic factors influencing livestock production among smallholder farmers, results showed that 80.8% of the farmers were married and 6.4% were single. Further, almost close result to the current study finding was revealed in a study by Adams and Ohene-Yankyera, (2014), on socio-economic characteristics of subsistent small ruminant farmers in three regions of northern Ghana, where they found that 73.5% of the small-scale farmers were married and 10% were single.

The result on the level of education of the small-scale dairy farmers showed that a large number of the small-scale farmers had primary levels of education (53.1%) followed by secondary levels of education (42.3%) and the least being college level of education (4.6%). These results imply that the low levels of literacy among farmers hinder their economic and commercial engagement in dairy production in the study area. Low levels of education and literacy among small-scale farmers lead to poor animal feed production practices, conservation, and utilization, which negatively impact milk production. Kenya has a literacy level of 78% where 54% have secondary education (Kenya National Bureau of Statistics, 2010). A study by Oduro *et al.*, (2015) revealed that education is significant in enhancing productivity among farming households.

This was likely because household heads with education are more likely to adopt new technologies and innovations that are vital for productivity enhancement. Generally, the more educated people are, the more efficient producers they become (Raj *et al.*, 2020). The high proportion of primary-level education in the current study converges with other

studies that have determined that the majority of Kenyan farmers often drop out of primary or secondary schools to concentrate on farming activities, as reported by Kirea *et al.*, (2023) in a study on factors influencing smallholder dairy cattle productivity in Tigania East sub-county, Meru County. In three Regions of Northern Ghana, 64% of males had no formal education, 13% had primary education, and 15% had secondary education (Adams and Ohene-Yankyera, 2014). However, according to Mabonga *et al.*, (2020), in the study on determinants of smallholder dairy farmers' access to credit in Uasin Gishu County, Kenya, 43.8% of the farmers had attained post-secondary education, which is in divergence from the current study's finding.

The results on the main occupation of the farmers shows that 63.3% of the farmers were full-time farmers, 21.4%, 9.2% and 6.1% were fully employed, part-time, and traders respectively. The current results indicate that most of the small-scale farmers are more involved in dairy production by being full-time farmers, which may positively impact dairy production if they make the right investments in terms of quality dairy breeds, housing, and feeds. This result agrees with the study by Otieno *et al.*, (2021) among dairy farmers in Nakuru and Nyandarua counties, who found that 81.1% of farmers in the study area depend on farming as their main source of occupation. Similarly, Sikumba, (2013) found out that 70% of the small-scale farmers in Sub-Saharan Africa are full-time farmers. The current results converges with the study by Nkonki-Mandleni *et al.*, (2019) among farmers in Free State in South Africa who found that 77.2% of the respondents' main occupation was farming, while 12.8% were employed and 10% were doing business. In Boditti, South Ethiopia, 48.5% of the small-scale farmers' occupations were farming activities, 25% were

government workers and 16.7% were traders (Ayza *et al.*, 2013). The current result is dissimilar from the finding in a study on fodder production on smallholder farmers' household income in Homa Bay County, Kenya, where it was found that 40% of livestock farmers had formal employment while 18.3% indicated that livestock farming was their main occupation (Ayuko *et al.*, 2024).

Table 4.2 of the results on land tenure shows that in the study area, 65.3% of the farmers have family-owned land, 21.4% private land and the remaining 13.3% use community-owned land. Community-owned land is prone to conflicts among members of the community and therefore, this may cause reduced dairy production. The management of land under family ownership results in overstocking and overgrazing leading to limited herbage production throughout the year (Bolo *et al.*, 2019). Given the scarcity of communal grazing land and difficulties with its access and management, it appears unlikely that the households can overcome their shortage of feed by greater reliance on communal feed supplies. The land ownership by the family is not consistent with several studies in Kenya including studies in Kiambu and Nyandarua where 95% of the land ownership was private ownership (Murage and Ilatsia, 2011). In another study in Isiolo County, the results found that 79.5% of the households owned community land and only 20.5% had private land (Gakuru, 2022). In a study conducted in Free State, South Africa, (Nkonki-Mandleni *et al.*, 2019) found that land ownership was dominated by farm groups (38%) and trust (28.4%) while individuals and families each owned 12%.

Results also show that access to credit for dairy enterprises was available for only 29.6% of the small-scale dairy farmers as compared to 70.4% who could not access credit. Economic theory suggests that farmers facing binding credit constraints tend to use lower levels and combinations of inputs than those whose production activities are not limited by credit constraints (Seck, 2021). Credit is required to purchase farm inputs, tools and equipment to manage the proper running of dairy farming even among small-scale farmers. Therefore, low access to credit may compromise the ability of small-scale farmers to properly manage dairy production. The low access to credit has been reported in several other studies in Kenya. In a study by Murage and Ilatsia, (2011) in Kiambu and Nyandarua Counties, results revealed that only 13.6% of the small-scale farmers accessed credit. In the study by Kissoly *et al.*, (2020), on access to credit among small-scale farmers in Kenya, results showed that 18% of the small-scale farmers accessed credits. However, according to the study by Abot, (2020), among pastoral farmers in Kajiado and Makueni Counties, results indicated that only 33% of the farmers accessed credit. In another study on the determinants of utilization of agricultural technologies among smallholder dairy farmers in Kenya, Okello *et al.* (2021) found that 56% of farmers had access to credit, which is in contrast with the low proportion in the current study finding. However, an almost similar result was found in the study on the socio-economic characteristics of subsistent small ruminant farmers in three regions of northern Ghana, where it was found that only 15% of the small-scale farmers accessed credit (Adams and Ohene-Yankyera, 2014).

From the results, improved feeds accessed by a few farmers were dairy meals (23.5%), hay (14.6%) and silage (20.9%). The majority of farmers who did not access improved feeds

used fresh pasture (68.4%), dry pasture (89.8%), and fresh crop stalks (56.1%). The current results indicate that there was low access to improved feeds (dairy meal (21%), hay (16%), and silage (19%)), which are the major constraints in dairy production and often lead to reduced milk production. These results concur with a study farmers' perceptions of dairy cattle breeds, breeding and feeding strategies: a case of smallholder dairy farmers in Western Kenya, where it was found that 73% of farms depended on unimproved natural feeds comprising grasses (Kikuyu grass, *Pennisetum clandestinum*, star grass *Cynodon* spp.) and Napier grass, *Pennisetum purpureum*) (Lukuyu *et al.*, 2019). This result is dissimilar to the study finding by Okello *et al.* (2021) on the determinants of utilization of agricultural technologies among smallholder dairy farmers in Kenya, which revealed that 95% of the farmers in Murang'a had access to improved dairy feeds.

Table 4.3 of the results shows the average annual milk production per household, the average annual milk production per cow, and the average daily milk production per cow.

The result in Table 4.3 of the results shows that the total average annual milk production per household is 2,925.2 liters in Marakwet East Sub-County. The current result is lower than the 6,307, 6,242, and 7,574 liters found in the study on the constraints to increased milk productivity and coping mechanisms in smallholder farms in Bomet, Nakuru and Nyeri Counties milk sheds, respectively (Wanyiri, 2022). This may be attributed to constraints faced by farmers during livestock production (Murkomen, 2011). The current milk production per household is also lower than the per household milk production values reported in developed countries, such as those found in the study on the analysis of milk

production and failure data using unit exponentiated half logistic power series class of distributions, where 12,450 liters were reported in the USA (Alghamdi *et al.*, 2023). However, in the study by Newton *et al.* (2020) on farming smarter with big data in Australia's national dairy herd milk recording scheme, the results reveal that a total of 6,754 liters of milk are produced annually per household. The current annual milk production per household is also lower than in another study on household dairy production, dairy intake, and anthropometric outcomes in rural Bangladesh, which reported that milk production per household was 5,150 liters (Bakhtiar and Hoddinott, 2023). A dissimilar result was also found in the study by Maina *et al.*, (2020a) on the economic efficiency of milk production among small-scale dairy farmers in Mukurweini, Nyeri County, Kenya, which found that the annual milk production per household was 4,500 liters.

Results also show that the average household annual milk production per cow was 975 liters, which was similar among the wards of Marakwet East Sub-County. The current milk production per cow per annum was lower than the national milk production average of 2,359 liters reported in a study by Marwa *et al.* (2020) on the impact of ICT-based extension services on dairy production and household welfare: the case of iCow service in Kenya. Additionally, the current milk production finding per individual cow of the world's best at 10,133 liters/cow/year, mainly due to factors including poor feeding (Bett, Munyiri and Nkari, 2021) in their study on the effect of mineral mix and concentrate feeds on milk revenue of smallholder dairy farmers in Kapseret Sub County, Kenya. The milk production per cow in the current study was lower than values reported in Kenya during a study on the effects of *Calliandra* and *Sesbania* on daily milk production in dairy cows on commercial

smallholder farms in Kenya, where a total annual cow milk production was 1,300 liters per cow per year (Makau *et al.*, 2020; Muturi, 2020). The average annual milk production per individual cow was, however, lower as compared to leading milk producers in the world. In a milk symposium review on the sustainability of dairy production and consumption in low-income countries, the production values for the USA were reported as 24,630 litres per cow per year (Tricarico *et al.*, 2020). In addition, a study on a multi-scale framework for advancing national dairy sector mitigation in Israel, it was reported that the average milk production was 13,043 liters per cow per year (Kissinger *et al.*, 2024). Furthermore, in a study on the factors shaping cow's milk production in the European Union, milk production was reported to be 7,960 liters per cow per year (Bórawski *et al.*, 2020). According to the study on the Australian cattle herd: A New Perspective on Structure, performance and Production, the total milk production was 5,782 litres per cow per year (Fordyce *et al.*, 2021), while in China, in a study on heat stress taking a toll on milk production, the findings indicated that milk production was 5695 litres per cow annually (Ranjitkar *et al.*, 2020). However, the current production level per year per cow is higher than the values reported in a study on modelling and forecasting of milk production in Chhattisgarh and India, which indicates that milk production was 766 liters per cow per year (Mishra *et al.*, 2020).

Further, results revealed that the household average daily milk production per cow was 4.5 liters. The current milk production in the study area is lower than the 10 to 12 liters per cow per day achievable under optimal dairy farming conditions in Kenya (Ongadi *et al.*, 2020). This shows that cows in the study area produced less milk per day due to several

challenges faced by farmers. The current milk production per cow was also lower than milk production per cow found in a study on the determinants of utilization of agricultural technologies among smallholder dairy farmers in Kenya, where 14.3 liters/cow/day was reported in Murang'a (Okello *et al.*, 2021). The current results on milk production were also lower than milk production per cow found in a study on smallholder dairy production in the high altitude Nyandarua milk shed in Kenya, where 8.42 ± 3.29 litres/cow/day was reported. A study by Kainda (2019), on the assessment of the performance of small-scale dairy farming in Meru County, Kenya, found that the average daily milk production per cow among small-scale farmers in Tigania was 21 liters per day, which is higher than the current study values. Higher milk production of 10 liters per day was also reported in the study on socioeconomic characteristics of dairy production in selected areas of the Central Highlands of Ethiopia (Bereda *et al.*, 2017). However, the current average milk production of 4.5 litres per cow per day was higher than that found in a study on exploring the determinants of milk production in smallholder dairy farming in Dhaka, Bangladesh, where daily milk production per cow was found to be 2.73 liters on average (Mitu, 2020).

5.4 Diagnostic Test Results

The diagnostic results were tested for multicollinearity using tolerance and Variance Inflation Factors (VIF) as shown in Table 4.4 of the results. The results in Table 4.4 show that all the variables under study had a VIF ranging between 1.061 and 2.365 and also tolerance values ranging from 0.423 to 0.943, which show that there were no potential multicollinearity symptoms among the predictors and hence found to have no potential influence on the estimates from the model. These were the indicators that there was a low correlation among the variables under consideration.

5.5 Econometric Analysis Results

To answer the four specific objectives of this study, econometric models were used to empirically analyse each objective separately. Multivariate linear regression model and Cobb-Douglas production function (double log-linear form) models were used to determine the factors influencing dairy cow milk production among small-scale farmers in the study area. The results are presented in the sub-sections that follow.

5.5.1 Estimates of Socio-Economic Factors on Dairy Cow Milk Production

The study's first objective sought to determine the socio-economic factors influencing dairy cow milk production among small-scale farmers in Marakwet East Sub-County, Kenya. The estimated results on the effects of socio-economic factors on dairy cow milk production are shown in Table 4.5 of results. As shown in Table 4.5 of the results, the value of *R*-Square indicates the goodness of fit of the linear regression. *R*-square and Adjusted *R* Square values are 0.800 and 0.791 respectively which means that 79.1% of the total variation in the dependent variable (milk yield) is attributed to the socio-economic factors and the remaining 20.9% lies within the error term in the regression model for this study.

ANOVA test was conducted to test the significance of the relationship between the independent variables (socio-economic factors) and dependent variable (milk production) by predicting the power of the model with that of an intercept-only model (Stoker *et al.*, 2020). The results established from the ANOVA test in Table 4.9 of results show that the *P*-value is <0.01 . This indicates a statistically significant relationship between milk

production and socioeconomic factors, which implies that socioeconomic factors affected milk production to a large extent.

From Table 4.5 of the results of the multiple linear regression analysis, the level of education, family/household size, farmer's experience and total farmer income were all statistically significant at a 1% level and influenced dairy cow milk production. The rest of the socio-economic factors were insignificant in dairy cow milk production among the small-scale dairy farmers.

Results in Table 4.5 revealed that the education level of the household head was statistically significant at a 1% level with a positive coefficient of 0.602. This implies that, as the level of education of the household head increases by one unit, there is a probable increase in milk production among small-scale farmers by 60.2% when other factors are kept constant. This implies that as the farmer attains a higher level of education, he has a better understanding of dairy farming and increases milk production from their dairy cows (Job *et al.*, 2020). Likewise, household heads with education are more likely to adopt new technologies, innovations, and best husbandry practices pivotal for improving dairy cow milk production (Wairimu *et al.*, 2022). The current findings on the level of education of the household head is in convergence with a study by (Paraffin, Zindove and Chimonyo, 2018) in Zimbabwe on factors affecting milk production in the smallholder dairy sector who found that the education level of the farmers facilitated a positive attitude toward appreciating new dairy technologies and hence increased milk production. Education improves knowledge, management skills and absorptive capacity of new ideas which are

important to drive milk production (Nuthall, 2018). Farmers who acquire higher levels of education are more inclined to practice and benefit from livestock production technologies such as improved dairy breeds, better breeding technologies, and improved feed technologies compared to the ones who have no formal education due to their higher levels of technical knowledge concerning livestock husbandry (Meijer *et al.*, 2015). The literacy level of farmers may also determine the rate of adoption of improved livestock production technology and directly affect their capacity to absorb new ideas that could affect milk production (Mdoda and Mdiya, 2022).

Further, results in Table 4.5 show that the household size of the smallholder dairy farmer was statistically significant at a 1% level with a positive coefficient of 1.091. This implies that as the family/household size increase by one additional member, there is a probable increase in milk production among small-scale farmers by 109% when other factors are kept constant. In Kenya, dairy production is largely subsistence, and off-farm income opportunities being limited in rural areas of Kenya, the positive association of household size and increased milk production is indeed not surprising. This could be attributed to the fact that a large household size acts as a source of cheap family labour thereby increasing the family's chances of more milk production. Relatively larger households would mean increased labour supply and also an incentive for increased farm productivity (Ramos, 2021). The current result is in agreement with those of Maina (2018) who studied the economic efficiency of milk production among small-scale dairy farmers in Mukurweini Sub-county, Nyeri Kenya and found that the size of the household positively affected milk production efficiency. In a study by Haile *et al.*, (2022) on determinants of market

participation among smallholder farmers in Southwest Ethiopia, family size was statistically significant where a one-person increase in family size decreased the level of participation by 3.6% which is in divergence with the current study. In a study by Cheruiyot and Otieno (2017), household size was positive (0.044) and statistically significant on access to credit among smallholder dairy farmers in Bomet County, Kenya which is also in divergence with the current study finding.

Results further show that farmer's years of experience in dairy production was statistically significant at a 1% level with a positive coefficient of 1.311. This implies that an increase of one year of farmers' experience increases the probability of milk production among small-scale farmers by 131% when other factors are kept constant. Many years in dairy farming imply that farmers are experienced in managing their dairy cattle better for improved milk productivity (Hyland *et al.*, 2018). The current study findings were in convergence that farmers with experience utilized their long-term acquired knowledge and skills to reduce risks related to dairying and the management of diseases. Further, the current study agrees with that done by Nyokabi, (2021) who showed that experience assists in making decisions and allocation of resources which meant that the more experience one has, the wiser decisions are being made in terms of allocating resources to new technologies such as artificial insemination, improving the breeds and breeding that may enhance milk production. This result is in line with previous studies conducted by Maina *et al.* (2020) in Mukurweini, Nyeri County, Kenya who have shown that a high farming experience would be related to high milk production.

Results in Table 4.5 further revealed that the total farmer's income was statistically significant at a 1% level with a positive coefficient of 1.122. This implies that as the household income increase by one unit, there would be a probable increase in milk production among small-scale farmers by 112% when other factors are kept constant. This implies that farmers with high income can have a high probability of purchasing required machinery, feeds, and requirement health management facilities that may increase dairy production. The role of income in improving milk production has been shown by Wairimu *et al.* (2022) in Mukurweini, Nyeri County where the author showed that the income of small-scale farmers affected the milk production in the household. In another study, (Giller *et al.*, 2021) reported that low household income among farmers in Sub-Saharan Africa is often associated with low milk production from dairy herds due to a lack of equipment for proper livestock management.

5.5.2 Estimates of Technological Factors on Dairy Cow Milk Production

The study's second objective sought to determine the technological factors influencing dairy cow milk production among small-scale farmers in Marakwet East Sub-County, Kenya. The estimated results on the effects of technological factors on dairy cow milk production are shown in Table 4.6 of results.

As shown in Table 4.6 of the results, the goodness of fit *R-squared* ($R^2 = 0.733$) and Adjusted *R-squared* values ($R^2 = 0.715$) showed that 71.5% of variations in the dependent variable (milk production), in the study area was accounted for by technological factors and the remaining 29.5% lied within the error term in the regression model.

Further, the ANOVA test was conducted to test the significance of the relationship between milk production and technological factors by predicting the power of the model with that of an intercept-only model and clearly showed a P -value of <0.01 as shown in Table 4.6 of the results. This indicates that there was a significant relationship between milk production and technological factors.

From Table 4.6 of the results of the multiple linear regression analysis, the use of artificial insemination technology, access to deworming services, adoption of high-yielding fodder/pasture, access to improved feeds (hay, silage), and adoption of improved dairy breeds were all statistically significant at a 1% level with a positive influence on dairy cow milk production.

The result of the use of artificial insemination, as shown in Table 4.6, shows that the variable was statistically significant at a 1% level with a positive coefficient of 0.690. This implies that a unit increase in the number of small-scale farmers using AI services leads to a 69% increase in milk production when other factors are kept constant. Artificial insemination results in superior reproductive traits in cows that are capable of producing more milk (Mohammed, 2018). This indicates that AI is a very effective reproductive technology that selectively increases genetic gain through increased selection pressure on males. In many countries, yield per cow has more than doubled in the last 40 years due to AI (Lafontaine *et al.*, 2023). The average energy-corrected milk (ECM) yield for Swedish

dairy cows increased from 4,200 to 9,000 kg between 1957 and 2003 when massive AI was initiated (Lund *et al.*, 2023).

The increased milk production from the use of AI has been reported in several studies in Kenya. In a study on factors influencing the adoption of artificial insemination by smallholder livestock farmers in dryland production systems of Kenya, Abot (2020) found that there was increased milk production among farmers adopting AI. Another study by Okello *et al.*, (2021) on factors influencing the adoption of artificial insemination by smallholder livestock farmers in the production systems of Kenya in Murang'a County found increased milk production by 30% among farmers who had to adopt AI technologies. Elsewhere in Western Uganda, in a study among selected dairy farms in and around Kigarama Sub-County, Sheema District, Ahisibwe (2019) established that increased milk production was due to the adoption of AI technology. Similarly, in a study by Mushonga *et al.*, (2017) on artificial insemination in Nyagatare District: Level of adoption and the factors determining its adoption , it was established that AI technology improved milk production. Changes in dairy cows in Austria from 1988 to 2007 show that the mean yield per lactation in Holsteins increased from 5,500 to 8,200 kg and in Simmentals from 4,500 to 6,600 kg following the massive adoption of AI countrywide (Bruno, 2020). Data from National Milk Records in the UK show an increase in average yields of dairy cows of about 200 kg per year from 1996 to 2002, and 50% of the progress in milk yield is attributed to genetic improvement following AI (Gicheha *et al.*, 2019). It is thus clear from this study, as well as other studies elsewhere, that the adoption and use of AI indeed improve milk production of dairy cattle.

Access to deworming services was statistically significant at a 1% level with a positive coefficient of 0.684. This implies that with a unit increase in the number of small-scale farmers using deworming services, there would be a probable increase in milk production by 68.4% when other factors are kept constant. Access to deworming ensures that animals are healthy and therefore likely to produce more milk than the parasite-infested animals (Gunathilaka *et al.*, 2018; Haymanot and Kaba, 2022). Increased milk production has been reported among farmers who regularly deworm their cows in Murang'a in a study on determinants of utilization of agricultural technologies among smallholder dairy farmers in Kenya (Okello *et al.*, 2021). A study by Maina *et al.*, (2018) on the economic efficiency of milk production among small-scale dairy farmers in Mukurweini, found that animal health, including deworming, significantly improved milk production. A study by Nyokabi *et al.*, (2021) in Nyandarua County on milk quality and hygiene: Knowledge, attitudes and practices of smallholder dairy farmers in central Kenya found that deworming improved milk production. Another study by Van den Oever *et al.*, (2021) reported that deworming improves cattle health among dairy farmers, which results in increased milk production. A study on the productivity and welfare of cows on smallholder dairy farms in Kenya found that deworming cows every four or more months resulted in a 30% increase in milk production (Kimeli, 2020).

Results on the adoption of high-yielding fodder/pasture were statistically significant at a 1% level with a positive coefficient of 1.834. This implies that a unit increase in the adoption of high-yielding fodder/pasture would result in a probable increase in milk

production among small-scale farmers by 183.4% when other factors are kept constant. This implies that when farmers have high-yielding pasture, then dairy animals will find the required nutrients and hence have higher milk production. The current study finding is in convergence with the result by Okello *et al.*, (2021) in a study on determinants of utilization of agricultural technologies among smallholder dairy farmers in Kenya, where it was found that farmers who adopted high-yielding fodder in Murang'a County had higher milk production. In the study on smallholder dairy production, motivations, perceptions, and challenges in Nyandarua and Nakuru Counties, Otieno, Muendo, and Mbeche (2020) found that milk production increased among farmers who had adopted high-yielding pasture/fodder.

The current study finding also concurred with the study on estimation of milk production efficiency of dairy cow farms in Embu and Meru Counties of Kenya, which indicated that a unit increase in improved feeds increased milk production by 59% (Mugambi *et al.*, 2019). Further, in the study on socio-economic determinants of small ruminant production among farmers in Osun state, Nigeria, farmers with improved fodder reported higher milk production (Adigun and Adeniyi-Oso, 2023). Likewise, in the study on factors affecting milk production in the smallholder dairy sector of Rusitu, Zimbabwe, results show that farmers who fed their animals with high-yielding pasture had higher milk production (Chirinda *et al.*, 2021). In the study on the characterization of the milk production system and opportunity for market orientation in Oromia, Ethiopia, results revealed that the adoption of high-yielding pasture positively influenced milk production (Duguma, 2022).

The result on access to improved feeds (hay, silage) was also statistically significant at a 1% level with a positive coefficient of 1.780. This implies that a unit increase in the use of improved feeds (hay, silage), would probably increase milk production among small-scale farmers in the study area by 178% when other factors are kept constant. Low quality of improved feeds can be a hindrance to proper feeding of quality feeds to the animal, which may have a negative influence on milk production. In a study on dry season feeding technologies: assessing the nutritional and economic benefits of feeding hay and silage to dairy cattle in South-Western Uganda, high milk output was reported among cows fed with improved dairy feeds (Ntakyo *et al.*, 2020). Meanwhile in Kenya, a study on the adoption of dairy feed technology and its impact on smallholder farmers' income and poverty in Kenya's South-Western region, found that improved feeds resulted in successful dairy production including improved dairy production (Ngeno, 2024). Further, a study on the economic analysis of sorghum silage potential for the dairy industry in Texas High Plains, results reveal that silage resulted in better milk production among dairy cows (Efrani *et al.*, 2024). The authors argue that silage offers higher economic benefits in terms of reduced costs and better nutritional composition, and improves milk production. In Kosovo, Liu *et al.* (2024) opine that although the costs of making silage and hay are high, constituting about 13% of farm costs, feeding silage and hay increases farm profits from abundant milk production.

The result of the adoption of improved dairy breeds was also statistically significant at a 1% level with a positive coefficient of 1.672. This implies that with a unit increase in the adoption of improved dairy breeds, there would be a probable increase in milk production

among small-scale farmers by 167.2% when other factors are kept constant. The current study implies that farmers were able to acquire improved dairy breeds that have high milk production. Results of the current study converge with a study finding by Kahi *et al.* (2018) on crossbreeding for dairy production in the lowland tropics of Kenya: Estimation of individual crossbreeding effects on milk production and reproductive traits and on cow live weight, who reported that there were differences in milk production between Ayrshire, Brown Swiss, Friesian, and Sahiwal. Further, the study on dairy cattle production related to landholding, value addition, and marketing of milk in Kericho and Bomet Counties of Kenya, Mutai *et al.*, (2024), indicated that there were differences in milk production among five dairy breeds (Friesian, Jersey, Guernsey, Ayrshire, local breeds) within the six Sub-Counties of Kericho. In another study, on successes in African agriculture: Lessons for the future (Ndihokubwayo *et al.*, 2024), it was shown that crossbreed livestock has a high yield potential is lower compared with pure breeds. In Malawi, a study on a comparison of economic performance between high-yielding temperate breeds and zebu-crossbreds on smallholder dairy farms in Malawi with a particular focus on reproductive performance reported milk yield of 2410 and 2362 liters per lactation for crossbreed and pure breeds, respectively (Kaonga *et al.*, 2024). Further, a study on the seasonal influence on milk production performance in different breeds of dairy cows reported that among the three breeds (Haryana, Sahiwal, and cross breed), the crossbreed had the highest milk production (8.86 litres), followed by Haryana (7.98 litres) and the least was Sahiwal (7.37 litre) (Singh *et al.*, 2020). However, a dissimilar result was found in a study on the effect of dairy cow breed on milk production, cow traffic, and milking characteristics in a pasture-based automatic milking system in Ireland, where the

results show that there were no significant differences in milk production among three dairy breeds (Prendergast *et al.*, 2024).

5.5.3 Estimates of Farm Production Factors on Dairy Cow Milk Production

The third objective of the study sought to determine the farm production factors influencing dairy cow milk production among small-scale farmers in Marakwet East Sub-County, Kenya. The estimated results on the effects of farm production factors on dairy cow milk production are shown in Table 4.7.

As shown in Table 4.7, the results of fit R-squared ($R^2 = 0.804$) and Adjusted R-squared values ($R^2 = 0.789$) show that 78.9% of variations in the dependent variable (milk production), in the study area are accounted for by farm production factors, and the remaining 21.1% lie within the error term in the regression model for this study.

An ANOVA test was conducted to test the significance of the relationship between the independent and dependent variables established to show that the P -value is <0.01 . This indicates from the model that there was a significant relationship between farm production factors and milk production.

From Table 4.7 of the results of the Cobb-Douglas production function (double log-linear form) analysis, farm size, access to capital, type of dairy breed, farming system (grazing system), access to veterinary services, and access to quality feeds were all statistically significant at a 1% level and influenced dairy cow milk production positively.

Farm size was statistically significant at a 1% level with a positive coefficient of 0.2151. This implies that with a unit increase in farm size among small-scale dairy farmers, there would be a probable increase in milk production by 21.51% when other factors are kept constant. Small farm sizes due to continuous land fragmentation into uneconomical units limit adequate animal feed production, thus hindering milk production because it consistently reduces the available land to produce livestock feeds, leading to low milk production.

This demonstrates that insufficient land availability in Kenya is still a challenge that many small-scale farmers face in increasing milk production from their dairy cows. The current study concurs with the study by Kurgat *et al.*, (2019) on determinants of smallholder dairy farmers' milk production and supply to the market in Uasin Gishu County, Kenya which found that a unit increase in land size increased milk production by 30.9%. The current results also concur with the study by Abate *et al.*, (2024) on milk production, composition, and reproductive performance of crossbred dairy stock on smallholder dairying in South Western Ethiopia, which found that a unit increase in land size increased milk production. In a study conducted by Bereda *et al.* (2017) on the dairy production system and constraints in Ezha Districts of the Gurage Zone, Southern Ethiopia, the authors pointed out that lack of land (45%), was reported to be the major constraint to the milk production in Southern Ethiopia. In the study by Billen *et al.*, (2024) on the efficiency of milk production in Reunion Island: Dealing with land scarcity, established that scarcity of land was one of the major constraints for milk production on the island. Similarly, a study by

Petrač *et al.*, (2024) on the strategic categorization of dairy cow farms in Croatia using cluster analysis found that land size owned and used to improve the milking environment positively affected milk production, this implies that, if farm size increases, the share of income from the farm income source would also increase and so farms' decision to purchase better dairy breeds will be realized.

Table 4.7 of the results further shows that access to capital was statistically significant at a 1% level with a positive coefficient of 0.8237. This implies that with a unit increase in access to capital among small-scale dairy farmers, there would be a probable increase in milk production by 82.37% when other factors are kept constant. The capital endowment is considered a major component of milk production since every item that runs dairy farms is constrained by capital. The importance of capital endowment in milk production is consistent with the literature on livestock farms in many countries of the world. Low capital among small-scale farmers is a hindrance to the acquisition of major inputs for dairy farming, which may result in lower milk production (Duguma, 2022).

Additionally, in the study by Kipaya *et al.*, (2020) on socio-economic factors influencing the adoption of improved livestock farming practices among members of livestock cooperatives in Kajiado County, Kenya, results show that access to capital drives milk production. Further, the study on the evidence of milk consumption and production linkages from Rural Bihar, India, revealed that the availability of capital increased milk production (Ravindran *et al.*, 2020). Further, the result of the study conducted in Nigeria on socio-economic determinants of small ruminant production among farmers in Osun State shows that access to capital improved milk production by 45% (Mustapha *et al.*,

2024). The current study results are also almost similar to those of Bórawski *et al.*, (2020) in a study on the factors shaping cow's milk production in the EU, where the results found that access to capital improved milk production among smallholder farmers by 69.1%.

Table 4.7 of the results also reveals that the type of dairy breeds was statistically significant at a 1% level with a positive coefficient of 0.4623. This shows that a unit change in the type of dairy cow breed kept by a small-scale dairy farmer would probably increase milk production by 46.23% when other factors are kept constant. The expected positive coefficient means that dairy cattle milk production increases with the type of breed since improved cows would give more milk than the local breeds and hence lead to more household income. The result of the current study converges with another study on the opportunities for innovation and intervention in Uganda's dairy value, where possession of cross/exotic cows influenced milk production by 33.1% (Ariong *et al.*, 2024). According to Kirimi *et al.*, (2024), on the adoption of modern dairy farming technologies, interrelated: A case of smallholder dairy farmers in Meru County, Kenya, small-scale dairy farmers in Kenya, dairy breed type was positive and statistically significant where a unit increase in breed type would result in a 0.815 increase in milk production which is in convergence with the current study. Further, a study by Kireia, (2023), on factors influencing smallholder dairy cattle productivity in Tigania East Sub-County, Meru County, Kenya, shows that breed type was positive and statistically significant in which a one-cow increase in the type of breed selected would increase the log odds of milk production levels by 0.212, which is also in convergence with the current study. However, Kimenchu *et al.* (2014) discovered that the dairy cow breed among dairy farmers in Central Kenya was negative and

statistically significant, which is in divergence from the current study. In another study on the dairy breed preferences and breeding practices among smallholder farmers in Githunguri Sub-county, Kenya, the breed of cattle positively influenced milk production, which is in convergence with the current study (Alaru *et al.*, 2024). However, a dissimilar result was found in a study by Ajak *et al.*, (2020) on the evaluation of dairy cattle performance in smallholder farms in Nyeri County, Kenya. The breed of cattle was negatively associated with milk production, where a unit increase in the breed of cattle would lead to a 0.059 decline in milk production, which is in divergence from the current study result.

The farming system (grazing system) was statistically significant at a 1% level with a positive coefficient of 0.8997 as shown in Table 4.8 of the results. This implies that with a unit increase in the farming/grazing system practiced by small-scale dairy farmers, there would be a probable increase in milk production by 89.97% when other factors are kept constant. The current result implies that the farming system for rearing dairy animals will enhance the utilization of feeds that will eventually determine the milk production from dairy farms. The current study result is in agreement with the study on the characterization and profitability assessment of dairy farms in Embu East and Igembe South Sub-counties of Central Kenya, which found that changes in the grazing system influenced milk production by 21% (Kimenchu *et al.*, 2014). However, a dissimilar result was found in the study by Nalunkuuma (2013) on the analysis of farmers' adoption of zero grazing and knowledge of cattle reproductive parameters in Western Kenya, where it was found that cow milk production was reportedly different between the two systems of grazing. Milk

production was 40% more in the zero-grazing system than in the semi-zero grazing system. Furthermore, a study on diversifying rural livestock production by the introduction of Holstein Friesian on zero grazing for rural dairy production, employment, poverty alleviation, and food security in the tropics results show that milk production was higher by 60% in the zero grazing system as compared to the free range system (Gwaza, Okwori, and Fombah, 2016).

Results also show that access to veterinary services was statistically significant at a 1% level with a positive coefficient of 0.8260. This implies that a unit increase in access to veterinary services among small-scale dairy farmers would likely lead to an increase in milk production by 82.6% when other factors are kept constant. Regular veterinary visits allow for the early detection of diseases, reducing the risk of outbreaks that could wipe out the dairy herd or make them sick, thus reducing milk production. The current finding is also almost in convergence with a study finding by Maina *et al.*, (2024) on farmer-friendly delivery of veterinary services in the Kenyan dairy sector, where results show that access to veterinary services accounted for 72% of the variation in milk productivity. However, the current finding is in divergence from a study by Ogola *et al.*, (2023) on the influence of access to extension services on milk productivity among smallholder dairy farmers in Njoro Sub-County, Nakuru County, Kenya, where results show that access to veterinary services accounted for only 3.6% of the variation in milk productivity. There is also divergence of the current finding from the study finding by Marwa *et al.*, (2020) in a study on the impact of ICT-based extension services on dairy production and household welfare, which indicated that access to veterinary services contributed only 29% of the milk

production in Kenya. There is also divergence of the current finding from the study by Singh and Datta, (2013) in a study on the importance of socio-economic and institutional factors in the use of veterinary services by smallholder dairy farmers in which indicated that access to veterinary services contributed only 21.68% of the milk production in India. There is also divergence of the current finding from the study by Waiswa and Günlü, (2023) in a study on analysis of challenges facing and factors influencing the profitability of dairy cattle enterprises, in which they found that access to veterinary services contributed only 11% of the milk production in South Western, Uganda.

Table 4.7 of the results further reveals that access to quality feeds was statistically significant at a 1% level with a positive coefficient of 1.0823. This implies that a unit increase in access to quality feeds among small-scale dairy farmers would probably lead to an increase in milk production by 108.23% when other factors are kept constant. Quality feeds supply the most nutrients required to meet the animals' requirements for body maintenance and milk production. Research consistently demonstrates that access to nutritious feed leads to higher milk yields in dairy cattle and improved reproductive performance in breeding stock (Baris, 2023). The current finding almost converges with a study conducted in Ethiopia by Hassen *et al.*, (2022) on the effect of feed supplementation on cow milk productivity and quality, which indicated that quality feeds contributed 70% of the milk production. However, there is divergence of the current finding from the study by Marwa *et al.* (2020) on the impact of ICT-based extension services on dairy production and household welfare in Kenya, which found that quality dairy feeds contributed only 69% of the milk production. Furthermore, is a divergence of the current finding from the

study by Makau *et al.*, (2020) on the effects of Calliandra and Sesbania on daily milk production in dairy cows on commercial smallholder farms in Kenya which found that quality dairy feeds increased daily milk production by 3.9%.

5.5.4 Estimates of the Institutional Factors on Dairy Cow Milk Production

The fourth objective of the study sought to determine the institutional factors influencing dairy cow milk production among small-scale farmers in Marakwet East Sub-County, Kenya. The estimated results on the effects of the institutional factors influencing dairy cow milk production are shown in Table 4.8.

The results revealed that the coefficients of determination (R^2) and adjusted R^2 were 0.630 and 0.617, respectively. This means that 61.7 % of variations in the dependent variable (milk production), in the study area, are accounted for by the specified independent variables, and the remaining 38.3% lies within the error term in the regression model for this study.

An ANOVA test was conducted to test the significance of the relationship between the institutional factors and cow milk production by predicting the power of the model with that of an intercept-only model. The results established from the ANOVA test in Table 4.8 show that the P -value is <0.01 . This indicated that there was a significant relationship between institutional factors and milk production.

Table 4.8 shows that the land tenure system was statistically significant at a 1% level with a positive coefficient of 0.450. This implies that a unit change in the land tenure system among small-scale dairy farmers would probably increase milk production by 45% when other factors are kept constant. Land tenure refers to the terms and conditions under which rights to land and land-based resources are acquired, retained, used, disposed of, or transmitted (GoK, 2009). Secure property rights are consistently associated with higher levels of livestock productivity, increased investment in animal husbandry practices, and improved land management strategies among rural households (Fujimori *et al.*, 2022). Moreover, tenure security facilitates long-term investments in livestock genetic improvement programs, leading to higher milk yields and improved household incomes among dairy farmers (Rishit, 2024).

Changes in land use and land tenure systems restrain access to grazing land, pastures, and water, thus influencing milk production. The result means that land ownership structure by small-scale farmers has been reported to influence livestock production in the Sub-Saharan African region (Opoola *et al.*, 2019). Land issues and land tenure reform in sub-Saharan Africa are characterized by a range of farming systems, all with varied rights under multiple forms of tenure (Stephan *et al.*, 2020). The study is similar to those of Rishit, (2024), who did a study in Ethiopia and found that farmers with secure land tenure increased dairy production by 22%. A study by Wanjala (2023) in Kiganjo Sub-Location on the impact of land size and land use change on rural livelihood in dairy farming zones in Kenya found that land tenure statistically increased milk production by 46% which is in agreement with the current study's finding. However, there is divergence of the current finding from the

study by Kangethe, (2012) in an evaluation of the effects of land tenure on land use in Kenya, who found that the land tenure system statistically increased milk production by 70%, which is higher than the current study findings. There is also divergence of the current finding from the study by Deininger and Jin (2006), in which they found that the land tenure system contributed only 22% of the milk production in Ethiopia. Furthermore, there is a divergence of the current finding from the study by Gido *et al.*, (2015) on demand for agricultural extension services among small-scale farmers in which they found that the land tenure system contributed slightly higher, at 68% of the milk production in Kenya, which is more than the current study finding.

Access to extension services was also found to be statistically significant at a 1% level with a positive coefficient of 1.724. This implies that with a unit increase in access to extension services among small-scale dairy farmers, there would be a probable increase in milk production by 172.4% when other factors are kept constant. Access to extension services by small-scale farmers improves their skills and knowledge, and hence their chances of adopting improved dairy production technologies such as AI, breed selection, parasite control, improved breeding, record keeping, deworming, and improved feeds, and hence, increases in milk production. However, there is divergence of the current finding from the study by Ogola *et al.* (2023), who found that access to extension services by small-scale farmers can improve milk production by only 16.5%. There is also divergence of the current finding from the study by Fabregas *et al.* (2019) on a study on realizing the potential of digital development in Sub-Saharan Africa and India, where they found that access to extension services enhanced milk production by only 4%. There is also divergence of the current finding from the study by Ogola (2023) on the influence of access to extension

services on milk productivity among smallholder dairy farmers in Njoro Sub-County, Nakuru County, Kenya, where they found that access to extension services improved milk production by only 52.9%. In addition, there is a divergence of the current finding from the study by Nicholas & Angubua (2019), where they found that access to extension services explained only 25.5% of milk production per cow per day. The current finding agrees with the findings in the study on the role of agricultural extension in learning for uptake and intensification of less-practiced dairy climate-smart practices in Kenya, where ease of accessing extension services influenced milk production positively (Mburu *et al.*, 2024). Keeping dairy records, an increase in knowledge about climate change, and a higher number of extension visits were positively associated with both adoption and intensity of adoption. Additionally, similar findings to the current study were reported in a study on a scoping review of the contributions of farmers' organizations to smallholder agriculture, which established that the access extension services improved production by 19% in Sub-Saharan Africa and India Bizikova *et al.*, (2020). The effect of access to extension services on milk production was also evident in the study in Dodoma, Tanzania, where decentralization of extension services enabled farmers at the grassroots level to access extension and consequently improved productivity (Mramba and Mohamed, 2024). Therefore, access to extension services by small-scale dairy farmers' influences milk production. Create paragraphs for the above. You can't have one paragraph on a whole page.

Table 4.8 of the results shows that access to credit services was statistically significant at a 1% level with a positive coefficient of 1.904. This implies that with a unit increase in

access to credit services among small-scale dairy farmers, there would be a probable increase in milk production by 190.4% when other factors are kept constant. This implies that dairy production relies on credit for the farmers to purchase inputs, feeds, machinery, and breeds for dairy production. Access to credit by a farmer increases their capacity to expand their dairy venture, including the purchase of the necessary farm inputs and equipment, as well as veterinary services. According to Maina *et al.* (2018), most dairy farmers benefited from credit services provided by their dairy cooperatives, mainly recovered through check off. Low credit access by small-scale farmers constrains their ability to make initial investments or finance the variable costs associated with improved dairy technologies, such as quality breeds and housing. Farmers with limited financial resources may struggle to afford high-quality commercial feeds in sufficient quantities because of the high costs involved. Limited availability of favourable credit hampers investments in the dairy industry and makes it difficult for small-scale farmers to access finance to purchase farm inputs and equipment. The current study result is in convergence with a study by Mutavi *et al.* (2016) on innovativeness and adaptations for small-scale peri-urban dairy farmers in semi-arid regions of South Eastern Kenya, who reported that frequent access to credit services enhances the embracing of technologies by smallholder dairy farmers in dairy production for improved milk productivity. Such technologies in dairy production include improved feeds, record keeping, parasite and disease control, breeding, and general animal management.

Results further show that membership in a farmer group was statistically significant at a 1% level with a positive coefficient of 1.056. This implies that a unit increase in

membership in farmer groups or cooperative societies among small-scale dairy farmers would likely lead to an increase in milk production by 105.6% when other factors are kept constant. Membership in a livestock organization has a significant positive impact on the availability of credit facilities, capital, and market information (Silong and Gadanakis, 2020). To benefit from the advantages of livestock markets, such as training, price information, loans, etc., most of the farmers participating in group membership are part of existing livestock farmer organizations. These findings show that farmers who enjoy group membership are likely to adopt such technologies since they are incentives for improved milk productivity and higher incomes for farmers. Most farmers also rely on tacit group knowledge, which seems effective over the years, helping them to adopt new technologies after seeking advice from a varied number of people (Vetter, 2020). The current study concurs with the study on the determinants of smallholder dairy farmers' milk production and supply to the market in Uasin Gishu County, Kenya, which indicated that a unit increase in membership to an organization increased milk production by 28.2% (Kurgat *et al.*, 2019).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Overview

The chapter presents conclusions, recommendations, and suggestions for further study.

6.2 Conclusions

This study employed multiple linear regression analysis and the Cobb-Douglas production function to analysis economic factors affecting dairy cow milk production among small-scale farmers in Marakwet East Sub-County. The findings underscore the significant influence of socio-economic, technological, farm production and institutional factors on milk production.

The regression results revealed that socio-economic characteristics play a crucial role in shaping dairy cow milk production. Specifically, improvements in the education level of household heads, larger household sizes, increased years of dairying experience and higher total farmer income were found to be strongly associated with higher milk yields. These factors reflect the importance of both human capital and household resource availability in supporting productive dairy practices among small-scale farmers in the study area.

In addition, the analysis confirmed that technological adoption significantly enhances milk production. The use of artificial insemination, access to regular deworming services, adoption of high-yielding pasture/fodder, access to improved feeds such as hay and silage and the uptake of genetically superior dairy breeds were all positively linked to increased

milk production. These findings highlight the need for improved access to modern dairy technologies and related support services for small-scale farmers.

Moreover, the Cobb-Douglas production function results indicated that key farm production factors also influence milk output. Variables such as farm size, access to capital, type of dairy breed kept, grazing system employed, availability of veterinary services and the use of quality feeds emerged as important contributors to milk production. Enhancing these factors would directly support more efficient and sustainable dairy farming among small-scale farmers.

Furthermore, institutional dimensions were shown to have a notable effect on milk production. Stronger land tenure systems, better access to extension services, availability of affordable credit and active participation in farmer groups were identified as institutional enablers of improved milk output. These findings emphasize the importance of institutional support mechanisms in fostering an enabling environment for dairy development.

In summary, the study concludes that boosting dairy cow milk production among small-scale farmers in Marakwet East Sub-County requires a multidimensional approach that addresses socio-economic, technological, farm production and institutional factors. Coordinated interventions across these domains will not only improve milk production among small-scale farmers but also strengthen rural incomes, food security and the broader agricultural economy.

6.3 Recommendations

The findings of this study highlight a number of strategic areas where interventions are necessary to enhance dairy cow milk production among small-scale farmers in Marakwet East Sub-County. One of the key observations was that factors such as the farmer's level of education, family/household size, farming experience and total farmer income significantly influence milk output. Therefore, it is recommended that strategies be developed to encourage the pursuit of further education and capacity building among small-scale dairy farmers. This can be achieved through training programs, adult education initiatives and farmer field schools aimed at enhancing technical knowledge and management skills. In addition, more women and youth should be actively encouraged to participate in dairy farming, as this would increase labour availability and inject new ideas into the dairy sector. Single individuals and part-time farmers should also be supported and incentivized to invest more time and resources in dairy production as a viable and commercial activity.

Technological advancement remains a key driver of improved milk production. The County Government, in collaboration with the National Government and relevant stakeholders, should promote the adoption of modern technologies and good agricultural practices that enhance milk production. These include the use of artificial insemination, timely access to deworming services, the use of improved dairy breeds and the adoption of high-yielding pasture/fodder and quality feed such as hay and silage. Further, technologies such as milking machines, milk cooling and storage facilities, feed mills, digital advisory platforms

and pregnancy diagnostic kits should be promoted and made accessible to small-scale farmers through subsidies or cooperative-based models. These innovations have the potential to reduce labour demands, improve milk hygiene and quality, and ultimately enhance production and profitability.

Land availability and management practices are equally important for dairy development. Farmers should be sensitized on the need to increase the land area allocated for dairy production, particularly for high-yielding pastures and fodder crops. The County Government and livestock sector stakeholders should work to promote the adoption of zero-grazing units as a means of optimizing land use and improving milk yields. There is also a need to promote on-farm feed production and conservation practices to reduce production costs and ensure feed availability during dry seasons. Small-scale dairy farmers should receive targeted training in areas such as breed improvement, disease management and efficient feeding systems to enhance their technical capacity.

Finally, in addition to technical and production-oriented interventions, institutional support is vital. There is a need to build institutional capacity to develop and implement policies that address key constraints affecting small-scale dairy farming. The County and National Governments, in collaboration with development partners and private sector actors, should develop and promote interventions aimed at improving land tenure systems, enhancing access to extension and veterinary services and expanding access to affordable credit. Membership in farmer groups or cooperative societies should also be encouraged, as these

organizations play a critical role in pooling resources, accessing markets and improving the overall bargaining power of small-scale farmers.

6.4 Suggestions for Further Research

To further enhance dairy cow milk production among small-scale farmers, future research should explore the influence of intervening variables, particularly County Government policies and regulatory frameworks, on dairy production. A deeper understanding of how these policies affect access to inputs, service delivery, market dynamics and overall farm productivity will provide valuable insights for designing more effective interventions and policy reforms tailored to the needs of small-scale dairy farmers.

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APPENDICES

Appendix I: Letter of Transmittal

Richard K. Chelanga,
P.O Box 220-30700
ITEN.

Dear Sir/Madam,

REF: REQUEST FOR PARTICIPATION IN RESEARCH STUDY

I am a student at the University of Eldoret pursuing a Master's Degree in Agricultural Economics. I am conducting a research study on "**Analysis of Economic Factors Affecting Dairy Cow Milk Production among Small-Scale Farmers in Marakwet East Sub-County, Elgeyo-Marakwet County, Kenya**".

You have been selected to participate in this study as a respondent. I kindly request that you respond to the questions in this questionnaire. The information collected from you will be kept confidential and used purely for this academic work.

Thank you for your cooperation.

Yours faithfully,

Richard Kaino Chelanga,
REG NO. SAGR/AGE/M/004/20
Tel. No. +254 725867654

Appendix II: Questionnaire

This questionnaire is designed to collect data to analyse economic factors affecting dairy cow milk production among small-scale farmers in Marakwet East Sub-County, Kenya. The data shall be used for academic purpose only and will be treated with at most confidentiality it deserves. The Small-scale dairy farmers (Respondents) are highly encouraged and persuaded to respond to the statements in this questionnaire in the most truthful and objective way possible. Your participation in facilitating this study is highly appreciated.

Kindly **tick** [✓] or **fill** appropriately the response(s) in the space provided with the correct answer or information. Please, specify and elaborate where required.

GPS Coordinates:
Name of the enumerator:
Household No:
Village:
Location:
Ward:
Name of the respondent: (Not compulsory)
Date:

Section A: Socio-Economic Factors

Note: Please **tick** [✓] or **fill** as appropriate the response(s)

- Age of Household Head: _____ (Years)
- Gender: Male [] Female []
- Marital Status: 1=Single [] 2=Married [] 3=Divorced [] 4=Widowed []
- Education level of respondent (Highest level):
 1= None [] 2=Primary level [] 3=Secondary level []
 4= Tertiary level [] 5=College [] 6=University []
- Family/Household size: _____ (Number)
- Farmer's occupation:

1=Full-time farmer [] 2=Part-time farmer [] 3=Full-time employed []
 4=Part-time employed [] 5=other (please specify) _____

7. Farmer's experience: _____(Number of years)
8. What is your main source(s) of family income?
 1=Farming [] 2=Employment []
 3=Business [] 4=Remittances []
9. What is total farm income per annum (Ksh) _____

Section B: Technological Factors

1. Are you using Artificial Insemination (AI) for your dairy cows?
 1=Yes [] 2=No []
2. Do you have access to vaccination services for your dairy cows?
 1=Yes [] 2=No []
3. Do you have access to deworming services for your dairy cows?
 1=Yes [] 2=No []
4. How often do you deworm your dairy cows? _____ (months)
5. Do you have access to curative services for your dairy cows?
 1=Yes [] 2=No []
6. What is the distance to the nearest veterinary clinic? _____ (Goffart *et al.*)
7. Do you have a milking machines?
 1=Yes [] 2=No []
8. Do you have access to a milk cooling machine?
 1=Yes [] 2=No []
9. What is the distance to the nearest milk cooling machine? _____
 (Goffart *et al.*)
10. Do you have high-yielding pasture/fodder varieties in your farm?
 1=Yes [] 2=No []

11. If yes, what are the high-yielding pasture/fodder in your farm (Select all that apply)

- Bracharia
- Boma Rhodes
- Lucerne
- Desmodium
- Napier grass
- Other (please specify): _____

12. What is the acreage of the high-yielding pasture/fodder varieties in your farm?
_____ (Acres)

13. Do you use livestock feed chopping/milling technology on your farm?

1=Yes 2=No

14. If yes, please specify the type of livestock feed chopping/milling technology on your farm. _____

15. Do you have access to improved feeds (Hay, Silage) on your farm?

1=Yes 2=No

16. If yes, please specify the improved feeds on your farm. _____

17. Other than grazing, which other method(s) of feeding are used on your farm?

- 1= Natural pasture served fresh
- 2= Natural pasture served dry
- 3= Crops stalks served fresh
- 4= Crops stalks served dry
- 5= Purchased dairy meal and concentrates

18. Do you have improved dairy breeds on your farm?

1=Yes 2=No

19. If yes, please specify the type of improved dairy breed(s) kept on your farm

20. Do you have access to communication services?

1=Yes 2=No

21. If yes, please specify the communication service(s) available for you

22. Do you have access to digital platform?

1=Yes [] 2=No []

23. If yes, please specify the digital platform _____

24. Do you have access to pregnancy diagnosis technology for your cows on your dairy farm?

1=Yes [] 2=No []

Section C: Farm Production Factors

1. What is the size of your farm? _____ (Acres)

2. Type of land tenure System?

1= Privately-owned; 2= Leased; 3= Family;

4= Communal/community owned; 5= State-owned

6 = Other (Specify)

3. Is labour available on your farm?

1=Yes [] 2=No []

4. What is the main source of labour for your dairy activities?

1=Family/Household labour []; 2=Non-family labour (casual labour) []

5. How many casual employees do you have? _____ (Number)

6. How many permanent employees do you have? _____ (Number)

7. What are the average man hours/ days _____ (Number)

8. Do you have access to capital for your dairy farm operation?

1=Yes [] 2=No []

9. What is the source of your capital for your dairy farm operation?

Specify _____

10. Please select the farming system (grazing system) practised on your farm:

- 1 = Zero Grazing []
 2 = Semi Zero Grazing []
 3 = Free range []
 4 =Tethering []
 5= other (please specify) _____

11. What is the actual current number (Herd size) of dairy cows kept on your farm?

_____ (Number)

12. What type of dairy breeds do you keep on your farm? (Select all that apply)

- Friesian [] _____ (Number)
- Ayrshire [] _____ (Number)
- Guernsey [] _____ (Number)
- Jersey [] _____ (Number)
- Cross breed [] _____ (Number)
- Local breed [] _____ (Number)
- Other (Specify type) _____ Number _____

13. What is your average milk production (output) per cow per day? _____ (Litres)

14. What is your average milk production (output) per cow per annum? _____ (Litres)

15. What is the average price per litre of milk on farm? _____ (Ksh)

16. Do you have access to veterinary care for your dairy?

1=Yes [] 2=No []

17. If yes, how much on average do you pay for drugs and veterinary services per year?

_____ (Ksh)

18. Do you have access to quality feeds for your dairy cows?

1=Yes [] 2=No []

19. If yes, what are the average cost of feeds you incurred for your dairy cows per month

(Fill all that apply in for your farm in Ksh)

1. Fodder/Pasture: _____ (Ksh)
2. Concentrate like dairy meal: _____ (Ksh)
3. Mineral salts: _____ (Ksh)
4. Other (please specify): _____ (Ksh)

20. Do you have access to clean drinking water for your dairy cows?

1=Yes [] 2=No []

21. If yes, please specify the source of the clean drinking water for your dairy cows

22. What is the distance to the clean drinking water for your dairy cows?

_____ (Goffart *et al.*)

23. Do you have access to market information?

1=Yes [] 2=No []

24. What is the distance to the milk market for your milk? _____ (Goffart *et al.*)

25. How many dairy cows do you have in your farm? _____ (Number)

26. How many of the dairy cows are currently lactating (being milked) in your farm?

_____ (Number)

27. What is the total milk production per day for your farm? _____ (Litres)

28. How much milk is consumed by the household/family per day? _____

(Litres)

29. How much milk is sold per day? _____ (Litres)

30. How much milk is given for free (If any) to neighbours and friends? _____

(Litres)

31. What is the current farm-gate selling price of milk per litre per day? _____ (Ksh)

Section D: Institutional Factors

1. Do you have access to agricultural extension services in your area?

1=Yes [] 2=No []

2. If yes in (Ngamau18) above, which type of agricultural extension services?

1= Government agricultural extension services []

2= Private agricultural extension services []

3= other (please specify): _____

3. What type of information or support do you receive from extension service providers? (Select all that apply)

- Livestock feeds and feeding management []
- Pest and disease control measures []
- Soil fertility and water conservation []
- Marketing and value-added activities []
- Access to credit and financial services []
- Other (please specify): _____

5. What is the frequency of access to agricultural extension services?

_____ (Number of visits per year)

4. Have you ever accessed credit facilities for dairy production?

1=Yes [] 2=No []

5. If yes, please specify the source(s) of credit or loans you have accessed:

1= Financial institutions (formal) []

2= Cooperative society []

3= Farmer groups []

4= other (please specify): _____

6. Are you a member of any farmer group or cooperative society?

1=Yes [] 2=No []

7. If yes, how has being part of a farmer group or cooperative society benefited you? (Select all that apply)

1= Access to collective bargaining power []

2= Joint procurement of inputs at lower costs []

3= Sharing of knowledge and skills among members []

4= Access to markets and market information []

5= Improved access to credit and financial services []

6= other (please specify): _____

8. Do you have access to marketing services?

1=Yes [] 2=No []

9. If yes, please specify the marketing service? _____

- 10 Where do you sell your milk?
1= Brookside [] 2= New KCC []
3= Cooperative society [] 4= Middle men []
5= Local customers [] 6= other (please specify) _____
- 11 How much do you pay for transporting your milk to the nearest milk market outlet?
_____ (Ksh)
- 12 Do you have access to milk market contracts?
1=Yes [] 2=No []
- 13 If yes, please specify the milk market contracts
1= Brookside
2= New KCC
3= other (please specify) _____
- 14 Did you receive any business plan training?
1=Yes [] 2=No []
- 15 Do you have access to service providers?
1=Yes [] 2=No []
- 16 If yes, what type of the service providers are accessible for you?
1= Public [] 2= Private []
- 17 Do you have available adequate infrastructure?
1=Yes [] 2=No []
- 18 If yes, please specify the infrastructure _____

THANK YOU SO MUCH FOR YOUR PARTICIPATION!

Appendix III: Clearance to undertake Research from the University of Eldoret



P. O. Box 1125 - 30100, Eldoret, Kenya
 Tel: +254 53 2063257 / 2033712/13 Ext. 2358
 Mob: 0774249552; Fax: +254 53 206 3257
 E-mail: bpgs@uoeld.ac.ke
 Website: www.uoeld.ac.ke

OFFICE OF THE DEPUTY VICE-CHANCELLOR (ASA) (Board of Postgraduate Studies)

NAME: Richard Chelang'a
 POSTAL ADDRESS: 1125- Eldoret.
 Email: richelanga@gmail.com
 TEL: 0725 867654
 DATE: 2nd January, 2024
 ADM NO. SAGR/AGE/M/004/20

Dear Chelang'a,

RE: CLEARANCE TO UNDERTAKE RESEARCH

Congratulations on the successful defense of your thesis research proposal titled "Analysis of Economic factors affecting dairy Cow milk production among small scale farmers in Marakwet East Sub-County, Elgeyo Marakwet County Kenya" on 23rd November, 2023.

The supervisors assigned to guide you through your research are:

Lead Supervisor Dr. Elijah K. Ngeno - Department of Applied Economic
 University of Eldoret
 Co-Supervisor Dr. Joseph Omega - Department of Animal Science
 University of Eldoret

Subsequently, the Board of Postgraduate Studies hereby grants you clearance to undertake the proposed research work. Please note that during the entire period of research you shall be expected to work closely with your supervisors. You are required to observe professionalism and ethics during the period of research.

As a requirement for study continuation at the university, you shall file quarterly written progress reports with the Board of Postgraduate Studies using the prescribed progress reporting form for review. Have a fruitful time in your research and publication activities.






DIRECTOR
 Board of Postgraduate Studies
 University of Eldoret
PROF. SAMUEL TUTTA

DIRECTOR, BOARD OF POSTGRADUATE STUDIES.

University of Eldoret is ISO 9001:2015 Certified



**Appendix IV: Research License from the National Commission for Science,
Technology and Innovation**

 REPUBLIC OF KENYA	 NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION
Ref No: 475385	Date of Issue: 20/February/2024
RESEARCH LICENSE	
	
<p>This is to Certify that Mr. RICHARD KAINO CHELANGA of University of Eldoret, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in on the topic: ANALYSIS OF ECONOMIC FACTORS AFFECTING DAIRY COW MILK PRODUCTION AMONG SMALL-SCALE FARMERS IN MARAKWET EAST SUB-COUNTY, ELGEYO-MARAKWET COUNTY, KENYA for the period ending : 20/February/2025.</p>	
License No: NACOSTI/P/24/33043	
475385	
Applicant Identification Number	Director General NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION
	Verification QR Code
	
<p>NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.</p>	
See overleaf for conditions	

Appendix V: Research Authorization from the County Commissioner



OFFICE OF THE PRESIDENT
 MINISTRY OF INTERIOR AND NATIONAL ADMINISTRATION
 State Department for Internal Security and National Administration

COUNTY COMMISSIONER'S OFFICE,
 ELGEYO-MARAKWET COUNTY,
 P.O. BOX 200-30700
ITEN

Telephone: (053) 42007
 Fax : (053) 42289
 E-mail: ccegeyomarakwet@yahoo.com
ccegeyomarakwet@gmail.com
 When replying please quote

Ref.....
 PUB.CC.24/2 VOL.III/192

21st February, 2024

TO WHOM IT MAY CONCERN

RE: RESEARCH AUTHORIZATION

MR. RICHARD KAINO CHELANGA

This is to confirm that the above named has been authorized to carry out a research on
 "ANALYSIS OF ECONOMIC FACTORS AFFECTING DAIRY COW MILK
 PRODUCTION AMONG SMALL-SCALE FARMERS IN MARAKWET EAST SUB-
 COUNTY, ELGEYO-MARAKWET COUNTY, KENYA" for the period ending 20th
 February, 2025.

Please accord him the necessary assistance.

COUNTY COMMISSIONER
 ELGEYO MARAKWET COUNTY

Eric Njuguna Chege,
 For: County Commissioner
ELGEYO MARAKWET COUNTY.

ENC/bjc

CC

Deputy County Commissioners,
MARAKWET EAST SUB COUNTY

Appendix VI: Research Authorization from the Ministry of Education



**REPUBLIC OF KENYA
MINISTRY OF EDUCATION
STATE DEPARTMENT FOR BASIC EDUCATION**

TELEGRAM:...EDUCATION - ITEN
TELEPHONE NO-----
WHEN REPLYING PLEASE QUOTE OUR REFERENCE
EMAIL: cdeelgevomarakwet@gmail.com

COUNTY DIRECTOR OF EDUCATION
ELGEYO MARAKWET COUNTY
P.O. BOX 214-30700
ITEN

DATE: 20th February, 2024

REF No: *CDE/EMC/R/26/VOL.IV (92)*

Mr. Richard Kaino Chelanga
University of Eldoret
P.O. Box 1125-30100
ELDORET

RE: RESEARCH AUTHORIZATION

Following the authorization by the National Commission for Science, Technology and Innovation (NACOSTI) to carry out research in Elgeyo Marakwet County vide authority letter Ref. No. NACOSTI/P/ 24/33043 dated 20th February, 2024, you are hereby formally granted authority by this office to proceed with your study on "*ANALYSIS OF ECONOMIC FACTORS AFFECTING DAIRY COW MILK PRODUCTION AMONG SMALL-SCALE FARMERS IN MARAKWET EAST SUB-COUNTY* in ELGEYO MARAKWET COUNTY ." for a period ending 20th February, 2025.


Kiprop Cheruiyot
For: County Director of Education
ELGEYO MARAKWET



Copy to:

1. The Director General/CEO -NACOSTI
2. Sub County Director of Education-MARAKWET EAST

Appendix VII: Similarity Report

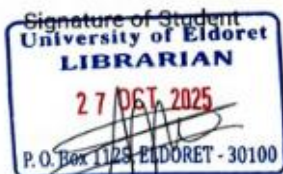


University of Eldoret

Certificate of Plagiarism Check for Thesis



Author Name	Richard Kaino Chelanga SAGR/AGE/M/004/20
Course of Study	Type here...
Name of Guide	Type here...
Department	Type here...
Acceptable Maximum Limit	Type here... 0
Submitted By	titustoo@uoeld.ac.ke
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