ECONOMIC ANALYSIS OF MILK QUALITY CERTIFICATION IN RWANDA

NAPHTAL HABIYAREMYE

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DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and it has not, wholly or in part been presented for an award of degree in any other university

Signature  September 2023

Naphtal Habiyaremye **Date**

KD15/16528/18

Department of Agricultural Economics and Agribusiness Management

Recommendation

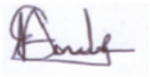
This thesis is submitted to Graduate School with our approval as supervisors:

Signature  September 2023

Prof. Gideon A. Obare PhD **Date**

Department of Agricultural Economics and Agribusiness Management

Egerton University

Signature  September 2023

Dr. Emily A. Ouma PhD **Date**

Senior Scientist, Agricultural Economist – International Livestock Research Institute

ILRI – Uganda

Signature  September 2023

Dr. Nadhem Mtimet PhD **Date**

Agricultural Economist – International Fund for Agricultural Development (IFAD), Cairo, Egypt

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DEDICATION

This thesis is dedicated to my beloved wife (Michelle) and children (Adrielle, Brielle, and Dariel) for their support and prayers.

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ABSTRACT

Despite the recent increase in milk production, the quality of the milk along the dairy value chain is still a concern mostly in Sab-Saharan Africa. The Government of Rwanda initiated the "dairy best practices" (DBP) scheme that lays out a set of practices and standards for proper handling of raw milk. The DBP acts as an instrument to enhance the quality and quantity of milk consumed through formal marketing channels, however, it is unclear why, over 60% of milk is still sold through informal marketing channels. Furthermore, the profitability and acceptability of DBP standards among milk producers remain unknown. In addition, there is no evidence of consumers' willingness to pay (WTP) for quality milk and this may be a hindrance to producers and other value chain actors who want to comply with quality-related standards. This study sought to fill these gaps by contributing towards the improvement of the formal milk marketing and milk quality certification in Rwanda. The cross-sectional data collected from 384 milk producers and experimental auction data from 386 milk consumers was analysed using various econometric approaches such as translog production frontier, endogenous switching probit model, and random effect Tobit model. The findings showed that milk production was profitable, although, farmers were producing at 13% below the production frontier. Adhering to DBP standards increased the profit efficiency significantly (p<0.05) and it generated higher gross margin (p<0.01) while feed supplement was the key input that significantly increased the profit efficiency. Moreover, the results showed that cooperative membership increased the probability of selling to milk traders and milk collection centres (MCCs) by 3 and 18 percentage points respectively for members of cooperatives along with a negative effect on the choice of other buyers (direct consumers and restaurants) as marketing channel. Finally, the results showed that consumers were willing to pay higher price premiums (22% more) for safe and quality milk and providing safety and quality related information increased consumers' WTP by 77% (p<0.05). Based on these results, the government is recommended to introduce measures that would enhance farmers' access to quality inputs together with formulation of policies that promote the adoption of DBP standards among smallholder dairy farmers. Furthermore, policies that support easy access to MCCs and enhancement of dairy cooperatives' governance will increase cooperative membership rate and access to a better marketing channel that safeguards the quality of milk. These policies should as well promote private sector to invest in upscaling of milk zones and establishment of the milk dispensing machines so that safe and quality milk is easily accessible to consumers.

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LIST OF ABBREVIATIONS AND ACRONYMS

ASF	Animal-Source Foods
BDM	Becker-DeGroot-Marschak
COMESA	Common Market for Eastern & Southern Africa
DBP	Dairy Best Practices
DVC	Dairy Value Chain
EAC	East African countries
ESPM	Eendogenous Switching Probit Model
GDP	Gross Domestic Product
GoR	The Government of Rwanda
HACCP	Hazard Analysis and Critical Control Points
IFAD	International Fund for Agricultural Development
ILRI	International Livestock Research Institute
LMIC	Low-and middle-income countries
MCC	Milk Collection Centres
MINAGRI	Ministry of Agriculture and Animal Resources
NIE	New Institutional Economics
NISR	National Institute of Statistics Rwanda
RALIS	Rwanda Agriculture and Livestock Inspection Services
RDCP II	Rwanda Dairy Competitiveness Program II
RDDP	Rwanda Dairy Development Project
SDG	Sustainable Development Goals
SoQ	Seal of Quality
SSA	Sub-Saharan Africa
USA	United States of America
USAID	United States Agency for International Development
WB	World Bank
WHO	World Health Organization
WTP	Willingness to Pay

CHAPTER ONE
INTRODUCTION

1.1. Background of the Study

Despite noticeable progress in nutrition worldwide, malnutrition is still a severe challenge where around 149 and 45 million children under five years of age were stunted and wasted, respectively, in 2020 as a result of deficient diets (Katoch, 2021; WHO, 2020). Most of the affected children are in Africa, where around 59 million were stunted; 14 million wasted in 2017 (WHO, 2019); and 31 million were underweight, while about 33% of post-natal deaths were linked to malnutrition in 2011 (Black *et al.,* 2013). The consumption of animal-source foods (ASF) has been proposed as one of the ways to curb this chronic malnutrition (Kavle et al., 2015). However, unsafe and low-quality ASF are associated with serious health-related risks and diseases. A study by the World Bank (WB, 2018) found that low-and middle-income countries (LMIC) lose around US$ 110 billion yearly on medical expenses and lost productivity caused by unsafe foods. These high economic costs of foodborne diseases become a key challenge mostly in developing countries even though a larger proportion can be avoided by improving food safety and quality.

The consumption of high-quality ASF such as milk, meat, fish, and eggs enhances the growth of children, improves the wellbeing of pregnant women and nursing mothers, and reduces the illness for all (Andrews *et al.,* 2022; Parikh *et al.,* 2022; Roesel & Grace, 2014). Milk is one of the most available ASF to poor rural households in Rwanda. However, raw milk has been traditionally of low-quality for several reasons. For instance, Ndahetuye *et al.* (2020) found that lack of hygienic milking area, uncleaned teat and udder, unwashed hands of the milker before milking, and inappropriate milking utensils are associated with high bacterial count, somatic cell count, and salmonella contamination found in milk at the farm level in Rwanda. Furthermore, they found that milk can be contaminated due to microorganisms such as mastitis or zoonotic pathogens from infected animals.

In addition to the production-side low quality milk, the same milk can also get contaminated along the value chain due to lack of proper cooling during transportation, inadequate processing capacity, and pollution by the environment from the farm level to consumer (Land O'Lakes, 2017b). The lack of fundamental practices such as hygiene, appropriate milking equipment, basic infrastructure, and tools may end up supplying low-quality or contaminated milk (Nyokabi *et al.,* 2021; Rakha *et al.,* 2022; Zavala & Revoredo-Giha, 2022). Hence, Kamana *et al.* (2017) suggest that milk productivity promoted in

Rwanda should go hand in hand with the application of good practices at all levels of the dairy value chain if the sector is to attain its optimal benefits of generating more income and improving nutrition.

Despite the critical share of the dairy sector in the Rwandan national economy where it contributes to about 6% of the country's total Gross Domestic Product (GDP) (Reeve, 2017), it is largely dominated by the informal sector. Over 60% of the milk traded in Rwanda is through informal channels (Shema *et al.* 2018). Generally, the government considers the milk in the informal channel as of low quality because it is raw milk (non-processed) sold to consumers in an unorganised way (Alonso *et al.,* 2018). On the other hand, the milk in the formal channel is perceived by the government to be of high quality as it is industrially processed and sold in an organized manner (Alonso *et al.,* 2018; Blackmore *et al.,* 2015). The government's main worry is that the informal marketing channel is associated with poor quality milk, potentially causing public health-related risks and diseases (Doyle *et al.,* 2015; Muunda *et al.,* 2021; Reeve, 2017). The public health-related diseases and challenges associated with the consumption of unprocessed milk from the informal sector may have some effects on consumers especially children, pregnant, and breastfeeding women (Doyle *et al.,* 2015; Rawlins *et al.,* 2014). However, this is a misperception, as milk sold in the informal sector is not automatically unsafe, and the milk in the formal sector is not certainly safe (Blackmore *et al.,* 2015).

The government of Rwanda (GoR) considers the dairy sector among the key solutions to improve nutrition and generate income mostly for rural households. Therefore, after the 1994 genocide, the government initiated different programs to improve the production and consumption of milk and increase incomes through livestock keeping. Among these programs, the Girinka program (One Cow per Poor Family program), initiated in 2006, aimed to improve livelihood and nutrition among poor households through increased milk consumption and livestock asset transfer in the form of a cross-bred heifer (Ezeanya, 2014). The Rwanda Dairy Development Project (RDDP) funded by the International Fund for Agricultural Development (IFAD) was also introduced in 2016 to enhance the welfare of dairy farmers (IFAD, 2016). All these programs have led to the growth of the dairy value chain in Rwanda and provided an opportunity for many households keeping livestock to get out of poverty through increased milk production and employment (IFAD, 2016). For example, milk production more than doubled between 2010 and 2018, from 372,619 to 847,178 metric tonnes (MINAGRI, 2019).

Despite the increase in milk production, milk quality along the dairy value chain is still a concern (De Vries *et al.*, 2020; Ndahetuye *et al.*, 2020). Therefore, to achieve the desired high-quality milk, the GoR together with different international organizations has undertaken several initiatives. For instance, the Rwanda Dairy Competitiveness Program (RDCP II) funded by the United States Agency for International Development (USAID), which was implemented between 2012 and 2017, aimed to improve the dairy competitiveness in the region, increase milk production and consumption as well as enhance milk quality (Land O'Lakes, 2017b). The RDCP II was implemented in 17 of the 30 districts of Rwanda. It was postulated that quality milk produced efficiently and well marketed throughout the entire value chain will improve the nutritional status of consumers and the income of smallholder producers (Grewer *et al.,* 2016).

The RDCP II project's "seal of quality" (SOQ) certification scheme, now referred to as "dairy best practices" (DBP) certification, was initiated and laid out a set of practices and standards for proper handling of raw milk. The DBP acts as an instrument for achieving quality milk production and supply. The dairy players found conforming to the standards are given the DBP certification that lasts for 12 months but is subject to renewal or withdrawal depending on the current compliance of the actors (Land O'Lakes, 2017b). The certification is done by the Rwanda Agriculture and Livestock Inspection Services (RALIS), which issues the certificate to the milk collection centres (MCCs) and small processors who comply with the given standards.

At the farm level, the DBP scheme entails many processes, including hygiene of the milker, cows, and milk utensils, animal disease controls and veterinary consultations, proper feeding of cows, and milk transport using stainless steel cans. Furthermore, the scheme requires farmers to transport milk to an MCC or to an aggregation point where basic quality tests such as alcohol, lactometer, and organoleptic are conducted (Land O'Lakes, 2017b). The MCCs then distribute the milk to large processors, raw milk sellers, and cottage processors. The inspection is done at the MCC and processor levels. It contains hygienic practices, mode of transportation, cooling systems, and a milk sample is sent to a laboratory to test for somatic cell counts and bacterial counts. These processes may pose a challenge to smallholder farmers to fulfill the requirements and hence make the alternative non-formal marketing channels more attractive.

The Rwandan milk quality certification and other components of RDCP II project have positively impacted the dairy sector in the country where the quality and volumes of

milk produced, consumed, sold, and demanded increased (Land O'Lakes, 2017a,b). Moreover, the milk sector in Rwanda has become competitive regionally as it has met the Common Market for Eastern & Southern Africa (COMESA) standards on quality, and the volume of milk exported has increased (Grewer *et al.*, 2016; Land O'Lakes, 2017b).

To support the DBP certification, the Ministerial Order was issued by the Ministry of Agriculture and Animal Resources (MINAGRI) that stipulates that all milk leaving the farm gate will be collected at MCCs, where it will be tested for quality prior to being sold. This further reinforces the government's effort to limit informal trade in the milk sector. However, eliminating the informal dairy sector completely in favour of the formal sector may have negative consequences on many poor households, mainly on the nutrition of infants and children (Blackmore *et al.,* 2015; Muunda *et al.,* 2021). This study focused on milk quality certification, which guarantees that high-quality milk is maintained along the Rwanda dairy value problem chain.

1.2. Statement of the Problem

Whereas the dairy best practice certification scheme introduced by the Government of Rwanda to enhance the quality and quantity of milk consumed through formal marketing channels, it is unclear why, according to Shema *et al.* (2018), over 60% of milk is still sold through informal marketing channels. Furthermore, the profitability and acceptability of dairy best practice standards among milk producers remain unknown. This is because there has been no farm-level analysis on the costs and benefits of this certification scheme to farmers and how it might influence farmers' choice of milk marketing channels. In addition, there is no evidence of consumers' willingness to pay for quality milk. This may be a hindrance to producers and other value chain actors who want to comply with dairy best practice standards. This study sought to fill these knowledge gaps.

1.3. Research Objectives

1.3.1. General Objective

The overall objective of this study was to contribute toward the improvement of the government policies that promote the formal milk marketing through the economic analysis of milk quality certification in Rwanda.

1.3.2. Specific Objectives

The specific objectives of the study were:

i. To determine farmer constraints of supplying quality milk that meets dairy best practice standards
ii. To estimate the costs and benefits to farmers of supplying quality milk that meets the dairy best practice standards
iii. To determine cooperative membership effects on farmers' choice of milk marketing channels
iv. To assess consumers' willingness to pay for quality milk that meets the dairy best practice standards

1.4. Research Questions

This study posited the following questions for inquiry:

i. What are the farmers' constraints of supplying quality milk that meets dairy best practice standards?
ii. What are the costs and benefits to farmers of supplying quality milk that meets the dairy best practice standards?
iii. What are the effects of cooperative membership on farmers' choice of milk marketing channels?
iv. Are consumers willing to pay for quality milk that meets the dairy best practice standards?

1.5. Justification of the Study

Considering the contribution of milk to the economy of Rwanda, the findings of this study will benefit the entire society. The call for quality milk to improve nutrition justifies the need to assess consumers' demand and evaluate the economic benefits of farmers. The findings of this study will help improve the DBP certification scheme so that quality milk is supplied, and farmers and other actors of the value chain be able to maximize the benefits. Furthermore, addressing the constraints farmers face and factors that influence their choice of marketing channels will play a role in formulating plans for upgrading the dairy sector. All stakeholders in the dairy sector will be informed of the viability of the DBP scheme. This will be used as a guiding document to policymakers for supportive policies that promote the supply and consumption of quality milk. Furthermore, this study complements and adds to the existing literature on milk quality and safety; and recommendations and adoption of DBP

certification are not only limited to Rwanda but could also be out-scaled to other regions of Sub-Saharan Africa (SSA).

1.6. Scope and Limitations of the Study

The production, market, and consumption of fresh milk in Rwanda were looked at in this study. On the production and market side of the study, Nyabihu district in the Western province and Ruhango district in the Southern province were considered. These districts were considered because they were targeted by the project that sought to enhance milk quality and consumption for improved income and nutrition in Rwanda, and they have been targeted by other projects that promote milk production and consumption in the country. On the consumption side, Ruhango district in the Southern province and Musanze district in the Northern province were selected for this study. This is because these districts have vibrant urban centers, and the milk market is assured. It would have been better to consider Kigali city for the consumption side due to its population; however, the type of milk that was used in the experimental auction was already in the milk markets of Kigali city. Hence, the selection of Ruhango and Musanze districts. While the entire country was not covered in this study, the four selected districts provided an overall picture of the production, marketing, and milk consumption in Rwanda. The other limitation would be the farmers' failure to accurately recall the information of the past 12 months since not all of them keep farm records. However, through more probing by experienced enumerators, this limitation was controlled, and there is no doubt that the needed information was obtained.

1.7. Operational Definition of Terms

Dairy best practices (DBP): This is a set of practices for properly handling raw milk to ensure high-quality milk (Land O'Lakes, 2017b). It entails the production, transportation, and storage of raw milk. Milk producers must feed their cows with balanced feeds (with feed supplements and concentrate), seek veterinary services, use stainless steel cans, and maintain the cleanness or hygiene of cows and the milker. The DBP scheme requires farmers to transport raw milk to the MCCs, where basic quality tests such as organoleptic, lacto densimeter, temperature, alcohol, antibiotic residue, and mastitis are conducted. Once the milk passes those tests, the MCCs accept it and chill it as they wait for the processor to come for it.

Experimental auction: It is an experimental economics method that provides incentives for individuals to truthfully reveal their values and imposes a cost for non-truthful

(or inaccurate) value revelation. The method involves an active market where people exchange real milk and real money (Lusk & Shogren, 2007).

Laboratory: Is a hall or room in which the experiment takes place (Lusk & Shogren, 2007).

Milk collection centre (MCC): They are centres/cooperatives mandated to collect and conduct basic milk quality tests such as alcohol, lactometer, and organoleptic and chill the milk before selling it to buyers. The milk from MCC is considered to have met DBP standards (Land O'Lakes, 2017b).

Milk consumer: The person who mainly bought and made milk purchase decisions in the household.

Milk producer: The person who owned a cow or cows, or who mainly made decisions regarding cow inputs, paid for those inputs, and made decisions on milk marketing in the household.

Milk quality certification: Is a certificate given to milk collection centres and small processors who comply with DBP standards (Land O'Lakes, 2017b).

Products: Types of milk that participants in an experimental auction were bidding for.

Second price auction: A type of auction where participants are asked to submit bids that correspond to their maximum willingness to pay for a product. The winner of the auction purchases the product at a price stated by the second-highest bid among the bidders in the auction (Vickrey, 1961).

Subjects: These are respondents or participants in an experimental auction.

Willingness to pay (WTP): Is the maximum amount of money a person would pay that makes her/him indifferent to improving the quality of the milk or keeping the status quo.

CHAPTER TWO
LITERATURE REVIEW

This chapter reviews various studies that have been done regarding agricultural products certification, costs and benefits of certification on smallholder producers, determinants of farmers' choice of milk marketing channels, as well as consumers' demand and WTP for certified agricultural products. From the literature reviewed, gaps that this study sought to fill were identified. Finally, the chapter concludes with theoretical and conceptual frameworks that were used in the study.

2.1. Agricultural Products Certification

Certification is the evaluation and approval of a set of defined standards by an accredited party (Evans *et al.,* 2021). Food quality certification is used to assure all stakeholders and the society about the quality of the product, and it serves as a tool for approving good practice compliance (My *et al.,* 2017; Wang *et al.,* 2020). Certification can be voluntary or compulsory; thus, the (dis)incentives for certification may differ across organizations. The expected profits from certification, such as improved food quality and safety, increased market share, and price premiums, may influence a firm to adopt the certification of its products (Evans, *et al.,* 2021; Fanasch & Frick, 2020; Roheim & Zhang, 2018). However, firms may adopt certification because of public policy and regulations where penalties and sanctions are charged to non-certified firms (Bovay & Alston, 2018; Guo *et al.,* 2019).

Agricultural product certification has received considerable attention in the past two decades. This may be due to increased environmental concerns and/or food safety requirements by customers (Hu *et al.,* 2022; Qijun & Batt, 2016; Stellmacher & Grote, 2011). Certification structures mostly follow a complete range of standards that consider the production and processing phases through which consumers are encouraged to offer good prices when purchasing goods with assured quality (Minten *et al.,* 2018). Moreover, certification schemes are progressively considering a variety of concerns such as human, animal, and plant health, biotechnology, and wrapping (Willemen *et al.,* 2019).

While certification may not be legally binding in some countries, food and beverage industries are adopting certification to increase their customers' confidence and trust in the quality and safety of their products (Evans *et al.,* 2021). Furthermore, developing countries are getting more involved in facilitating and ensuring that food and beverage industries, including the dairy industry, acquire quality-related certifications to safeguard consumers

(Ortega *et al.,* 2012; Vroegindewey *et al.,* 2021; Wang *et al.,* 2008). Milk is a highly perishable drink as it gets contaminated through milker hygiene challenges , udder, and milking equipment or through inappropriate means of transport and cooling (Ndahetuye *et al.,* 2020). Hence, several scholars (such as Akinyemi *et al.,* 2021; Amuta *et al.,* 2021; Kamana *et al.,* 2017; Kussaga *et al.,* 2015) have advised the adoption of good dairy farming practices in Africa. While the adoption of good dairy practices is highly recommended in these studies, the estimation of the costs incurred by farmers who try to comply with the stipulated good practices is still a gap in dairy production literature, which may limit their adoption.

Milk quality studies have been conducted recently in some developing countries such as Kenya, India, and Tanzania (Alonso *et al.,* 2018; Johnson *et al.,* 2015; Lindahl *et al.,* 2018; Nyokabi *et al.,* 2021). They focussed on the improvements of informal milk markets through trainings and certification of dairy traders. Their findings show that trainings and certifications increase participants' information and skills in milk-handling practices, which leads to a supply of high-quality milk. Furthermore, they found significant benefits and improved incomes in some instances because of quality-based payment systems. Whereas these studies found significant economic benefits, they only focused on traders and did not consider the producers who are key players in ensuring milk quality is upheld. While milk certification may not always bring monetary benefits, some social benefits such as reduced food-borne diseases, government appreciation, and access to supportive services are realised (Aworh, 2021; Johnson *et al.,* 2015).

In Rwanda, the DBP standards certification is done at the MCCs and processors' levels as processors get milk from MCCs, which ought to have checked the quality of milk before accepting it from the farmers (Land O'Lakes, 2017b). This is because milk gets contaminated from the farm level (due to milking an infected animal, poor hygiene of the milker, the water and detergent used to clean milk utensils as well as the time they are cleaned), and the contamination increases along the value chain due to means of transport and utensils used, and longer time between milking and cooling (Mpatswenumugabo *et al.,* 2019). While the certification has been implemented successfully in the country (Land O'Lakes, 2017a,b), the economic benefits of this certification and the consumer demand for certified milk have not been assessed. The costs and benefits associated with certification and the consumer willingness to pay for certified milk need to be provided to all stakeholders in the

dairy value chain. Evaluating the financial benefits of milk quality certification will provide evidence for requisite policy intervention in the milk subsector.

2.2. The costs and Benefits of Certification for Smallholder Producers

While there is a growing market for certified products, the process of certification entails some costs. For instance, Pramudya *et al.* (2022) found that palm oil producers face difficulty in complying with mandatory certification standards in Indonesia due to lack of funding and limited capacity. Furthermore, Jena and Grote (2022) studied the effect of coffee fairtrade certification on yields and income in Ethiopia, India, and Nicaragua. They found that certification costs, including the cost of compliance to quality standards, may change the inputs use, the fixed and/or variable costs, and ultimately the producers' total cost of production. Although these studies focused on the certification of palm oil and coffee, which are cash crops, it is unclear whether the changes in input use and production costs are also realised in livestock production system such as milk milk production.

Certification may come with different benefits depending on the firms that are certified. In most cases, there is an increase in market value and a price premium paid to certified products because they are improved and differentiated from others (Asche *et al.*, 2021; Hossain *et al.*, 2022). Studies have shown that farmers may earn a price premium from certified agricultural products. For example, Hossain *et al.* (2021) assessed markets of GLOBALG.A.P. certified chickens in Bangladesh and found that certified live broilers and certified live Sonali chicken are bought with price premiums of 36.7% and 26% respectively. Similarly, Tran *et al.* (2022) conducted a field experiment to evaluate consumers' WTP for safety-certified catfish in Nigeria. Their findings show that safe certified farm-raised catfish has a varying price premium between 3.1% to 18.8% of the base price. Despite the huge benefits reported in these studies, it is unclear whether the same benefits can be realized on a highly perishable product such as milk.

The price premiums in the dairy sector are also reported in different developing countries. Gao *et al.* (2020) used a double-bounded contingent valuation method and found that consumers in China are willing to pay a price premium of 40% for sustainable milk over conventional milk price. Similarly, Vroegindewey *et al.* (2021) used a stacked choice experiment and found that urban consumers in Mali are willing to pay for safety certified milk, particularly when a government institution does the certification. They further recommended packaging, labelling, and government certification as ways of signalling information among consumers of dairy products made from fresh milk. Furthermore,

consumers in the South and Northwest of China consider mainly the safety and quality of dairy products they consume; hence, they are less sensitive to the prices they pay for milk of guaranteed quality (Maitiniyazi & Canavari, 2021). These findings are confirmed by Mtimet *et al.* (2015) in their study in Kenya, where they found that milk consumers are willing to pay a premium for aflatoxin-free certified milk despite their trust in milk supplied in informal markets. Notwithstanding the price premiums for certified milk, these studies could not identify the proportion of these premiums received by farmers and estimate the costs incurred in the certification process.

Certification may also lead to reduced price volatility of certified products and create a trade relationship for a long period, ensuring price stability and enabling both sellers and buyers to plan appropriately (Furumo *et al.,* 2020). Several studies (Andersson, 2019; Fiankor *et al.,* 2019; Hu *et al.,* 2022; Yadav *et al.,* 2021) demonstrate that certification of food products enhances smallholder farmers' access to export markets in terms of values or volumes, eases their entrance in global markets, and puts them in a better connection with their clients. This allows them to compete internationally and gain higher prices from those markets. Moreover, Henson *et al.* (2011) conducted a study on certification effects on export revenues in ten Sub-Saharan African countries, and their findings suggest that exporters of fresh certified produce gain considerable returns on needed investment. Similarly, Schader *et al.* (2021) established that organic agriculture (OA) can lead to more than 100% gross margin increase compared to conventional agriculture for bananas, maize, coffee, peas, and roots in SSA and a further possibility of price premiums for OA-certified production for exports. However, whether the same benefits obtained by crop producers can be obtained by milk producers remains an empirical question.

Since most of the certification schemes require smallholder farmers to form cooperatives or farmer groups, these cooperatives may benefit from reduced transaction costs compared to individual farmers (Imami *et al.,* 2021; Teague, 2022). A cooperative assists in the cost reduction of inputs and provides an opportunity to access capital and financial services to its members (Blackmore *et al.,* 2012; Blekking *et al.,* 2021; Li & Ito, 2021). Moreover, through cooperatives, farmers can bargain prices with other agents of the value chain or directly with buyers, which leads to good cooperation and trust along the value chain (Gava *et al.,* 2021; Vorley *et al.,* 2016). Furthermore, certification improves the producers' reputation and internal and external competitiveness. Certification is linked with improved

quality of the product, which creates a good reputation for producers and gives them a comparative advantage over their competitors (Ikram *et al.*, 2020).

In addition, Hoffman *et al.* (2019) stated the training benefits of certification. In their empirical research review, they found that the capacity building associated with a certification scheme gives different actors of the value chain an opportunity to gain new skills that improve food safety and access to niche markets. Imperfect information has been among the challenges faced by smallholder farmers in developing countries, therefore, training emanating from certification may be a channel for farmers to access information on potential markets and prices of their products (Blackmore *et al.*, 2012; Brako *et al.*, 2021; Chon *et al.*, 2021). However, this is a postulation as the authors did not test the cause-effect relationship of trainings on the choice of marketing channels that offer different prices.

The impact of certification costs and benefits on the returns received by the producers is not always positive. Jena and Grote (2022) conclude that the effect of certification may be case and/or context-specific. This was after they found that Fairtrade certification reduced smallholder coffee farmers' incomes and livelihoods in Ethiopia while it increased farmers' incomes in India and Nicaragua. In some cases, the certification impact is negative when costs are high, while in others, the impact is positive when benefits are higher (Abate *et al.*, 2021; Brandi *et al.*, 2015; Jena & Grote, 2022). For example, high certification costs negatively affected producers' income when the certification costs were not paid by donors or any other third party (Frey *et al.*, 2022; Sexsmith & Potts, 2009). On the other hand, producers in various developing countries have gained more profits from high yield and quality products that fetched a premium price for complying with certification orders (Dragusanu & Nunn, 2013; Schader *et al.*, 2021; Tscharntke *et al.*, 2021). These mixed findings imply that the effect of certification on producers has yet to be definitively demonstrated and settled.

Despite the monetary benefits associated with certification, there are non-monetary benefits such as environmental benefits and improved food quality to health. Certification standards may require practices that contribute to the preservation of the environment and better soil management, which lead to the sustainability of farming (Hassauer & Roosen, 2020; Klauser & Negra, 2020). Furthermore, certification is associated with higher food quality, improved health status, and reduced morbidity and mortality rates (Aworh, 2021; Jaffee *et al.*, 2018). Apart from people being unable to work when they are sick, they also spend more money on medical treatment. Therefore, food quality certification benefits may

be observed through avoided costs of sickness such as medical costs, lost working time, and productivity lost due to illness (Hoffmann, *et al.,* 2019; Kirk *et al.,* 2015).

While there are many previous studies that assessed the impact of certification on export income, price premiums, and return on investment (Fiankor *et al.,* 2019; Kleemann *et al.,* 2014; Subervie & Vagneron, 2013; Yadav *et al.,* 2021), most of these studies focused on staple or commercial crops, fruits, and vegetables that are mainly produced for export. However, there is a dearth of literature on whether the same certification impacts can be realised on livestock products such as milk. In addition, different agents in the value chain may incur some costs of certification, but it is mostly the producers who pay a big share of the cost of certification (Blackmore *et al.,* 2012). Hence, the estimation of costs incurred by producers to get certified and the monetary benefits they receive from certified products is still a gap to be filled in the literature.

2.3. Determinants of Farmers' Choice of Milk Marketing Channels

Milk and dairy products have two main marketing channels: informal and formal. An informal marketing channel is dominant in most developing countries and is characterized by an unorganized system where milk is sold from farmers or vendors directly to consumers (Alonso *et al.,* 2018; Muunda *et al.,* 2021). The milk in this channel is not industrially processed. It is sold in corner shops, milk bars, and streets as well as door-to-door selling, which makes the quality of milk questionable as the monitoring process and traceability is difficult (Alonso *et al.,* 2018; Sikawa & Mugisha, 2011). Conversely, a formal marketing channel is legally licensed, well organized, and sells industrially pasteurized and packed milk products (Alonso *et al.,* 2018; Blackmore *et al.,* 2015). This channel is characterized by high operating costs such as transport and processing costs and a big gap between buying and selling prices where actors buy raw milk from farmers at a lower price and sell processed milk to consumers at a higher price; making it less common mostly in locations with low-income levels (Blackmore *et al.,* 2015; Zavala & Revoredo-Giha, 2022). Nevertheless, there is a lack of price differentials in different milk marketing channels, especially in SSA.

Generally, when farmers have different marketing channels for their produce, they consider several factors before choosing a particular marketing channel (Carmona *et al.,* 2021; Nwafor, 2021). This is a similar case for dairy farmers as they settle on a specific marketing channel from the available alternative channels. For instance, using nationally representative data, Kumar *et al.* (2018) found that Indian dairy farmers prefer to sell their milk to cooperatives and government agencies compared to other milk marketing outlets such

as local traders, direct to consumers, commission agents, and processors. They further found that access to institutional credit, education level, association with social groups, and selling price are the main factors behind their choice of marketing channel. A similar study was conducted in the Bihar state of India by Singh (2018) and found that the selling price, distance to production centres, and delayed payment influence dairy farmers to sell their output directly to consumers (regarded as an informal outlet) while the size of the farm and education level influence them to sell to formal buyers such as cooperatives. The key assumption in both studies is that they considered the milk marketing channels as mutually exclusive, which may not be the case in the Rwandan dairy sector.

Few studies have analysed the factors influencing the choice of milk marketing channels in SSA. For instance, Koyi and Wakhungu (2018) found that access to markets, credit, and information, as well as gender, age, and education level of the household head and selling price, are the main factors influencing the choice of milk marketing channel in Bungoma county of Kenya. However, the findings of this study may be biased and/or incorrect as they relied on descriptive statistics while omitting the relationship between variables obtained through econometric analysis (Jitmun *et al.*, 2020). Furthermore, Cheelo and Van der Merwe (2021) used a multinomial logit model to estimate the factors behind the farmers' choice of milk marketing channels in Zambia. Their findings show that gender and education of the household head, the quantity of milk produced, off-farm income, and distance to market influence dairy farmers' choice of traditional or modern channels compared to selling directly to consumers. However, this study did not consider the effect of the cooperative membership variable. It also used an econometric model that imposes mutual exclusivity of marketing channels, which is not always the case in many developing countries.

A study by Jitmun and Kuwornu (2019) conducted in Thailand included the MCC's membership duration and found that farmers who have been members of MCCs for a longer period are likely to sell to cooperatives. Nevertheless, the probit model used in this study does not allow farmers to sell to multiple marketing channels, nor does it account for the possibility of a selection bias of MCC membership when farmers target to sell to dairy cooperatives. A recent study by Mamo *et al.* (2021) also included the cooperative membership variable and found that the cooperative dairy membership, the distance to the nearest market, farming experience, education level, and farm size are key determinants of the choice of milk marketing channel in Ethiopia. While this study used a multivariate probit

model that allows farmers to sell to more than one marketing channel, its limitation is that it fails to account for the likelihood of cooperative membership being endogenous to farmers' choice of cooperatives as a marketing channel. Furthermore, this study targeted commercial dairy producers in urban and peri-urban areas. Hence, it is unclear whether similar effects can be realised in a rural setting that is comprised of smallholder dairy producers.

The milk marketing channels in Rwanda do not differ from those in other developing countries. The informal channel comprises different informal retailers that include producers selling directly to consumers, mobile traders, restaurants or milk shops, and markets (TRAIDE Rwanda, 2019). On the other hand, the formal channel has formal retailers such as supermarkets and dispensers who mainly get their milk from processors and/or MCCs, where milk is believed to have met DBP standards (TRAIDE Rwanda, 2019). Despite the government's effort to limit the informal market channel in the milk sector through the introduction of the DBP scheme, the informal market channel is still dominant (Shema *et al.,* 2018). One could argue that non-compliance to DBP standards leaves non-compliant farmers with no option except to trade their milk in the informal market, while compliant farmers have the option to sell in either formal or informal markets, or both. However, suppose farmers who have met the DBP standards do not sell all their milk to MCCs (i.e. formal market). In that case, there are other factors other than DBP standards that are influencing farmers to not participate in formal market channels.

Although cooperative membership has several benefits, such as decreased transaction costs, better access to markets, and increased price bargaining power (Blekking *et al.,* 2021; Lin *et al.,* 2022), it also consists of some costs, such as time spent in cooperative activities as well as membership fees (Ankrah *et al.,* 2021; Olagunju *et al.,* 2021). Hao *et al.* (2018) used an endogenous switching probit model, which not only allows farmers to sell to more than one marketing channel but also controls for endogeneity problem. They found that cooperative membership is a key factor influencing farmers' choice of marketing channels for apples in China. Notwithstanding the interesting results from the study, the effect of cooperative membership on the counterfactual (non-members of cooperatives) was not estimated. As such, my study builds on the model of Hao *et al.* (2018) by estimating the effect of dairy cooperative membership on farmers' choice of milk marketing channels and extends the model to estimate the effect of cooperative membership on non-members of cooperatives (had they been members).

2.4. Consumer Demand and Willingness to Pay for Certified Agricultural Products

Economic theory assumes that economic agents, including consumers, are rational and make informed decisions to achieve their pre-determined objectives. Perceptions and beliefs about a certain product influence the consumer's demand and willingness to pay (WTP) for that product (Huang & Lee, 2014; Wemette *et al.*, 2021). Therefore, consumers' attitudes about certification will determine the level of demand for a certified product. Despite the budget constraint consumers face, they usually prefer to purchase certified over non-certified products, even if the latter are less expensive (Lappeman *et al.,* 2019). This demonstrates that consumers' interest for safety and quality certified food is increasing over time (Morone *et al.,* 2021; Yang & Fang, 2021).

Most consumers in developed countries pay attention to the quality attributes of food products. These consumers are prepared and willing to pay higher prices for products that they believe improve their health status and are produced ethically when the environment is less affected (Hoffmann *et al.,* 2019; Li & Kallas, 2021). Sun *et al.* (2017) established a positive relationship between eco-friendly labelled canned tuna products and consumer demand in the United States of America (USA). Using the generalized synthetic demand system, they found that the demand for canned tuna is influenced by whether it is eco-friendly certified or not, implying possible benefits associated with certification. While this may be true in a developed country, where consumers have access to different types of information and have relatively higher incomes, it is not certain that the same higher demand and premiums can be realised in a developing country such as Rwanda.

Despite food shortages in developing countries, the importance of consuming quality and safe milk is recognized. Studies are being done on milk quality and safety. For instance, Tegegne and Tesfaye (2017) conducted a study on foodborne pathogens in milk and bacteriological milk quality in Ethiopia. Their findings show that milk is among the highest group of food products at high risk of bacteriological contamination, and consumption of poor-quality milk can be harmful to people's health since it can cause food-borne diseases. Furthermore, in their study on food safety along the informal milk supply chain in Kenya Zavala and Revoredo-Giha (2022) found a lack of hygiene, health controls, and awareness about milk safety in an informal dairy sector which poses food safety risks. Whereas these two studies focused more on bacteriological concerns, they did not look at the costs of supplying high-quality milk, and they didn't assess consumers' ability and WTP for high-quality milk mainly sold in the formal sector.

Certification is used to communicate the product's unobservable quality to the consumers (Hoffmann *et al.,* 2019). There is an increasing existence of agricultural products' certification schemes in most SSA countries, although the downstream WTP higher prices remain unbalanced (Abate *et al.,* 2021). Sub-Saharan African countries are experiencing fast population growth with increasing incomes and a rapid industrialization which are contributing to consumers' demand and search for quality certified food products (Noort *et al.,* 2022). Scholars have used different methods to estimate African consumers' demand and WTP for several products. For example, Tepe *et al.* (2021) used sensory testing and an experimental auction technique to estimate consumers' WP for extended shelf lives of fruits and vegetables in Kenya, Tanzania, and Uganda. Their findings confirm that consumers, mostly in urban areas, were willing to pay price premiums for processed fruits and vegetables, while a positive sensory acumen led to higher premiums.

Moreover, Merlino *et al.* (2020) used a choice experiment method to examine Italian milk consumers' perception of milk packaging innovation. They found that consumers were willing to pay price premiums of up to 20% more for milk packaged in an environmentally sustainable way such as recyclable materials. Similarly, Nam *et al.* (2020) estimated consumers' WTP for milk produced in a sustainable production system, such as in the mountain areas of Korea, and they found that consumers are willing to pay higher price premiums when such information is made aware to them. Furthermore, using the contingent valuation method, Yormirzoev *et al.* (2021) found that over 50% of milk consumers in Russia were willing to pay higher prices for organic milk when perceived to be linked to health benefits. Nevertheless, these studies were hypothetical, which may not reveal the respondents' true WTP values.

To address the hypothetical bias, Akaichi *et al.* (2012) conducted an experimental auction while evaluating the WTP for certified organic milk in Spain, and they found that consumers were willing to pay premium prices for organically produced milk provided that they had positive information about organic farming. Likewise, Shibata *et al.* (2021) conducted a non-hypothetical study in Japan using the n^{th}-price auction mechanism to estimate consumers' WTP for safe milk and the effect of access to safety-related information. Their findings show that consumers are willing to pay 45% extra for milk that is free from antibiotics and around 29% more for milk whose cows are not fed genetically modified feeds. Although some countries in SSA such as Kenya and Tanzania have proposed different policies that promote quality in the milk sector (Blackmore *et al.,* 2015; Land O'Lakes,

2017b; Omore & Baker, 2011), they have not assessed the consumers' WTP for that quality milk which should be considered for an effective implementation of such policies. However, the results from these studies suggest that certification of milk, as an indicator of quality, is likely to matter in milk pricing.

The absence of buyers of certified product may be risky. Therefore, it is very important to understand the demand for certified products since the lack of market for these products may limit the financial benefits of producers who are engaged in certification (Abate *et al.*, 2021). Notwithstanding the consumers' WTP for different food safety and quality products in different countries, the consumers' willingness to pay for quality milk has not yet been assessed in Rwanda. When dealing with low-income consumers like the majority of consumers in a developing country such as Rwanda, it is crucial to identify whether consumers are able and willing to pay for the improved quality milk. This study addresses this research gap by eliciting consumers' willingness to pay for quality milk and estimating the premium or discount compared to the conventional and most consumed milk.

2.5. Theoretical Framework

This study used both producer and consumer theories. The main objective of producers is to maximize profits. In a competitive market, prices of inputs and outputs are assumed to be given; hence, the producers can maximize profits by adjusting production inputs so that they can use the minimum possible inputs and attain the maximum output (Basov, 2017).

2.5.1. Producer Theory

The producer theory has been used to explain the supply of products or services. Assuming a competitive market in which the producers are input and output price takers, the producers will maximize their profits by choosing a technologically efficient production plan (Wang, 2018). A producer is considered technically efficient if he/she uses the minimum possible inputs to produce the maximum possible output. When the relationship between inputs and output (i.e., production function) is known, one can discover the substitutability of production factors and estimate input combinations in the production process. Assuming that the producer produces one output using different inputs, Basov (2017) estimated the standard production function as:

$$Y = f(x_1, x_{2n}, \dots, x_n) \quad (2.1)$$

where Y is the output and $(x_1, x_{2n}, \ldots, x_n)$ are the vector of inputs. While the general production theory assumes that all production activities are on the frontier of the possible production set, producers may produce below the production frontier because of the technical inefficiency and random error term (Kumbhakar *et al.*, 2015, p. 30). Hence, the production functions can take different functional forms as they are characterised by their elasticity of substitution and return to scale (Önalan & Başeğmez, 2022). This study built on the producer theory to estimate the profit efficiency of milk producers in Rwanda (section 4.3.3 & 4.3.4).

2.5.2. Utility Theory

Choice experiments and experimental auctions have used utility theory to explain consumer decision-making regarding the demand for a product. Assuming that a consumer derives utility by choosing among the substitute alternatives and assume further that there is a random uncertainty resulting from the analyst's lack of accurate information on consumer's decision process or from the consumer's being inattentive in the choice process (Louviere *et al.*, 2000). It follows that the probability *Pr (i)* that a decision-maker n will choose alternative *i* (from a finite set of alternatives in choice set C_n) is the probability that the added utility U_i from this choice is greater than (or equals to) selecting another alternative in the choice set. This is presented as:

$$Pr(i) = Pr\left(U_{ni} \geq U_{nj}\right) \quad i \neq j \ \ \forall j \in C_n \tag{2.2}$$

The utility function U contains the deterministic (V_n) (which consists of the attributes of the alternatives and the socioeconomic characteristics of the decision-maker) and stochastic (u_n) components:

$$Pr(i) = Pr\left(V_{ni} + \ u_{ni} \geq V_{nj} + \ u_{nj}\right) \quad i \neq j \ \ \forall j \in C_n \tag{2.3}$$

Rearranging equation (2.3) gives:

$$Pr(i) = Pr\left(V_{ni} - \ V_{nj} \geq u_{nj} - \ u_{ni}\right) \tag{2.4}$$

where *u* is a random variable with some joint density function that induces a density on utility *U*. The distributional assumptions on stochastic component *u* lead to several choice models which yield the outputs representing the probabilities of decision-makers selecting each alternative. While the utility theory supports the choice of milk marketing channels (section

5.2.1), it is also linked to the second price auction mechanism (section 6.2) used to estimate consumers' WTP for quality milk.

2.6. Conceptual Framework

Figure 2.1 presents a conceptual framework that demonstrates the interaction of different factors and how they influence the choice of milk marketing channels. The production side builds on Antle (2001), who argues that the total production cost of a quality-differentiated product is a sum of the cost of conventional production inputs and quality-related cost of inputs that are non-joint in conventional production cost. Similarly, Theuvsen (2007) established that food quality requirements increase production costs and yields attained. This implies that the production cost of quality milk is higher than that of conventional milk due to additional DBP-related costs, however, the quantity of milk produced is also increased. Farmers producing milk conventionally are incurring normal costs of production, while those adhering to DBP standards are incurring extra costs. The observed higher production costs are associated with higher quality and quantity of milk produced, which in turn affect milk marketing channels. It is argued that when farmers know the quality of their milk and the high costs incurred in its production process, they choose a marketing channel that gives them the maximum possible returns. This argument is based on Verhaegen and Huylenbroeck (2001) who established that farmers with quality food products abandon the old marketing channel and sell in a new marketing channel if the new channel pays off the higher production costs incurred and all related transaction costs.

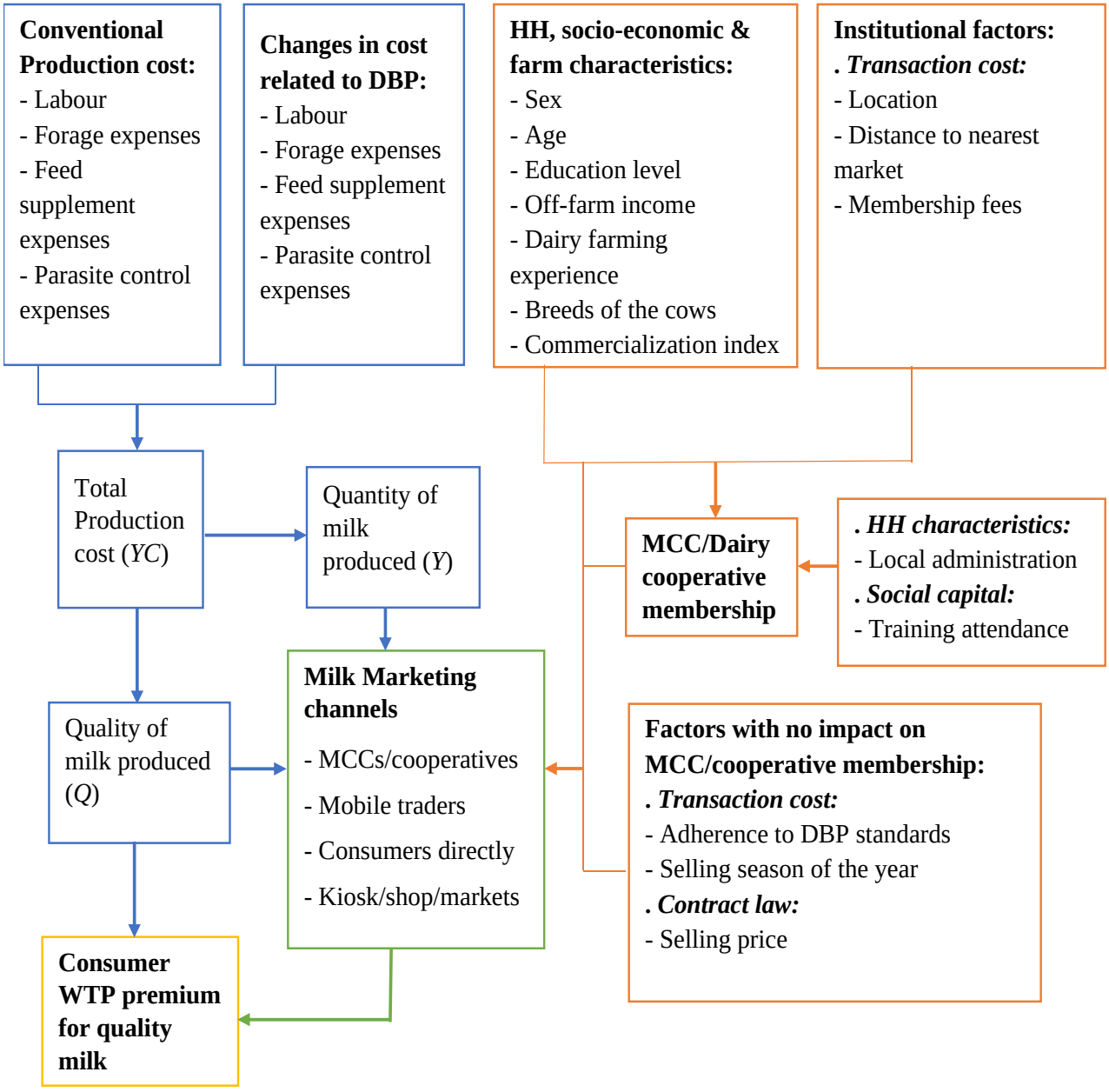

Figure 2.1: Conceptual framework for factors that influence milk marketing channels

On top of production factors, the choice of milk marketing channels can be influenced by household, socio-economic, farm characteristics, and institutional factors. These factors may influence both cooperative membership and choice of marketing channels, however, some factors may influence the choice of milk marketing channels with no impact on membership to a dairy cooperative/MCC. Household, socio-economic, and farm characteristics included in this study were sex, age, education level, off-farm income, dairy farming experience, breeds of the cows, and commercialization index. A household head with

a higher education level was expected to have better skills and information to evaluate the relevance of joining a cooperative and to select a better milk marketing channel. The commercialization index (saleable milk) calculated as the proportion of milk sold over milk produced, was expected to influence the farmer's decision to join a cooperative as well as the choice of milk marketing channel (Ravneet *et al.,* 2018). This is because a farmer with a higher commercialization index may join a dairy cooperative/MCC due to stable milk markets.

The institutional factors are derived from the new institutional economics (NIE) theory that shows the link between elements of institutions, actors, and activities (Dorward *et al.,* 2005; Kirsten *et al.,* 2009). The new institutional economics (NIE) is divided into the institutional environment and institutions of governance which are generally grouped into four categories namely transaction cost, social capital, contract law, and property rights (Dorward *et al.,* 2005; Kirsten *et al.,* 2009; Williamson, 1991, 1998). Institutional factors in this study were grouped into three categories (transaction cost, social capital, and contract law).

The transaction cost variables included in this study were distance to the nearest market, membership fees, adherence to DBP standards, selling season of the year, and location of farmers. Higher membership fees and longer distances to the nearest milk markets were expected to increase farmers' transaction costs. Similarly, farmers' adherence to DBP standards and selling milk in the rainy season were expected to increase their transaction costs. The transaction costs were expected to affect both the choice of milk marketing channel and the farmers' decision to join a dairy cooperative/MCC (Hao *et al.,* 2018). The social capital variables considered in this study were cooperative/MCC membership and training attendance. Membership in a dairy cooperative/MCC was expected to have varying effects on the choice of different marketing channels while participating in dairy farm management training was expected to increase the household's likelihood of joining dairy cooperatives. The contract law category of the institutional factors in this study was the selling price variable. While the selling price was not expected to affect the farmers' decision to join a dairy cooperative/MCC, it was expected to influence the choice of milk marketing channel as producers are more likely to sell their milk in channels that offer higher prices (Ravneet *et al.,* 2018).

While farmers' membership into a dairy cooperative/MCC was expected to influence the choice of milk marketing channel, it is important to note that most of the variables that

were expected to affect the farmers' decision to join a dairy cooperative/MCC were also expected to affect their choice of milk marketing channel. This creates a potential endogeneity problem between the cooperative/MCC membership variable and the choice of milk marketing channel. To address this bias, Deb and Trivedi (2006) advise having some variables that are expected to influence the cooperative/MCC membership without having a direct effect on the choice of milk marketing channel. This study considered the number of trainings attended and being in local government administration. It was expected that having a household member in local government administration and attending more training would influence the household to join a cooperative/MCC while both variables had no expected direct effect on the choice of marketing channels.

CHAPTER THREE

A REVIEW OF THE EVOLUTION OF DAIRY POLICIES AND REGULATIONS IN RWANDA AND ITS IMPLICATIONS ON INPUTS AND SERVICES DELIVERY

Abstract

The dairy sector in Rwanda plays a key role in improving nutrition and generating income mostly for rural households. Despite the Rwandan 1994 genocide that left around 80% of dairy cows decimated, the dairy sector has experienced significant growth in the past two decades through government, development organizations, and donor programs, and through the nascent vibrant public–private partnership. In this paper, the evolution of dairy policies, programs, and regulations in Rwanda was reviewed and documented how they have contributed to the development of the dairy sector. The policy change has impacted the provision and use of inputs and services that have shaped the sector's milk production and productivity, milk quality, and demand. The results suggest that various policy- and program-level interventions have positively contributed to the growth of the dairy sector and improved the livelihoods of low-income households. This has been achieved through increased access to inputs and services, enhanced capacities of the public and private sectors to deliver services, strengthened dairy cooperatives' governance, increased value proposition to members of various farmer groups, and promotion of milk consumption. The findings show that some of the implemented policies and programs, such as the "Girinka" (one cow per poor family) program, Rwanda Dairy Competitiveness Program II, and Rwanda Dairy Development Project, have resulted in improved farmer access to improved cow breeds and improved milk quality and cow productivity through enhanced health inputs and other services. While the dairy policies, programs, and regulations in Rwanda have paved the way for the development of the dairy sector and contributed to the provision and use of inputs and services, there are still challenges that need to be addressed. Accessibility and use of veterinary and artificial insemination services are limited by the quality of veterinary products, while the inadequate quality of feeds leads to low productivity of improved cow breeds. Consequently, farmers' uptake and use of inputs and services can be enhanced through a strengthened capacity of milk collection centres and health and animal feed policies that guide and control the quality of veterinary products and feeds sold in the markets.

3.1. Introduction

The 1994 genocide heavily devastated the country's physical, economic and social infrastructure, yet Rwanda experienced economic growth over the past two decades (Abbott *et al.*, 2017). This growth was led by an ambitious Vision 2020, which was the country's long-term framework for development that sought to transform Rwanda into a middle-income country by 2020 (Bizoza & Simons, 2019). Although Rwanda did not achieve all its targeted goals of Vision 2020, the country recorded an impressive Gross Domestic Product (GDP) growth of 8% per annum (p.a) that led to an increase in GDP per capita from 211 to 718 USD between 2001 and 2014 and a poverty reduction from 59% to 39% (Bizoza & Simons, 2019; Grewer *et al.*, 2016). Recognising the importance of the agricultural sector, the government of Rwanda (GoR) increased public investment in the sector and identified the sector as among the key drivers of Vision 2020.

Over the past decade, the Rwandan agricultural sector has grown at an average rate of 6% p.a (MINAGRI, 2019). The sector plays a significant role in the economy of the country; it contributes about 31% of the total GDP and serves as the country's leading sector towards the achievement of the first and second Sustainable Development Goals (SDGs) of no poverty and zero hunger (Bizoza & Simons, 2019; MINAGRI, 2018). Furthermore, over two-thirds of Rwanda's labour force is employed in the agriculture sector, while more than 60% of the country's exports are from agriculture (Chantal *et al.*, 2018). Although various subsectors of agriculture have contributed to Rwanda's rapid aggregate growth, the dairy sub-sector is regarded as the fastest growing sub-sector within agriculture as it contributes about 10.5% to the agriculture GDP (IFAD, 2016).

Rwandan milk comes from cattle and goats. However, dairy policies and interventions have been targeting milk from cattle as that from goats is negligible (FAO, 2017). In Rwanda, milk is consumed as raw, fermented (also commonly referred to as "Ikivuguto"), pasteurised, or processed products such as cheese, butter, ghee, and yoghurt (Umuzigambeho, 2017). The country has three major dairy production systems namely: zero-grazing, open-grazing, and semi-grazing (IFAD, 2016, TechnoServe, 2019). Due to land resource scarcity in the country, zero-grazing is the most common system in all regions where over 70% of production costs are related to feeds as cattle are kept in a shed and fed on forages. Open-grazing is mostly found in Western and Northern highlands where cattle freely graze on individual or communal grazing lands. Semi-grazing is primarily practiced in Eastern province and it is

characterized by a mixture of zero and open grazing where cattle are kept in stalls, fed on both forages and grazing.

The GoR considers the dairy sector as a valuable pathway to economic growth. It not only contributes significantly to the country's total GDP, but also offers a means of addressing malnutrition, famine, and poverty to the majority of cattle keepers and service providers along the dairy value chain (DVC) (Reeve, 2017). In support of this dual function of the sector, the Rwandan government has been implementing different policies and regulations as well as partnering with various organizations aimed at initiating programs that improve the production, and consumption of milk, and increase incomes through livestock keeping. In this review, the wide definition of policy by Anderson (1975) as a "purposive course of action followed by an actor or set of actors" was considered, which means that, the written government policies were not only considered but also the actions and programs of various dairy stakeholders and DVC agents that lead to behavioural changes. Most policies and regulations were initiated to support government investments and programs that seek to transform the dairy sector from subsistence to a modern sector.

In this study, the evolution of the dairy policies, programs, and regulations in Rwanda were documented and their contribution towards the development of the dairy sector were assessed, particularly in the provision and use of inputs and services that shaped the sector with regard to milk production and productivity, milk quality and demand in the country. The gaps that are not addressed by the current policies and the barriers to implementing specific regulations were also identified. The findings from this review will ultimately better inform dairy policy and decision making in Rwanda.

3.2. Materials and Methods

This study comprised a literature review and key informant interviews. The journal articles, conference papers, reports, and "grey" literature were reviewed. A wide internet search using search syntax such as (title: (dairy OR milk OR "dairy products") AND (policy OR policies OR regulations OR program* OR "dairy strategies" OR "dairy guidelines") AND Rwanda) OR ab: ((dairy OR milk OR "dairy products") AND (policy OR policies OR regulations OR program* OR "dairy strategies" OR "dairy guidelines") was done. The stakeholder websites, including the Ministry of Agriculture and Animal Resources (MINAGRI), Rwanda Agriculture Board (RAB), and Land O'Lakes were also explored. Other sites that provided important resources included: Heifer International, International Fund for Agricultural Development (IFAD), International Livestock Research Institute (ILRI)

and the Food and Agriculture Organization of the United Nations (FAO). While 97 related documents were reviewed, the considered information was from 35 documents which included: 19 journal papers, 1 book, 7 project reports, and 8 websites.

To get information on different policies and programs that were implemented, the key informant interviews with 34 different dairy stakeholders in the country were conducted. The key informants included one MINAGRI and two RAB staff, two staff members from Rwanda Agriculture and Livestock Inspection Services, one staff from Rwanda National Dairy Platform (RNDP), one staff from TechnoServe, one staff from Rwanda Dairy Development Project (RDDP), and former staff of Rwanda Dairy Competitiveness Program II (RDCP II). Furthermore, other key informants included two board members and one manager from each of the seven Milk Collection Centres (MCCs) located in four different districts (Nyabihu, Ruhango, Rubavu and Kamonyi) and three staff of "inyange" milk processor as well as one staff of a milk retailer (fresh dairy kiosk) in Kigali. Eight farmers from the four MCCs districts were also interviewed to understand the effects of the initiated programs and six consumers to identify different types of milk available to consumers. All the interviews were conducted in-person while taking notes.

The collected information was qualitatively analysed and used the data from the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) to provide a comprehensive image of the dairy sector in Rwanda. The findings serve as a basis for further grounded theory on dairy sector outcomes from policy interventions and complement the existing literature on the dairy sector development in Rwanda.

3.3. Dairy Policies and Programs

3.3.1. Girinka Program "One Cow Per Poor Family Program"

Over the past two decades, the GoR made important gains in rebuilding its livestock sector. After the 1994 genocide, around 90% of small ruminants and 80% of cattle were decimated, leaving the total cattle population at 162,683 in the country (IFAD, 2016; TechnoServe, 2019). From 1995 to 2000, the cattle population started to increase as Rwandan refugees returning into the country came back with cattle. Dairy companies also started operations. In 2006, the GoR initiated the Girinka program, which means "One cow per poor family" to enhance social cohesion and improve family incomes, soil fertility, and nutrition. The Girinka program targeted the lowest resource endowed households who then received a

dairy cow and were required to transfer the first calf to a qualified neighbour (Argent *et al.*, 2014; Hahirwa & Karinganire, 2017).

The low resource endowed households are usually identified using the "ubudehe" system, a comprehensive wealth-ranking system in Rwanda and is embedded into all administrative levels. Households are periodically classified into social classes in their areas on a scale of 1 to 4 according to their resource endowment or wealth status (where social class 1 is the lowest resource endowed household and social class 4 is the highest resource endowed household) (IFAD, 2016). For a household to benefit from the Girinka program, it must be in social class 1 of ubudehe with the capacity to build a cowshed and holding land area between 0.3 ha and 0.75 ha (where 0.2 ha is allocated for cow feed) (Argent *et al.*, 2014).

The Girinka program's rationale is to improve livelihood and increase nutrition among limited resource endowed households through increased household income, milk consumption, and agricultural productivity (Argent *et al.*, 2014; Ezeanya, 2014). It was expected that a given cow would produce milk that is consumed by the household, generate income through milk sales, and produce manure that is used as fertilizer in crop fields. Considering that most cattle that were previously kept in Rwanda were indigenous or local breeds, the Girinka program distributed the pure breeds, consisting of mostly Friesian/Holstein and Jersey breeds. Despite the high feed rations demand of these breeds, they were, nevertheless, preferred due to their high milk production and that their progeny from crossbreeding with local cows are compatible with the local environment (Argent *et al.*, 2014; Militery *et al.*, 2013).

The main agencies that have been implementing the program include the MINAGRI and non-government organizations such as Heifer International and Send a Cow. By 2015, around 203,000 households had received cows from the Girinka program, and these beneficiaries constantly receive services such as vaccinations, breeding, and advisory services from public veterinary personnel at subsidised costs (Hahirwa & Karinganire, 2017, IFAD, 2016). Overall, the program has contributed to economic empowerment, poverty reduction, crop production, and improved nutritional status of beneficiary households (Ezeanya, 2014; Nilsson *et al.*, 2017). Furthermore, the total cattle population increased from 645,848 to about 1,350,000 heads between 1997 and 2015, and the crossbreeds increased from 17% to 33%, while the pure breeds increased from 6% to 22% of total cattle between 2008 and 2015 - (IFAD, 2016; MINAGRI, 2009).

3.3.2. Rwanda Dairy Competitiveness Programs I & II

The government's investments and efforts to support the dairy sector aroused different investors and donors' interest in the sector in Rwanda. In 2007, the Rwanda Dairy Competitiveness Program I (RDCP I) was launched and implemented by Land O'Lakes International Development in collaboration with MINAGRI. The four-year project that aimed at improving the competitiveness of the dairy sector in Rwanda, mostly targeting dairy farmers and the MCCs, ended in 2011 and was funded by United States Agency for International Development (USAID) (Land O'Lakes, 2017a). The project's "push" approach targeted the production side and strengthened the capacity of dairy farmers, giving more attention to farmers living with HIV/AIDS. It enhanced the profitability of dairy farms through increased milk production, improved milk quality at the MCCs, and enhanced the nutritional status of children in poor households and orphans by supporting the government's initiative of school milk feeding program known as "One cup of milk per child". Furthermore, the project trained about 3,500 farmers living with HIV/AIDS on cooperative management and animal husbandry and assisted in establishing a private Dairy Quality Assurance Laboratory (DQAL) that tests the quality of dairy products (Land O'Lakes, 2017a).

Despite the increase in milk production, the quality of the milk along the dairy value chain was still a concern. Therefore, to achieve the desired high-quality milk, Land O'Lakes, leveraging the momentum of RDCP I, implemented the Rwanda Dairy Competitiveness Program II (RDCP II). The RDCP II project was also funded by USAID and was implemented between 2012 and 2017 with the aim of improving the dairy competitiveness in the region, increasing milk production and consumption, as well as enhancing milk quality (Land O'Lakes, 2017b). The RDCP II was piloted in four milksheds (Northern, Southern, Eastern and Kigali) covering 17 of the 30 districts of Rwanda. It was expected that quality milk that is produced efficiently and well marketed throughout the entire value chain, would improve the nutritional status of consumers and the income of smallholder producers (Grewer *et al.,* 2016).

In collaboration with MINAGRI, the RDCP II project initiated the dairy "seal of quality" (SOQ) certification scheme, which lays out a set of practices and standards for properly handling raw milk. The SOQ acts as an instrument for achieving the production and supply of quality milk. In this scheme, the dairy players that conform to the standards are given the SOQ certification that lasts for 12 months but is subject to renewal or withdrawal

depending on the current compliance of the actors (Land O'Lakes, 2017b). The certification process is administered by the Rwanda Agriculture and Livestock Inspection Services (RALIS), a department under MINAGRI that issues the certificate to the MCCs and small processors who comply with the given standards. The awarded certificate is an intermediary stage that prepares those small processors to aim for the quality marks from Rwanda Standards Board (RSB). Figure 3.1 presents the elements of the SOQ initiative.

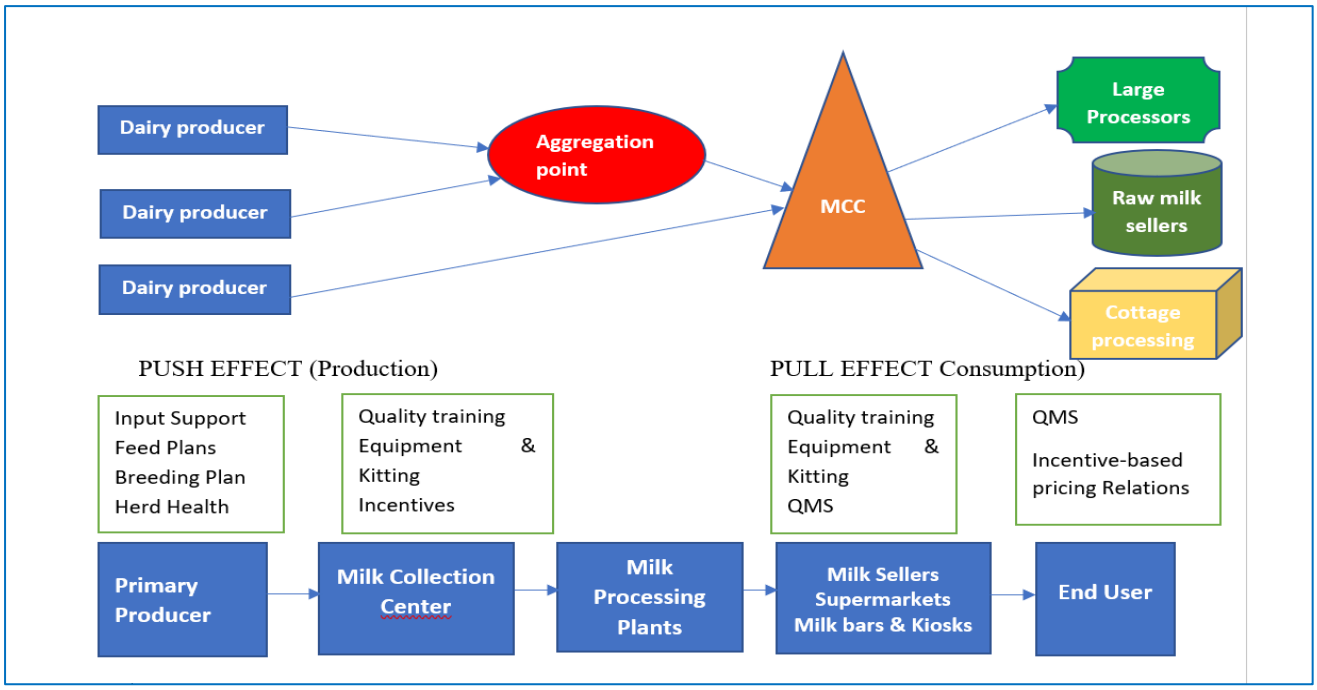

Figure 3.1: Schematic of the SOQ scheme

Source: Adapted from Land O'Lakes (2017b)

The SOQ scheme at the farm level entails many processes that include: hygiene of the milker, cows and milk utensils, animal disease control and veterinary consultations, proper feeding of cows, and milk transport using stainless steel cans. Furthermore, farmers are required to transport milk to an MCC or to an aggregation point where basic quality tests such as alcohol, lactometer, and organoleptic tests are conducted. The MCCs then distribute the milk to large processors, raw milk sellers, cottage cheese makers, and individual consumers. The milk quality inspection is done at the MCC and at the small processor levels, and it consists of an assessment of hygienic practices, mode of transportation, and milk cooling systems. In addition, a sample of milk is sent to a laboratory to test for somatic cell counts and bacterial counts.

The entry point of the RDCP II project was through the infrastructural improvement of dairy cooperatives and the MCCs in which they could reach out to the members. The project reached out to cooperative members through training in quality feed formulation, use of artificial insemination (AI), veterinary services, and milk handling practices (Land O'Lakes, 2017b). It also partnered with Rwanda Council of Veterinary Doctors (RCVD) to train the AI technicians to enhance the accessibility and quality of AI services to farmers. The RDCP II encouraged the decentralization of breeding technology and AI services through private service providers to enhance AI use in rural areas. Furthermore, RDCP II initiated a dialogue with different stakeholders, and in collaboration with RAB and the University of California, Davis, designed a strategic plan for national mastitis control that sought to reduce the occurrence of mastitis in the country (Land O'Lakes, 2017a,b). In addition, MCC workers were trained on milk handling and quality, and the project supplied the MCCs with milk cooling tanks and milk testing kits, and it encouraged incentive-based pricing of milk using a milk grading system (Land O'Lakes, 2017b).

Upon the end of RDCP II, the MINAGRI changed the SOQ name to "Dairy Best Practice (DBP)" scheme to make it a national scheme and to distinguish it from the SOQ project-led scheme. However, the standards of SOQ scheme and DBP scheme remained the same. Besides, in line with the policy pillar of the project, some dairy-related policies were implemented through the partnership of RDCP II, MINAGRI, and other stakeholders in the dairy sector. Some of the activities included the design of national dairy strategy (NDS), the creation of the Rwanda national dairy platform (RNDP), supporting the one cup of milk per child program, and a ministerial order to formalise the dairy sector.

3.3.3. National Dairy Strategy

The National Dairy Strategy (NDS) was a MINAGRI policy document designed and approved in 2013. It identified priorities and approaches to sustainably grow the dairy sector in Rwanda. The NDS was developed in consultation with stakeholders in the public and private sectors; hence, it was considered a roadmap to highlight possible barriers to developing the dairy sector and probable solutions (MINAGRI, 2013). The NDS underlined the needed policies and strategies that would make the dairy sector competitive by providing affordable, accessible, and quality dairy products (MINAGRI, 2013). Furthermore, the NDS emphasized the importance of public and private partnership (PPP) to achieve its objectives of improved production, stable marketing, and required policies that support the dairy sector.

The production objective of NDS was to increase milk productivity at the farm level while maintaining high-quality milk along the value chain. While the pure breeds from Girinka contributed to this, the GoR also invested in accessibility to AI and provision of animal health services and enhanced animal feed production during the dry and rainy seasons (IFAD, 2016). This was done by promoting public-private collaboration that requires private veterinarians and AI technicians to work closely with the MCCs. On the other hand, the marketing objective of NDS was to increase national milk consumption and to formalize the dairy value chain. Therefore, the government and RDCP II project created awareness on nutritional benefits of consuming milk among the population and boosted consumers' willingness to pay for processed milk instead of the unprocessed (Land O'Lakes, 2017b).

Various campaigns, such as *shisha wumva*, which means "feel the goodness" that used different strategies like radio slots, signs and billboards, were launched, to drive behavioural change and create awareness of milk consumption in rural and urban areas (AgriLinks, 2015; Land O'Lakes, 2017b). These campaigns supported the already existing "One cup of milk per child" program that the government launched through RAB in 2010. The RAB program sought to address malnutrition among school children in districts with a high malnutrition rate. Over 83,000 pupils from 112 schools located in 15 districts were enrolled in this program where each child gets a half litre of milk twice a week (RAB, 2017). Furthermore, the government invested in improving rural roads and electrification as well as water supply and encouraged actors in DVC to improve milk value addition that expands milk marketing (IFAD, 2016). Through the partnership of GoR and RDCP II, there was a renovation and establishment of new MCCs and dairy cooperatives to facilitate market access and enhance milk quality.

The policy side of NDS was aimed at attracting new investments in the dairy sector and initiating policies that support business transactions and competitiveness. The NDS proposed restructuring of the Rwanda National Dairy Board into the Rwanda National Dairy Platform (RNDP) as an inclusive organization representing the interests of all dairy stakeholders (MINAGRI, 2013). The RNDP was to ensure the implementation of the NDS and to advocate and promote the interests of all actors in DVC as it was formed based on a strong public and private partnership (PPP) (Land O'Lakes, 2017b; MINAGRI, 2013). Furthermore, the NDS sought to increase the trade of dairy products by proposing a harmonization of tax and trade policies with those of Common Market for Eastern & Southern Africa (COMESA) and regional trade organizations. After meeting the COMESA

standards, Rwanda's dairy trade improved, and the country is no longer a net importer of milk but also an exporter (MINAGRI, 2019). While Rwanda has two main milk marketing channels (formal and informal), the NDS proposed a formalization of the dairy value chain and due support for the SOQ program, which the government later backed through the issuance of a ministerial order (IFAD, 2016; MINAGRI, 2013).

3.3.4. The Ministerial Order

The GoR through MINAGRI issued the Ministerial Order (M.O) N° 001/11.30 of 10/02/2016 that stipulates the guidelines for collection, transportation and selling of milk in Rwanda. The M.O supports the DBP certification by providing a set of procedures to farmers, milk transporters, MCCs, processors, and milk sellers, and whose execution is to ensure that consumed milk is of high quality. The M.O requires that all milk leaving the farm gate should be collected at the MCCs where it is tested for quality prior to being sold. This means that the MCCs must have enough space, cooling tanks, trained technicians, and be equipped with milk quality testing equipment such as alcoholmeter, lacto-densimeter, thermometer, and antibiotic residue and mastitis test kits. Moreover, the M.O requires milk transporters to use well-closed stainless-steel cans or an appropriate vehicle with a cooling tank, while raw milk sellers are required to comply with the cleanliness of related utensils (GoR, 2016).

Despite the M.O's guidelines for formalizing the dairy value chain, over 60% of milk is still sold through informal marketing channels in Rwanda (Shema *et al.,* 2018). Generally, the informal marketing channel is characterized by an unorganized system where milk is not-industrially processed and sold directly to consumers in corner shops, streets, from farmers or vendors, as well as door-to-door, which make the quality of milk questionable as the monitoring process and traceability is difficult (Alonso *et al.,* 2018; Sikawa & Mugisha, 2011). Moreover, the informal milk marketing channel in Rwanda is the channel that does not follow the guidelines stipulated in the M.O, while the marketing channel follows the M.O's guidelines regulating the production, collection, transportation, and selling of milk (GoR, 2016). Conversely, the formal marketing channel is well organized, characterized by legal licensing, and the milk sold in this channel is industrially pasteurized (Alonso *et al.,* 2018; Blackmore *et al.,* 2015).

While Doyle *et al.* (2015) and Reeve (2017) argue that the informal milk sector is associated with poor quality milk potentially causing public health-related risks and diseases, there is a misperception that the milk sold in the informal sector is not automatically unsafe and the milk in the formal sector is not certainly safe (Alonso *et al.,* 2018; Blackmore *et al.,*

2015). This means that eliminating the informal sector based on quality achievement may negatively affect many poor households, mainly on the nutrition of infants and children (Blackmore *et al.,* 2015). Therefore, it is prudent to identify the gaps that are yet to be addressed by the current policies and the barriers to implementing specific regulations.

3.3.5. East African Dairy Development (EADD) project

The East African Dairy Development project (EADD) was a regional dairy sector development program whose phase one was implemented in Kenya, Rwanda, and Uganda from 2008 to 2013 and phase two was executed in Kenya, Tanzania, and Uganda from 2014 to 2018 (Heifer International, 2018). The project's aim was to lift farmers out of poverty through increased milk production and marketing (Heifer International, 2018; IFAD, 2016). The Bill and Melinda Gates Foundation funded the project, led by Heifer International in partnership with ILRI, Techno Serve, the African Breeders Service Total Cattle Management and the World Agroforestry Centre.

The EADD project involved farmers and supported the initiation of milk hubs operated by dairy cooperatives, where farmers supply their milk for quality testing and chilling before it is sold (Heifer International, 2018). The project also linked the milk hubs with larger dairy companies and processors for stable milk markets. The EADD project supported dairy farmers in Rwanda by bringing the regional outlook in the country and providing training, and establishing MCCs as dairy hubs (IFAD, 2016; Land O'Lakes, 2017b). Besides the farmers' training on feed and cows' health improvement, the EADD project also trained local veterinarians on the provision of basic services such as vaccinations so that they are easily accessible at an affordable price (Heifer International, 2018). While the primary role of the MCCs is to provide a market and to ensure that the quality of milk is maintained, they also enhance farmers access and use of inputs and services. For instance, through the inbuilt check-off system, farmers can access veterinary services and purchase feed supplements and milk cans from MCCs' stores at a lower price even when they don't have cash to pay for them as they are checked-off against the milk supplied (Heifer International, 2018).

3.3.6. Rwanda Dairy Development Project

The Rwanda Dairy Development Project (RDDP) is an ongoing project that was launched in 2016 to contribute to pro-poor economic growth and enhance the livelihood of poor rural households through dairy farming (IFAD, 2016). The project seeks to promote climate-smart dairy farming practices and empower women and youth by integrating them

into the dairy value chain (IFAD, 2016). The project is funded by a concessional loan and grant from the International Fund for Agricultural Development (IFAD), private sector/banks, Heifer International and the Rwandan government through tax exemptions. The RAB is the leading implementing agency in partnership with Heifer International, the Rwanda Cooperative Agency, the RNDP, the Business Development Foundation, and the Rwanda Council of Veterinary Doctors.

The RDDP has built on the past achievements in the dairy sector and is now concentrating on increasing cattle productivity, milk quality and processing capacity of the dairy industry and strengthening the policy and institutional framework for the sector (IFAD, 2016). This is done by improving farmer proximity to public and private animal health services reinforcing the capacities of public sector veterinarians and establishing private sector-based networks, comprising animal health workers working under trained veterinary professionals. The RDDP is also focusing on strengthening dairy farmer cooperatives to efficiently provide services to farmers in the form of milk collection and payments and deliver dairy farming inputs to members through bulk purchases. It is also promoting the "hub model" that was successfully tested previously in other countries like Kenya, whereby the dairy cooperatives provide extension, AI, and animal health and financial services either directly or indirectly through linkages with the business development service providers, all geared towards a reduction in dairy market transaction costs (IFAD, 2016).

The RDDP's target is to meet the projected high domestic milk demand and maintain the upward trend in cross-border exports, mostly to the Democratic Republic of Congo and Burundi markets. Though the project is still ongoing, Taiwo *et al.* (2019) found an increase in incomes of RDDP beneficiaries and improved access to extension services and credit facilities. Furthermore, the authors also found that the project has empowered many dairy hubs and dairy farmers' organizations and that, through the Livestock Farmer Field School approach, there has been an increase in the number of farmers able to access inputs and services such as AI, vaccinations, and improved forage seeds.

3.3.7. Rwanda Livestock Master Plan

The Rwanda Livestock Master Plan (LMP) was developed in 2017 by ILRI, with substantial input from MINAGRI, RAB and other research institutes and universities in Rwanda. Funding support was provided by the Food and Agriculture Organisation (FAO). It is assumed that the livestock sector will positively impact food and nutritional security in the country if the proposed investments are successfully implemented. The LMP is a series of 5

years investment plans for key livestock commodity value chains and production systems chosen based on priority development goals of the GoR. This document presents the visions, targets, challenges, and policy required to achieve the expected outcomes in the government's priority value chains, which include cow dairy, red meat, poultry, and pork (FAO, 2017). The Rwanda LMP is considered as a guiding document to policymakers and all agents engaged in livestock development. The priority investment interventions are meant to meet the agreed national goals, including poverty reduction, achieving food security, increasing economic growth and exports, contributing to industrialization and employment, and mitigating Greenhouse Gas (GHG) emissions (FAO, 2017).

To increase milk production to meet the projected increased domestic demand and surplus for export, the LMP presented the dairy value chain development roadmap of 2017/18 to 2021/22. To achieve this, the plan highlighted priority interventions in feeds and feeding, animal health, extension services, genetics, processing and marketing. It also identified livestock feeds, as the main challenge towards improving livestock productivity and particularly cattle farming (FAO, 2017). Therefore, the LMP proposed the promotion of improved grass and leguminous feed productions in all available areas such as backyards, hedges, and fences. It also recommended creating an industry that produces feed additives and allocation of land for production of improved forage and promotion of the use of concentrates or processed feeds (FAO, 2017).

The priority intervention in animal health highlighted in the LMP was to address the insufficiently trained veterinary personnel and the prevalence of mastitis. Over 60% of cattle in the country have mastitis cases (FAO, 2017). Therefore, the plan sought to support veterinary diagnosis laboratories, enhance veterinary coverage through PPP, and reinforce disease surveillance and mass vaccination programs' capacity. It projected that by 2021/22, Rwanda was to be free from Foot and Mouth Disease (FMD) and Contagious Bovine Pleuropneumonia (CBPP) (FAO, 2017). Furthermore, LMP planned to make vaccines accessible and projected that around 60% of farmers would have adopted mastitis control and management technologies and the recommended rate of tick control treatments by the year 2021/22 (FAO, 2017). Furthermore, the LMP recommended building the capacity of extension agents, providing intensive farmers' training on dairy improvement, and increasing extension service delivery through producer organizations.

Cattle genetics was also the priority intervention in Rwanda LMP where the target was to reduce the local breed while increasing the number of cross and pure breeds. While

the number of local breeds decreased annually at a rate of 4% in the past decade, the LMP's goal was to increase crossbreed cattle by a rate of 8% annually by the year 2021/22 (FAO, 2017). Considering that in 2016/17, only 15% of cows were getting AI services, the training of AI technicians and the promotion of private AI practitioners to make AI service more accessible to rural communities were among recommendations of the LMP. On processing and marketing priority interventions, the plan had some ambitious goals of establishing around 150 MCCs, 200 milk collection points (MCP), and 150 dairy cooperatives while strengthening the existing ones to fully comply with milk quality standards found in the M.O (FAO, 2017). Moreover, the LMP aimed to attain a functional linkage between private milk traders, MCCs, cooperatives and processing plants so that milk price is based on quality. In addition, the LMP sought to improve feeder roads to and from the MCCs and enforce the M.O so that around 80% of milk is sold in formal market. These were not only to incentivize the establishment of new processing plants but would also increase the attraction of local and international investors in Rwandan DVC (FAO, 2017).

3.4. Results and Discussion

For the past two decades, several dairy policies, regulations, and programs have been implemented in Rwanda with the aim of improving and promoting the dairy sector, as discussed in the previous sections. Investment in the dairy sector have become financially viable as long as farmers and other DVC actors follow the dairy best practices (Nikolayev *et al.,* 2017). Undoubtedly, these policies and programs have increased farmers' access and use of different inputs and services, leading to the growth of the dairy sector in the country. Some of the subsequent effects include: an increase in cattle population (Figure 3.2), a shift from local breeds to cross and pure breeds of cattle (Figure 3.3), and enhanced dairy cow productivity in the form of milk volume (Figure 3.4). Furthermore, the dairy sector has been well shaped as a result of improving different agents of the value chain (Figure 3.5).

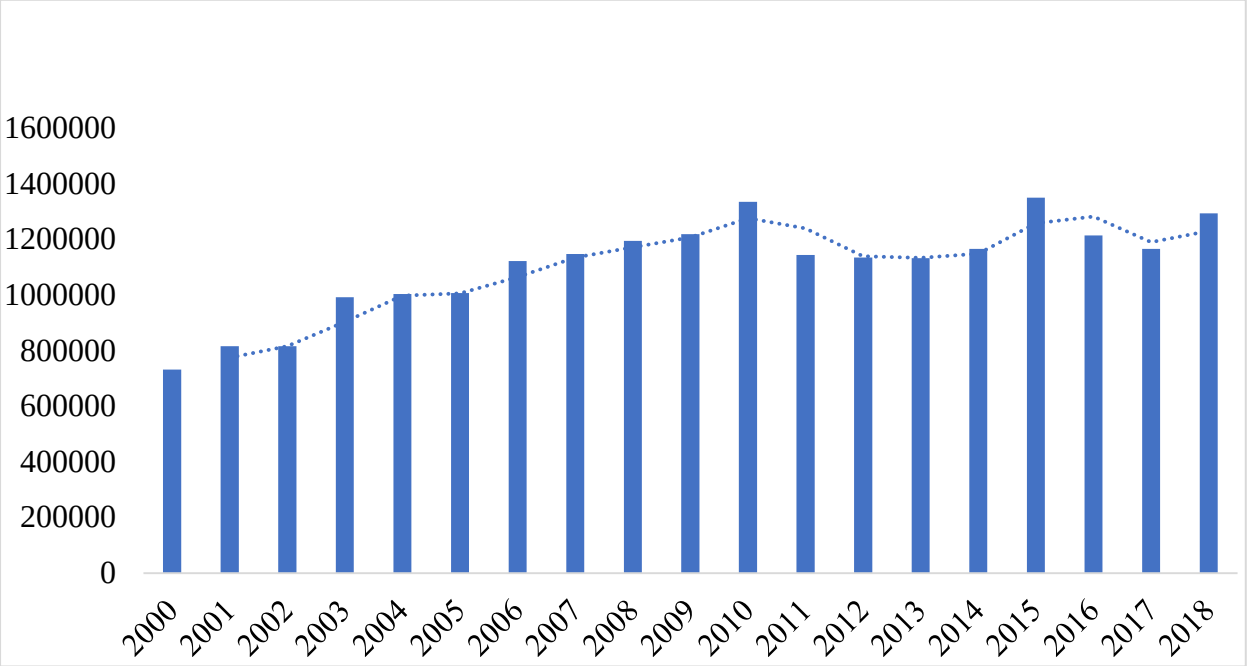

Figure 3.2: Total number of cattle in Rwanda over time

Source: Based on FAO data (FAOSTAT: *http://www.fao.org/faostat/en/#data/QA*)

An analysis of the FAOSTAT data shows that the total cattle population in Rwanda has increased in the past two decades from about 732,000 in 2000 to approximately 1.3 million in 2018 (Figure 3.2). There was a decrease in total cattle population between 2015 and 2017 caused by cattle mortality due to diseases such as tick-borne diseases and Rift Valley Fever (RVF) and a prolonged drought experienced during that period (MINAGRI, 2018). The key informant farmers, who were Girinka program beneficiaries, confirmed that receiving a cow has not only given them access to milk which they were previously unable to purchase, but they also some income from milk sales.

Conversely, Figure 3.3 shows a significant shift from local cattle breeds to crossbreeds and pure breeds because of the Girinka program implementation and investments in AI services. In 2008, the local breeds represented 77% of the total cattle population in Rwanda, but by the year 2015, the crossbreeds and pure breeds were 33% and 22% of total cattle, respectively. The interviews with farmers confirmed that every farmer was striving to get a crossbreed or a pure breed cow. Farmers expressed their preference for improved breeds due to their high productivity, longer lactation length and shorter calving interval. Moreover, those farmers with sufficient finances preferred to buy the cross or pure breeds, while those with inadequate money used AI or pure breed bulls until they get an improved-breed calf.

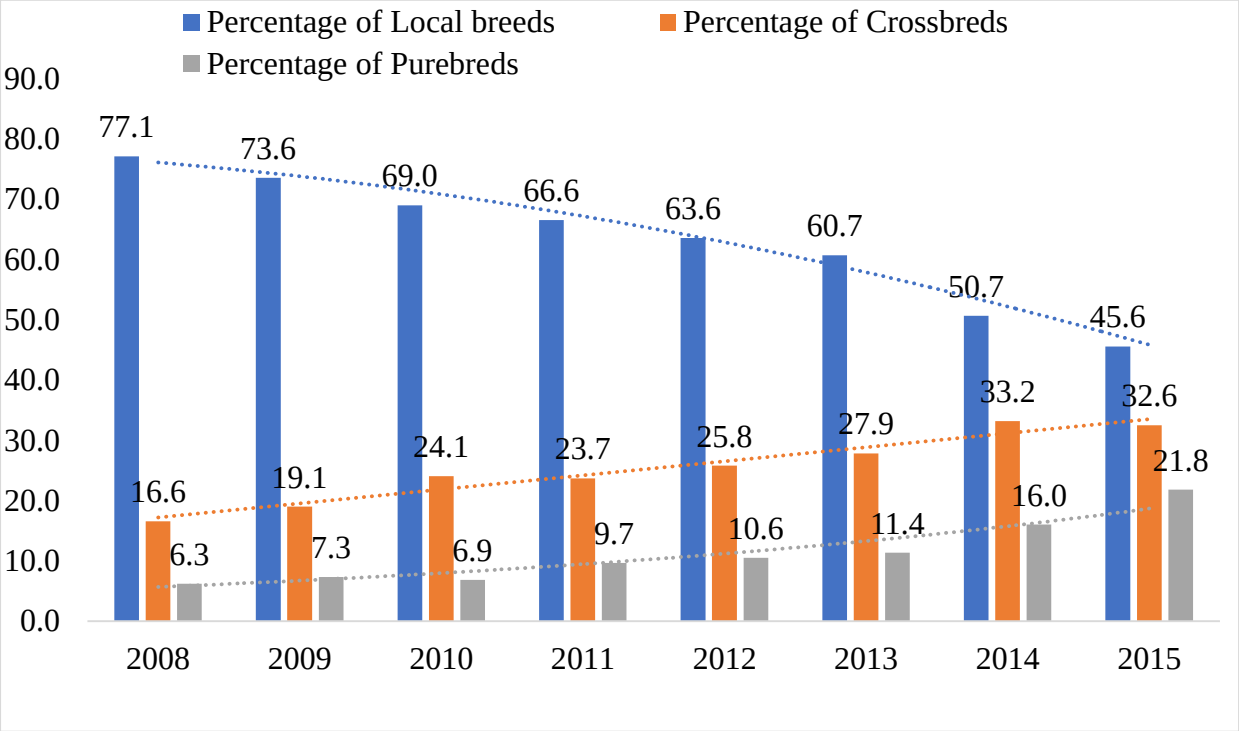

Figure 3.3: Percentage of cattle breeds in Rwanda between 2008 and 2015

Source: Based on data from IFAD (2016)

The interviews with key informants from RAB and MINAGRI attributed the increased milk production to the increase in cattle population and the gradual shift from local breeds to crossbreeds and pure breeds. They argued that crossbreed and pure breed cows have higher productivity compared to local breeds when properly fed and if appropriate animal husbandry practices are followed. The MINAGRI annual report of 2018/19 showed that milk production had more than doubled between 2010 and 2018, and milk consumption had increased from 37.3 litres per capita in 2010 to 69.4 litres per capita in 2018 (MINAGRI, 2019). Though milk consumption per capita is still below the World Health Organization (WHO) recommended 220 litres per capita per year, the LMP aims to achieve this level by the year 2031/32 (FAO, 2017). Figure 3.4 shows a general increase in milk production in Rwanda between 2010 and 2018.

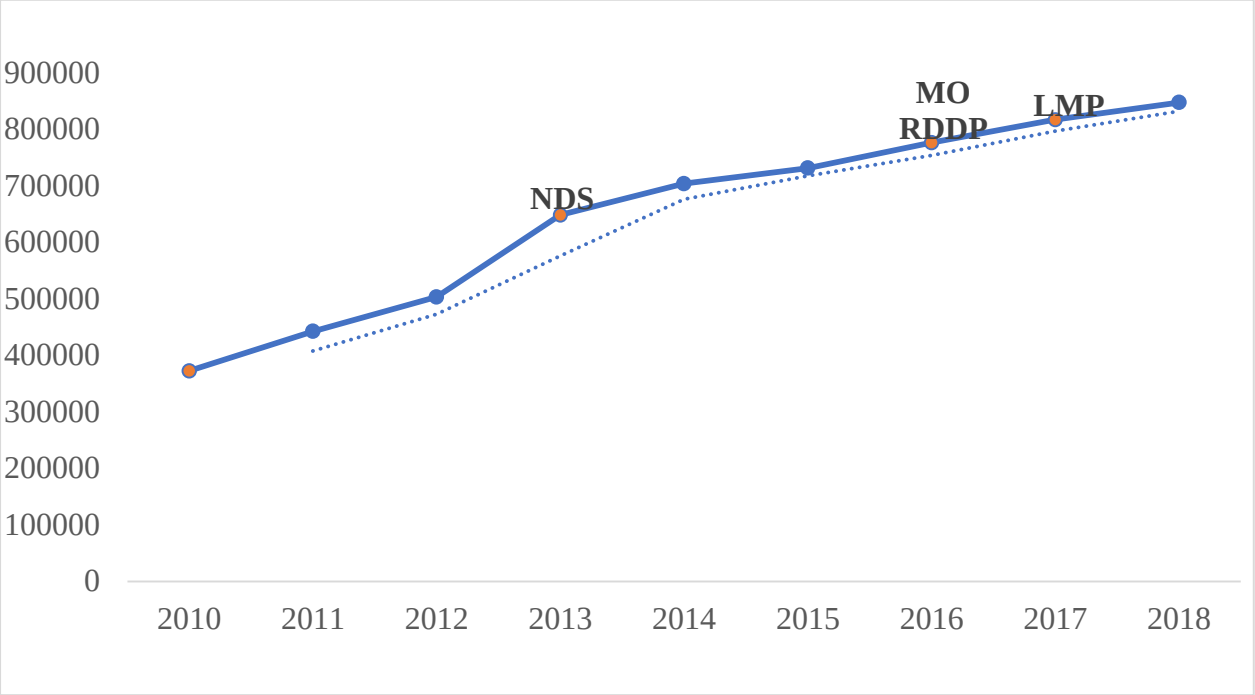

Figure 3.4: Cow milk production trend in Rwanda in metric tons (MT)

Source: Based on data from MINAGRI annual report 2018 – 2019

The productivity gains on milk and manure production as well as on improved animal health were realized. Miklyaev *et al.* (2017) found that daily milk production doubled from 5 to 10 litres per cow which led to an annual increase of milk yield per cow from 608 to 1,949 litres in RDCP II coverage areas. It was also established that there was a decrease in the calving interval from 18 to 15 months, a twofold manure production at farm level, and a drop in calf mortality from 15 to 10% due to increased feed and adoption of animal health services. The interviews with RAB and MINAGRI staff corroborated these findings, although they recognized the gap in milk productivity as improved breeds are producing below their potential. They attributed the low productivity to farmers' lack of proper cow management, such as insufficient and/or imbalanced feeds and inappropriate animal husbandry practices.

Increased milk production was realized together with improved milk quality along the DVC, which enabled the sector to become competitive regionally by meeting the COMESA quality standards (Grewer *et al.*, 2016; Land O'Lakes, 2017b). The interview with RALIS staff and the MCCs key Board Members confirmed that many MCCs were working with farmers to comply with quality requirements, an element that reduced the quantity of milk rejected at the MCCs. Whereas Rwanda has been a net importer of milk, the increased milk production and improved milk quality enabled the country to export surplus milk. In 2018, the country imported 0.118 MT of milk products such as powdered milk and butter, while it

formally exported about 4 million litres of pasteurized milk and 1.5 million litres of UHT milk (MINAGRI, 2019). In addition, informal milk exports to Burundi and the Democratic Republic of Congo (DRC) were estimated to be around 15 million litres annually (IFAD, 2016). Furthermore, the SoQ expanded the business opportunities to milk agents through existing milk products such as cheese, butter, and ghee that are both consumed locally and exported (Land O'Lakes, 2017b). The Rwanda LMP aimed at 46% increase of crossbreed dairy cattle, 65% increase of milk production, and 41% increase of cattle productivity under the recommended level of investment scenario (FAO, 2017). If these targets were achieved, then further policy outcomes would have been realized in 2021/22.

While there has been a progressive shift from local cattle breeds to crossbreeds and pure breeds, the interviewed farmers were concerned about the availability of feeds required to ensure consistency of milk supply, especially during the dry season when feeds are insufficient. This is because improved breeds may not attain their potential productivity if they are not fed on balanced feed rations. The implemented interventions have enhanced training on technologies related to conservation of forages for dry seasons, incorporating crop residues and crop by-products as feeds, establishing feed processing plants, and feeding on complementary feed sources (IFAD, 2016; Land O'Lakes, 2017b). The interview with former RDCP II staff confirmed that the project promoted feed conservation technology such as making silage and cultivation of legumes. However, the MCC board members were worried about the sustainability of these interventions as they require a strong support from the private sector to ensure that these inputs are accessible to farmers.

To facilitate milk marketing and processing, the dairy sector in Rwanda was divided into five milk-sheds, namely: Eastern, Western, Southern, Northern, and Kigali (IFAD, 2016). Each milk-shed has a big processor responsible for collecting and buying milk from MCCs located in that geographical area. Besides, the MCCs have been empowered through leadership, governance and management training, and enhanced storage capacity. Furthermore, the compliance to the M.O has increased the volumes of milk supplied to the MCCs which further improved the formal milk marketing channel (Land O'Lakes, 2017b). Despite the role of the milk-shed system in providing markets by linking MCCs to processors, it is also disadvantageous to farmers as it limits competition among buyers. This is because processors are only allowed to buy milk from their milk-shed. Thus, this system is more beneficial to processors as they buy milk from the MCCs at a low price while the price farmers sell to the MCCs depends on the price the MCCs receive from the processors.

Although farmers are encouraged to adopt better farming practices, farm-gate milk prices were relatively low, where the farmers' share of the final consumer price of milk is 16% compared to international standards of 50% (MINAGRI, 2013). Packaging costs and limited competition among processors were the main contributors to the high price of processed milk (TechnoServe, 2019). Policies geared towards reducing production costs at the upstream channel, including packaging, would reduce the margins between the consumer and producer prices to the advantage of both market participants. At the same time, an expansion of marketing options within milk sheds would improve competition from the demand side. Although "Inyange" processor has invested in milk zones that sell fresh pasteurized but unpackaged milk at an affordable price (Land O'Lakes, 2017b), this system can be upscaled to all districts to easily make this type of milk accessible to the majority of consumers, especially in peri-urban and rural areas. This can be done by introducing milk dispensing machines (or milk ATMs) as it is the case in Kenya, which require less infrastructure and human resource than milk zones. Figure 3.5 below presents the current dairy value chain in Rwanda.

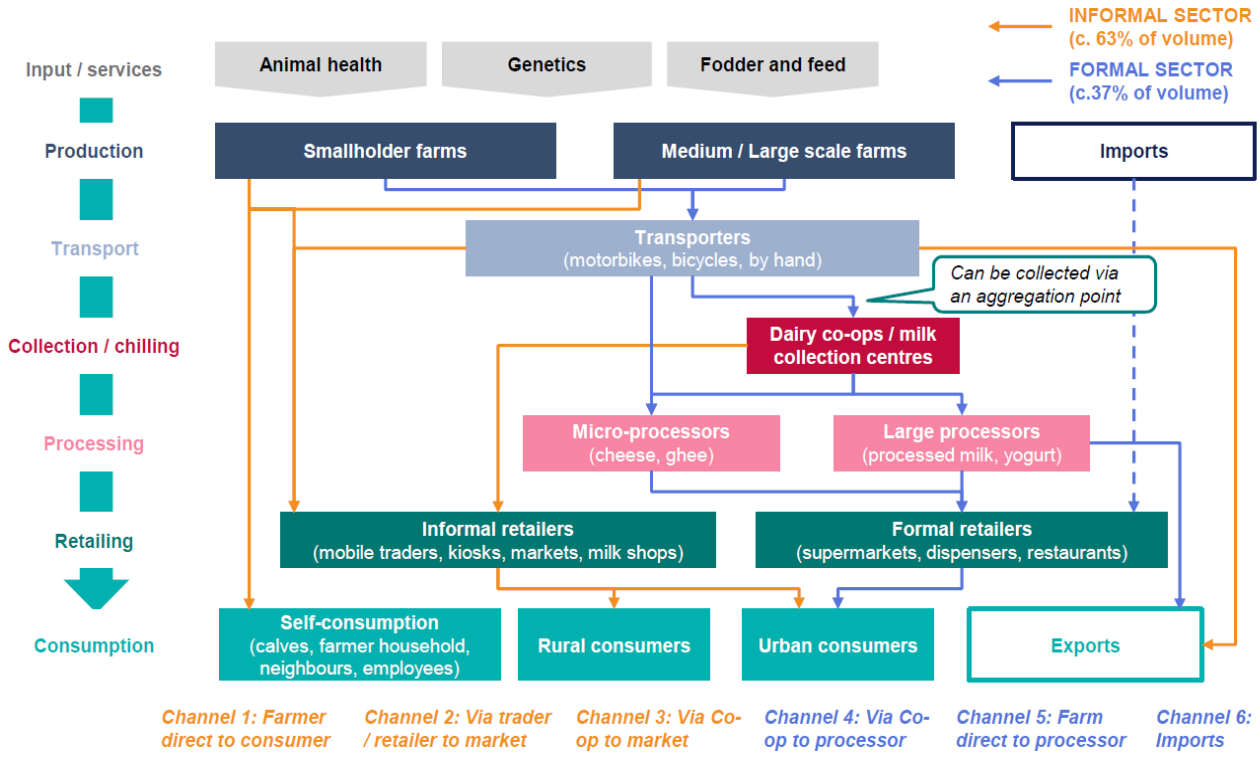

Figure 3.5: Dairy value chain in Rwanda

Source: TechnoServe (2019)

While the dairy sector may be vulnerable to climate change both on the production and marketing sides, it may also contribute to climate change as an increase in dairy production may lead to high GHG emissions if better dairy management practices are not used. Grewer *et al.* (2016) analysed and estimated the effects of RDCP II on GHG emission intensification using the FAO Ex-Ante Carbon Balance Tool (EX-ACT). They found that RDCP II contributed to a reduction of GHG emission intensity (in the project area) by -4.11 tCO2e per 1000 litres of milk (-60%) and -1.7 tCO2e per 1000 litres (-47%) in extensive and intensive production systems, respectively. This was achieved through improved feed quality and quantity, herd weights, herd size management, and breeding services (Grewer *et al.*, 2016). Herrero *et al.* (2016) found that low-quality feeds may lead to reasonably high GHG emissions from enteric fermentation per unit of meat or milk due to its low digestibility.

It thus follows that feeding quality forage – based diets supplemented with concentrates and agro-industrial by-products would lead to higher milk production per cow, and hence lowering GHG emission per unit of milk produced (Gerber *et al.,* 2013). Similarly, improved animal health and breeding services such as the use of AI decrease GHG emission levels through reduced herd overhead (Gerber *et al.,* 2013; Herrero *et al.,* 2016). It is expected that Rwanda dairy policies will further contribute to a reduction of GHG emissions as mitigating the contribution of livestock to GHG emissions is one of the Rwanda LMP objectives (FAO, 2017). Moreover, the ongoing RDDP promotes climate-smart dairy farming (IFAD, 2016).

3.5. Conclusion and Recommendations

The dairy policies, programs and regulations in Rwanda have led to an improved dairy sector in the country and contributed to the provision and use of inputs and services. Some the policies and programs that have been implemented, such as Girinka**,** RDCP I & II, and RDDP, have enhanced dairy productivity, input market, and milk production through enhanced health inputs and other services. Despite the remarkable growth of the Rwandan dairy sector, the sector still lags behind those of other countries in the region, such as Kenya and Uganda, in terms of milk productivity and consumption (TechnoServe, 2019). There are still some challenges in the dairy sector and barriers to implementing specific regulations. These include the quality of veterinary and AI services, insufficient human resource capacity, low productivity of crossbreeds and pure breeds, insufficient and inadequate quality of feeds, limited competition among milk buyers, lower prices for milk compared to the high costs of adhering to DBP standards, informal marketing channels, and insufficient number of MCCs.

This calls for strategic investments and more in-depth research that would lead to the formulation of evidence-based policies.

Whereas accessibility and use of veterinary and AI services have improved, they are still limited by the quality of veterinary products, inadequate human resource capacity, and semen scarcity, while the insufficient and inadequate quality of feeds contributes to low productivity of crossbreeds and pure breeds (Umuzigambeho, 2017). More policy driven responses in terms of access to semen and enhancing the number of bull stations are needed, along with health and animal feed policies that guide and control the quality of veterinary products and feeds sold in the markets. It is recommended that a strong PPP, that provides adequate youth training on veterinary services, as well as AI technicians to improve farmers' access and use of inputs and services, be initiated and promoted. Furthermore, policies that promote legumes and grass conservation would boost the availability of enough feed from the same land allocated to feed cultivation.

While the MCCs make inputs and services accessible to farmers, the primary concern is that they are still insufficient, and not all established MCCs are well functioning (IFAD, 2016). Therefore, there is a need for designing and implementing policies that provide incentives to the private sector to invest in the establishment of the MCCs across the country and improve their capacity so that farmers can easily access and use the inputs and services. Also, there is a challenge in the transitioning of local breeds to pure breeds or crossbreeds as local breeds still represent 43% of the total cattle population while they only contribute 9% of total milk production in the country (FAO, 2017). Interventions geared towards enhancing the gradual reduction of local dairy cows with improved breeds combined with better management and animal husbandry practices would address the negative correlation between milk production and the number of cattle.

Any policy intervention that seeks to eliminate the informal sector completely may not be successful as it happened in Kenya 10 years ago. Given the failure of the policy, Kenya chose to integrate informal market traders through a training and certification scheme, which ended up improving the quality of milk in the informal sector (Blackmore *et al.,* 2015; Omore & Baker, 2011). Incorporating the informal marketing channel in dairy policy formulation rather than its elimination would improve the dairy sector in Rwanda, and other developing countries, where the informal sector is more dorminant. This can be done by training and integrating informal milk traders and middlemen to test the milk before they collect it from the farmers as it is the case in the formal sector.

Credible evidence is relevant in lieu of any policy changes. Leksmono *et al.* (2006) highlight the role of research in developing the dairy policy. They found that policy change can easily be realized when the focus is first made on research and development rather than on policy formulation. Therefore, appropriate marketing research may lead to evidence-based policy that accommodates and improves the informal marketing channel. Conducting research on breeds' productivity under different environments would be a useful input to a national breed policy while farmers' adoption of research-based improved forages will address the low productivity of crossbreeds and pure breeds. This study recommends that further farm-level studies are conducted to assess the profitability of better dairy farming practices given the current policies and more research on dairy projects before dairy policies and programs are initiated.

CHAPTER FOUR
PROFIT EFFICIENCY AND FARM PRODUCTIVITY: IMPLICATIONS FOR ADOPTION OF DAIRY BEST PRACTICES AMONG MILK PRODUCERS IN RWANDA

Abstract

In this paper, a translog production frontier and inefficiency effects models were used to estimate the profit efficiency and determinants of profit inefficiency among milk producers in Rwanda focusing more on the effect of dairy best practice (DBP) standards. The results show that milk production in Rwanda is profitable as farmers get a gross margin of 487,098 Rwf per household and 149,166 Rwf per lactating cow while the revenues almost double the cost incurred. Furthermore, a profit efficiency score of 87% was found implying that farmers were not getting the maximum possible profits. While investing in milk production was beneficial, adhering to DBP yielded more profits (p<0.01) and increased the profit efficiency (p<0.05). Forage and feed supplement expenses as well as parasite control were key inputs that played a significant role in increasing or decreasing the profit efficiency. The results also showed that sex of the household head had a positive effect on profit efficiency while cow parity and the proportion of family labour had a negative effect, confirming the possibility of disguised unemployment problem. The government intervention in the enhancement of access to quality inputs are recommended together with formulation of policies that promote the adoption of DBP standards among smallholder dairy farmers.

4.1. Introduction

The dairy sector is among the fast-growing sectors in developing countries including Rwanda. This is probably due to increased demand for animal-source food (ASF) products as developing countries fight malnutrition. Milk is not only one of the most available and affordable ASF product, but also a source of regular income to many rural poor households as it is produced daily (Bahta *et al.,* 2021). The government of Rwanda (GoR) considers the dairy sector among the key solutions to improve the welfare of smallholder farmers. In partnership with different organizations, the GoR has been implementing different projects that seek to improve milk production, quality as well as consumption that further improve the livelihood of many poor households. Some of the implemented projects include one cow per poor family known as the "Girinka"**,** Rwanda Dairy Competitiveness Programs one and two (RDCP I&II), and Rwanda Dairy Development Project (RDDP).

One of the strategies employed under the RDCP II to increase the production and improve quality of milk was the "seal of quality" (SOQ) certification scheme now referred to as "dairy best practices" (DBP) scheme that provides a set of practices and standards for proper handling of raw milk (Land O'Lakes, 2017b). The DBP scheme has the push effect which requires farmers to use well the inputs of production such as high-quality feeds, better breeding, and animal health services that contribute to increased quality and volumes of milk produced. Once the milk is produced, it is transported to the milk collection centre (MCC) where it is tested for basic quality checks such as organoleptic, alcohol, and lactometer before being sold to different buyers. It is hypothesised that adhering to DBP standards will not only improve the quality of milk but also the quantity of milk produced.

The initiated projects have unquestionably improved the Rwandan dairy sector by increasing population of improved breeds, milk production and consumption. Furthermore, Miklyaev *et al.* (2017) confirm that investing in milk production is economically feasible if farmers and other dairy value chain actors adhere to DBP standards. However, low productivity of cows has been highlighted as the main constraint that hinders farmers from achieving the maximum possible profits. Hence, it is not clear whether the increased volumes of milk produced is linked to DBP adherence or increased population of improved breeds or if those volumes translate into profits received by farmers. This gap was filled in this paper by estimating the profitability of DBP standards through answering the following questions, (1) what are the costs and benefits emanating from adhering to DBP standards? (2) does adhering to DBP standards increase the profit efficiency of farmers? (3) how much more profits could be obtained if farmers were producing efficiently, given the amount of inputs? Answering these questions provides the evidences for requisite policy intervention in the dairy sector.

The dairy sector being ferociously competitive, many food processing firms and different governments in developing countries are responding to quality and productivity concerns (Wang *et al.,* 2008). Different scholars have proposed the adoption of good practices in African dairy value chain to achieve the high-quality milk and increase cow productivity. They reveal that, most of African countries lack the fundamental practices such as proper feeding and cow treatment, appropriate cleanness, and basic infrastructure which may have an end-result of low productivity and/or supplying of low quality milk (Kussaga *et al.,* 2015; Mhone *et al.,* 2011). Although these studies promoted the adoption of good practices in dairy sector, they did not estimate the profitability of the stipulated practices,

which may be a hindrance to its adoption. Evaluating the financial benefits of DBP standards play a vital role in maintaining the growing dairy sector in Rwanda.

Under normal settings, farmers who are producing milk conventionally are incurring normal cost of production while those adhering to DBP standards are incurring extra costs. However, the observed higher production costs are associated with higher quantity of milk produced. Thus, it becomes crucial to estimate if the revenues obtained from increased milk production offset the extra costs incurred by adhering farmers. Furthermore, it is important to establish the effects of adhering to DBP standards on profit efficiency of milk production. This is because the efficiency is a key element in increasing the production and it is achieved through appropriate allocation of resources (Pagés, 2010; Sarker *et al.,* 2019). The scarce resources are key hindrances to farm's objective of profit maximization. Therefore, it is vital to evaluate how any technology or novel production system improves farms' production efficiency and is directly linked to its profits (Adnan *et al.*, 2021).

Most studies on profit efficiency of dairy production were conducted in developed countries where collection of accurate data is a non-issue (Ang & Oude Lansink, 2018; Drews *et al.,* 2018; Ojo *et al.,* 2020; Roibas & Alvarez, 2010). While few studies focus on dairy profit efficiency in Sub-Saharan Africa (SSA) (For example, Bahta *et al.,* 2021; Maina *et al.,* 2018; Nganga *et al.,* 2010), these studies mostly used a basic Cobb–Douglas production function that has many restrictions. In this study, the efficiency and factors influencing the profit inefficiency among milk producers in Rwanda were estimated using a translog production frontier function and inefficiency effects model. To the best of my knowledge, this is the first paper to estimate the profit efficiency of dairy production farms in Rwanda giving more focus on the effect of DBP standards on milk production. The paper contributes to the dearth of literature on profit efficiency of dairy production in SSA and gives a first attempt to estimate the profitability of DBP standards in Rwanda. Furthermore, the profit efficiency findings will help policymakers in formulating efficiency-enhancing policies for the dairy sector in Rwanda.

4.2. Profit Efficiency in Dairy Production

Profit efficiency is defined as "the ability of a farm to achieve highest possible profit given the prices and levels of fixed factors of that farm" (Ali & Flinn, 1989). Based on this definition, the profit inefficiency is the loss of profit from not operating on the frontier. There are several studies that have estimated profit efficiency in dairy production using different efficiency measures. For example, Ma *et al.* (2019) employed a fixed effects stochastic

production frontier model to estimate the effect of feed use intensification on the technical efficiency in New Zealand. They found that the use of supplementary feeds, farm size and milking frequency have a positive and significant influence on technical efficiency. Similarly, Balcombe *et al.* (2006) used three different methods (Bayesian and Classical stochastic frontiers, and Data Envelopment Analysis) to estimate the technical efficiency of Australian dairy farms and they found the presence of a technical inefficiency regardless of the method used.

Improved farm management and better practices have been found to increase the farms' profitability in both developing and developed countries through efficiency gains. For instance, Roibas and Alvarez (2010) estimated the effect of genetic progress on the profits of dairy farmers in Spain using a frontier production function and they found that genetic progress increased farmers profits by 5%. Recently, Pérez-Méndez *et al.* (2020) used a stochastic production frontier to estimate the effect of animal health and reproduction indicators on milk production in Northern Spain. They found that higher somatic cell count, aged cow at first calving, and longer calving intervals have a negative effect on profits as they increase farmers' technical inefficiency. Similar studies in other European countries such as Germany, France, United Kingdom, Belgium, Netherlands, Poland, and Hungary have found that optimal management of inputs and adoption of dairy best farming practices reduce the input use while achieving the farms' profitability (Ang & Oude Lansink, 2018; Drews *et al.*, 2018; Ojo *et al.*, 2020).

Few studies on profit efficiency have been conducted in SSA considering the dairy farming setting in the region. For example, Maina *et al.* (2018) and Nganga *et al.* (2010) conducted the profit efficiency among Kenyan smallholder milk producers and found that farmers are operating at 68% and 60% levels respectively while the cost of the feed is the key determinant of profit efficiency. Despite the use of a more restrictive Cobb–Douglas functional form, their sample sizes (91 and 27 dairy farms respectively) were also little to make an inference on the country. Recently, Bahta *et al.* (2021) employed a stochastic frontier analysis to evaluate the technical efficiency among Tanzanians' milk producers focusing more on commercialization. They found that Tanzanian farmers are producing below the frontier (at 80%) and mobilized commercialization among milk producers. However, this study did not include any new production technology or better farming practice that improves the quantity produced for farmers to have surplus to adopt commercialization. Therefore, this study does not only estimate the profit efficiency under conventional

production system only but also in the presence of a new farming technology such as DBP standards.

4.3. Methodology

4.3.1. Study Area, Data Collection, and Sample Size

In this paper, a household-level, cross-sectional data was used. This data was collected from January to March 2020 in Nyabihu and Ruhango districts, two of major milk producing districts in Rwanda. Nyabihu district located in Western province covers a land area of 512 km^2 while Ruhango district is in Southern province covering a land area of 627 km^2 (NISR, 2014). A structured questionnaire was used to collect information from 384 farmers who are producing milk in both districts and eight focus group discussions (FGDs) were conducted (disaggregated by gender and whether participants adhere to DBP standards or not) with five to nine participants per group. The collected information on farm inputs, costs attached to those inputs, and returns of dairy production enabled the establishment of the profitability and technical efficiency of milk producers in those districts. A two-stage random sampling procedure was used where the first stage involved choosing Nyabihu and Ruhango districts due to the pre-determined sites of the project[1]. The second stage was the random selection of DBP adhering farmers from a sampling frame (a list of farmers supplying milk to MCCs) and a random selection of non-adhering milk producers in consultation with local extension agents.

The sample size was determined following Cochran, (1963) as:

$$n = \frac{z^2 pq}{e^2} \tag{4.1}$$

where n is the sample size, p is the maximum possible variance which was assumed to be 0.5, q equals 1-p, e is the level of precision, and z is the standard value at a given confidence level. In this study, a confidence level of 95% corresponding to a Z-score of 1.96 and a precision level of ±5% were desired; hence, the sample size of 384 milk producers.

[1] This is one of the Feed the Future Livestock Systems Innovations Lab projects on "Enhancing milk quality and consumption for improved income and nutrition in Rwanda"which was led by International Livestock Research Institute (ILRI)

4.3.2. Gross Margin and Benefit to Cost Ratio

To estimate the costs and benefits of DBP standards, a Gross Margin (GM) analysis and benefit to cost ratio were used. The two approaches have been used in previous studies from various disciplines including dairy sector, to determine the profitability of a proposed technology (Cowley *et al.*, 2020; Flower *et al.*, 2017; Valvekar *et al.*, 2011). The GM is represented by the formula:

$$GM = TR - TVC \tag{4.2}$$

where GM is the gross margin; the difference between the total revenue and total variable cost; TR is the total revenue; the product of output price and quantity of output produced; and TVC is the total variable cost; the difference between the total cost and fixed cost.

The investment in DBP standards is considered profitable if the benefit to cost ratio (BCR) of adhering to DBP standards is greater than one and higher than that of non-adhering. The BCR was calculated as:

$$BCR_i = \frac{\sum_{j=1}^{N} B_{ij}}{\sum_{k=1}^{M} C_{ik}} \tag{4.3}$$

where BCR_i is the benefit-cost ratio of household i, B_{ij} represents the jth element of benefit obtained by household i, C_{ik} represents the kth element of cost incurred by household i while N and M represent the number of benefit items and number of costs items respectively. The annual total benefits were obtained by summing up the total revenue from milk sales and the estimated revenue from milk produced but not sold which was calculated using the prevailing market price of milk. On the other hand, the annual total cost is the sum of all TVC incurred in production milk.

While the GM and BCR approaches give an insight on the profitability of DBP standards, the effect of DBP standards on profit efficiency was also estimated in this study. This was done by assessing whether milk producers were getting the maximum possible profits and if not, how much producers were operating below the profit frontier was established.

4.3.3. Profit Frontier Model

There are two main approaches that are used to model the profit inefficiency (Kumbhakar *et al.*, 2015, p. 204). The first approach is the derivation of a profit function under profit maximizing behaviour which is widely used in neoclassical production theory. The second approach which was used in this study assumes that, holding everything else constant, a producer who produces efficiently gets higher profits compared to an inefficient

one (Kumbhakar *et al.*, 2015, p. 205). This is because, assuming the same output price, an efficient producer gets the maximum possible output that yield higher profits. This approach is like a production function model in that, the observed profit is specified as a function of observed exogenous profit drivers and unobserved inefficiency. The profit frontier model was then specified as the stochastic production frontier developed by Aigner *et al.* (1977) as follows:

$$y_i = f(x_i, \beta) + \varepsilon_i \quad (4.4)$$

$$\varepsilon_i = v_i - u_i \quad (4.5)$$

where y_i is the observed output by household *I*, x_i is a vector of input and other explanatory variables, β is a vector of the corresponding coefficients to be estimated and ε_i is an error term composed of two types of errors (v_i and u_i). v_i is a mean zero random error term assumed to follow a normal distribution with a constant variance $[v_i \sim iidN\ (0, \sigma_v^2)]$ while u_i is a non-negative stochastic error which reflects the technical inefficiency of the i^{th} household.

To estimate the inefficiency effects of farmers, there are two approaches that are generally used. The first approach is a two-stage procedure where the first stage involves the estimation of inefficiency measure while the second stage is the prediction of a vector of exogenous variables. This approach has been criticized for producing biased estimates due to either correlation between inputs and exogenous variables or under-dispersion of first-step technical efficiency index caused by ignoring the dependence of the inefficiency on exogenous variables (Battese & Coelli, 1995; Wang & Schmidt, 2002). The second approach is a single-stage procedure which concurrently estimates the parameters of the relationship between inefficiency and exogenous variables. In this study, the single-stage procedure to estimate the technical efficiency as the ratio between the actual output (y_i) and the maximum attainable output (y_i^*) was used as:

$$TE = \frac{y_i}{y_i^*} = \frac{f(x_i,\beta)+v_i-u_i}{f(x_i,\beta)+v_i} = \exp(-u_i) \quad (4.6)$$

Because $u_i \geq 0$, the technical efficiency $\exp(-u_i)$ is bound between 0 and 1 where a value that equals to 1 indicates that the household is fully efficient technically and is getting the maximum possible output.

4.3.4. Model Specification

When estimating the technical efficiency and its determinants, it is necessary to carefully select the appropriate functional form as the accurate production function is

unknown. Cobb-Douglas and translog functional forms are two mostly used functional forms. Cobb-Douglas is regarded as a relatively simple functional form and several studies have used it because of its linearity in logarithms (Moreira & Bravo-Ureta, 2016). However, Cobb-Douglas functional form is more restrictive and has a constant elasticity of substitution (Arrow *et al.*, 1961). Contrary, the translog functional form first introduced by Christensen *et al.* (1973) is more flexible as it imposes few assumptions on the function and its elasticities (Chambers, 1988) and it is a second-order Taylor approximation for random function (Lin & Liu, 2017). Therefore, like many dairy studies (Alvarez & Arias, 2004; Lawson *et al.*, 2004; Pérez-Méndez *et al.*, 2020; Roibas & Alvarez, 2010), the translog production functional form was used in this study and estimated as:

$$ln\, y_i = \beta_0 + \sum_j \beta_j\, ln\, x_{ji} + \frac{1}{2}\sum_j \sum_k \beta_{jk}\, ln\, x_{ji}\, ln\, x_{ki} + v_i - u_i \quad (4.7)$$

where $ln\, y_i$ is household i^{th} milk production in litres transformed in log-form, $ln\, x_{ji}$ is the logarithm of a vector of input variables, and β_j is a vector of parameters to be estimated. Subscripts *j* and *k* represent the four different inputs of production and when *j* is one input, *k* represents the other input.

Milk production inputs and exogenous variables used in this study were selected based on past dairy production studies conducted in both developed and developing countries (Alvarez & Arias, 2004; Bahta *et al.*, 2021; Lawson *et al.*, 2004; Moreira & Bravo-Ureta, 2016; Orea *et al.*, 2015; Pérez-Méndez *et al.*, 2019, 2020; Roibas & Alvarez, 2010). The four inputs included labour (L) which was measured in man-days and was composed of hired and family labour. The second input was parasite control (PC) which was the household's expenditure in Rwandan franks (Rwf[2]) on parasite control such as deworming and tick control. The third input was forage expenses (FE) in Rwf which included the expenditure on purchased fodder and the opportunity cost of grown fodder. The fourth input was feed supplements (FS) in Rwf, composed of costs incurred on industrial concentrates fed to milking cows. The monetary expenses on PC, FE, and FS inputs were used as proxies for their quantities following Moreira and Bravo-Ureta (2016) and Pérez-Méndez *et al.* (2020) while assuming that their input prices were constant as farmers were close to each other.

The inefficiency effects (u_i) in equation (4.7) can be expressed as:

$$u_i = \sum_i \delta_i\, z_i + w_i \quad (4.8)$$

[2] 1 USD = 920 Rwf when the data was collected in February 2020.

where δ_i is a vector of parameters to be estimated while w_i is a mean zero random variable defined by the truncation of the normal distribution with variance σ_u^2, and z_i is a vector of variables that may influence the farmers' efficiency. The exogenous variables from the above cited studies on efficiency in dairy production were selected and they included sex, education level, and dairy farming experience of the household head, dairy cooperative membership, proportion of family labour, and cow parity. The adherence to DBP standards variable was also included in the model as the variable of interest.

It is postulated that female headed households are less likely to be technically efficient than male headed households probably because males tend to have more networks in society that may enhance their access to new farming technologies while females have less access to production resources (Asante *et al.,* 2014, Habiyaremye *et al.,* 2019). A positive influence of education level of the household head on efficiency was expected as more educated farmers are more knowledgeable and likely to adopt novel farming techniques that may eventually increase their production (Asadullah & Rahman, 2009). The proportion of family labour defined as the percentage of family labour to total labour has an ambiguous effect on technical efficiency. This is because family-supplied labour maybe more motivated and work harder than hired labour as they work in their own farm. However, hired external labour may be more efficient as they may have the required knowledge and probably more active due to payment they receive for the work done (Pérez-Méndez *et al.,* 2020).

In general, farming experience is positively related to efficiency levels (Adnan *et al.,* 2021; Masunda & Chiweshe, 2015). Therefore, more experienced farmers were expected to have higher efficiency levels than non-experienced farmers because they have been facing many different challenges in dairy farming for a long time and they have been looking for solutions to those challenges. Moreover, experienced farmers have built some connections in society and they are more knowledgeable and skilled in milk production which work to their benefit in increasing cow productivity (Masunda & Chiweshe, 2015). Similarly, being a member of a dairy cooperative or a MCC was expected to reduce inefficiency levels. This is because, members of cooperatives have higher bargaining power and lower transaction costs as they act collectively (Bahta *et al.,* 2021). Furthermore, they get more opportunities in form of trainings and extension services that improve their farming skills (Gyau *et al.,* 2014). Mid-parity cows were expected to be more efficient as milk yield increases from the second to fourth parity (at peak) while it decreases at the fifth parity (Manzi *et al.,* 2020).

4.4. Results and Discussion

4.4.1. Descriptive Statistics

Table 4.1 presents the summary statistics of key variables by adherence to DBP standards. On average, farmers have two lactating cows where adhering farmers have three while non-adhering farmers have one lactating cow. Around 51 % of farmers were adhering to DBP standards as their milk passes the basic quality checks conducted by the MCC or by the milk trader. The output is milk production measured in litres and adhering farmers were producing 8,040 litres of milk per year which was significantly higher ($p<0.01$) than 3,440 litres produced by non-adhering farmers. Comparing the two groups of farmers in terms of inputs used in milk production, adhering farmers significantly used more inputs than non-adhering farmers. For instance, adhering farmers used more labour ($p<0.05$) per household than non-adhering probably because they have more lactating cows. In addition, adhering farmers dewormed and controlled ticks more than non-adhering farmers ($p<0.01$) while they also spent more on forages and feed supplements ($p<0.01$). One could argue that the higher usage of inputs explains the larger difference observed in milk production as the cow that is in good health and well-fed will produce larger volumes of milk. However, it was important to substantiate this claim through further analysis such as efficiency analysis.

Looking at the farmer's characteristics, there was no difference between the two groups of farmers in terms of sex, education level and dairy experience. Generally, around 86% of the households were headed by males with an experience of 11.5 years in dairy farming and 4.9 years of formal education. In overall, few farmers were members of the MCC or dairy cooperatives (25%), however, the adhering group had more dairy cooperative's members (42%) than non-adhering (7%). Non-adhering farmers used more of family-supplied labour (66% of total used labour) unlike adhering farmers who used more of paid labourers in their farms. Both adhering and non-adhering farmers' cows' parities (3.2 and 2.8 times respectively) fall into mid-parity category of cows that are believed to be more efficient. However, it was important to establish if that claim holds in this study.

Table 4.1: Summary statistics of key variables by adherence to DBP standards (N=384)

Variables measured per household/farm	Overall (N=384) Mean	Non-adhering (1) (N=188) Mean	Adhering (2) (N=196) Mean	t-test (1-2)
Number of lactating cows	2.05	1.27	2.81	-8.01***
	(1.85)	(0.61)	(2.56)	
Milk produced per household in litres	5,788.38	3,440.08	8,040.83	-6.99***
	(6,835.54)	(2,954.75)	(8,543.03)	
Labour per household in man days	635.34	588.85	679.93	-2.46**
	(365.10)	(316.38)	(402.17)	
Parasite control cost in Rwf	10,043.67	6,989.39	12,973.28	-4.44***
	(13,530.58)	(10,656.79)	(15,266.07)	
Forage expenses in Rwf	137,252.0	62,223.48	209,218.10	-8.17***
	(190,749.3)	(79,990.80)	(233,870.90)	
Feed supplement expenses in Rwf	38,459.3	20,714.04	55,480.26	-5.73***
	(61,818.79)	(34,285.11)	(76,052.01)	
Sex of the household head (= 1 if male)	0.86	0.86	0.85	0.42
	(0.35)	(0.34)	(0.35)	
Education level of the household head in years	4.93	5.13	4.75	1.01
	(3.66)	(3.82)	(3.50)	
Dairy farming experience in years	11.55	10.98	12.09	-1.0
	(10.82)	(11.19)	(10.46)	
MCC or dairy coop membership (=1 if a member)	0.25	0.07	0.42	-0.76***
	(0.43)	(0.25)	(0.49)	
Proportion of family labour (% of family labour)	0.56	0.66	0.47	4.10***
	(0.46)	(0.44)	(0.46)	
Cow parity (number)	2.98	2.76	3.19	-3.06***
	(1.39)	(1.33)	(1.41)	

Note: *****, **, *** denote the level of significance of difference in means at 1%, 5%, and 10% respectively while the figures in parentheses are standard deviations.

4.4.2. Cost of Milk Production

From Table 4.2, the total variable cost (TVC) was calculated per year and was composed of six different elements such as forage expenses, feed supplements expenses, animal health, labour, hygiene-related, and transport cost. These cost components were all

estimated per household and per lactating cow. The forage expenses included the cost of purchased fodder and the opportunity cost of grown fodder. Adhering farmers incurred more forage expenses ($p<0.01$) both per household (Table 4.1) and per lactating cow (Table 4.2). This was expected as DBP scheme promotes cow feeding program in terms quantity and quality forage which is otherwise expensive than the conventional feeding. Similarly, the DBP requires farmers to supplement the forage with concentrates that increase the quality and quantity of milk produced. The results showed that, the adhering farmers incurred more costs on feed supplements than non-adhering farmers both per household ($p<0.01$) and per lactating cow ($p<0.05$).

The labour cost was calculated by summing up the cost of paid labour and the opportunity cost of family-supplied labour. This is because the family-supplied labour would have been employed somewhere else and earn some income if its labour was not used in its own farm. While there was no difference in labour cost per household between adhering and non-adhering farmers, non-adhering farmers were not utilising labour efficiently as they incurred significantly higher labour cost per lactating cow ($p<0.01$). The other component was the animal health which included all expenses on veterinary drugs and services such as parasite control, vaccinations, and the breeding cost of bulls and artificial insemination (AI). The adhering farmers incurred significantly more expenses on animal health per household ($p<0.01$), however, both adhering and non-adhering farmers incurred more of the same costs on animal health per lactating cow.

The hygiene-related cost which included the cost of cowshed repairment and soaps used to clean milking utensils was significantly higher for adhering households ($p<0.01$), but this cost per lactating cow was not significant between both groups of farmers. Lastly, the cost incurred by farmers when transporting their milk from farms to salespoint was calculated. Expectedly, the adhering farmers were found to incur more milk transport cost per household ($p<0.01$) and per lactation cow ($p<0.05$) probably because they sold more milk than non-adhering farmers and mostly sold to MCCs which are far from their farms. These findings were confirmed in FGDs[3] with adhering farmers who normally got more of those inputs and services on credit. For instance, adhering farmers could access veterinary services and purchase feed from MCCs' stores when they didn't have cash as they were checked-off against the milk supplied. This check-off system gives adhering farmers an advantage to

[3] The data was analysed using Dedoose: 8.3.17 software

invest more into inputs which increases their production costs compared to non-adhering farmers.

Table 4.2: Average costs of milk production by adherence to DBP standards

Cost items	Overall (N=384) Mean	Non-adhering (1) (N=188) Mean	Adhering (2) (N=196) Mean	t-test (1-2)
Forage expenses per lactating cow in Rwf	58,088.06	48,274.93	67,500.64	-3.08
	(50,363.99)	(45,635.07)	(52,943.32)	***
Feed supplements expenses per lactating cow	20,202.04	16,243.62	253,998.9	-2.37
in Rwf	(32,175.41)	(28305.65)	(35,148.46)	**
Labour cost per household in Rwf	273,559.3	269,837.6	277,129.2	-0.38
	(188,939.7)	(167,729.9)	(207,635.6)	
Labour cost per lactating cow in Rwf	197,413.2	236,297.7	160,115.7	4.99
	(154,133.1)	(157,398.5)	(141,588.6)	***
Animal health expenses per household in Rwf	20,217.32	15,969.95	24,291.33	-4.29
	(19,404.87)	(16,555.52)	(21,039.6)	***
Animal health expenses per lactating cow in	13,493.49	13,045.04	13,923.65	-0.63
Rwf	(13,586.47)	(13,264.46)	(13,908.65)	
Hygiene related cost per household in Rwf	10,370.31	8,422.87	12,238.27	-3.95
	(9,647.56)	(8,693.65)	(10,157.14)	***
Hygiene related cost per lactating cow in Rwf	7,081.18	6,967.96	7,189.77	-0.31
	(7,029.42)	(6,818.14)	(7,242.09)	
Transport cost per household in Rwf	8,469.29	650.60	15,720.13	-2.98
	(47,408.51)	(8,382.43)	(64,564.68)	***
Transport cost per lactating cow in Rwf	2,937.99	325.30	5,360.93	-2.29
	(20,561.24)	(4,191.21)	(28,079.81)	**

Note: *****, **, *** denote the level of significance of difference in means at 1%, 5%, and 10% respectively while the figures in parentheses are standard deviations.

4.4.3. Profits From Milk Production

To assess the profitability of DBP standards, the GM analysis was carried out. Table 4.3 presents the TVC, TR, GM, and BCR per household and per lactating cow. In overall, the TVC of milk production per household was 487,467 Rwf and adhering farmers incurred significantly higher TVC (592,714 Rwf) than non-adhering farmers (377,742Rwf) (p<0.01). While this was expected as adhering farmers keep more lactating cows than non-adhering and

DBP standards is associated with additional costs on some inputs, it is important to note that, non-adhering farmers incurred significantly more TVC per lactating cow (p<0.01). On the other hand, the total revenue (TR) was the product of milk price per litre and the quantity of milk produced. The adhering farmers were getting significantly higher revenues per household (p<0.01) and per lactating cow (p<0.05) than non-adhering farmers.

Table 4.3: Revenues, and GM from milk production by adherence to DBP standards

Variables	**Overall (N=384) Mean**	**Non-adhering (1) (N=188) Mean**	**Adhering (2) (N=196) Mean**	**t-test (1-2)**
Total variable cost per household in Rwf	487,467.4	377,742.4	592,713.8	-6.01***
	(326,765.6)	(189,570.1)	(390,531.7)	
Total variable cost per lactating cow in Rwf	298,917.5	321,116.5	277,624.6	2.70***
	(159,212)	(160,399.5)	(155,511)	
Total revenues per household in Rwf	974,465.2	534,667.1	1,396,508	-6.98***
	(1,282,013)	(542,933.9)	(1,606,212)	
Total revenues per lactating cow in Rwf	448,084	410,076.8	484,084	-2.36**
	(310,285.8)	(317,812.3)	(299,180.5)	
Gross margin per household in Rwf	487,097.8	156,924.7	803,794.5	-6.04***
	(1,096,857)	(510,237)	(1,381,098)	
Gross margin per lactating cow in Rwf	149,166.5	88,960.23	206,915.3	-3.50***
	(335,283.1)	(340,307.7)	(320,763.4)	
Benefit to cost ratio per household	1.92	1.54	2.27	-4.07***
	(1.76)	(1.45)	(1.96)	

Note: *****, **, *** denote the level of significance of difference in means at 1%, 5%, and 10% respectively while the figures in parentheses are standard deviations.

On profitability of milk production, milk production was found to be profitable as farmers could get a GM of 487,098 Rwf per household and 149,166 Rwf per lactating cow (Table 4.3). However, the GM varied significantly depending on whether farmers were adhering to DBP standards or not. The adhering farmers got a GM of 803,795 Rwf per household which was significantly higher (p<0.01) than 156,925 Rwf obtained by non-adhering farmers. Similarly, cows kept by adhering farmers were more productive and generated a GM of 206,915 Rwf per lactating cow which was as well higher (p<0.01) than 88,960 Rwf generated by a cow kept by a non-adhering farmer. The BCR was also calculated and it was 1.9 in overall, confirming that milk production was profitable as the returns nearly

doubled the cost of production. Nevertheless, adhering farmers had a BCR of 2.3 which was significantly higher than that of non-adhering (1.5), implying that adhering to DBP standards was more profitable.

4.4.4. Profit Efficiency and Determinants of Profit Inefficiency

Before estimating the translog production frontier, the validity test of the stochastic frontier specification as advised by Kumbhakar *et al.* (2015, p. 92) was conducted first. The ordinary least squares (OLS) residual test was used to test the validity of the model as proposed by Schmidt and Lin (1984). The findings showed that the distribution of OLS residuals skewed to the left which is consistent with a production frontier specification. The estimates of translog production frontier are presented in Table 4.4. Following Coelli *et al.* (2003), the inputs are first normalised and the exogenous variables are transformed by subtracting their geometric mean. This process allows one to interpret the input coefficients as partial elasticities of production for a representative farm characterized by an input endowment equal to the sample geometric mean (Orea *et al.*, 2015).

The results show that the estimated parameters of three of four inputs, two squares, and two interaction terms were significant. The non-significance of labour input seems to be a usual finding in many dairy studies when a higher proportion of labour is family-supplied labour (Cuesta, 2000; Pérez-Méndez *et al.* 2020; Roibas & Alvarez, 2012). The output elasticities of expenses on parasite control and forages were significantly negative. Although this was unexpected, it inferred the possibility of poor quality of forages and veterinary services. The FGDs with both adhering and non-adhering farmers highlighted their worries of spending a lot of money on veterinary services and fodder purchase which did not translate into the expected quantity of milk produced. Expectedly, the output elasticity of feed supplements was positive and significant, implying that 1% increase in feed supplements contributed to 0.26% increase in milk production ($p<0.05$). This finding is consistent with previous studies on dairy which found that feed supplement such as concentrates is an important input that increases milk production (Moreira & Bravo-Ureta, 2016; Roibas & Alvarez, 2010).

Table 4.4: Parameter estimates for the translog production frontier model

Variables	Coefficients	Std. Err.
Frontier model		
Constant	22.82 ***	4.89
ln L	-0.95	1.00
ln PC	-0.40 *	0.214
ln FE	-2.54 ***	0.494
ln FS	0.26 **	0.13
½ $(\ln L)^2$	0.16	0.14
½ $(\ln PC)^2$	0.01	0.01
½ $(\ln FE)^2$	0.26 ***	0.04
½ $(\ln FS)^2$	0.02 **	0.01
ln L x ln PC	0.06 *	0.03
ln L x ln FE	-0.002	0.06
ln L x ln FS	-0.03	0.02
ln PC x ln FE	-0.0002	0.01
ln PC x ln FS	-0.0007	0.004
ln FE x ln FS	-0.01 *	0.01
sigma u	0.035	0.05
sigma v	0.70 ***	0.02
Lambda	0.05	0.06
Log likelihood	-408.2377	

Note: *****, **, *** denote the level of significance of difference in means at 1%, 5%, and 10% respectively. L=labour, PC= parasite control cost, FE= forage expenses, and FS= feed supplements.

Table 4.5: Parameter estimation from production inefficiency equation

Variables	Coefficients	Std. Err.
Constant	-0.13	0.16
Sex of the household head (= 1 if male)	-0.40 ***	0.15
Education level of the household head in years	-0.003	0.01
Dairy farming experience in years	-0.001	0.004
MCC or dairy coop membership (=1 if a member)	-0.62	0.58
DBP Adhering (=1 if adhering to DBP standards)	-0.32 **	0.17
Proportion of family labour (% of family labour)	0.43 ***	0.15
Cow parity (number)	0.16 ***	0.04

Note: ***,** denote the level of significance of difference in means at 1% and 5% respectively.

The determinants of the production inefficiency are presented in Table 4.5. The sign of coefficients plays a role in interpretation as the negative sign implies that the variable has a positive effect on the efficiency (i.e. it decreases the inefficiency) while a positive sign indicates that the variable has a negative effect on the efficiency (Coelli *et al.,* 2005). The variable of interest (DBP adherence) is positive and significant (p<0.05) implying that adhering to DBP standards increases the technical efficiency of milk production. The adhering farmers have an average efficiency score of 94% compared to 80% of non-adhering farmers (Table 4.5). While there are no previous empirical studies that estimated the effect of DBP standards on milk production efficiency, the FGDs results show that adhering to DBP standards is usually followed by higher quality and volumes of milk. "When your cow is vaccinated, treated well and well-fed, you rest assured of an increase in milk production." *(FGD participant in Nyabihu district*). However, the FGDs with non-adhering farmers highlight lack of information and financial incapacity to meet the DBP costs as the main constraints to adoption of DBP standards.

The sex of the head of the household had a significant positive effect (p<0.05) on technical efficiency implying that male-headed households were more technically efficient than female-headed households. This is probably due to energy required in milk production or the fact that males have more connections in community which may facilitate their access to advanced farming technologies. Furthermore, men are more involved in dairy production activities and some those activities are culturally done by men only. For instance, the FGDs

highlighted that milking cows is culturally done by men only. “Our cultural beliefs don’t allow married women to milk cows.” (*FGD participant in Ruhango district*).

The proportion of family labour had a negative and significant effect (p<0.01) on technical efficiency indicating that the higher the proportion of family labour working in its own farm, the less efficient that farm is. The negative effect of higher proportion of family labour may be due to disguised unemployment of family members. This finding is in line with previous studies of Aurea *et al.* (2015) and Pérez-Méndez *et al.* (2020) who found a negative effect of family labour on dairy farm productivity except that their effect was not significant. Similarly, cow parity had a significant negative effect (p<0.01) on technical efficiency implying that an increase in number of times the cow gives offspring leads to a decrease in technical efficiency. This result is consistent with the previous findings of Goni *et al.* (2015) in Ghana and Nyamushamba *et al.* (2014) in Zimbabwe who found that milk yield is at peak on 3rd and 4th parities respectively but start declining at the 5th parity. Furthermore, Manzi *et al.* (2020) found a similar decrease in milk production with an increasing parity probably due to slow deterioration of udder tissue.

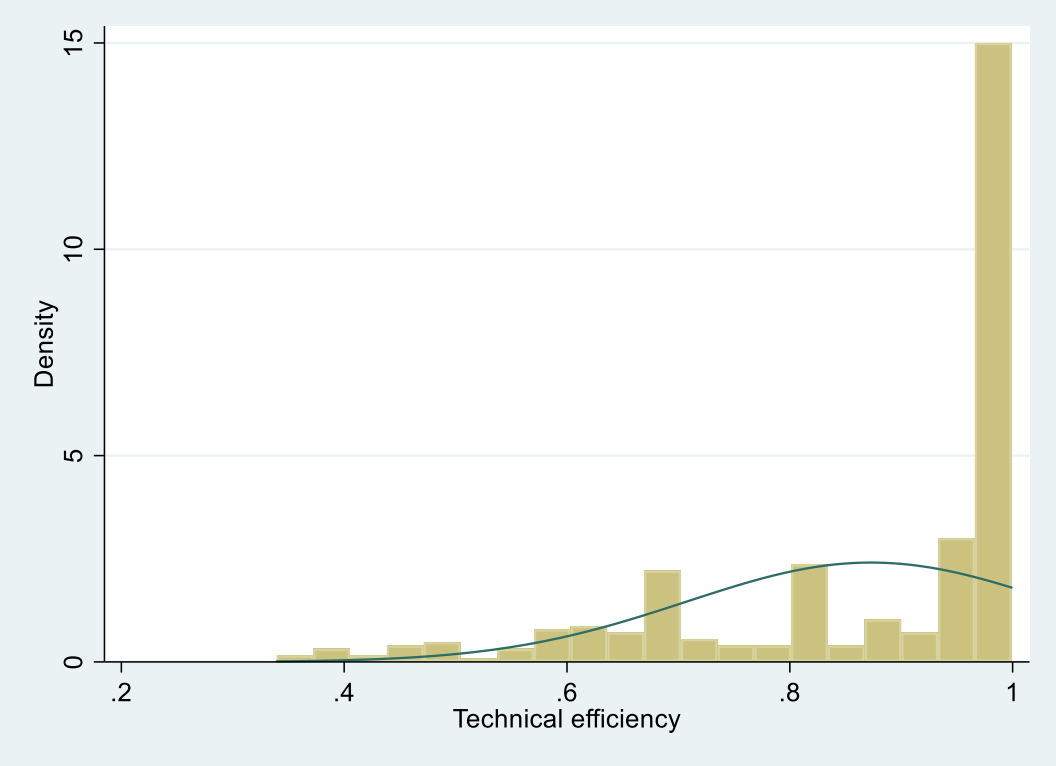

Figure 4.1 : Overall distribution of Technical Efficiency, average TE = 87%

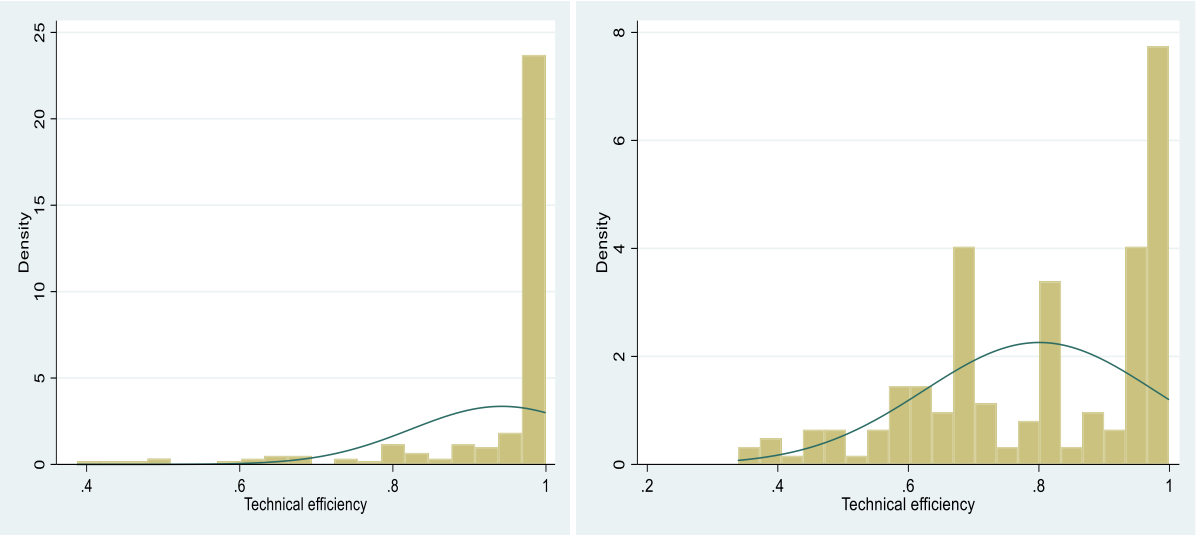

Figure 4.2: Adhering Technical Efficiency Non-adhering Technical Efficiency

Table 4.6: Technical efficiency scores by adherence to DBP standards

	Mean	Std. Dev.	Min	Max
Overall (N=384)	0.87	0.17	0.34	0.99
Non-adhering (N=188)	0.80	0.18	0.34	0.99
Adhering (N=196)	0.94	0.12	0.39	0.99

Looking at the overall distribution of technical efficiency (Table 4.6), the scores range from 34% to 99% with an overall mean of technical efficiency of 87%, implying that dairy farmers in Rwanda are operating below the production frontier. With the current production technology in place, farmers have an opportunity to increase milk production by 13% to achieve the maximum possible output. Moreira and Bravo-Ureta (2009) conducted a systematic review of 32 dairy farm studies from 17 different countries and found an average efficiency score of 83% which is slightly lower than our finding. It is worth noting that a higher proportion of adhering farmers have an efficiency score of around 90% (Figure 4.2) while majority of non-adhering farmers are operating at around 80% (Figure 4.3), an indication that indeed the adherence to DBP standards affects production efficiency. Bahta *et al.* (2021) found similar technical efficiency score of 80% among milk producers in Tanzania.

4.5. Conclusion and Recommendations

This paper attempted to assess the profit efficiency and determinants of profit inefficiency among milk producers in Rwanda while focusing on the effect of DBP standards on milk production. A translog production frontier function and inefficiency effects model

were used, which are rarely used in dairy studies in SSA. While several production efficiency studies have been conducted for various crops such as groundnut, rice, maize, coffee, etc (Asekenye *et al.*, 2016; Hyuha *et al.*, 2007; Mwalupaso *et al.*, 2019; Ngango & Kim, 2019), few studies have been conducted on dairy farm efficiency especially in SSA. Therefore, this study added a significant contribution to the scarce literature on profit efficiency of dairy production in SSA and gave a first attempt to estimate the profitability of DBP standards in Rwanda.

The findings showed that milk production in Rwanda is profitable as farmers produce 5,788 litres of milk per household yearly and get a GM of 487,098 Rwf per household while the revenues from milk production almost double the cost incurred (BCR of 1.92). Furthermore, the estimated profit efficiency was 0.87 indicating that there is a room for farmers to improve their technical efficiency by 13% to achieve the maximum possible output. Production inputs play a significant role in increasing the productivity and profitability of milk production. The results also show that adhering to DBP standards yields more profits and increases the profit efficiency. Sex of the household head has a positive effect on profit efficiency while cow parity has a negative effect. The results also show that the proportion of family labour is negatively related to profit efficiency confirming the possibility of disguised unemployment problem.

The recommendations emanate from the above results. Since farm inputs are key to improving the production of milk, the government intervention in the enhancement of access to milk production inputs such as quality forages, feeds supplement as well as quality veterinary services are highly recommended. Furthermore, there were unnecessary cost caused by much labour working in dairy farming while contributing little or nothing to the output. Therefore, the government can reduce this hidden employment by creating other jobs outside dairy farming so that the sector remains with active and necessary labour. While adhering to DBP standards prove to be more beneficial, there are many farmers who have not yet adopted this noble scheme due to financial incapacity or lack of information on DBP or its profitability. Therefore, policies that promote the adoption of DBP standards together with knowledge and information sharing among smallholder dairy farmers are recommended. This can be done through increased extension services and trainings and easy access to credits to meet the costs involved. In this study, a production function was used which estimates the relationship between inputs and output without making any behavioural assumptions. Therefore, future studies are recommended to focus on data on input quantities and prices

that allows the use of profit maximisation or cost minimization approach to test the robustness this study's findings.

CHAPTER FIVE
COOPERATIVE MEMBERSHIP EFFECTS ON FARMERS' CHOICE OF MILK MARKETING CHANNELS IN RWANDA

Abstract

Although cooperatives play a critical role in reducing transaction costs and enhancing farmers' adoption of better farming practices, little is known on the effects of dairy cooperative membership on the choice of milk marketing channels. This paper employed an endogenous switching probit model to estimate the determinants of farmers' choice of milk marketing channels while controlling for the potential selection bias of cooperative membership. The results show that cooperative membership has positive and significant effects on the choice of both milk collection centres (MCCs) and milk traders as marketing channels along with a negative effect on the choice of other buyers (direct consumers and restaurants). The varying effect of cooperative membership on choice of different marketing channels holds also for non-members had they been cooperative members. Furthermore, the selling price positively affects farmers' choice of MCCs, but the longer distance to MCCs may make farmers (including cooperative members) to choose milk traders who offer lower prices than MCCs. Since the MCCs are managed by dairy cooperatives and they are the only marketing channels that conduct basic milk quality tests while offering higher prices to farmers, policies that support easy access to MCCs and enhance dairy cooperatives' governance are recommended. This will facilitate dairy farmers' access to a better marketing channel while meeting an already growing consumer demand for products safety and quality in the food industry.

5.1. Introduction

Over the past decade, milk production and its contribution to food security, nutrition, and farmers' welfare have been recognised worldwide. The dairy sector constitutes around 30% of livestock production (FAO, 2016) and is a source of livelihood for over 150 million households engaged in milk production worldwide (FAO, 2018). Furthermore, developing countries contribution to global dairy production has increased despite the slow African growth as compared to other developing countries (FAO, 2018). The Rwandan dairy sector has grown tremendously as milk production has more than doubled between 2010 and 2018 (MINAGRI, 2019). This growth is a result of increased cow population, a shift from local to improved cow breeds, and the adoption of better management and farming practices (IFAD,

2016; Land O'Lakes, 2017b). While increasing farmers' production and marketing capacities have been at the centre of dairy sector development in Rwanda, the dairy sector is still behind those of other regional countries such as Kenya and Uganda, in areas of milk productivity, supply, and consumption (TechnoServe, 2019).

Most smallholder farmers, including milk producers, face different challenges that hinder them from getting the opportunities offered by various markets. For instance, high transaction costs may exclude some farmers from selling to certain marketing channels, which otherwise would generate more income (Barrett, 2010; Hao *et al.,* 2018). Producer organizations or cooperatives serve to reduce transaction costs through collective action that enhances production and eases input and output marketing (Francesconi & Heerink, 2011; Mutonyi, 2019). Furthermore, some cooperatives offer extension and financial services that improve members' skills and ability to adopt better farming technologies that eventually increase farmers' production and incomes (Bizikova *et al.,* 2020; Verhofstadt & Maertens, 2014). Based on this, the government of Rwanda in partnership with different donors has supported the initiation and formation of cooperatives among smallholder farmers across the country (Mujawamariya *et al.,* 2013; Verhofstadt & Maertens, 2014).

What is unclear is whether the use of cooperatives as an institutional change is the right solution to boost the agricultural sector, especially in improving farmers' commercialization and choice of marketing channels in developing countries. While there are cases in which cooperatives failed to generate benefits for farmers (for example, Bernard & Taffesse, 2012; Mujawamariya *et al.,* 2013; Schmitt, 2021), the literature records many successes of cooperatives in farmers' profit generation, market participation, in agricultural technology adoption, and access to production inputs (Abebaw & Haile, 2013; Blekking *et al.,* 2021; Manda *et al.,* 2020; Mojo *et al.,* 2017; Sultana *et al.,* 2020; Tran *et al.,* 2023). Whereas the positive and negative impacts of cooperatives continue to make cooperative membership an interesting topic in the literature, there is scanty literature on cooperative membership and choice of marketing channel.

Previous studies especially in developing countries, have mainly focused on factors influencing farmers to join cooperatives and the effect of cooperatives on production, adoption of new farming techniques, access to inputs, and market participation (Blekking *et al.,* 2021; Chagwiza *et al.,* 2016; Fischer & Qaim, 2012). For studies conducted in Rwanda, the emphasis has been mainly on the impact of cooperatives on farm performance (Verhofstadt & Maertens, 2014), income and poverty (Verhofstadt & Maertens, 2015), and

the effect of transaction costs on double side-selling of farmers (Mujawamariya *et al.*, 2013). In the study of Mujawamariya *et al.* (2013), they evaluated the double side-selling[4] behaviours of coffee farmers where some coffee cooperative members sell their coffee to traders while some non-cooperative members sell to cooperatives. Their findings confirmed that cooperative membership is a key determinant of coffee farmers' decision to sell to either cooperatives or traders, however, the transaction costs highly influenced the decision to side-sell. Their findings form the basis of this study which sought to estimate the effects of cooperative membership on the choice of milk marketing channel in the presence of a government policy such as the Ministerial Order (M.O).

The "Ministerial Order N° 001/11.30 of 10/02/2016, (henceforth M.O.), regulating the collection, transportation, and selling of milk" was issued in Rwanda. This M.O. came in to support the Dairy Best Practices (DBPs) scheme which stipulates a set of practices and standards for the proper handling of raw milk aiming at the production of quality milk (Land O'Lakes, 2017b). The DBPs at the farm level include proper feeding of cows, animal disease controls and veterinary consultations, cleanliness, and carrying milk in stainless aluminum milk cans while the M.O requires farmers to sell all milk through the milk collection centres (MCCs) which conduct the basic milk quality tests and chill the milk before selling it to various buyers along the dairy value chain (GoR, 2016).

Whereas the M.O. policy was to make the MCCs the most used milk marketing channel for producers, other milk marketing channels are still dominant in the Rwandan dairy sector (Shema *et al.,* 2018). This channel is characterized by sales of raw milk in an unorganized way, possibly of low-quality or contaminated due to minimal compliance to good dairy milk handling practices including hygiene, appropriate cleanness, and basic infrastructure (Nyokabi *et al.,* 2021; Rakha *et al.,* 2022; Zavala & Revoredo-Giha, 2022). These findings seem to suggest that cooperatives, through their MCCs marketing channel, can play a positive and significant role in promoting food safety and nutrition by ensuring that basic safety and quality tests are conducted (Land O'Lakes, 2017b). Furthermore, cooperatives facilitate trainings that increase participants' information and skills in milk-handling practices, which leads to the production and supply of high-quality milk (Nyokabi *et al.,* 2021). Despite the M.O., one would expect that at least members of dairy cooperatives

[4]Double side-selling is a situation where cooperative members who are expected to sell products to their cooperatives choose to sell to alternative marketing channels while non-cooperative members sell their products to cooperatives instead of the alternative marketing channels.

sell all their milk through the MCCs which are owned and managed by the cooperatives. However, this is not the case as some cooperative members may prefer not to sell all milk through the MCCs while non-members may as well sell to either the MCCs or alternative marketing channels. Thus, this paper establishes the factors behind farmers' choice of milk marketing channels given their cooperative membership status.

Dairy farmers' choice of a marketing channel may be influenced by several contextual factors. Scholars have proposed different factors that may determine the farmers' choice of milk marketing channel, and these factors vary depending on the country or region and the set-up of these markets (Berem *et al.,* 2015; Moturi *et al.,* 2015; Ravneet *et al.,* 2018). For example, the selling price of the product and transaction costs play a key role in the farmers' choice of marketing channel. Milk producers are sensitive to prices and the stability of those prices; hence, they are more likely to sell their milk in marketing channels that offer them higher and/or stable prices (Ravneet *et al.,* 2018). Also, Ngigi *et al.* (2000) found that dairy farmers in Kenya decide to sell in a particular market outlet based on the prices offered and the structure of that outlet in terms of payment reliability. In addition, Berem *et al.* (2015) used a multinomial logit regression to analyse determinants of the choice of milk marketing channels in Nakuru County, Kenya, and they found that the selling price significantly influences the choice of marketing channels. Similarly, Rao *et al.* (2019) confirm that milk producers in Tanzania prefer dairy hubs with higher prices and a fortnightly payment provided that the hubs give them bundled inputs on a check-off system. However, these studies did not capture the effect of cooperative membership on the choice of marketing channel.

Few studies have estimated the determinants of the choice of milk marketing channels while considering the dairy cooperative membership variable. For instance, Sikawa and Mugisha (2011) used a Heckman probit model to determine the factors that influence dairy farmers in South-Western Uganda to choose a marketing channel. They found that the farmers' choices were influenced by cooperative membership, age and education level of the dairy farmer, and the volume of milk produced. Furthermore, Moturi *et al.* (2015) used a multinomial logit model to estimate the determinants of the choice of milk marketing channel and found that cooperative membership increases the likelihood of selling milk to cooperative and private marketing channels. They also found that education level and age of the household head have significant effects on the choice of marketing channels. In addition, Jitmun and Kuwornu (2019) employed a probit model and found that the number of years of

membership in the MCC has a positive effect on the probability of selling milk to dairy cooperatives. The limitation of these three studies is that they did not control for selection bias of cooperative membership yet ignoring the selectivity effect is likely to lead to biased and inconsistent estimates (Lokshin & Sajaia, 2011).

The study of Hao *et al.* (2018) lays a good starting point for analysing the effect of farmers' membership in cooperatives membership on marketing channel choice(s). They used an endogenous switching probit model, which controls for the potential selection bias of cooperative membership. They established that cooperative membership is a key factor influencing apple farmers' choice of marketing channels in China. They confirmed that the collective action of cooperatives gives its members some benefits such as marketing information and increased price bargaining power. The limitation of this study is that the authors did not estimate the effect of cooperative membership on the counterfactual (non-members of cooperatives) had they been members. Hence, this study comes in to fill this gap. In addition, most previous studies on the effect of cooperative membership focused on non-perishable and high-value crops, which tend always to portray a positive effect (Alene *et al.*, 2008; Bernard & Spielman, 2009). This paper contributes to milk marketing literature which is an under-researched area in the dairy sector. It also adds to the scanty literature on the effect of cooperative membership on the choice of marketing channels for low-value and highly perishable products. To the best of my knowledge, this study is the first to estimate the effect of cooperative membership on the choice of milk marketing channels while controlling for selection bias of membership.

5.2. Methodology

5.2.1. Model Specification

The model was based on the assumption that farm households are rational in decision-making. Farmers will only be incentivised to join cooperatives if their perceived benefits of membership are more than that of non-membership. Following a random utility model (RUM), a milk producer i chooses to be a cooperative member if the utility derived from membership (U_1) is greater than that of not being a member (U_0). Since the net benefit or utility from membership ($C_i^* = U_1^* - U_0$) is unobservable; it is functionally represented by a latent variable as:

$$C_i^* = \beta X_i + \varepsilon_i \quad (5.1)$$

where (X_i) is a vector of observed explanatory variables, β is a vector of parameter estimates, and (ε_i) is the stochastic error term. If a milk producer's decision is known, the observable pattern of cooperative membership can be presented by a dummy outcome equation for each choice (C_i) whereby the observed values of C_i are related to C_i^* as:

$$C_i = \begin{cases} 1 & if\ C_i^* > 0 \\ 0 & otherwise \end{cases} \tag{5.2}$$

The resulting probability of a household being a member of a cooperative is:

$$\Pr(C_i = 1) = \Pr(C_i^* > 0) = \Pr(C_i > -\beta X_i) = 1 - F(-\beta X_i) \tag{5.3}$$

where *F* is the cumulative distribution function for the error term ε_i.

5.2.2. Estimation Strategy

The interest in this paper was to estimate the effects of cooperative membership on the choice of milk marketing channel. The milk marketing channels in Rwanda were grouped into three major categories in this study namely, milk traders, MCCs, and other buyers. Milk traders are mobile traders mostly riding bicycles who move from farm to farm collecting milk. They directly buy milk from farmers and resell it to different clients with a mark-up. The MCCs are linked to farmer cooperatives in that they are owned and/or operated by dairy cooperatives, making the MCCs and dairy cooperatives one similar marketing channel (for the rest of this paper, the cooperative milk marketing channel is represented by the MCC channel). The MCCs buy milk from farmers after conducting basic quality tests such as alcohol, lactometer, and organoleptic test, chill it and distribute it to large processors, milk bars/zones, raw milk sellers, cottage cheese makers, and individual consumers. It is important to note that the MCCs buy milk from every farmer irrespective of their membership in the cooperative. In addition, being a cooperative member does not unavoidably mean choosing the MCC as the marketing channel. However, cooperative members usually get various benefits including discounted prices on inputs such as veterinary services, feed supplements, and purchase of milk cans that are checked-off against milk supplied, and shared annual bonuses from profits made by the cooperative (Heifer International, 2018). The other buyers' channel constitutes both restaurants and direct consumers who neighbour farmers and who usually give advances to farmers to be supplied milk daily or on an as-need basis.

It was assumed that a milk producer chooses a marketing channel from a set of three channels (milk traders, MCCs, and other buyers) after assessing transaction costs and profits

associated with each marketing channel. When estimating the effects of dairy cooperative membership on milk producers' choice of marketing channels, one cannot disregard the likelihood of membership being endogenous to farmers' choice of marketing channels as dairy cooperatives represented by MCCs are among the main milk marketing channels. For instance, if farmers target the benefits of being members of a cooperative, they can self-select themselves into a cooperative that will affect their choice of marketing channel. Consequently, some factors may affect the outcome variable (choice of marketing channel) but cannot be observed in real life. Therefore, they form part of the error term that is correlated with the main explanatory variable resulting in an endogeneity problem. This underestimates or overestimates the effect of cooperative membership on the choice of marketing channel.

Previous studies have used quasi-experimental methods such as propensity score matching (PSM) to control the potential selection bias of cooperative membership (see, for example, Abebaw & Haile, 2013; Verhofstadt & Maertens, 2014, 2015). With this approach, a propensity score is used to construct a control group by matching each treated element with a non-treated element based on similar observable characteristics. However, the PSM may produce biased estimates as the selection into a cooperative is also caused by unobservable characteristics. On the other hand, instrumental variables (IV) and proxy variables are generally used to solve the endogeneity problem (Wooldridge, 2014). However, Wooldridge (2010) argues that an IV procedure is not appropriate to deal with endogeneity in limited dependent variable models due to the nonlinearity of the model.

The alternative approaches that are used in binary outcomes are the linear probability model (LPM) and two-stage least squares (2SLS) (Angrist, 2001), and the bivariate probit model (BPM) (Holm & Jæger, 2011). The LPM is criticized for producing constant marginal effects and predicting outside (0,1) intervals. While 2SLS and BPM produce better estimates, they are less efficient than a full information maximum likelihood (FIML) approach (Hao *et al.*, 2018). Therefore, an endogenous switching probit (ESP) model was used in this study, which uses the FIML as framed by Miranda and Rabe-Hesketh (2006). The ESP model contemplates both the correlation and the dependence between the error terms of the outcome variable and the selection equations through shared random effect, an attribute that impersonates the selection problem (Hao *et al.*, 2018). The shared random effect property of the ESP model is a remedy for the unobserved heterogeneity between the choice of marketing

channel and cooperative membership. Following Hao *et al.* (2018) approach, the outcome variable can be framed as:

$$Y_{ij}^{*} = \alpha Z_i + \varphi C_i^{*} + u_i, \quad Y_{ij} = \begin{cases} 1 & if\ Y_{ij}^{*} > 0 \\ 0 & otherwise \end{cases} \ (J = Y_1,\ Y_2,\ Y_3) \tag{5.4}$$

where Y_{ij}^{*} is the outcome equation (the choice of marketing channel), and *J* represents the three marketing channels (Y_1= milk traders, Y_2= MCCs, Y_3= other buyers). Z_i represents the vector of explanatory variables of choice of marketing channels while $C_i^{*}$is the dummy variable for cooperative membership, α, and φ are coefficients to be estimated and u_i is the error term. Following Miranda and Rabe-Hesketh (2006), the potential endogeneity of membership is modelled using a shared random effect discussed above to induce the dependence between the error terms of equations (5.1) and (5.4) as:

$$\varepsilon_i = \theta\mu_i + \gamma_i \tag{5.5}$$

$$u_i = \mu_i + \omega_i \tag{5.6}$$

It is assumed that μ_i, γ_i and ω_i are independently and identically distributed, with mean 0 and variance 1. θ represents the factor loading which is used in deriving the correlation (ρ) between error terms (u_i and v_i) as follows: $\rho = \frac{\theta}{\sqrt{2(\theta^2+1)}}$. The correlation ($\rho$) is used to establish the exogeneity or endogeneity of C_i in Y_{ij}. If $\rho = 0$, then the cooperative membership is exogenous in the choice of marketing channel decision equation, and coefficients α and φ are estimated by fitting equation (5.4) with the ordinary probit models. On the contrary, if $\rho \neq 0$, then C_i^{*} is correlated with u_i, an endogenous switching model is used to solve the endogeneity problem.

While the ESP model divides farmers into different regimes that are mutually exclusive, around 43 farmers (11.6%) in the sample used in this study were selling to 2 marketing channels which complicate the error structure not only between equations (5.1) and (5.4) but also the error terms within the equation (5.4). Following Hao *et al.* (2018), the outcome variables were made dummies for each of the marketing channels used by farmers. Furthermore, a multivariate probit regression (MVPM) was performed to verify whether this cross-correlation bias the analysis. The results of MVPM (Appendix E.1) supported the impact of cooperative membership on the choice of milk marketing channels, but the model had few parameters that are statistically significant compared to the ESP model while its

parameters were less efficient than a FIML approach. Despite this caveat, the ESP model[5] was preferred due to its strength to separately estimate the effect of control variables on the choice of marketing channels based on whether the farmer is a cooperative member or non-member.

The ESP model requires an exclusion restriction for better identification. This approach involves the inclusion of at least one variable in the selection equation with no direct effect on the outcome equation based on the economic theory and/or empirical literature (Deb & Trivedi, 2006; Hao *et al.,* 2018; Tabe-Ojong *et al.,* 2020). Previous studies have used different variables as exclusion restrictions. For instance, Di Falco *et al.* (2011) and Shiferaw *et al.* (2014) have used government and farmer-to-farmer extension while Tesfaye and Tirivayi (2018) have used the presence of an extension agent in the community as exclusion restrictions. Furthermore, Khonje *et al.* (2015) used group membership as an exclusion restriction while Hao *et al.* (2018) used the frequency of participating in training and whether any family member has experience as village cadre.

In this study, the number of trainings attended on dairy farm management in 2019 and whether any household member was in local administration were used as exclusion restrictions. Participating in dairy farm management trainings increases farmers' possibility of specializing in dairy production, and hence joining dairy cooperatives while the trainings have no direct effect on the choice of a marketing channel. Given the efforts that the government of Rwanda has put into the formation of agricultural cooperatives (Verhofstadt & Maertens, 2014), it is apparent that having a household member in a local government administration increases the likelihood of that household joining a cooperative. A simple falsification test was performed following Di Falco *et al.* (2011) to establish the admissibility of these two instruments (Appendix E.2). The results show that the instruments can be considered valid since they statistically influence the decision to join a dairy cooperative or not, but they do not influence the choice of a marketing channel for non-members. A further correlation analysis performed confirms that the correlations between the outcome variables and the instruments are weak (below 0.2 in absolute value and close to 0 in most cases).

5.2.3. Treatment Effects

The ESP model allows for estimating the average treatment effects on the treated (ATT) and the average treatment effects on the untreated (ATU). The ATT is the expected

[5] The analysis was performed in Stata 16 using the "switch_probit" command

treatment effect on milk producers with observed characteristics (x) who are members of dairy cooperatives. The ATU is the expected effect of the treatment on milk producers with observed characteristics (x) who are not members of dairy cooperatives. The average treatment effect (ATE) of cooperative membership for a milk producer with observed characteristics (x) randomly selected from the population of milk producers was also estimated. Since the treatment effect can be changed by observed and/or unobserved household characteristics (x), the marginal treatment effect (MTE) is also estimated to account for unobserved heterogeneity ($\bar{\varepsilon_i}$). These effects are estimated following Lokshin and Sajaia (2011), thus:

$$ATT = E(Y_{1i} | C_i = 1, X = x) - E(Y_{0i} | C_i = 1, X = x) \quad (5.7)$$

$$ATU = E(Y_{1i} | C_i = 0, X = x) - E(Y_{0i} | C_i = 0, X = x) \quad (5.8)$$

$$ATE = E(C_i = 1, X = x) - E(C_i = 0, X = x) \quad (5.9)$$

$$MTE = E(C_i = 1 | X = x, \varepsilon_i = \bar{\varepsilon_i}) - E(C_i = 0 | X = x, \varepsilon_i = \bar{\varepsilon_i}) \quad (5.10)$$

5.2.4. Study Area and Data Collection

The household survey was conducted between January and March 2020 in Nyabihu and Ruhango districts of Rwanda, two of the country's main milk-producing districts (Figure 5.1). Nyabihu district is among seven districts in the Western province of Rwanda, with a population of 294,740 people from 65,855 households (NISR, 2014). On the other hand, Ruhango district is one of the eight districts of the Southern province of Rwanda, with 319,885 population and 76,968 households (NISR, 2014). In both districts, there are seven MCCs managed by several dairy cooperatives, five small and medium enterprises (SMEs) making cheese, and one dairy factory (Mukamira) in Nyabihu; all these make the dairy sector active in these districts.

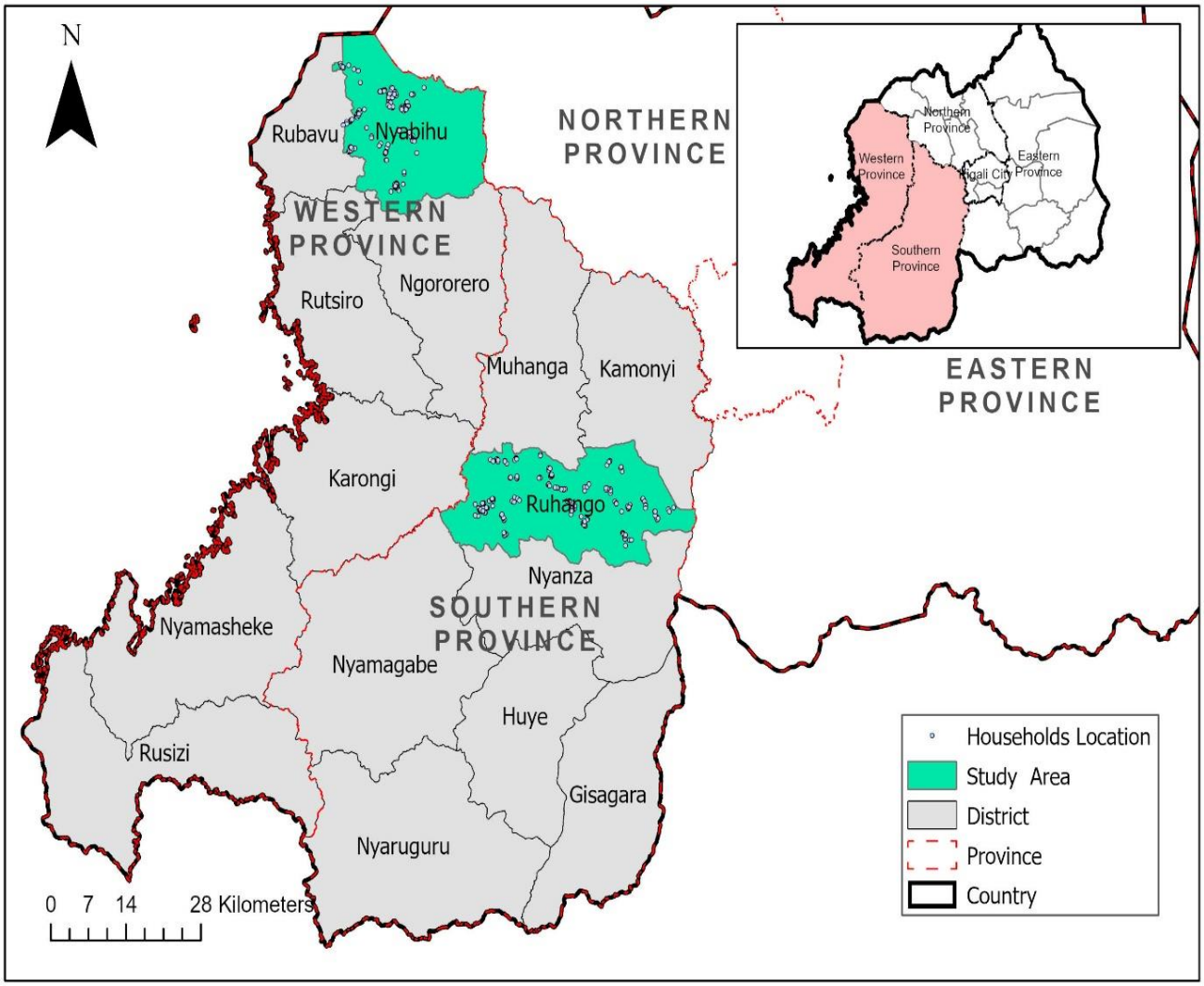

Figure 5.1: Map of the study area.

A two-stage random sampling procedure was used where the first stage was the selection of Nyabihu and Ruhango districts due to the pre-determined sites of the project. The second stage was the random selection of milk producers from a sampling frame of farmers who supply milk to MCCs and milk traders and a random selection of the rest of the milk producers in consultation with local extension agents. A structured questionnaire was used to collect information from 370 farmers who were producing and selling milk in both districts during the survey period. In addition, the information on farmer and farm characteristics, dairy cooperative membership, milk production, and marketing was collected which enabled to establish the determinants of the choice of milk marketing channels in Rwanda.

5.3. Variables and Descriptive Statistics

5.3.1. Selection and Outcome Variables

The selection variable (the dairy cooperative membership) was a dummy variable constructed based on the questions: “Have you or has any other member of your household been a member of a dairy cooperative?” and “Are you or is your other household member currently still a dairy cooperative member?”. There was zero dropping in cooperative membership where all 99 households representing 27% of the sample which had membership into dairy cooperatives were still active during the survey period in 2019. On the other hand, the outcome variable (choice of marketing channel) was constructed based on the questions: “Did you sell milk in the year 2019?” and “What is your main marketing channel did you sell to?”. In this paper, the marketing channel choice measured participation on the extensive margin without considering the quantity of milk sold to different channels.

The results show that the main marketing channels for milk producers in Rwanda are milk traders, MCCs, direct consumers, and restaurants (Table 5.1). However, due to a small share of direct consumers (15.5%) and restaurants (14.3%), these two marketing channels were combined to form one marketing channel named “other buyers” channel as explained in section 5.2.2 above. Hence, the outcome variable was grouped into 3 dummy variables namely, milk traders equal 1 if farmers sell to milk traders and 0 otherwise, MCCs equals 1 if they sell to MCCs and 0 otherwise, and other buyers that equal 1 if they sell directly to consumers or restaurant and 0 otherwise.

Milk traders and MCCs have almost equal shares of marketing channels (35.6% and 34.6% respectively) while other buyers have a share of 29.8%. More non-member farmers sell to milk traders and other buyers than they sell to MCCs while cooperative member farmers sell their milk to MCCs more than any other marketing channel. This is probably because MCCs are managed by cooperatives and hence they may prefer to sell to this channel as a way of promoting their cooperatives which have value propositions for its members. On the other hand, non-members may not feel the need to transport their milk to MCCs while there are milk traders who can collect it at the farm or other buyers who are close to them.

Table 5.1: Milk marketing channels by cooperative membership

Marketing channels	Non-members	Members	Total
Milk traders	129 (42.6%)	18 (16.4%)	147 (35.6%)
MCCs	71 (23.4%)	72 (65.4%)	143 (34.6%)
Direct consumers	50 (16.5%)	14 (12.7%)	64 (15.5%)
Restaurants	53 (17.5 %)	6 (5.5%)	59 (14.3%)
Total	303 (100%)	110 (100%)	413 (100%)

5.3.2. Explanatory Variables and Expected Effects

Table 5.2 below presents the explanatory variables used to model the farmer's decision to join a dairy cooperative and the choice of marketing channel. The choice of these variables was based on previous empirical literature on cooperative membership and/or choice of marketing channels (Abebaw & Haile, 2013; Bernard & Spielman, 2009; Brar *et al.,* 2018; Chagwiza *et al.,* 2016; Hao *et al.,* 2018; Jitmun & Kuwornu, 2019; Tabe-Ojong *et al.,* 2020; Verhofstad & Maertens, 2015). It was hypothesised that membership in dairy cooperatives has a positive effect on the choice of MCCs as marketing channels and unclear effects on the choice of milk traders and other buyers. This is because MCCs are managed by dairy cooperatives and farmers may self-select themselves into cooperatives while targeting to sell to MCCs.

Adherence to DBP standards was expected to positively influence the choice of an MCC marketing channel since it is the only marketing channel that tests milk and pays higher prices to farmers. Verhofstad and Maertens (2014) found a positive relationship between the quantity of produce sold and cooperative membership. In this study, the commercialization index was used which is the ratio of the total quantity of milk sold to the total milk produced, and it was expected to positively influence the cooperatives' membership. Distance to the nearest milk sales point has been found to have a non-linear positive influence on cooperative membership (Abebaw & Haile, 2013; Fischer & Qaim, 2012). Therefore, it was included in this study and expected it to either positively or negatively influence the cooperative membership. Furthermore, this variable was expected to have a positive effect on the choice of both milk traders and other buyers and a negative effect on the choice of MCC as a marketing channel probably because MCCs are usually located far from farmers.

Table 5.2: Variables and expected effects (N=370)

Variable	Description	Selection equation: expected effect on cooperative membership	Outcome equation: expected effect on choice of marketing channel		
			Milk traders	MCCs	Other buyers
Adherence to DBP standards	Dummy (=1 if the household adheres to DBP, 0 otherwise)	0	−/+	+	−/+
Commercialization index	Proportion of milk sold to milk produced	+	−/+	−/+	−
Distance	Distance from farm to nearest milk selling point in Km	−/+	+	−	+
Experience	Dairy farming experience years	+	−/+	−/+	−/+
Sex	Sex of the household head (=1 if male, 0 otherwise)	+	−/+	−/+	−/+
Age	Age of the household head in years	+	−/+	−/+	−/+
Education level	Number of years of formal education of the household head	+	−/+	−/+	−/+
Off-farm income	Dummy (=1 if the household has an off-farming income, 0 otherwise)	+	−/+	−/+	−/+
Crossbreed lactating cows	Dummy (=1 if the household has a crossbreed lactating cow)	+	−/+	−/+	−/+
Pure breed lactating cows	Dummy (=1 if the household has a pure breed lactating cow)	+	−/+	−/+	−/+
Membership fee	The amount of money paid to become a cooperative member in Rwf	−	−/+	+	−/+
Local administration	Dummy (=1 if any household member is in local administration, 0 otherwise)	+	0	0	0
Training	The number of trainings attended on dairy farm management in 2019	+	0	0	0
Selling price	Price of milk in Rwf per litre	0	−	+	−

Selling season	Dummy (=1 if milk is sold in rainy season, 0 in dry season)	0	+	−	−/+
Location	Dummy (=1 if the household resides in Nyabihu district, 0 otherwise)	+	−/+	+	−/+

Note: − is for negative impact; + is for positive impact; +/− stands for unclear direction; 0 stands for no impact.

Concerning household head's characteristics, previous studies have found that sex, age (Abebaw & Haile, 2013; Bernard & Spielman, 2009), education level, and farming experience of the household head (Tabe-Ojong et al., 2020; Verhofstad & Maertens, 2015) are positively associated with cooperative participation. Thus, the similar effects of these variables on the probability of farmers joining cooperatives were expected in this study, but with an unclear effect on the choice of marketing channel. Likewise, cooperative membership was expected to be positively related to off-farm income as found by Abebaw and Haile (2013) and Fischer and Qaim (2012). In their study on cooperative membership and dairy performance among smallholders in Ethiopia, Chagwiza *et al.* (2016) found a significant positive relationship between the proportion of crossbreed cows and cooperative membership. Two dummies for keeping crossbreeds and pure breed lactating cows were included in this study and they were expected to positively influence the cooperative membership as farmers who keep these breeds can be regarded as commercial-oriented farmers compared to those keeping local breeds.

The cooperative membership fee is an amount of money set by the cooperative management to be paid by every farmer who wishes to be a member of the cooperative. The membership fee may vary between different cooperatives, but there is no variation in the services provided across the MCC by the membership fee. The membership fee paid by farmers was expected to have a negative effect on joining a cooperative as a high membership fee can be an entry barrier (Mujawamariya *et al.*, 2013; Verhofstadt & Maertens, 2014). On the other hand, membership fee has no clear effect on the choice of milk traders and other buyers as marketing channels, but it is expected to have a positive effect on the choice of MCCs since farmers may consider the paid fee as a sunk cost and hence, get attached to the MCCs channel.

Regarding the selling price, the expectation was based on the findings of Brar *et al.* (2018) and Jitmun and Kuwornu (2019) who found that farmers sell their milk in a marketing channel that offers them higher prices in India and Thailand respectively. Given that MCCs

offer better prices than other marketing channels, it was expected that the price of milk received by farmers would have a positive effect on the choice of MCCs and conversely on the choice of both milk traders and other buyers. The selling season was expected to negatively affect the choice of the MCCs as marketing channels because farmers produce more milk in the rainy season (due to the availability of feeds) which farmers might find challenging to transport to MCCs that are far from them. Farmers residing in Nyabihu district were expected to join cooperatives more than those in Ruhango because Nyabihu has many active dairy cooperatives.

5.3.3. Descriptive Statistics

Table 5.3 presents summary statistics and a description of the variables used in the model and mean differences between member and non-member farmers. On average, 86% of households are headed by males with a mean age of 52 years, 12 years of dairy farming experience, and an education level of 5 years, which is close to completing primary education. Around 54% of farmers in the sample reside in the Nyabihu district, and about 53% adhere to DBP standards while selling milk to buyers located 1.3 km from the farm. The commercialization index is 0.61 indicating that 61% of milk produced is sold and nearly 46% of households are engaged in off-farm activities.

Table 5.3: Descriptive statistics of variables used in the estimation models by cooperative membership

Variables and description	Full sample (N=370) Mean	Non-members (N=271) Mean	Members (N=99) Mean	Difference
Commercialization index	0.611	0.598	0.647	-0.049 **
	(0.173)	(0.174)	(0.163)	
Distance from farm to nearest milk selling	1.342	1.108	1.984	-0.876 ***
point	(1.804)	(1.724)	(1.871)	
Dairy farming experience	12.042	10.876	15.232	-4.356 ***
	(10.882)	(10.395)	(11.584)	
Sex of the household head	0.865	0.863	0.869	-0.005
	(0.342)	(0.344)	(0.339)	
Age of the household head	51.965	50.089	57.101	-7.012 ***
	(14.135)	(14.048)	(13.124)	
Education level of the household head	4.911	5.221	4.061	1.161 ***
	(3.708)	(3.717)	(3.565)	
Off-farm income	0.465	0.472	0.444	0.028
	(0.499)	(0.500)	(0.499)	
Crossbreed lactating cows	0.843	0.838	0.859	-0.021
	(0.364)	(0.369)	(0.350)	
Pure breed lactating cows	0.192	0.125	0.374	-0.248 ***
	(0.194)	(0.122)	(0.286)	
Membership fee	8,606.757	0.00	32,166.67	-32166.67
	(22,754.44)	(0.00)	(34,408.78)	***
Local administration	0.235	0.199	0.333	-0.134 ***
	(0.425)	(0.400)	(0.473)	
Training	1.449	1.148	2.272	-1.125 ***
	(1.673)	(1.568)	(1.683)	
Adherence to DBP	0.527	0.406	0.858	-0.453 ***
	(0.50)	(0.492)	(0.350)	
Selling price	156.882	151.611	171.313	-19.702 ***
	(40.625)	(43.159)	(28.199)	
Selling season	0.538	0.513	0.606	-0.093

	(0.499)	(0.501)	(0.491)	
Location	0.538	0.472	0.717	-0.241 ***
	(0.489)	(0.500)	(0.453)	

Note: Standard deviations are in parentheses and *** $p<0.01$, ** $p<0.05$, * $p<0.1$

In Table 5.3, the results of a mean difference test conducted to differentiate between cooperative members and non-members are also presented. Out of 370 farmers, 99 farmers were dairy cooperative members with a mean membership fee of 32,167 Rwf. Non-cooperative members were younger and more educated than cooperative members ($p<0.01$). On the other hand, dairy cooperative members are more experienced in dairy farming, adhere to DBP standards, and they attended more dairy farm management trainings than non-members ($p<0.01$). This was expected because cooperatives may provide their members with information on available trainings and make the necessary arrangements for their members to attend such trainings. In addition, 33% of cooperative members were into local government administration compared to 20% of non-members, they had a higher commercialization index, and more pure breed cows ($p<0.01$) implying that they are more commercial oriented than non-members.

Furthermore, cooperative members sold milk at a higher price than non-members ($p<0.01$). This could be attributed to the fact that the members mostly sold to MCCs, which offered them higher prices because standard quality tests were conducted before accepting the milk. On the other hand, long distance from cooperative members' farms to their nearest selling points would explain why they join a cooperative, unlike non-members who may not be incentivized to join as they have alternative selling points that are nearer to the farm-gate. Expectedly, the location dummy variable shows that more cooperative members reside in Nyabihu district which has more dairy cooperatives than Ruhango district. Based on the mean differences between cooperative members and non-members, one can see the effect of cooperative membership on the choice of a marketing channel. However, one cannot draw that inference based on these results as other observable and unobservable confounding factors are not controlled for. Hence, the results of the models that controlled for these confounding in the subsequent section.

5.4. Results and Discussions

5.4.1. Treatment Effects Results

Table 5.4 presents the average treatment effects for actual and counterfactual situations. The results showed that cooperative membership increased the probability of selling to milk traders by 3 percentage points for members of cooperatives compared to an increase of 20 percentage points for non-members had they been members. Furthermore, the cooperative membership increased the likelihood of selling to MCCs by 18 percentage points. This implies that households who are members of dairy cooperatives were more likely to sell to MCCs than the counterfactual scenario of non-members (12 percentage points). The results further show that cooperative membership decreased the likelihood of members selling their milk to other buyers by 5 percentage points. Contrary, in counterfactual, the probability of non-members selling to other buyers would increase by 11 percentage points had they chosen to be members of dairy cooperatives.

Table 5.4: Treatment effects

Outcomes	**Treatment effects**			
	ATT	**ATU**	**ATE**	**MTE**
Milk traders	0.032 ***	0.204 ***	0.238 ***	-0.690
	(0.166)	(0.289)	(0.299)	(0.465)
MCCs	0.183 ***	0.122 ***	0.311 ***	0.940 ***
	(0.361)	(0.325)	(0.428)	(0.239)
Other buyers	-0.052 ***	0.115 ***	0.065 ***	-0.047 ***
	(0.0.141)	(0.270)	(0.302)	(0.092)

Note: ATT – Average Treatment Effect on the Treated, ATU – Average Treatment Effect on the Untreated, ATE – Average Treatment Effect, and MTE – Marginal Treatment Effect; clustered standard errors in parentheses; *** $p<0.01$.

5.4.2. Selection Model: Dairy Cooperative Membership

Each outcome model (each marketing channel) has one corresponding selection model. The second, fourth, and sixth columns of Table 5.5 present the estimation results of three selection models i.e. determinants of cooperative membership. All significant variables in each selection model have the same signs and have almost similar statistical significance except for being in local government administration and owning a crossbreed cow variable that have different levels of significance and age variable which is only significant in the second selection model. Consistent with Abebaw and Haile (2013), and Fischer and Qaim

(2012), it was found that the distance to the nearest selling point has a significant positive effect on cooperative membership. This is probably because farmers located far from selling points may likely join cooperatives expecting to gain some collective marketing while those that are close to selling points may not recognise the importance of cooperatives as they already have better access to markets (Fischer & Qaim, 2012). The age variable had a significant positive relationship with cooperative membership, suggesting that older household heads are more likely to join a dairy cooperative than younger ones. This is consistent with the findings of Tabe-Ojong et al. (2020), who argue that older farmers understand the importance of cooperatives well due to their farming experience and connections in society.

Table 5.5: Endogenous switch probit model results of three main milk marketing channels (N=370)

Variables	Milk traders		MCCs		Other buyers	
	Selection1	**Members**	**Selection2**	**Members**	**Selection3**	**Members**
Commercialization	-0.427	-0.461	-0.565	-13.826 **	-0.187	-0.437
index	(0.607)	(1.367)	(0.738)	(6.988)	(0.727)	(1.011)
Distance to nearest	0.146 ***	0.238 **	0.175 ***	-0.233	0.153 ***	0.090
milk selling point	(0.053)	(0.122)	(0.059)	(0.220)	(0.055)	(0.095)
Dairy farming	-0.002	-0.059 *	-0.013	-0.057	-0.007	0.010
experience	(0.012)	(0.031)	(0.012)	(0.051)	(0.013)	(0.019)
Sex of the household	0.198	-2.111 **	0.252	0.144	0.450	-0.036
head	(0.373)	(1.026)	(0.392)	(1.748)	(0.430)	(0.571)
Age of the household	0.010	0.095 *	0.020 **	-0.112 **	0.018	-0.023
head	(0.010)	(0.051)	(0.009)	(0.057)	(0.011)	(0.018)
Education level of the	-0.017	0.067	-0.023	-0.168	-0.015	-0.184 **
household head	(0.033)	(0.103)	(0.037)	(0.147)	(0.038)	(0.077)
Off-farm income	-0.323	1.279	-0.186	-0.215	0.374	-0.062
	(0.285)	(1.077)	(0.302)	(0.828)	(0.299)	(0.407)
Crossbreed lactating	1.512 ***	1.034	0.963 **	1.455	1.346 **	-0.140
cows	(0.561)	(1.292)	(0.507)	(2.906)	(0.626)	(0.719)
Pure breed lactating	2.184 ***	-0.039	1.889 ***	2.048	2.002 ***	-0.460
cows	(0.533)	(1.061)	(0.473)	(2.823)	(0.576)	(0.622)
Membership fee[6]	0.288 ***	-0.264 ***	0.302 ***	-0.197	0.290 ***	0.050
	(0.029)	(0.080)	(0.032)	(0.133)	(0.031)	(0.113)
Local administration	0.919 ***		0.784 **		0.971 ***	
	(0.257)		(0.341)		(0.321)	
Training	0.259 ***		0.233 ***		0.254 ***	
	(0.074)		(0.068)		(0.075)	
Adherence to DBP		-0.698		8.259 **		-2.287 ***
		(0.679)		(4.038)		(0.752)

[6] The membership fee variable is transformed using the inverse hyperbolic sine transformation as it approximates the natural logarithm and allows retaining zero-valued observations (Bellemare & Wichman, 2020)

Selling price	−	-0.063 **	−	0.111 **	−	-0.009
		(0.031)		(0.052)		(0.006)
Selling season	−	-0.509	−	-1.019	−	0.095
		(0.716)		(1.267)		(0.414)
Location	-0.080	-3.967 **	-0.253	6.577 **	-0.190	-0.847 *
	(0.261)	(1.694)	(0.274)	(2.889)	(0.270)	(0.473)
Constant	-4.260 ***	13.514 **	-3.871 ***	-16.474	-4.655 ***	5.936 **
	(0.952)	(5.214)	(0.898)	(10.297)	(1.068)	(2.327)
Wald $\chi 2$	−	119.88 ***	−	106.71 ***	−	107.86 ***
ρ_1	−	-1.00	−	-0.99	−	-495
ρ_2	−	-1.00	−	-1.00	−	0.405

Note: Standard errors clustered at the household level are in parentheses and *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

While membership fee was expected to have a negative association on cooperative membership, the findings show a significant positive association. This is possibly due to cooperatives' value proposition to members where cooperatives that charge higher membership fees may be offering more benefits to their members that offset their membership fee. Some of the benefits that farmers get include access to inputs at lower prices and on a check-off system as well as sharing dividends at the end of the year (Heifer International, 2018). Therefore, if there is no membership fee charged, farmers may lack the incentives to join such cooperatives as they do not see the benefits of becoming members. Alternatively, there might have been no fee or low membership fee charged when cooperatives were initiated, but initiate fee or increase in the fee for newcomers after the services and benefits of cooperatives are seen. Novkovic (2008) argues that membership fees may limit more people from joining a cooperative while sustaining incentive-compatible profitability. Furthermore, Chagwiza *et al*. (2016) confirm that "the joining fee that cooperatives charge can be an entry barrier but cannot be considered as a serious hindrance to cooperative participation among small-scale producers".

Expectedly, the exclusion variables were both significant in all selection models confirming that they are highly correlated with cooperative membership. Having a household member in local government administration increases the likelihood of joining a cooperative as the local government administration is used to drive the government's programs. Likewise, the more farmers attend the dairy farm management trainings, the more likely they are to join

cooperatives since they may specialise in dairy farming and learn the benefits of cooperatives in those trainings. The results concur with Hao *et al.* (2018) who found that cooperative membership is significantly influenced by having a family member as a village cadre and the frequency of technical training attended by farmers.

Finally, a positive significant effect of keeping crossbreeds and pure-breed lactating cows on cooperative membership was found implying that farmers who own crossbreeds or pure-breed lactating cows are more likely to join cooperatives compared to those keeping local breed cows. This is probably because farmers with crossbreeds and pure-breed cows maybe regarded as dairy commercial-oriented farmers as these breeds produce higher volumes of milk. Consequently, more cooperative members keep pure breeds than non-members. This is consistent to the findings by Kumar *et al.* (2018) who established that a higher proportion of crossbred cows influences the farmers' decisions to join dairy cooperatives in India. Besides, Chagwiza *et al.* (2016) found a positive relationship between cooperative membership and the proportion of crossbreed cows to the total number of cows in the herd in Ethiopia.

5.4.3. Outcome Model: Choice of Marketing Channels

The estimated correlation coefficients[7] (ρ_1 and ρ_2) between the error terms of the cooperative membership and choice of milk traders and MCCs outcome equations are both negative confirming that there is a hierarchical sorting (Fuglie & Bosch, 1995; Narayanan, 2014). This implies that dairy cooperative members (regime 1) have above-average returns irrespective of their membership, but they are better off when they are members. On the other hand, non-members (regime 2) have below-average returns irrespective of their membership, but they are better off when they are members. Conversely, in other buyers' equation, the correlation coefficients have different signs where ρ_1 is negative while ρ_2 is positive. This implies that dairy cooperative membership is propelled by comparative advantage (Narayanan, 2014; Tesfaye & Tirivayi, 2018) where farmers who are members have above-average returns from membership and non-members have above-average returns from not being members. The results for cooperative members are presented in table 5.5 while the results for non-members are attached in appendix E.3. The third, fifth and seventh columns of

[7] ρ_1 is the correlation coefficient between the error term of cooperative membership and the choice of a marketing channel in regime 1 (members) while ρ_2 is the correlation coefficient between the error term of cooperative membership and the choice of a marketing channel in regime 2 (non-members).

Table 5.5 present the estimates of the effect of cooperative membership (for members) on the choice of milk traders, MCCs, and other buyers as marketing channels respectively.

The results showed that adherence to DBP standards had a significant positive effect on the probability that members of dairy cooperatives would sell to MCCs, and a significant negative effect on the probability of selling to other buyers. These results confirm the importance of dairy cooperatives in improving the safety and quality of milk through selling to MCCs. A recent study by Kiambi *et al.* (2022) in Kenya found that, despite the lack of milk cooling tanks in most of MCCs, milk from MCCs is the only raw milk that is within the acceptable East African Standards (EAS) limits for total coliform counts. On the other hand, milk from other outlets (restaurants, milk bars, roadside vendors, and shops/kiosks) exceeded the acceptable EAS limits and its bacterial quality deteriorates faster; confirming further that indeed MCCs can play a positive role in promoting food safety and quality in developing countries.

Similarly, the selling price variable has a positive and significant effect on the probability of members selling to MCCs while it has a significant negative effect on the probability of selling to milk traders. The findings for adherence to DBP standards and selling price variables are not surprising as MCCs buy milk of high quality at a higher price than the price offered by milk traders and other buyers (IFAD, 2016). Therefore, farmers who target higher prices may adopt DBP and choose MCC as a marketing channel that incentivises them for the quality of milk produced. Previous studies (Brar *et al.*, 2018; Jitmun & Kuwornu, 2019; Shema *et al.*, 2018) found a similar positive relationship between the price of milk and the choice of a marketing channel. Furthermore, MCCs have a check-off system (which may be preferred by DBP-adhering farmers) of offering veterinary services and feed supplements on credit to its milk suppliers and deducting the money from the milk supplied (Heifer International, 2018). The check-off system is mostly preferred to cash on purchase when dairy farmers acquire inputs and services (Rao *et al.*, 2019).

For cooperative members, the distance to the nearest selling point has a positive significant effect ($p<0.05$) on the probability of selling to milk traders while the commercialization index has a negative significant effect on the probability of selling to MCCs ($p<0.05$). Furthermore, the effect of age on the probability of selling to milk traders is positive and significant, and negatively significant on the probability of selling to MCCs. This suggests that older farmers are likely to sell to milk traders while they are less likely to sell to MCCs. These findings can be attributed to the fact that milk traders collect milk

themselves from the farms while MCCs are located far from the farms. Consequently, farmers who sell larger volumes of milk are likely to sell to milk traders at a lower price than transport their milk to MCCs that are located far from them. In addition, while older farmers are members of dairy cooperatives (Table 3) and are expected to sell more to MCCs, their overall health could be problematic and they may not have the physical energy to transport milk to the MCCs unlike their younger counterparts, hence, their choice for milk traders. Similar findings are reported by Brar *et al.* (2018) who found that age of the farmer is negatively associated with the choice of an organized milk marketing channel such as MCCs.

The education level of the household head has a negative significant influence on the probability of selling to other buyers while cooperative membership fee, the experience, and sex of the household head have negative and significant effects on the probability of selling to milk traders. This implies that the more experienced farmers are not enticed by milk traders while male-headed households are less likely to sell to milk traders since they have the physical energy to transport their milk to other marketing channels. Furthermore, female-headed households may be more time-constrained given their involvement in other household activities such as domestic chores and child care which may limit them from transporting milk. Lastly, residing in Nyabihu district has a positive and significant effect on the probability of selling to MCCs, and a negative significant effect on the probability of selling to both milk traders and other buyers. This is probably due to the district's hilly terrain; hence, it becomes difficult for milk traders to reach farms as they use bicycles to transport milk (farmers mainly remain with the option of head loading to sell to MCCs). Moreover, Nyabihu is less dense with few urban centers implying that few restaurants and individual customers are making the 'other buyers' channel less common in the district.

5.5. Conclusions and Policy Implications

5.5.1. Conclusions

The contribution of milk production to food security, nutrition, and farmers' welfare has been documented worldwide. However, smallholder milk producers face different constraints such as high transaction costs that hinder them from getting the opportunities offered by various marketing channels (Hao *et al.,* 2018). While cooperatives play a critical role in the reduction of transaction costs (Francesconi & Heerink, 2011) and enhancement of farmers' adoption of better farming technologies (Verhofstadt & Maertens, 2014), little is known on the effect of dairy cooperative membership on the choice of milk marketing channels. In this paper, the effects of cooperative membership on the choice of milk

marketing channels were estimated and other factors that influence the farmers' choice of milk marketing channels were assessed. Using data collected from 370 milk producers in Rwanda, an endogenous switching probit model was employed to control for the selection bias of cooperative membership.

The model allowed to first establish the determinants of cooperative membership and then estimate the effect of membership on the choice of marketing channel. It was found that the distance to the nearest milk sale point, age of the household head, owning lactating crossbreeds and pure breed cows, membership fee, being into local government administration, and the number of dairy farm management trainings attended are key factors that influence farmers' decision to join a dairy cooperative. For the main research interest, the results lead to the conclusion that cooperative membership has positive and significant effects on the choice of both MCCs and milk traders and the positive effects would hold for non-members had they been members. Contrary, cooperative membership reduces the likelihood of selling to other buyers while non-members would be more likely to sell to other buyers had they been members. The variability in the treatment effects confirms that each marketing channel has its inherent characteristic features that motivate farmers to choose that channel. The presence of non-member farmers (selling to milk traders or MCCs) who can be better off from being members informs the possibility of cooperative expansion while it is evident that non-member farmers who are selling to other buyers do not have a comparative advantage of becoming members.

It was also found that adhering to DBP standards has a varying effect on different marketing channels depending on whether the farmer is a cooperative member or not. For cooperative members, adhering to DBP standards has no significant effect on the choice of milk traders marketing channels but it has a positive significant effect on the choice of MCCs and a negative effect on the choice of other buyers. For non-members, adherence to DBP standards has significant positive effects on both milk traders and MCCs and negatively affect the choice of other buyers. Furthermore, the selling price has a positive effect on farmers' choice of MCCs, but the longer distance to MCCs may make farmers (including cooperative members) choose milk traders who offer lower prices than MCCs. Other determinants of the choice of marketing channels include the commercialization index, sex, age, experience, and education level of the household head, membership fee, and location of the household. These variables have varying effects on different marketing channels.

5.5.2. Policy Implications

Based on these findings, four key policy recommendations are suggested. First, the variety and heterogeneity in sorting are crucial in policy-making process. While cooperative membership has an undisputable role in the choice of milk marketing channels, few farmers are members of dairy cooperatives. Therefore, one would recommend policies that enhance dairy cooperatives' governance and structures so that mandy farmers get incentivised to be members. Such policies can as well promote the creation of new dairy cooperatives across the country. Well-structured, strengthened, and active cooperatives may attract dairy farmers to seek membership. While this recommendation is justifiable, it is vital to note that cooperative membership may not be the best option for all farmers. Farmers are diverse and only a section of farmers will be better off becoming cooperative members while others are likely to be worse off irrespective of their membership status. Therefore, when farmers can do better as members but are hindered to join cooperatives, then this becomes a serious policy concern. However, if farmers choose not to be members willingly, after their assessment and realising that they are better off when not members, then, there should be less concern about farmers' ability to join cooperatives.

Secondly, adherence to DBP standards is a noble scheme and it influences farmers to sell to MCCs which not only offer higher prices to farmers but also ensure the quality of milk is somewhat guaranteed, as well as the regular and continued purchase of milk. The Ministerial Order policy that prohibits selling milk through other marketing channels except through MCCs may use cooperative membership and food safety concerns to rationalise the reasons behind the preference of MCCs marketing outlet. Hao *et al.* (2018) recommended a blend of policies that promote cooperative membership and public health policies to explain the choice of cooperative marketing channel for apples in China. In addition, policymakers in Rwanda can increase the use of MCCs' attractive milk marketing channels by sharing the advantages of MCCs to dairy farmers through radios and television and the provision of quality extension services. This approach was recently recommended by Kumar *et al.* (2019) to increase the adoption of modern-milk marketing channels among smallholder dairy farmers in India.

Thirdly, although the MCCs are the only marketing channels that conduct basic milk quality tests before buying the milk from farmers, many MCCs are distant from dairy farmers, reducing the incentives for dairy producers to sell to them. Thus, a strong public–private partnership that supports the establishment of new MCCs is recommended so that

farmers have easy access to them. While some MCCs have aggregation points called Milk Collection Points (MCPs) that collect milk from farmers that are located very far from the MCCs, these MCPs are still few and lack infrastructure such as roads (from farms to MCPs). Hence, the construction or rehabilitation of all-weather roads together with an increased number of MCPs and MCCs and their improved financial capacity will facilitate farmers' access to a better marketing channel while meeting an already growing consumer demand for safety and quality in the food industry. Recently, Vandercasteelen *et al.* (2021) promoted the proximity of remotely located dairy farmers to modern buyers such as MCCs as they can improve dairy farms' productivity and farmers' welfare.

Lastly, these findings give an insight into farmers' choice of marketing channels and the role of dairy cooperatives, however, further studies that expand the scope of this analysis are recommended. The limitation of this study is that the analysis was only limited to farmers' standpoints. Future studies that collect information from farmers and agents of each marketing channel will give additional acumens into dairy farmers' choice of marketing channel. Furthermore, there was no data on the characteristics of dairy cooperatives in this study. The type of cooperatives such as farmers-initiated versus government-initiated or open versus closed cooperatives is a key factor that can influence the membership. Therefore, future studies on the effect of cooperatives can include this information in their analysis to give further light to policy makers. Finally, future studies can perform formal tests of equality of coefficients between regimes which were beyond the scope of this paper.

CHAPTER SIX
CONSUMERS' WILLINGNESS TO PAY FOR SAFE AND QUALITY MILK: EVIDENCE FROM EXPERIMENTAL AUCTIONS IN RWANDA

Abstract

A major concern of the Rwandan government and other dairy stakeholders is the safety and quality of milk that goes through informal delivery systems until it gets to the consumers. While the government introduced the dairy best practices scheme that stipulates standards and practices for proper handling of raw milk, consumers' willingness to pay (WTP) for such milk has not yet been assessed. It is also unclear whether consumers are aware of and/or value the safety and quality-related information on types of milk sold in different marketing channels. In this paper, the second price auction mechanism was used to elicit consumers' WTP for pasteurised but unpackaged milk in Rwanda and the effect of providing safety and quality related information on WTP was estimated using the random effect Tobit model. The results show that consumers are willing to pay a price premium for safe and quality milk implying that there is an opportunity for market transformation in the dairy sector. Furthermore, there is a positive and significant effect of providing information to consumers on willingness to pay for safe and quality milk. Based on the results, policies that promote private sector investments in upscaling of milk zones and the establishment of milk dispensing machines selling this type of milk are recommended. There is also a need for information campaigns that increase consumers' knowledge and awareness of the quality of milk consumed.

6.1. Introduction

Although much has been done to improve nutrition worldwide, a quarter of children under five years of age are stunted due to deficient diets. Malnutrition is the main cause of annual child deaths globally (Black *et al.,* 2013; Von Grebmer *et al.,* 2016). Most of the affected children are in Africa, where approximately 31 million are underweight, and about 33% of post-natal deaths are linked to malnutrition (Black *et al.,* 2013). The consumption of animal-source foods (ASF) is one of the ways to curb chronic malnutrition as it provides a variety of micronutrients that are difficult to obtain in adequate quantities from plant-based foods alone (Adesogan *et al.,* 2020). The consumption of safe and quality ASF, such as milk, meat, fish, and eggs enhances children's growth, improves the well-being of pregnant women

and nursing mothers, and reduces illness (Roesel & Grace, 2014). However, low-quality and contaminated ASF are associated with serious health-related diseases (Grace *et al.*, 2018).

Milk is one of the most available ASF in Rwanda as it can be produced daily. While there are processed products from milk such as butter, yoghurt, cheese, and ghee in Rwandan markets, milk is mainly consumed as raw, pasteurised, or fermented also known as Ikivuguto (Karenzi *et al.*, 2013). Over 60% of Rwandan milk is sold through informal marketing channels (farmer-to-consumer directly or farmer-to-consumer via milk traders) (Shema *et al.* 2018). While it is difficult to precisely estimate milk consumption in Rwanda due to the dominance of the informal channels (Karenzi *et al.*, 2013; Rawlins *et al.*, 2014), the Ministry of Agriculture and Animal Resources (MINAGRI) estimates that annual per capita milk consumption has nearly doubled from 37.3 litres to 69.4 litres between 2010 and 2018 (MINAGRI, 2019). Although the country's milk consumption is still below the 220 litres per capita per year recommended by the World Health Organisation (WHO), the overall trend shows an increase in milk consumption in Rwanda.

A major concern of the dairy industry players is that the informal milk sector is selling raw milk (non-processed) susceptible to contamination due to poor on-farm handling and along the different nodes of the milk value chain (Doyle *et al.*, 2015; Reeve, 2017). At the farm level, disease-infected animals and poor adherence to withdrawal periods during cow treatment are also potential sources of contamination (Land O'Lakes, 2017b). Limited or lack of fundamental practices such as hygiene, appropriate cleanness, and basic tools are likely to lead to the supply of unsafe or low-quality milk (Belli *et al.*, 2013; Kussaga *et al.*, 2015). Consequently, in partnership with different international organisations, the Government of Rwanda (GoR) has undertaken several initiatives to achieve the desired safety and quality milk standards (IFAD, 2016).

In 2016, the seal of quality (SoQ) certification scheme, now known as the dairy best practices (DBP) scheme, was introduced. The scheme stipulates standards and practices for proper handling of raw milk geared towards safeguarding the safety and quality of milk sold in the market (Land O'Lakes, 2017). While improving milk safety and quality is an important step forward, Chege *et al.* (2019) argue that assessing consumers' willingness to pay (WTP) for improved food quality, especially in developing countries with low-income consumers is vital. Given the Rwandan dairy sector setting, it is unclear whether consumers are willing to pay for safe and quality milk being promoted and whether consumers are aware of and/or

value the safety and quality-related information on types of milk sold in different marketing channels. This paper seeks to fill this knowledge gap.

The effect of information on consumers' WTP has been a subject of discussion in the literature. McCallum *et al.* (2021) note that in the absence of information, there is a possibility of food fraud, and consumers generally buy in uncertain situations, whereas they would be willing to pay a premium for assured food quality. Some studies have found that consumers are willing to pay higher premiums when they receive positive nutrition or quality-related information about the product (Chege *et al.*, 2019; De Groote *et al.*, 2018; Oparinde *et al.*, 2016). Similarly, Kilders and Caputo (2021) reaffirm an increase in WTP when more information is provided. However, consumers are likely to respond negatively when they have some negative information about the product (Akaichi *et al.*, 2012; De Groote *et al.*, 2016). Hence, the causal effect of information on WTP has become an interesting topic in the recent literature.

The effect of information on consumers' WTP may vary depending on how it is presented to consumers. For instance, consumers in Italy were willing to pay higher premiums for Fairtrade-certified sugar, but their premiums increased, even more, when they got additional information on the Fairtrade system (Ruggeri *et al.*, 2021). Furthermore, Ufer *et al.* (2022) used the Becker-DeGroot-Marschak (BDM) mechanism and applied a within-sample design to test the effects of information regarding the relationship between organic, non-GMO, and animal-friendly dairy production practices in the United States of America (USA). They found that consumers are willing to pay higher premiums for milk with such labels after receiving the information. They also found that adding a redundant label (that has no additional information) to the previous label is associated with greater premiums. For example, in the Netherlands, farmer-owned labels were found to significantly influence consumers' WTP only if there is additional information given to consumers regarding the profit obtained by farmers contrary to investors (Grashuis, 2021). In this study, it is postulated that providing information on the safety and quality of milk to consumers has a positive effect on their WTP.

This postulation is based on previous studies in both developed and developing countries that have assessed consumers' WTP for safe and/or quality foods (Akaichi *et al.*, 2012; Alphonce & Alfnes, 2017; Fadiga & Makokha, 2014; Mtimet *et al.*, 2015; Probst *et al.*, 2012; Wayua *et al.*, 2009). Most consumers in developed countries pay attention to the safety and quality attributes of food products and are willing to pay higher prices if they have

quality-related information on those products (Hoffmann *et al.*, 2019). For instance, Akaichi *et al.* (2012) conducted an experimental auction to evaluate the WTP for certified organic milk in Spain. They found that consumers were willing to pay premium prices for organically produced milk provided they had positive information about organic farming.

Consumers' demand for safe and quality food products in developing countries is also increasing due to income growth and rapid urbanisation (Fadiga & Makokha, 2014; Vandeplas & Minten, 2015). Ortega and Tschirley (2017) reviewed different empirical studies on demand for food safety and quality in Asia and Sub-Saharan Africa (SSA). They found that consumers' concerns about food safety and quality are increasing; hence, the demand for safe and quality food in local markets is projected to be high in SSA. Besides, Alphonce and Alfnes (2017) used four elicitation methods (the Becker-DeGroot-Marschak BDM, the real-choice experiments, the multiple price list, and the multiple price list with stated quantities) in local markets of Tanzania. All four methods showed that consumers were willing to pay a premium for organic and food-safety-inspected tomatoes. Similar findings were also found in many SSA countries, such as Burkina Faso, Benin, Ghana, and Kenya, where consumers in the cities were willing to pay premiums for certified vegetables (Lagerkvist *et al.*, 2013; Probst *et al.*, 2012).

While the mentioned studies present interesting insights into consumer preferences for safe and high-quality food products, those conducted on consumer milk preferences in developing countries are limited. For example, Mtimet *et al.* (2015), using choice experiments, examined Kenyan milk consumers' behaviour toward aflatoxin and found that consumers were willing to pay a significant premium for certified aflatoxin-free milk. Similarly, Wayua *et al.* (2009) assessed consumers' WTP for quality milk using experimental auctions and found that even poor consumers are willing to pay higher premiums for improved sensory characteristics of milk in Moyale town of Kenya. However, this study targeted only milk consumers in open-air markets and considered milk sensory characteristics and safety assurances as the only quality measures.

Although some countries in SSA, such as Rwanda, Kenya and Tanzania, have proposed different policies that promote safety and quality in the dairy sector (Blackmore *et al.*, 2015; Land O'Lakes, 2017b; Omore & Baker, 2011), consumers' WTP for such milk has not yet been assessed. When dealing with low-income consumers, like those in a developing country such as Rwanda, it is crucial to identify (1) whether consumers are able and willing to pay for safe and quality milk, (2) whether providing safety and quality related information

of different types of milk affects consumers' preference for safe and quality milk. Elucidating these can play a critical role in informing implementation plans of such policies.

This research gap is addressed by eliciting consumers' WTP for safe and quality milk and estimate the premium or discount compared to the common[8] and mostly consumed milk. Furthermore, the effect of providing safety and quality-related information on consumers' WTP for safe and quality milk is estimated while controlling for consumers' demographics and socio-economic characteristics, among other variables. Understanding the extent of such an effect can help develop effective sensitisation workshops and campaigns, and use the appropriate channels for information dissemination, leading to an increase in consumers demand for safe and quality milk. Finally, it was hypothesised that (1) consumers are willing to pay higher premiums for safe and quality milk and (2) providing milk safety and quality-related information has a positive effect on consumers' WTP.

This study contributes to the literature in several ways. First, it deals with a topical and relevant issue of the effect of information on WTP for safe and quality food, particularly in developing countries. Furthermore, it contributes to the ongoing discussion of ensuring the safety and quality guidelines in the dairy sector, where consumers' demand for safe and quality dairy products is increasing. Finally, this paper contributes methodologically to the existing literature by expanding the use of incentive compatible methods which are rarely used in developing countries when estimating consumers' WTP. To the best of my knowledge, this study is the first to use an experimental auction mechanism to estimate consumer WTP for milk in Rwanda.

In this paper, safe and quality milk is defined as milk that has met DBP standards and is pasteurised. This definition of safety and quality is based on two components, the DBP requirements and milk pasteurisation. The DBP scheme, which requires farmers to feed cows properly, consult veterinarians regularly for disease control, follow the appropriate husbandry practices, maintain personal hygiene of the milker and of milk utensils, and transport milk to the milk collection centres (MCCs) using stainless-steel cans (IFAD, 2016). Once the milk is at the MCCs, basic safety tests such as antibiotic residues and mastitis tests are conducted to ensure that milk is free from harmful contaminants (Land O'Lakes, 2017b). Furthermore, the milk at the MCC is chilled, which reduces bacterial growth and spoilage, since unrefrigerated raw milk degrades rapidly (Sur *et al.*, 2020; Zhang *et al.*, 2020). In addition,

[8] The common milk is defined as the raw milk that has not gone through any processing stage.

the MCCs conduct alcohol test (that guarantees that there is no coagulation, clotting or precipitation), lacto-densimeter (that tests the density of the milk and ensures that the milk is not adulterated), and organoleptic tests (smell and sight) which are regarded as the basic milk quality tests (Belloque *et al.*, 2009; Tessema & Tibbo, 2009).

Second, the component of pasteurisation is included which is defined as "a microbiocidal heat treatment aimed at reducing the number of any pathogenic microorganisms in milk and liquid milk products, if present, to a level at which they do not constitute a significant health hazard" (FAO/WHO, 2004). Despite the safety of pasteurised milk, it is also considered as milk of high quality as pasteurisation leads to a longer milk shelf-life and it requires a higher number of bacteria (more than 1 million Colony Forming Units per milliliter- cfu/mL) in raw milk to develop enough enzymes that can defect milk post pasteurisation (Murphy *et al.,* 2016). Thus, pasteurisation of milk is necessary to ensure that safety and quality of milk are maintained (Akbay & Tiryaki, 2008; Zhang *et al.,* 2020). In this paper, the considered safe and quality milk is the one which is pasteurised but unpackaged and sold through milk dispensing machines.

6.2. Conceptual Framework

Choice experiments and Contingent Valuation Methods (CVMs) have been widely used to estimate consumer preferences and WTP for food products. However, the methods' hypothetical nature and non-market valuation have been highlighted as limits to reveal the respondents' actual WTP values (Akaichi *et al.,* 2012; Britwum & Bernard, 2018). Experimental auctions are being used as alternative methods due to their revealed preferences nature, where the exchange of real products and real money takes place (Chege *et al.,* 2019; Lusk & Shogren, 2007; Nayga *et al.,* 2006). In experimental auctions, participants are placed in an active market setting where they bid for the product, knowing their bids' economic consequences (Lusk & Shogren, 2007).

While there are several mechanisms in experimental auctions, the second price auction introduced by Vickrey (1961) and the BDM mechanism by Becker *et al.* (1964), are mostly applied as they are relatively easy to implement and to explain to participants (Canavari *et al.,* 2019, Chege *et al.,* 2019). Given that both mechanisms are incentive compatible, and milk is highly perishable (not suitable to be carried to each household as some types of milk should be refrigerated), the second price auction mechanism was applied in this study. In the second price auction, participants are asked to simultaneously submit sealed bids that represent their WTP for the product. The highest bidder wins the auction and

purchases the product not at his/her own bid but rather at the second-highest bid among participants in the auction.

The theoretical behaviour of auctions was limited to the incentive compatibility of the second price auction mechanism. An incentive-compatible auction is one that makes bidders bid truthfully (the bids that represent their true values for the product). When each bidder bids truthfully, then the bidder's market price does not depend on what she/he bids. Assuming (v_i) is the value that person i places toward a product. If this person is interested in the product, she/he submits a bid (b_i) to compete with N bidders whose values are independently drawn from a known distribution. If the person is the highest bidder, she/he wins the auction and pays the market price (p), which is equal to the second-highest bid in the second-price auction mechanism. On the other hand, if the person does not win the auction, her/his bid is normalised to zero i.e. $U\,(0) = 0$. Consequently, the winner's utility is derived from the difference between her/his value for the product and the market price, presented as: $U_i(v_i - p)$, where U_i is a utility function increasing in income, and p is the market price.

Assuming individual i's anticipation about the price is characterised by the cumulative distribution function $G_i(p)$ with support $\{\overline{p_i}, \underline{p_i}\}$ and the associated probability density function $g_i(p)$. The individual submits a bid (b_i) to maximize expected utility, such that:

$$E[U_i] = \int_{\underline{p_i}}^{b_i} U_i\,(v_i - p) dG_i(p) + \int_{b_i}^{\overline{p_i}} U_i(0) = \int_{\underline{p_i}}^{b_i} U_i\,(v_i - p) g_i(p) dp + \int_{b_i}^{\overline{p_i}} U_i(0) \qquad (6.1)$$

where the first and second integrals represent the case of the winner and the loser of the auction, respectively. The optimal bid is obtained by taking the first-order condition of equation (6.1) with respect to b_i (Lusk & Shogren, 2007, p. 21), thus:

$$\frac{\partial E[U_i]}{\partial b_i} = U_i(v_i - b_i) g_i(b_i) = 0 \qquad (6.2)$$

Solving equation (6.2), the person's expected utility is maximized when she/he submits a bid equal to her/his true value for the product $(b_i = v_i)$. However, there are consequences of paying more when the bidder over-bid $(b_i > v_i)$ or losing a good deal when the bidder under-bid $(b_i < v_i)$ her/his true value.

6.3. Methodology

6.3.1. Study Area and Sampling Design

The WTP experiments were conducted in September 2020 in Musanze and Ruhango districts of Rwanda. Musanze district is located in the Northern province and covers an area of 530 km^2 while Ruhango district is in Southern province covers 627 km^2 (NISR, 2014). The larger parts of these districts are rural areas where most of the population own cows and consume self-produced milk. However, the districts have vibrant urban centres (towns). The focus on the large urban centres of these districts as most of their residents buy and consume large volumes of milk.

The multi-stage sampling procedure was used to recruit respondents for the experiment. The information from local administrative offices at the district level and the National Institute of Statistics of Rwanda (NISR), were used to identify the villages within the urban centres. In total, a list of 54 villages (26 in Musanze town and 28 in Ruhango town) was received, and in collaboration with village leaders, a sampling frame of all households in these villages that only consume purchased milk (i.e. they do not keep cows) was obtained.

The total sample was estimated based on the power calculation approach. The power of 0.80 is enough to detect an effect of at least 0.20 difference in bids between treatment groups when $\alpha = 0.05$ (Spybrook *et al.*, 2011). This power has a corresponding minimum detectable effect size of 2.93 (Bloom, 1995). Using the optimal design (OD) software, the minimum sample size required was 370 participants in this study. To get an equal number of participants in each session, 384 participants (192 in each treatment group and 192 in each district) were targeted. Using a systematic random sampling technique, participants from 384 households were invited but 386[9] showed up (194 in Musanze and 192 in Ruhango district). The participants were heads of households (63%) or spouses (33%) who mainly make decisions on household milk purchases.

6.3.2. Experimental Design

In this study, lab experiments were used. The lab experiments were preferred over field experiments for several reasons. First, there is less noise[10] in a lab experiment and the experimenter has more control over the experimental procedure, which reduces the effects of

[9] There were 2 incidences where 2 people had the same names in the same village and the village leaders informed both to participate to the experiment.

[10] Less noise because lab experiments have a limited number of people (only the experimenters and participants) which increases the participants' concentration, unlike field experiments or real market environments, which have several people including non-participants who may even interfere with the experimental procedures.

confounding factors (Lusk & Shogren, 2007; Vecchio & Borrello, 2019). Second, the lab experiment makes the sampling procedure easy as participants are randomly drawn from a population, while in a field experiment, there is a higher probability of getting a biased sample as participants self-select themselves into the experiment (Belot & James, 2014). Furthermore, Harrison and List (2004) argue that the product type to be auctioned and the experimental environment should be considered, among other factors, when choosing between lab and field experiments. Since some types of milk in this experiment were to be kept refrigerated and due to COVID-19 guidelines, the lab experiment was more appropriate.

After getting the Institutional Review Board (IRB) approvals for the study, two hotels (one in each district) were rented. Each hotel had two separate half-open tents (one far from the other) set in gardens to allow for better aeration as a requirement for COVID-19 guidelines. The participants were invited into the lab experiments and were informed that they would be participating in auction experiments of milk, where they would have an opportunity to buy some types of milk that would be presented to them. While it is a common practice to give participation fees in economic experiments to avoid participants' cash constraints, participation fees increase participants' disposable income, which may affect the bids, especially for low-priced products (Rutström, 1998, Schmidt, & Bijmolt, 2020). Furthermore, Berry *et al.* (2020) argue that participation fees have the house money effect and participants may be less price sensitive for products of small prices. Hence, there was no participation fees provided in this experiment. However, participants were informed that their transport costs would be reimbursed at the end of the experiment. When all participants arrived in the lab, the study was described to them and their consents to participate was asked.

The experimental design followed the approach of Chege *et al.* (2019) to estimate the effect of information on WTP. The between-sample-design was applied by randomly assigning participants into either treatment or control groups using a systematic random sampling. Each participant randomly picked one piece of paper (from a pool of sealed pieces of paper), and those with odd numbers were sent to the control group tent while those with even numbers were sent to the treatment tent. The same piece of paper also contained the participant's identification number to ensure their anonymity during the experiment. After assigning each participant to either the control or treatment group, a written script translated in Kinyarwanda (English version is in appendix F.1), explaining the second price auction

mechanism was read to all participants. The experimenters clearly demonstrated the benefits of bidding truthfully and explained the risks of overbidding and underbidding.

There were two rounds of trials with one litre of mango juice that were conducted to familiarize participants with the auction procedure and to test if they clearly understood the bidding process before the actual bidding with milk. While some studies make the trial sessions real, the method of Akaichi *et al.* (2012) of no actual economic exchange when each trial session is over was adopted in this study. This is because the cash-in-hand winners of the trial rounds reduce when they pay for the products, which may affect their bids for the actual product (Morawetz *et al.*, 2011). After the trial sessions, the experimenters encouraged participants to think about the process and gave a simple quiz to test further their individual's understanding of the mechanism (English version of the quiz is in appendix F.2). Lastly, the experimenters provided time for questions and answers until they were convinced that every participant understood the auction mechanism. The actual experiment on milk was then conducted following the steps in Figure 6.1 below. Participants were clearly explained that they could bid zero Rwf for any type of milk if they were disinterested or did not wish to buy that specific type of milk. Each session lasted for two hours.

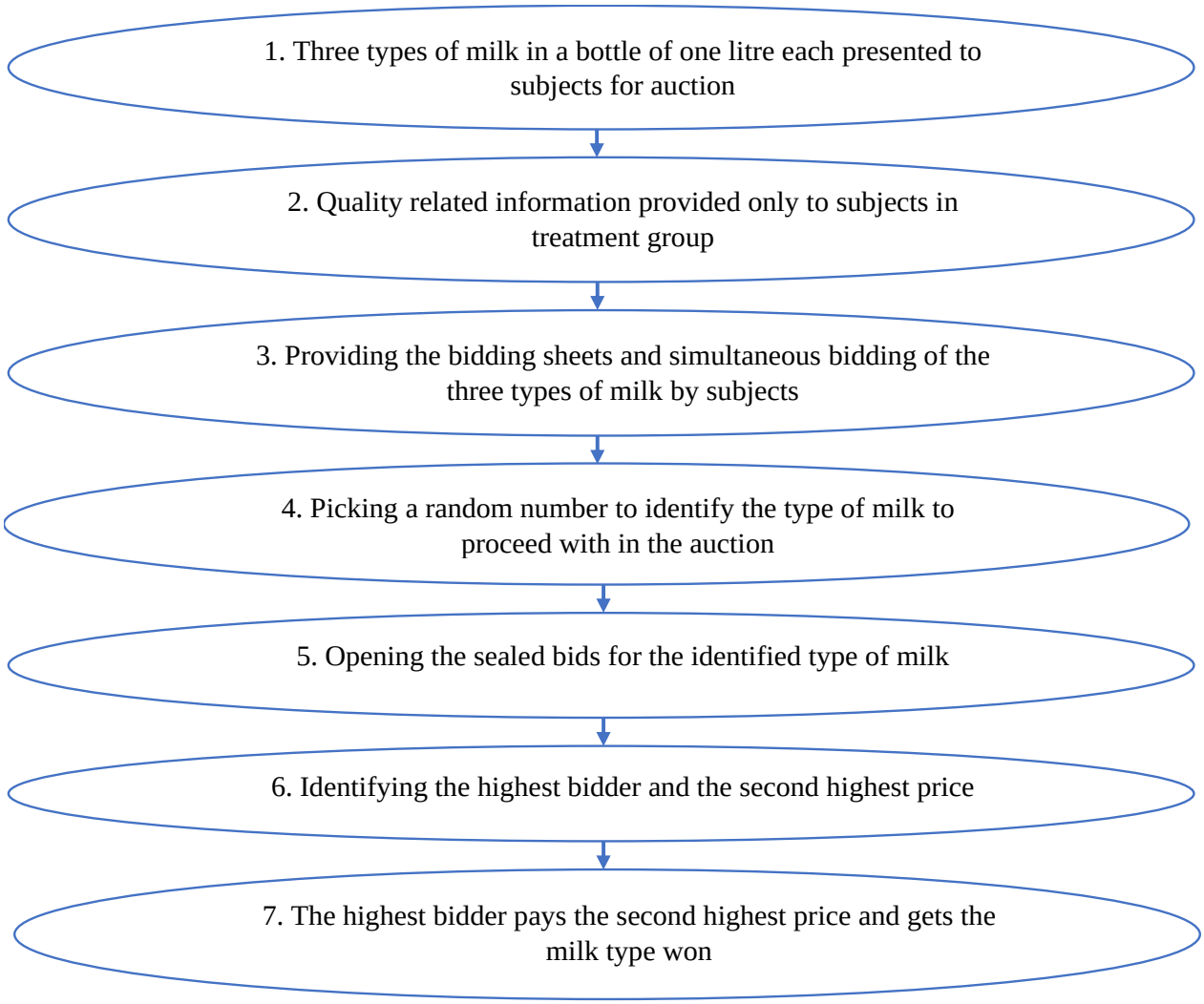

Figure 6.1: Steps followed in implementing the WTP experiment using second-price auction

The three types of milk in a bottle of one litre each were presented to participants for auction. These three types were milk A (raw milk bought directly from the dairy farmer), milk B (raw milk bought from the MCC), and milk C (Pasteurised but unpackaged milk bought from the milk processor). It is important to note that milk C is the only type of milk that is not common in the study area; hence, participants consider it as the new or unfamiliar product. Each milk type was in a transparent one-litre bottle labelled in Kinyarwanda, indicating the type of milk with a picture showing the source of the milk (see appendix F.3).

The treated group received milk safety and quality-related information that the experimenter read out in Kinyarwanda to ensure that every participant in the treatment group gets the same piece of information. Following Teuber *et al.* (2016), the safety and quality related information card was designed in Kinyarwanda and its English version is shown below.

Milk safety and quality related information card

Milk of different qualities depending on the source, is available for sale in various outlets. The milk safety and quality attributes vary according to organoleptic test, mastitis, and pasteurization, among others. The following milk types, according to sources, are presented with a profile of safety and quality attributes.

Milk type A: Raw milk from the farmer	**Milk type B: Raw milk from the MCC**	**Milk type C: Milk from Processor**
1. Basic tests such as lacto densimeter, temperature, alcohol, antibiotic residue, and mastitis are not conducted	**1.** Basic tests such as lacto densimeter, temperature, alcohol, antibiotic residue, and mastitis are conducted	**1.** Basic tests such as lacto densimeter, temperature, alcohol, antibiotic residue, and mastitis are conducted
2. Boiled (Not 106asteurized)	**2.** Chilled and boiled (Not 106asteurized)	**2.** Not boiled (Pasteurised)

The difference between boiling, chilling, and pasteurization

- Contamination of milk with germs and poisons (such as drug residues) is often not detected by the smell, taste, or appearance of milk. Chilling milk is cooling raw milk to low temperature which reduces its bacterial growth and spoilage. While the safety and quality of non-pasteurised milk (either chilled or not) is unknown, most consumers boil it first before consumption. Boiling raw milk kills most harmful bacteria or pathogens to prevent illness but does not remove some bacteria like coliforms and some poisons. However, boiling for a long time (more than 5 minutes) may make milk less nutritious.
- Pasteurisation involves heating milk to kill the majority (but not necessarily all) of bacteria, yeasts and moulds. The bacteria that survive mostly do so in a damaged, non-viable form. Note that non-pasteurised milk contains significantly higher quantities of harmful and introduced bacteria than the pasteurised milk. The process also increases the product's shelf life. Pasteurising milk does not result in a significant loss of vitamins, carbohydrates, minerals or fats. Studies show that only minor losses of the water-soluble vitamins B1, B6, B9, B12 and C occur through this process. However, considering the already low levels of these nutrients in milk, these losses are insignificant.

Each participant was given the bidding sheets and simultaneously bade for each type of milk. Afterwards, one participant randomly picked a piece of paper to identify the type of

milk to proceed with the auction. Then, the experimenter opened all bids for the identified type of milk and together with the participants, they identified the highest bidder and the second highest bid. Finally, the highest bidder paid the second highest price and was given that type of milk.

Each session concluded with a short post-experiment questionnaire that had questions about the participant's socio-demographic characteristics, milk purchasing habits, and knowledge about DBP. Four sessions per day (two in the morning and two in the afternoon) were conducted, where each session had eight participants except the last two sessions, which had nine participants. The treatment and control sessions were conducted simultaneously during morning and afternoon sessions. Hence, 48 sessions in total were conducted, with 24 in each district and 24 for each treatment group.

6.3.3. Empirical Model

Participants in the experiment would bid positive amounts for any type of milk, including zero price if disinterested in the product; hence the bids are left censored. The ordinary least squares (OLS) model becomes inappropriate when the dependent variable is censored at zero. In such cases, the Tobit model developed by Tobin (1958) is suitable because it accounts for the left-censored nature of the outcome variable. However, given that there was a single session in which consumers submitted bids for three different types of milk, it follows that the data is panel in nature, and the error terms are likely to be correlated. Consequently, following Dinc-Cavlak and Ozdemir (2021) and Teuber *et al.* (2016), the random-effects Tobit model was used to account for left censoring and panel data type while controlling for unobserved heterogeneity. The random effect Tobit model was estimated as:

$$WTP_{ij}^{*} = \alpha + \gamma T_i + \beta X_{ij} + u_i + \varepsilon_i \tag{6.3}$$

$$WTP_{ij} = \begin{cases} WTP_{ij}^{*} & if \ WTP_{ij}^{*} > 0 \\ 0 & if \ WTP_{ij}^{*} \leq 0 \end{cases} \qquad \varepsilon_i \sim N(0, \sigma^2) \tag{6.4}$$

where WTP_{ij}^{*} is a latent variable for bids while WTP_{ij} is consumer *i*'s WTP (observed bid) for milk *j*, T_i is a vector of treatment variables that identify the effect of information and X_{ij} is a vector of consumer and milk characteristics, α is an intercept parameter, while γ and β are parameter estimates corresponding to treatment, and consumer and product characteristics, respectively, u_i is the consumer's specific disturbance due to correlations across submitted bids for different types of milk, and ε_i is the normally distributed individual bid's specific error term with mean 0 and constant variance.

6.3.4. Control Variables

In estimating the effect of information, other variables that may influence the WTP for safe and quality milk were also controlled for. These variables were categorised into six categories; respondents' demographics and socio-economic variables, milk purchasing habits, type of milk frequently purchased, time of the day, consumer risk perception and attitudes, and location variable. For instance, sex of the respondent may influence the WTP as women are more involved in food purchasing and preparation, especially in Africa; hence, they are in a better position to value different food products than men (Chege *et al.*, 2019). However, the effect of sex of the participant may be ambiguous as women may have little disposable income, which may limit their WTP for quality food products (Maxwell *et al.*, 2000). It was expected that participants with higher education levels would be willing to pay a premium for quality milk as they may be aware of bacteria and pathogens risks in non-processed milk (Wayua *et al.*, 2009).

Likewise, having children below five years was expected to positively influence the WTP as parents are more conscious about the quality of food fed to their children; hence, they may be willing to pay more for quality and nutritious food products (Oparinde *et al.*, 2016). Since there were no participation fees given, it was expected that the participant's income would positively influence the WTP, as income is a good proxy for a consumer's economic status. It follows, therefore, that high incomes would be associated with high purchasing power. The type of mainly purchased milk was also included to account for habitual purchasing that may influence the WTP for food products (Grunert, 2005). It was anticipated that habitual consumers of milk B were likely to pay premiums than habitual consumers of milk A since milk B is usually more expensive than milk A.

Consumer risk perception and attitudes were represented by the level of trust participants have in food safety and quality labels and the influence of quality on milk purchase decision. Both variables were measured using 4-point Likert scale. Hunter *et al.* (2012) and Liu *et al.* (2019) found that consumer perceptions and attitudes towards health risks affect the WTP for food products. The experiments were conducted in the morning (9:00 – 11:00 am) and in the afternoon (1:00 – 3:00 pm). Therefore, a dummy variable was included to represent the time of day the experiment was conducted to control for the hunger effect. It was expected that experiments held in the afternoon (lunch hour) would positively influence the WTP as participants may bid with the intention of consuming the milk immediately. District-specific factors were controlled by including a dummy location

variable in the model specifying whether the participant resides in Musanze or Ruhango district.

6.4. Results and Discussions

6.4.1. Descriptive Statistics

The summary statistics of key variables used in the analysis, by treatments, are presented in Table 6.1. Overall, around 60% of participants were females who are mostly in charge of food purchasing in the household. On average, participants were relatively young (43 years) and educated (as 40% have primary education level and 54% have higher than primary level), implying that they could understand the bidding mechanism. On average, a household had recently purchased 1.7 litres of milk while 10% and 90% are habitual consumers of milk B and milk A, respectively. Participants in treatment group trust in food safety and quality labels more than those in control group though the statistical difference is small ($p<0.1$). Likewise, milk quality slightly influences milk purchase decision of participants in control group ($p<0.01$) compared to treatment group that is highly influenced by the quality ($p<0.01$).

A complete balance between treatments is difficult to achieve as it requires larger sample sizes, so that means of participants' characteristics in the sample get closer to the population's means (Canavari *et al.,* 2019). The data indicate that more participants with primary education level were in the control group ($p<0.01$) while those with higher than primary were in the treatment group ($p<0.01$). Participants in the treatment group had recently purchased larger quantities of milk ($p<0.01$), and they had heard about DBP prior to the experiment ($p<0.01$) compared to participants in the control group. On the other hand, participants in the control group mainly buy milk B and travel relatively a shorter distance to buy milk ($p<0.05$) compared to participants in the treatment group. Despite the mentioned few variables that vary across treatments, most of the key participant's characteristics are similar between control and treatment groups (Table 1). Consequently, the randomization was quite good as "proper randomization to treatment does not always ensure complete balance" (Altman, 1985; Briz *et al.,* 2017; Canavari *et al.,* 2019).

Table 6.1: Summary statistics of key variables by treatment group

Variables	Description	Overall (N=386)	Control (1) (N=194)	Treatment (2) (N=192)	t-test (1-2)
		Mean	Mean	Mean	
Sex of the participant	=1 if male	0.40	0.39	0.42	-0.60
		(0.49)	(0.49)	(0.49)	
Age of the participant	Age in years	43.26	43.42	43.10	0.26
		(11.10)	(12.57)	(11.40)	
Education level of the participant	=1 if no formal education	0.06	0.07	0.05	1.48
		(0.01)	(0.01)	(0.01)	
	= 1 if primary level	0.40	0.48	0.32	5.50***
		(0.01)	(0.02)	(0.02)	
	=1 if higher than primary	0.54	0.45	0.63	-6.12***
		(0.01)	(0.02)	(0.02)	
Marital status of the participant	=1 if married/living together	0.71	0.70	0.71	-0.47
		(0.46)	(0.46)	(0.45)	
	=1 if divorced/separated	0.11	0.12	0.10	1.05
		(0.38)	(0.33)	(0.31)	
	=1 if widowed	0.12	0.12	0.11	0.48
		(0.32)	(0.33)	(0.32)	
	=1 if single	0.06	0.05	0.07	-1.16
		(0.24)	(0.22)	(0.25)	
Children below 5 years	Number of children below 5 years in the household	0.71	0.70	0.72	-0.52
		(0.76)	(0.76)	(0.75)	
Income in Rwandan Francs[a] (Rwf)	HH monthly income in Rwf	79,633	79,025	80,247	-0.11
		(105,536)	(113,952)	(96,586)	
Prior safety information	(=1 if heard about DBP before)	0.89	0.86	0.92	-3.35***
		(0.31)	(0.35)	(0.27)	
Price of milk purchased	Price of milk purchased recently in Rwf per litre	252	253	251	0.27
		(74)	(68)	(79)	

Amount of milk purchased	Average amount of milk purchased recently in litres	1.69 (0.99)	1.56 (0.95)	1.82 (1.01)	-4.53***
Type of milk mainly purchased	=1 if milk B	0.10 (0.30)	0.12 (0.32)	0.08 (0.28)	2.00**
Distance to source of milk	Distance from the HH to source of milk in km	0.66 (1.07)	0.59 (0.92)	0.73 (1.21)	-2.31**
Time of day	=1 if participant is in the afternoon experiment	0.49 (0.50)	0.49 (0.50)	0.50 (0.50)	-0.20
Trust in food safety and quality labels	=1 if participant fully trusts	0.35 (0.47)	0.32 (0.47)	0.38 (0.48)	-1.79 *
	=1 if participant slightly trusts	0.42 (0.49)	0.46 (0.49)	0.38 (0.48)	2.89 ***
	=1 if participant doesn't really trust	0.20 (0.39)	0.19 (0.39)	0.20 (0.40)	-0.53
	=1 if participant doesn't at all trust	0.04 (0.18)	0.03 (0.15)	0.05 (0.21)	-1.92 *
Quality influence on milk purchase decision	=1 if quality highly influences	0.48 (0.50)	0.29 (0.45)	0.67 (0.47)	-13.89 ***
	=1 if quality slightly influences	0.34 (0.47)	0.49 (0.50)	0.19 (0.39)	11.45 ***
	=1 if quality doesn't really	0.07 (0.26)	0.09 (0.29)	0.05 (0.22)	2.67 ***
	=1 if quality doesn't at all influence	0.11 (0.31)	0.12 (0.33)	0.09 (0.28)	1.94 *
Location	=1 if participant resides in Musanze district	0.50 (0.50)	0.51 (0.50)	0.49 (0.50)	0.30

Note: Standard deviations in parentheses and ***, **, * denote the difference in means at 1%, 5%, and 10% levels of significance, respectively. [a] 1 USD = 940 Rwf when the experiment was conducted in September 2020.

6.4.2. Willingness To Pay for Safe and Quality Milk

Consumers' mean WTP for each type of milk by treatment group and their WTP a premium or discount by type of milk are presented in Tables 6.2 and 6.3, respectively. On average, consumers are willing to pay 215 Rwf and 304 Rwf for one litre of milk A and B, respectively (Table 6.2). The bids are within the milk price range in actual markets. For instance, milk type A price ranges between 150 – 250 Rwf/l when a consumer buys directly from the producer or a milk trader as there is room for negotiation. On the other hand, milk type B is sold by MCCs at 220 Rwf/l. However, few individual consumers buy from the MCCs (essentially those residing near the MCCs) as their main purchase points are shops/kiosks that resell this milk at a price varying between 250 – 350 Rwf/l. The overall mean WTP for milk type C is 457 Rwf/l and it is higher than its actual price of 430 Rwf/l in milk zones of Kigali city.

Table 6.2: Consumer' WTP for one litre of different types of milk by treatment

Variables	Overall		Control (1)		Treatment (2)		t-test
	Mean	SD	Mean	SD	Mean	SD	(1-2)
Bids for milk A in Rwf/litre	215.08	66.80	207.68	69.19	222.55	63.60	-2.20**
Bids for milk B in Rwf/litre	304.30	108.92	285.98	112.57	322.81	102.11	-3.37***
Bids for milk C in Rwf/litre	457.31	206.79	410.82	201.59	504.27	201.80	-4.55***
WTP a premium for milk B from milk A in Rwf/litre	89.22	76.66	78.30	5.84	100.26	5.06	-2.84***
WTP a premium for milk C from milk A in Rwf/litre	242.22	191.01	203.14	184.51	281.72	189.80	-4.12***
WTP a premium for milk C from milk B in Rwf/litre	153.01	153.59	124.84	144.97	181.46	157.15	-3.68***

Note: ***, **, denote the difference in means at 1% and 5% level of significance of, respectively.

Comparing treatments, consumers in the treatment group are willing to pay 222 Rwf/l (7% more) for common milk type A which is statistically significantly higher ($p<0.05$) than 208 Rwf/l of those in the control group. While this contradicts the findings of Kanter et al. (2009), who found a premium reduction for the conventional product when information about the new product is provided, it concurs with De Groote et al. (2018), who found that providing information increases the WTP for all products though not at the same magnitude.

In their BDM experiment, De Groote *et al.* (2018) found that providing information to consumers in Senegal increased their WTP by 6% for traditional millet flour while their WTP for different improved porridge flour increased by 13-21%. Expectedly, the treatment group's bids for milk B and C were significantly higher ($p<0.01$) than the bids of the control group. The treatment group was willing to pay 323 Rwf/l (13% more) for milk B and 504 Rwf/l for milk C (22% more) compared to the control group's mean WTP of 286 Rwf/l and 411 Rwf/l for milk B and C, respectively.

Furthermore, Table 6.2 displays the differences in mean WTP between treatment and control groups. Both consumers in treatment and control groups were willing to pay premiums to upgrade from milk A to milk B and milk C as well as from milk B to milk C. However, consumers in the treatment group were willing to pay significantly higher premiums ($p<0.01$) than those in the control group, probably due to safety and quality related information received. Consumers in treatment group are willing to pay 100 Rwf/l more than the price of milk A to upgrade to milk B, while those in control group are willing to pay a premium of 78.30 Rwf/l. Likewise, the treatment group was willing to pay 282 Rwf/l and 181 Rwf/l while the control group was willing to pay 203 Rwf/l and 125 Rwf/l more to upgrade from milk A and from milk B to milk C, respectively.

Table 6.3: Consumers' WTP a premium or discount by type of milk

x) Percentage of consumers who are willing to pay a premium, discount, or the same price to upgrade from milk A to B												
	Overall				**Control**				**Treatment**			
	Overall	WTP > by 25%	WTP > by 50%	WTP > by 75%	Overall	WTP > by 25%	WTP > by 50%	WTP > by 75%	Overall	WTP > by 25%	WTP > by 50%	WTP > by 75%
[a]WTP a premium(%)	93.01	66.32	23.06	11.66	89.69	61.34	20.10	10.82	96.35	71.35	26.04	12.50
[b]WTP a discount(%)	4.92				8.25				1.56			
[c]WTP the same (%)	2.07				2.06				2.08			
y) Percentage of consumers who are willing to pay a premium, discount, or the same price to upgrade from milk A to C												
	Overall				**Control**				**Treatment**			
	Overall	WTP > by 25%	WTP > by 50%	WTP > by 75%	Overall	WTP > by 25%	WTP > by 50%	WTP > by 75%	Overall	WTP > by 25%	WTP > by 50%	WTP > by 75%
[a]WTP a premium(%)	96.37	93.01	77.72	58.81	93.81	89.18	69.07	50.00	98.96	96.88	86.46	67.71
[b]WTP a discount(%)	2.59				4.64				0.52			
[c]WTP the same (%)	1.04				1.55				0.52			
z) Percentage of consumers who are willing to pay a premium, discount, or the same price to upgrade from milk B to C												
	Overall				**Control**				**Treatment**			
	Overall	WTP > by 25%	WTP > by 50%	WTP > by 75%	Overall	WTP > by 25%	WTP > by 50%	WTP > by 75%	Overall	WTP > by 25%	WTP > by 50%	WTP > by 75%
[a]WTP a premium(%)	92.11	63.47	35.49	19.69	87.11	54.12	28.87	16.49	96.36	72.92	42.19	22.92

[b]WTP a discount(%)	3.89	6.19	1.56
[c]WTP the same (%)	4.40	6.70	2.08

Notes: [a]WTP for milk B is > WTP for milk A or [a]WTP for milk C is > WTP for milk A and B; [b]WTP for milk B is < WTP for milk A or [b]WTP for milk C is < WTP for milk A and B; and [c]WTP for milk B = WTP for milk A or [c]WTP for milk C = WTP for milk A and B

Results in Table 6.3 show that 93% of consumers were willing to pay a premium for milk B on top of price of milk A, while 2% are willing to pay the same price for milk A and milk B, and another 5% would instead require a discount to prefer milk B over milk A. Similarly, 96%, 1%, and 3% of consumers were willing to pay a premium, the exact price and require a discount for milk C on top of price of milk A respectively. Also, 92% of consumers were willing to pay a premium for milk C from milk B while 4% of consumers were willing to pay the same price and 4% would require a discount to upgrade to milk C from milk B. Considering the premium, 66%, 23%, and 12% of consumers were willing to pay respectively at least 25%, 50%, and 75% more than the price of common milk A to upgrade to milk B. On the other hand, 93%, 78%, and 59% of consumers were willing to pay at least 25%, 50%, and 75% more than the price of common milk A to upgrade to milk C, respectively. Lastly, 63%, 35%, and 20% of consumers were willing to pay at least 25%, 50%, and 75% more than the price of milk B as a premium to upgrade to milk C, respectively. Hence, the treatment group had higher percentages of consumers willing to pay higher premiums for higher quality milk than the control group.

6.4.3. Effect of Safety and Quality-Related Information on WTP

Following the model estimations, the WTP for milk in hundreds of Rwandan francs was used as a dependent variable, and two dummies for milk B and C were included as explanatory variables while milk A was used as the base for comparison. A dummy variable of whether consumers had heard about DBP before was also included in the model as a proxy for safety information that consumers may have prior to the experiment. The safety and quality-related information dummy was interacted with the Milk B and C dummies and the prior safety information dummy to test the real effect of safety and quality-related information on WTP. The robustness of the findings was further tested by estimating the random effect model, and the similar results were found (appendix F.4). The similarity of results is probably because there was no zero bid in the data, hence, the random effect Tobit

model results are presented as consumers were requested not to bid a negative price. Table 6.4 below presents the parameter estimates of determinants of WTP for one litre of milk.

The results showed that consumers were willing to pay significant premiums ($p<0.01$) of 78 Rwf/l for milk B and 203 Rwf/l for milk C on top of milk A, ceteris paribus. The coefficient of safety and quality-related information was positive and had a significant effect ($p<0.05$), implying that providing milk safety and quality information to consumers increases their WTP for that milk. Probably, after consumers had received information about the safety and quality of the new type of milk, they are likely to value the new product more than the common milk they usually consume. This finding is consistent with Alphonce and Alfnes (2017) and Mtimet *et al.* (2015), who found higher premiums for food-safety-inspected tomatoes in Tanzania and aflatoxin-free certified milk in Kenya, respectively, after exposing consumers to food safety and quality information. Furthermore, this result concurs with Chege *et al.* (2019) and Oparinde *et al.* (2016), who found larger premiums for porridge flour in Kenya and Uganda and for biofortified cassava in Nigeria, respectively, after providing nutrition information to consumers.

Generally, consumers' safety information before the experiment increases their WTP by 46 Rwf/litre ($p<0.05$). This explains the control group's higher bids for milk B and milk C than milk A, where consumers rely on previous safety or quality information they may have prior to the experiment even if they are not exposed to additional quality-related information. Conversely, the interaction of safety-quality related information given in the experiment and safety information that consumers have prior to the experiment had a negative and significant effect ($p<0.05$) on WTP. This result demonstrates that farmers who had some milk safety-related information prior to the experiment may suffer from 'I know it all' syndrome, consequently downplaying the safety and quality-related information provided in the treated group. The interaction variable between milk C and safety-quality related information dummy is positive and significant ($p<0.01$), implying that the safety-quality related information increases the premiums paid for milk C on top of milk A by 79 Rwf/litre. However, the interaction variable between milk B and the safety-quality related dummy was insignificant, indicating that providing safety-quality-related information does not affect premiums paid for milk B over milk A.

Table 6.4: Parameter estimates of Random Effect Tobit Model estimating determinants of WTP for one litre of safe and quality milk

Dependent variable: WTP for milk in hundreds of Rwf/litre	Coefficients	Std. Err.
Milk B (Yes=1, 0 otherwise)	0.78 ***	0.10
Milk C (Yes=1, 0 otherwise)	2.03 ***	0.10
Safety and quality-related information (=1 if received)	0.77 **	0.34
Prior safety information (=1 if heard about DBP before)	0.44 **	0.23
Safety and quality-related information x Prior safety information	-0.75 **	0.36
Safety and quality-related information x Milk B	0.22	0.15
Safety and quality-related information x Milk C	0.79 ***	0.15
Sex of the participant (=1 if male)	-0.17	0.12
Age of the participant in years	0.01 *	0.01
Education level of the participant		
=1 if the participant has primary education level	0.44 *	0.25
=1 if the participant has higher than primary level	0.25	0.25
Marital status of the participant		
=1 if the participant is divorced or separated	-0.03	0.18
=1 if the participant is widowed	-0.38 **	0.20
=1 if the participant is single	0.58 **	0.24
Number of children below 5 years in the household	0.10	0.08
Household monthly income in hundreds of Rwf	-0.0001	0.0001
Price of milk purchased recently (in hundreds of Rwf/litre)	0.31 ***	0.08
Amount of milk purchased recently in litres	-0.03	0.06
Type of milk mainly purchased (=1 if milk B)	-0.61 ***	0.18
Distance from the household to source of milk in km	0.15 ***	0.05
Time of day (=1 if in the afternoon)	0.19 **	0.10
Trust in food safety and quality labels[c]		
=1 if the participant slightly trusts	-0.07	0.12
=1 if the participant doesn't really trust	-0.26 *	0.15
=1 if the participant doesn't trust at all	-0.07	0.29
Quality influence on milk purchase decision[d]		
=1 if quality highly influences	0.08	0.20
=1 if quality slightly influences	-0.001	0.20

=1 if quality doesn't really influence	-0.06	0.26
Location (=1 if in Musanze district)	0.10	0.12
Constant	0.21	0.49
Sigma_u	0.81 ***	0.05
Sigma_e	1.03 ***	0.03
Log-likelihood	-1,877.57	
Number of observations	1,158	

[a] No formal education serves as reference, [b] married serves as a reference, [c] fully trusts serves as reference, and [d] doesn't influence at all serves as reference. *****, **, *** denote the level of significance at 1%, 5%, and 10% respectively.

6.4.4. Other Factors Influencing WTP

In addition to provision of information, there were other factors that influence the WTP for safe and quality milk (Table 4). Education level, age, and marital status of participants significantly influence the WTP for quality milk. Participants who have primary level of education were willing to pay more (p<0.1) for safe and quality milk than those with no formal education. This was expected as educated consumers may be aware of bacteria and pathogens found in unprocessed milk, hence, they are willing to pay higher premiums for quality milk. This finding concurs with previous studies that found a positive and significant influence of education on WTP for tested and labelled aflatoxin-free maize in Kenya (De Groote *et al.,* 2016) and instant fortified pearl millet in Senegal (De Groote *et al.,* 2018). Similarly, widowed participants were willing to pay less (p<0.05) for quality milk than married (living with spouses) participants while single participants have higher WTP (p<0.05) compared to married ones. This may be associated with high price of safe and quality milk that may limit the WTP for widows/widowers while single people may not feel the burden since they buy small quantities for own consumption. Like Chege *et al.* (2019), the WTP was positively influenced by age of participants, implying that elderly consumers may be willing to pay more for safe and quality milk than younger ones.

Consumers in the sample were mainly consuming milk A and milk B that were available in the two districts. Unexpectedly, results show that the WTP of habitual consumers of milk B decreases by 59 Rwf/litre (p<0.01) compared to that of typical consumers of milk A. This may be due to the quality perception of consumers of milk B, knowing that the milk they consume is bought from the MCCs and goes through safety and quality checks before its acceptance from farmers. Expectedly, the price of milk purchased recently increases the WTP

(p<0.01), implying that the previous price paid for the substitute product can be used as a reference price and can influence consumers' WTP. This result concurs with He *et al.* (2021), who found that consumers' WTP for strawberries is influenced by the price paid for their most recent strawberries purchase. Similarly, the reference price effect in WTP experiments is confirmed by Grunert *et al.* (2009) and Ruggeri *et al.* (2021) who argue that a higher reference price increases the WTP while a lower reference price decreases the WTP in real buying settings.

Distance from the household to the point of milk purchase positively and significantly influenced the WTP (p<0.01). One possible reason is that consumers who buy milk far from their households probably buy it from supermarkets, where milk is generally more expensive compared to milk that is bought from the neighbouring producer or milk trader. Hence, their WTP is higher as they are used to expensive and quality milk sold in supermarkets. On consumer risk perception, the WTP decreased (p<0.1) for participants who do not really trust in food safety and quality labels compared to participants who fully trust in them. This reaffirms that the trust consumers have in safety and/or quality of food products may affect their preferences and WTP for those products (Bernard *et al.*, 2019; Liu *et al.*, 2019). Lastly, the time of the day when the experiment was conducted influenced the WTP (p<0.05) as experiments conducted in the afternoon increased the WTP by 20 Rwf/litre, thus confirming the prospect of hunger effect. This finding concurs with Briz *et al.* (2015) and Morawetz *et al.* (2011) who found that hungry participants may bid more for a ready-to-eat product such as milk during lunchtime.

6.5. Conclusion and Recommendations

The main objective of this paper was to assess consumers' WTP for safe and quality milk and to estimate the effect of providing safety and quality-related information on WTP. The incentive-compatible experimental auction mechanism (second-price auction) was used, which is fairly new in the SSA to reduce hypothetical bias associated with stated preference elicitation methods. Using Random Effect Tobit model, the effect of providing safety and quality related information on consumers' WTP was estimated and other factors influencing their WTP were analysed.

The results show that consumers in Rwanda are willing to pay price premiums for safe and quality milk (pasteurised but unpackaged) from the processor relative to common milk bought directly from the producer, implying its acceptability among consumers. The results also show that providing milk safety and quality related information to consumers

increases their WTP. However, the effect varies depending on prior safety and quality information that consumers have and the type of milk that they usually consume. The education level and marital status of the participant as well as the price of recently purchased milk and the distance to milk buying point are other factors that have a significant influence on WTP for safe and quality milk. The results also confirm the possibility of hunger effect when eliciting a ready-to-eat-food product such as milk.

Based on these results, three key recommendations could be drawn. First, consumers in urban centres of Rwanda are willing to pay a premium for pasteurised unpackaged milk, however, this type of milk is sold by milk zones mainly found in Kigali city. This implies that there is an opportunity for market transformation in the dairy sector in the country. Therefore, there is a need for policies that promote the private sector to invest in the upscaling of milk zones in all urban centres so that consumers can easily access this type of milk within the range of premiums they are willing to pay. Also, processors can follow the Kenyan example of introducing the milk dispensing machines (milk ATMs) that sell pasteurized milk at a reduced price due to reduction in packaging costs, infrastructure, and human resources related costs. This marketing strategy will not only fetch premiums for processors but also serve as an entry point to improve the safety and quality of milk sold in Rwanda.

Second, given that information is a key factor influencing WTP, the results imply that consumers respond positively to safety and quality-related information. Hence, policies that promote quality in the dairy sector should go hand in hand with information campaigns that increase consumers' knowledge and raise their awareness of the quality of milk they consume. This can be done through various forms of advertisements on radio and/or television as they represent the main sources of information for many households.

Third, the WTP was estimated for a single unit of milk (one litre of milk), however, this may result in underestimating aggregate demand if the study is conducted for multiple quantities of milk (Akaichi *et al.*, 2012; Elbakidze *et al.*, 2014). Therefore, further studies on multiple quantities of milk and using other non-hypothetical mechanisms, such as field experiments or multiple rounds, are recommended to test the robustness of these findings. Finally, while this study focused on Rwanda, the findings can be extrapolated to the wider East African region and/or developing countries as they have almost similar dairy sector settings.

CHAPTER SEVEN
GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1. General Discussion

Certification of agricultural food products has recently been given an extensive attention. This is probably due to the world's determination of reducing foodborne diseases, countries' commitments to safeguard the environment, and increased consumers' concerns on safety and quality of food products. The dairy sector is of a major concern as milk is prone to contamination at any node of the dairy value chain. Consequently, the Government of Rwanda introduced the DBP certification scheme together with other policies and information campaigns with an aim of regulating and improving the safety and quality of milk produced and consumed. Despite the presence of those policies in the country, over 60% of milk is still sold through informal marketing channels (Shema *et al.,* 2018), which may be associated with poor milk handling practices that lead to unsafe and low quality milk possibly causing diseases (Reeve, 2017). This study contributes towards the improvement of the formal milk marketing and milk quality certification in several ways.

Firstly, in this study, the Rwandan dairy policies and regulations were documented and the farmer constraints of supplying quality milk that meets the DBP standards were identified. The results in chapter three, show that several programs such as the "Girinka" (one cow per poor family), RDCP I & II, RDDP, NDS, and RNDP were implemented and some policies like DBP scheme and ministerial order were initiated. These policies and programs have enhanced farmer access to improved cow breeds, increased cow population as well as increased milk production through enhanced health inputs and other services. However, there are still some barriers to implementing some regulations and constraints that hinder farmers from supplying milk that meets the DBP standards.

Consequently, the constraints that hinder farmers from supplying milk that meets the DBP standards were identified in this study. The constraints include the insufficient and inadequate quality of feeds, quality of veterinary and AI services, low productivity of improved breeds, limited competition among milk buyers, insufficient number of MCCs, and farm-gate lower prices for milk compared to the costs incurred in adhering to DBP standards. These challenges limit farmers' ability and capacity to produce and supply quality milk. The similar challenges were recently found in Ethiopia by Gebreyohanes *et al.* (2021) who argue that these challenges do not only limit farmers from supplying quality milk but also slow the improvement of the dairy value chains in several of developing countries.

Secondly, the costs and benefits to farmers of supplying quality milk that meets the DBP standards were estimated in this study. The results (in chapter four) show that milk production in Rwanda is profitable as farmers get a positive GM per household and per lactating cow, and the revenues from milk production nearly double the costs of production. Forage expenses, feed supplements expenses, animal health, labour, hygiene-related, and transport cost are the major costs incurred when producing milk and these costs increase when farmers adhere to DBP standards ($p<0.01$). On the other hand, there are benefits emanating from adherence to DBP standards. These include the increased volumes of milk produced and improved quality of milk which make the adherence to DBP standards more profitable as revenues from adherence to DBP standards yield higher GM ($p<0.01$) compared to conventional milk production.

In addition, the profit efficiency and determinants of profit inefficiency were estimated in the study and the results show that farmers are producing below the production frontier by 13 percentage point. The profit efficiency results reaffirm that adhering to DBP standards reduces the profit inefficiency as adhering farmers operate at 6 percentage point below the production frontier while non-adhering farmers operate at 20 percentage point below the production frontier. The comparable results were found in Tanzania where dairy farmers were operating at 20% below the production frontier (Bahta *et al.,* 2021). This study also provides the connection between farmers' constraints and profit efficiency where forage, feed supplement, and parasite control are the main inputs that significantly increase or reduce the profit efficiency.

Thirdly, the cooperative membership effects on farmers' choice of milk marketing channels were estimated in this study along with other determinants of farmers' choice of milk marketing channels. Three milk marketing channels namely MCCs, milk traders, and others (composed of direct consumers and restaurants) were found in the study area. The results in chapter five confirm that dairy cooperative membership positively influences the choice of both MCCs and milk traders while it negatively affects the choice of other buyers as marketing channels. These results concur with the findings of Hao *et al.* (2018) who found that cooperative membership has a varying effect on different apple marketing channels in China.

The findings (in chapter five) also indicate that the milk price has a positive effect on farmers' choice of MCCs, however, the longer distance to MCCs make farmers choose milk traders who offer lower prices than MCCs. This was not surprising as farmers always target

to sell to a marketing channel that offers higher prices given similar payment conditions in all marketing channels (Carmona *et al.,* 2021; Donkor *et al.,* 2021). In this study, what would happen to non-members of dairy cooperative if they had been members was also assessed. Interestingly, cooperative membership effect is still realised on counterfactual, however, the effect becomes larger or smaller for counterfactual depending on the marketing channel. This reaffirms the role of cooperative in choice of marketing channel.

Lastly, consumers' WTP for quality milk that meets the DBP standards was assessed and the effect of providing consumers with safety and quality related information on WTP was determined in this study. While the initiation of policies that promote and motivate farmers to supply quality milk is a noble initiative, the implementation of such policies may not work without consumers' demand and WTP for that quality milk. Hence, this analysis was needed to culminate this study. The three types of milk namely milk A (raw milk directly from the farmer), milk B (raw milk from the MCC), and milk C (pasteurized but unpackaged milk from the milk processor) were presented to consumers. While milk B and C are regarded as of high quality compared to milk A, milk C is of higher quality due to pasteurization.

The results of in chapter six confirm that consumers are willing to pay higher premiums for quality milk that meets the DBP standards. Furthermore, 96% and 93% of consumers were willing to pay price premiums for milk C and B respectively on top the price of milk A while 92% were willing to upgrade from milk B to milk C. These results were recently found by Coutinho *et al.* (2021) who established that consumers are willing to pay for new products provided that those products have no negative health risks. Also, Yang *et al.* (2021) found that dairy products are mostly linked to higher premiums when health benefits are of concerns. Moreover, providing safety and quality related information increases consumers WTP. This finding confirms that indeed consumers are always willing to pay price premiums for new products if they have positive information about those products (Gross *et al.,* 2021; Ruggeri *et al.,* 2021).

7.2. Conclusions and Recommendations

The main objective of this study was to contribute toward the improvement of the government policies that promote the formal milk marketing through the economic analysis of milk quality certification in Rwanda. To achieve this, the different nodes of dairy value chain such as production, marketing, and consumption of milk were considered. The production and marketing parts of the study were conducted in Nyabihu and Ruhango districts of Rwanda while the consumption part of the duty was conducted in Musanze and

Ruhango districts. All quantitative data was analysed using STATA version 15 while the qualitative data was analysed using Dedoose: 8.3.17 software. This study adds significant contribution to the scarce literature on several topics such as control of selection bias, profit efficiency of dairy production in SSA, and mainly the use of experimental auctions in SSA. Although the study was conducted in Rwanda, its findings can be deduced to a broader East African region or in SSA which have almost similar dairy sector settings. Below are key conclusions and recommendations of this study as per specific objectives.

The literature review and qualitative research method were used to document the dairy policies and farmers' constraints to supplying quality milk. The findings show that the Rwandan dairy sector has grown tremendously due to many policies and programs that have been implemented. However, lack of or insufficient quality of forages, low quality of veterinary and AI services, and inadequate and incapacitated MCCs remain the key constraints faced by farmers. Therefore, the government is recommended to put extra efforts in establishment and strengthening of the MCCs which can be used as channels to provide farmers with quality inputs and services. This can be done together with policies that regulate and monitor the quality of veterinary products and forages sold in the markets.

Furthermore, the data was collected from 384 farmers who are producing milk in Nyabihu and Ruhango districts using a structured questionnaire and eight FGDs to estimate the costs and benefits to farmers of suppling quality milk. The GM and BCR analysis were used to estimate the profitability of DBP standards and a translog production frontier function was estimated to determine the profit efficiency. The findings show that adhering to DBP standards increases the production costs due to extra costs incurred on forage, feed supplements, animal health, labour, hygiene-related, and milk transport. However, the benefits obtained offset the costs, implying that adhering to DBP standards is more profitable than the conventional production system. Generally, milk production in Rwanda is profitable, although, farmers are not producing at the production frontier. The results further show that the production inputs are key factors influencing the profitability of milk production and adhering to DBP standards increases the profit efficiency of farmers.

Based on these results, the government's intervention in accessing inputs such as quality forages, feeds supplements, and quality veterinary services is highly recommended. Furthermore, there is a need to increase farmers' adoption of DBP scheme since it is not only beneficial but also increases profit efficiency of farmers. Some of the barriers to adoption of DBP standards could be linked to farmers' lack of information on its profitability or their

financial incapacity. Hence, it is recommended to improve and/or initiate knowledge sharing programs such as increased extension services and trainings, and policies that improve farmers' access to credits.

In addition, an endogenous switching probit model was used in this study to estimate the effects of cooperative membership on choice of milk marketing channels. The results show that dairy cooperative membership is a key factor that influences farmers' choice of milk marketing channel, though the membership rate is very low. This could be due to few dairy cooperatives and/or poor management of cooperatives. Hence, there is a need to initiate new dairy cooperatives around dairy farms and to incentivise farmers to join dairy cooperatives through policies that improve cooperatives' structure and governance. The positive effect of cooperative membership on choice of MCCs as a marketing channel implies that, members of dairy cooperatives are not only disposed to higher prices offered by MCCs, but they also supply milk of high quality since the MCCs test the milk before accepting it. Therefore, since there are few MCCs around dairy farms, a public-private partnership that facilitates the construction of new MCCs and their equipment is recommended. Also, there is a need for infrastructure such as passable roads so that MCCs are easily accessible.

Finally, an incentive-compatible experiment with 386 milk consumers from Musanze and Ruhango districts was conducted to evaluate consumers' WTP for safe and quality milk and to assess the effect of safety and quality related information on WTP. The strength of the second-price auction mechanism used in this study is that it reduces the hypothetical bias associated with stated preference approaches. Using a Random Effect Tobit model, the results show that consumers are willing to pay higher premiums for safe and quality milk that is pasteurized but unpackaged compared to conventional milk bought directly from the farmer. Nevertheless, this type of milk is not easily accessible as it is mainly sold by milk zones found in Kigali city. Consequently, there is a need to increase milk zones and introduce the milk dispensing machines in all urban centres of Rwanda. This can be done by promoting policies that facilitate private investors in dairy sector which will not only give them high premiums but also provide consumers with easily accessible quality milk within the price ranges they are willing to pay. Furthermore, the findings confirmed that provision of safety and quality related information increases consumers' WTP though the extent of the effect depends on prior information that consumers have and the frequently type of milk they buy. Thus, the information campaigns are recommended so that consumers are aware of quality of different types of milk available in the market.

7.3. Suggestions for Further Research

Whereas the production, marketing, and consumption of milk in Rwanda were covered in this study, there are some limitations of the study. First, the evolution of dairy policies and regulations in Rwanda were reviewed, however, the focus in this study was more on the strengths of the policies, leaving their weaknesses to remain unknown. Therefore, future studies that conduct a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of those policies may shed more light on their real impacts. The production and market sides in this study relied on a cross-sectional data which may be prone to misclassification bias. Since the dairy sector in Rwanda is rapidly growing and changing, the future research relying on a multi-dimensional data may be more appropriate to validate the findings of this study. To estimate the profit efficiency, an input-output relationship method was used without making any behavioural assumptions. This limits the researcher from using a profit maximisation or cost minimization approaches. Hence, future studies that consider input quantities and prices rather than expenses on inputs will be more appropriate to confirm the robustness of the results of this study.

On the choice of milk marketing channel, the study is limited in that the farmers' viewpoints were only considered and the types of dairy cooperatives (farmers-initiated versus government-initiated or open versus closed cooperatives) were not included. Thus, future studies may give more insights on the effects of dairy cooperatives on choice of milk marketing channels by collecting additional information from processors and incorporating the types of cooperatives in the analysis. Lastly, consumers' WTP experiment was conducted on a single unit (one litre of milk) for one round. This may underestimate the aggregate demand if the experiment is done on multiple units (several quantities of milk) or for several rounds. Therefore, the future experiments could consider multiple quantities of milk and try multiple rounds of bidding to validate the results of this study.

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APPENDICES

Appendix A: Checklist for Focus Group Discussions

1.1. Informed Consent to Participate in Focus Group Discussions

Participants: Participants are livestock farmers who are producing milk in Nyabihu and Ruhango districts, Rwanda.

Title of Study: Economic analysis of milk quality certification in Rwanda: identifying farmer constraints to supplying milk that meets dairy best practice certification

The student: Naphtal Habiyaremye, ILRI/ Egerton University

Contact Phone number: +254741095455

Contact email: habiyaremyen@gmail.com

Funding Source or Sponsor: United States Agency for International Development (USAID) through University of California Davis

What are some general things you should know about research studies?

You are being asked to take part in this research study on economic analysis of milk quality certification in Rwanda as a focus group discussion participant. To join the study is voluntary. You may refuse to join, or you may withdraw your consent to be in the study, for any reason.

The focus group discussions are designed to share experiences, knowledge and understanding of dairy sector. You may or may not receive any direct benefit from being in the research study. Details about this study are discussed below. It is important that you understand this information so that you can make an informed choice about participating in this research study. The discussions will be audio recorded and notes also taken during the discussions. Collected data and field notes will be safely stored. The content of the consent form will be read to you. If you agree to participate in the study, you will be asked to sign the consent form. You should ask the researchers named above, or staff members who may assist them, any questions you have about this study at any time.

What is the purpose of this study?

The purpose of the focus group discussion is to understand milk production considering the constraints and challenges to supplying milk that meets the dairy best practices standards. In addition, I would like to find out what can be done to improve dairy best practice scheme.

How long will your part in this study last?

This focus group discussion will last a maximum of 2 hours. You may have participated in a previous general and shorter assessment conducted by the team. This one will be more in-depth focusing on dairy best practice program.

What are the possible benefits from being in this study?

This research in the long run will benefit dairy value chain actors and policy makers by gaining new knowledge about challenges and constraints faced by farmers who want to adhere to dairy best practice standards and therefore advise on what can be amended/improved in dairy best practice to increase its adoption among farmers.

What are the possible risks or discomforts involved with being in this study?

There are no sensitive questions, but if you feel uncomfortable answering a specific question, you may remain silent and you will not be penalized in any way.

How will your privacy be protected?

I will make every effort to protect your privacy and confidentiality. No study participant will be identified in any report or publication about this study. Every effort will be made to keep research records private. In some cases, however, your information (names, contact, value chain node of operation) in this research study could be reviewed by the national institutional review board/ethics committees, other government agencies, or project collaborators (ILRI, University of Rwanda, or University of Florida).

What if you want to stop before your part in the study is complete?

You can withdraw from this study at any time, without penalty.

Will you receive anything for being in this study?

There will be in-kind appreciation for participating in the study.

Who is sponsoring this study?

This research is funded by the United States Agency for International Development (USAID). The researchers working on this project do not have a direct financial interest in the final results of the study

What if you have questions about this study?

You have the right to ask, and have answered, any questions you may have about this research. If you have questions, complaints, or concerns, you should contact the researchers listed on the first page of this form.

Title of Study: Economic analysis of milk quality certification in Rwanda: Identifying farmer constraints to supplying milk that meets dairy best practice certification

The student: Naphtal Habiyaremye, ILRI/ Egerton University

Participant's Agreement:

If you have read this consent form, or had it read and explained to you, and you understand the information, and you voluntarily agree to participate, please sign your name or make your mark below.

PART A: LITERATE PARTICIPANT

Participant is literate: ☐

_____	_____	_____
Participant Name (print)	Participant Signature	Date
_____	_____	_____
Staff Conducting Consent Discussion	Staff Signature	Date

PART B: ILLITERATE PARTICIPANT

Participant is illiterate: ☐

The study staff must complete this section. This form can ONLY be completed in the case of an illiterate participant if an impartial witness is available.

_____	_____	_____
Participant Name (print)	Participant thumbprint	Date
_____	_____	
Staff Conducting Consent Discussion	Study Staff Signature	Date
_____	_____	
Impartial Witness Name	Impartial Witness Signature	Date

1.2. Checklist for FGDs for DBP adhering farmers

1. Briefly describe the seal of quality (SoQ) or dairy best practice (DBP) schemes
2. What is the source of your information?
3. What are the practices/inputs needed at farm level to produce milk in compliance with dairy best practice standards?
4. What are the costs attached/related to those practices/inputs?
5. What are the main challenges/constraints you face in producing milk in compliance with DBP? Are these different for men and women farmers?
6. How can such challenges/constraints be alleviated?
7. What do you perceive as benefits/advantages to farmers of adhering to DBP standards?
8. What are the disadvantages to you for adhering to DBP standards?
9. What could be done to improve the quality of your milk? Which players can support you to achieve it?
10. How can dairy best practice scheme be further improved?

1.3. Checklist for FGDs for DBP non-adhering farmers

1. Have you heard about dairy best practice (DBP) schemes?
2. Briefly describe the dairy best practice (DBP) schemes
3. What is the source of your information?
4. What do you think are the practices/inputs needed at farm level to enable adherence to dairy best practice standards?
5. What could be the costs attached to those practices/inputs?
6. Why are you not selling your milk to milk collection centers (MCC)?
7. What are the main challenges/constraints that hinder your adherence to DBP? Are these different for men and women dairy farmers?
8. How can such challenges/constraints be alleviated?
9. What are the disadvantages to you for not adhering to DBP standards?
10. What are the advantages you perceive for not adhering to DBP standards?
11. What can be done to improve the quality of your milk? Which players can support you to achieve it?
12. How can dairy best practice scheme be further improved?

Appendix B: Household Survey Questionnaire

2.1. Informed Consent to Participate in Household Survey Questionnaire

Participants: Livestock farmers who are producing milk in Nyabihu and Ruhango districts, Rwanda.

Title of Study: Economic analysis of milk quality certification in Rwanda

The student: Naphtal Habiyaremye, ILRI/ Egerton University

Contact Phone number: +254741095455

Contact email: habiyaremyen@gmail.com

Funding Source or Sponsor: United States Agency for International Development (USAID) through University of California Davis

What are some general things you should know about this research study?

You are being asked to take part in this research study on economic analysis of milk quality certification in Rwanda as a respondent to a semi-structured questionnaire. To join the study is voluntary. You may refuse to join, or you may withdraw your consent to be in the study, for any reason.

I am using this questionnaire to get a deep understanding of milk production and marketing. You may or may not receive any direct benefit from being in the research study. Details about this study are discussed below. It is important that you understand this information so that you can make an informed choice about participating in this research study. The discussions will be noted down and the collected data will be safely stored. The content of the consent form will be read to you. If you agree to participate in the study, you will be asked to sign the consent form. You should ask the researchers named above, or staff members who may assist them, any questions you have about this study at any time.

What is the purpose of this study?

The purpose of the survey is to understand milk production considering the costs and benefits farmers get in presence of dairy best practices. In addition, I would like to find out the marketing channels available to farmers and milk attributes preferred by milk buyers and consumers.

How long will your part in this study last?

This survey questionnaire will take a maximum of 2 hours.

What are the possible benefits from being in this study?

This research in the long run will benefit dairy value chains actors by gaining new knowledge about costs of producing quality milk, market availability information and advising on what can be amended/improved in dairy best practice to increase its adoption among farmers.

What are the possible risks or discomforts involved with being in this study?

There are no sensitive questions, but if you feel uncomfortable answering a specific question, you may remain silent and you will not be penalized in any way.

How will your privacy be protected?

I will make every effort to protect your privacy and confidentiality. No study participant will be identified in any report or publication about this study. Every effort will be made to keep collected data private. In some cases, however, your information (names and contact) in this research study could be reviewed by the national institutional review board/ethics committees, other government agencies, or project collaborators (ILRI, University of Rwanda, or University of Florida).

What if you want to stop before your part in the study is complete?

You can withdraw from this study at any time, without penalty.

Will you receive anything for being in this study?

There will be in-kind appreciation for participating in the study

Who is sponsoring this study?

This research is funded by the United States Agency for International Development (USAID). The researchers working on this project do not have a direct financial interest in the final results of the study.

What if you have questions about this study?

You have the right to ask, and have answered, any questions you may have about this research. If you have questions, complaints, or concerns, you should contact the researchers listed on the first page of this form.

Participant's Agreement:

If you have read this consent form, or had it read and explained to you, and you understand the information, and you voluntarily agree to participate, please sign your name or make your mark below.

PART A: LITERATE PARTICIPANT

Participant is literate: ☐

_____ _____ _____

Participant Name (print) Participant Signature Date

_____ _____ _____

Study enumerator (print) Enumerator Signatur Date

PART B: ILLITERATE PARTICIPANT

Participant is illiterate: ☐

The enumerator must complete this section. This form can ONLY be completed in the case of an illiterate participant if an impartial witness is available.

_____ _____ _____

Participant Name (print) Participant thumbprint Date

_____ _____ _____

Study enumerator (print) Study Staff Signature Date

_____ _____

_____

Impartial Witness Name Impartial Witness Signature Date

2.2. Household Questionnaire

Does the household keep cows? [__] Yes=1, No=0 ***(Do not continue with the interview)***

Have you been milking any cows in the last 12 months? (Feb 2019-Jan 2020)? [__] 1=Yes; 0 = No ***(Do not continue with the interview)***

INTERVIEW THE PERSON IN CHARGE OF CATTLE ENTERPRISE IN THE HOUSEHOLD, IF NO, DO NOT PROCEED WITH THE INTERVIEW

MODULE A: GENERAL INFORMATION

A1	Consent read and obtained *Tick the box*	☐
A2	Enumerator's name	
A3	Date of interview	**……/02/2020**

A4	Household ID	
A5	GPS coordinates	Lat…… Long……
A6	District identification	**1**= Nyabihu **2**= Ruhango
A7	Sector identification	**1**= Bigogwe, **2**= Jenda, **3**= Rambura **6**= Byimana, **7**= Bweramana, **8**= Ruhango
A8	Full names of the respondent	
A9	Position of the respondent in the household [__]	**1**= Household head **2**=Spouse of the household head **3**= Son/Daughter **4**= Other (Specify)
A10	Gender of respondent [__]	**0** = Female **1** = Male

MODULE B: HOUSEHOLD SCHEDULE (*Please consider all members that are living together in one homestead for at least six months)*

1. ID	**2**. Name of HH member (***Only one name)***	**3**.Relationship to head of HH ***(See codes 3.a)***	**4.** Sex 0=Female 1= Male	**5.** Age in years ***(use fraction for less than one year)***	**6.** The highest level of formal education completed? (***number of years of schooling***)	**7**.Marital status (***See codes 7.a)***	**8.** Occupation? ***(See codes 8.a)***		**10.** Farm experience How many years of (***head and the person in charge of dairy enterprise only)***		**12.** Is (Name) a member of a **MCC** or dairy co-op? ***(see codes 12.a)***
							8.Primary activity	**9**.Secondary activity	**10**.farming experience?	**11. dairy** farming experience?	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Table of codes

(3.a)	**4**=Grandchild	**8**=Son/daughter-in-law	**(7.a)**
1= Head	**5**=Nephew/Nice	**9=**Parent-in-law	**1**=Married/living together
2=Wife/husband	**6**=Parent	**10=**House maid/labourer	**2=**Divorced/separated
3=Daughter/Son	**7**=Sister/Brother	**11**=Not related	**3**=Widowed
			4=Single
(8.a)	**4=**Labour on another	**9=**Retired without	**(12.a)**

0=None, **1=**Farmer/farm management **2=**Household work (wife) **3**=Labour on his/her HH farm	HH farm **5**=Employed **6**=Business **7**=Student **8=**Retired with pension	pension **10**=Religious leader **11**=Labour on non-farm activities **12**=Casual worker **13=**Other (specify)	**0=**No, never been a member **1**=Yes, a member now **2**=Yes, was a member before, but not anymore

MODULE C: MILK PRODUCTION AND MARKETING

SECTION 1: MILK PRODUCTION

a) Please enter the following details on milk production for up to **<u>3 cows milked</u>** during the last one (1) year (Feb 2019-Jan 2020). *(record up to a maximum of 3 cows; 1 cow per breed that are currently being milked*)

	Local breed	**Cross breed**	**Exotic**	**Total**
Number of lactating cows				

	Cow1	**Cow2**	**Cow3**	
Breed of cow (1 = local; 2 = cross bred; 3 = pure exotic)				
Date of birth *(MM/YY) (99/9999 if unknown)*				
Parity- Number of times it has had offspring (999=unknown)				
When did the cow calve down (give birth)? *(MM/YY) (99/9999 if unknown)*				
Milk production per day (*morning and evening milk*) at calving				
Milk production per day (*morning and evening milk*) at peak				
Milk production **yesterday** (*morning and evening milk*)				
Milk production per day (*morning and evening milk*) at late lactation				
Lactation length (number of months cow is milked between 2 calvings)				
Calving interval (time between one calving (cow) to the next in months)				
Breeding method used for the last calving [1=Own bull 2=Other bull 3= AI 4=Unknown]				
Number of services (repeats) before conception for this service				
Price paid for the last breeding service (Frw)				

b) Milk utilization: Complete the table below by indicating how much of fresh and fermented milk (ikivuguto) that is utilised

B_1) Do you separate calves from cows? (to limit them suck? 0= No, 1= Yes

1. For milk produced **yesterday** or the **last day** milking was done	**2. Morning milk** Quantity per day (Litres)	**3. Evening milk** Quantity per day (Litres)	**4. If this is not done daily (*See codes 4.b)***	
			Quantity (Liters)	Codes **4.b**
Amount of milk fed to calves (if any) (excludes what the calves sucks on its own)				
Amount used/consumed by household fresh				
Amount of fresh milk given to relatives, workers, neighbors, etc.				
Amount of fresh milk sold				
Amount kept for making ikivuguto				
Amount of fresh milk retained for making other milk products apart from ikivuguto (specify)				
Amount used for other purposes (specify)				
Amount spoilt milk (thrown away) (both fresh and ikivuguto)				

Codes 4.b

(4.b)	**3=** Fortnightly
1= Weekly	**4=** Other (specify)
2= 2-3 times per week	

SECTION 2: COW MILK SALES (REVENUE) AND MARKETING CHANNELS

a) Did you sell fresh milk in the last 12 months (Feb 2019-Jan 2020)? [__]
1=Yes; 0 = No ***(If No, go to question e)***

b) Do you sell fresh milk currently? [__] 1=Yes; 0 = No ***(If No, go to question e)***

c) What is the distance to the nearest fresh milk salespoint? In Km [__]

d) Indicate how much of fresh milk you sell currently per day (***Take an average day during the last week***) to different types of buyers.

		Morning milk						**Evening milk**									
1. No	**2.** Buyers	**3.** Quantity per day (***If= 0 skip to Q8)***	**4.** Unit (***4. a codes)***	**5.** Price /unit	**6.** No. of buyers	**7.** When paid? (***11 .a codes)***	**8.** Delays 0= No 1= Yes	**9.** Quantity per day	**10.** Unit (***4. a codes)***	**11.** Price /unit	**12.** No. of buyers	**13.** When paid? (***11. a codes)***	**14.** Delays 0= No 1= Yes	**15.** Distance to sale point (***km*)**	**16.** Transport cost ***(if any)***	**17.** Who transports? **(15. a *codes)***	**18.**Seasonalisty of sale to the buyer 1= dry 2= rainy 3=throughout the year
1	Individual customers																
2	MCCs																

3	Mobile milk traders/middlemen																
4	Restaurants/ milk bars																
5	Processors																
6	Dairy interest group/co-op																
7	Another buyer (Specify)																

Table of codes

(11.a)	**(4.a)**	**(15.a)**
1= cash on spot (1 day)	**1=** Litres	**1=** Producer/farmer
2= In advance	**2**= Inkongoro (2 litres)	**2=** Hired transport, organized by farmer
3= 30 days	**3**= Small jerrycan (5 litres)	**3=** Hired transport organized by MCC/buyer
4= In 15 days	**4=** Medium jerrycan (10 litres)	**4=** Other (specify)
5= Other specify	**5**= Big jerrycan (20 litres)	
	6= Milk can (22 litres)	
	7= Others (specify)	

e) Did you sell ikivuguto in the last 12 months (Feb 2019-Jan 2020)? [__]
1=Yes; 0 = No ***(If No, go to question i)***

f) Do you sell ikivuguto currently? [__] 1=Yes; 0 = No ***(If No, go to question i)***

g) What is the distance to the nearest ikivuguto salespoint? In Km [__]

h) Indicate how much of ikivuguto you sell currently (***On average day during the last week***) to different types of buyers in litres.

		Morning milk						**Evening milk**									
1. No	**2.** Buyers	**3.** Quantity per day (***If= 0 skip to Q8)***	**4**. Unit (***4. a codes)***	**5**. Price /unit	**6.** No. of buyers	**7.** When paid? (***11 .a codes)***	**8.** Delays 0= No 1= Yes	**9.** Quantity per day	**10.** Unit (***4. a codes)***	**11**. Price /unit	**12.** No. of buyers	**13.** When paid? (***11. a codes)***	**14.** Delays 0= No 1= Yes	**15.** Distance to sale point (***km***)	**16.** Transport cost ***(if any)***	**17.** Who transports? **(15. a *codes)***	**18.**Seasonalisty of sale to the buyer 0= dry 1= rainy 3=throughout the year
1	Individual customers																
2	Mobile milk																

	traders																
3	Restaurants/ milk bars																
4	Dairy interest group/co-op																
5	Another buyer (Specify)																

Table of codes

(11.a)	**(4.a)**	**(15.a)**
1= cash on spot (1 day)	**1=** Litres	**1=** Producer/farmer
2= In advance	**2**= Inkongoro (2 litres)	**2=** Hired transport, organized by farmer
3= 30 days	**3**= Small jerrycan (5 litres)	**3=** Hired transport organized by MCC/buyer
4= In 15 days	**4=** Medium jerrycan (10 litres)	**4=** Other (specify)
5= Other specify	**5**= Big jerrycan (20 litres)	
	6= Milk can (22 litres)	
	7= Others (specify)	

i) Indicate the person who makes the decision regarding milk sales and milk consumption in the household.

1. Decision making			**2.** Who makes the decision? **(*See codes 8.b*)**	**3.** What influences the decision? **(*See codes 3.c*)**
Morning milk	**1**	How much milk to sell vs home consumption		
	2	Where to sell		
Afternoon/evening milk	**3**	How much milk to sell vs home consumption		
	4	Where to sell		

Table of codes

(8.b)	**(3.c)**
1= Head	**1=** Price of milk
2= Spouse	**2**= Needs of the family
3= Joint head and spouse	**3**= Buyer availability
4= Another male	**4**= Quantity of milk produced
5= Another female	**5**= Having children below 5 years
6= Other (specify)	**6**= Other (specify)

SECTION 3: TRANSACTION UNCERTAINTY

i. **Ex-ante transaction uncertainty 1**: To what extent do you agree with the statement that "I know beforehand about the quality requirements in each marketing channel"? ***(codes 3.1 below)***

ii. **Ex-ante transaction uncertainty 2:** To what extent do you agree with the statement that "I have no idea about prices to be offered by buyers beforehand"? ***(codes 3.1 below)***

iii. **During transaction uncertainty:** To what extent do you agree with the statement that "I was affected by decisions that were changed by buyers alone during the transaction"? ***(codes 3.1 below)***

iv. **Ex-post transaction uncertainty:** To what extent do you agree with the statement that "I suffered losses caused by delayed payments by buyers"? ***(codes 3.1 below)***

Table of codes

(3.1)	**2**= Slightly Disagree	**4**= Slightly Agree
1= Strongly Disagree	**3**= Neither Agree nor Disagree	**5**= Strongly Agree

MODULE D: AWARENESS OF DAIRY BEST PRACTICE (DBP) OR SEAL OF QUALITY (SOQ) STANDARDS AND COSTS INVOLVED

SECTION 1: Awareness of DBP or SOQ standards

1.1. Are you aware of/have you heard about DBP/ SOQ standards? [__]
1= Yes, 0= No. If Yes, continue. If No, go to question 1.3

1.2. Are you following the DBP/SOQ requirements? [__]
1= Yes, 0= No

1.3. Do you sell your milk to an MCC? [__]
1= Yes, 0= No **(*What are the reasons? 1.4 codes below).*** If No, go to question 1.5

1.4. What tests are conducted by the MCC before accepting your milk? [__] Name all that apply (***1.5 codes below)***

1.5. In the last 12 months, how often has your milk been rejected by buyers? [__] (***1.6 codes below)***

1.6. What is the average quantity of milk rejected by buyers in the last 12 months? [__] (***in litres***)

1.7.Which type of buyer rejected your milk? [__] ***(1.7 codes below)***

1.8. Are there specific recommended practices you use to avoid milk rejection? [__]
0= No, 1= Yes (***If Yes***, ***what are they? 1.9 codes below, If No, go to question 1.10***)

1.9. What is the source of informaton on these practices? (***1.10 codes below)***

1.10. Which grade of milk do you produce currently? [__]
1= grade 1, 0= grade 2

1.11. Which grade of milk were you producing in the last 12 months? [__] 1= grade 1, 0= grade 2

Table of codes

(1.4)	**(1.5)**	**(1.6)**
1= Selling milk elsewhere at a higher		**1**= 0 times

price **2**= delayed payments **3**= MCC located far from the HH **4**= consuming all the milk/no excess milk to sell **5**= Higher transport costs **6=** insufficient/irregular milk production **7**= Other (specify)	**1=** lacto densimeter **2=** thermometer **3=** Alcohol **4=** organoleptic **5**= antibiotic residue **6**= mastitis **7**= milk grade **8=** Other (specify) **9=** I don't know	**2**= once a month **3**= twice a month **4**= once a quarter **5**= once in six months **6**= once a year **7**= other (specify)
(1.9) **1**= balanced feeds **2**= improved hygiene **3**= veterinary consultations **4**= appropriate utensils **5**= avoid milking under treatment **6**= other (specify)	**(1.10)** **1=** Friends/ neighbors **2**= Local opinion leader/model farmers **3**= Radio/TV programs/ gazette **4**= Mobile phone /internet **5**= Print media **6**= MCC **7=**Trainings/extensionists **8**= Milk traders/collectors/middlemen **9=**Other (specify)	**(1.7)** **1**= None **2**= MCCs **3**= Dairy interest group/co-op **4**= Mobile milk traders/middlemen **5**= Restaurants/milk bars **6**= Individual customers **7**= Processors **8**= Another buyer (specify)

SECTION 2: COSTS OF MILK PRODUCTION

1.1. Feed costs

A/1. Main feeding system

Indicate the feeding system used for each cattle type owned, and how much land was allocated for grazing if your cattle were grazed for the last 12 months (Feb 2019-Jan 2020)

Cattle type	Feeding system 1= Only grazing 2= Grazing with some stall feeding 3= Only stall feeding
Bulls	[_____]
Cows	[_____]
Heifers	[_____]
Immature males	[_____]
Calves	[_____]

A/2. How much land was set aside for grazing cattle last year [_____] hectares

A/2. What is the tenure system of the grazing land? [_____] 1= Freehold, 2 = Leasehold, 3=Communal, 4 = Rented

A/3. If rented in A/2 how much was it per year? _____Frw

B. Fodder grown

B_1. Besides grazing/harvested grass from forest/roadside/farm, did you grow any kind of forages Jan 2019 – Dec 2019 (i.e. fodder crops, legumes and/or fodder trees)? [__] 1= Yes; No =0 If Yes, continue, if No go to question C.

B_2. Have you set aside a plot for growing improved forages/fodder or you grow on hedges/fence? [__] 1= Plot set aside, 2= On hedges/fence, 3= I don't grow forages/fodder ***(If 1 or 2, how much would you have bought the grown forages/fodder? In Frw***)

B_3. If fodder/forage was grown, please provide the following details for each fodder type grown

Fodder type ***(Codes B_3)***	Total area grown	Units 1 = Ha 2 = Sq. metres 3 = Acres	Tenure type for forage land 1=freehold 2=rented in 3=communal	If rented, what area was rented in?	Units 1 = Ha 2 = Sq. metres 3 = Acres	How much rent was paid? ***In Frw***

Table of codes

(B_3)	**4**= Fodder shrubs (Calliandra, Sesbania, Lucaenia)
1= Napier grass	**5=** Other fodder legumes (Desmodium, lucern, vetch)
2= Planted grasses e.g. Rhodes grass	**6**= Brachiaria
3= Fodder maize	**8**= Other (specify)

C) Purchased fodder

C_1. Have you purchased fodder to feed your cows in the last 12 months (Feb 2019-Jan 2020)? [__] Yes = 1; No = 0

C_2. If yes, please enter the following details.

1. Fodder type ***(codes B_3)***	**2.** Cattle type fed? ***(codes C_3)***	**3.** Yearly costs			**4**. In which month did you purchase? ***(Feb 2019-Jan 2020) Codes C_6***	**5.** Where purchased? ***(codes C_5)***
		Quantity	Unit ***(codes C_4)***	Price/unit		

Table of codes

(B_3)	**4**= Fodder shrubs (Calliandra, Sesbania, Lucaenia)
1= Napier grass	**5=** Other fodder legumes (Desmodium, lucern, vetch)
2= Planted grasses e.g. Rhodes grass	**6**= Brachiaria
	8= Other (specify)

3= Fodder maize

(C_3)
1= All
2= Lactating cows only
3= Calves only
4= Bulls only
5= Other (specify)

(C_4)
1= Kgs
2= Tones
3= Bales
4**=** Handcart/Wheel Barrow
5= Standard sac
6= Bundle
7= Other (specify)

(C_5)
1= Other farmers
2= Market, traders
3= Supplier affiliated to farmer group
4= Other fodder supplier
5= Other (specify)

(C_6)
1= January
2= February
3= March
4= April
5= May
6= June
7= July
8= August
9= September
10= October
11=November
12=December

D) Crop residues

D_1. Have you fed your cows with crop residues in the last 12 months (Feb 2019-Jan 2020)? [__] 1= Yes; No =0. (If No, How much would you be willing to buy the residues if there was a market for them? [__] in ***Frw/kg***)

D_2. If yes, please enter the following details.

Crop residue type ***(codes D_3)***	Cattle type fed? ***(codes C_3)***	Source: 1=Own farm; 2=Purchased ; 3=Other farm;	Yearly costs			In which month did you purchase? ***(Feb 2019-Jan 2020) Codes C_6***	Where purchased? ***(codes C_5)***
			Quantity	Unit ***(codes C_4)***	Price/unit		

Table of codes

(D_3)
1= Green/dry maize stovers and thinning
2= Cereal (wheat, barley, rice etc.) straws and millet, sorghum stalks
3= Legumes (beans, cowpeas, soya etc.)
4= Root and tubers peelings (potato, cassava, bananas etc)
5= Crop by-products (sweet potato vines, cassava leave etc.)
6= Other (specify)

(C_3)
1= All
2= Lactating cows only
3= Calves only
4= Bulls only
5= Other (specify)

(C_4)
1= Kgs
2= Tones
3= Bales
4**=** Handcart/Wheel Barrow
5= Standard sac
6= Bundle
7= Other (specify)

(C_5)
1= Other farmers
2= Market, traders
3= Supplier affiliated to farmer group
4= Other fodder supplier
5= Other (specify)

(C_6) **1=** January **2=** February **3=** March	**4=** April **5**= May **6**= June	**7=** July **8=** August **9=** September	**10=** October **11=**November **12=**December

E) Feed supplements

E_1. Did you feed your cows with supplements such as concentrates and mineral licks in the last 12 months (Feb 2019-Jan 2020)? [__] 1= Yes; No =0. (If No, how much would you be willing to spend on feed supplements per year? [__] ***In Frw***)

E_2. If yes, please enter the following details.

Supplements type ***(codes E_3***	Cattle type fed? ***(codes C_3)***	Yearly costs			In which month did you purchase? ***(Feb 2019-Jan 2020)*** ***Codes C_6***	Where purchased? ***(codes C_5)***
		Quantity	Unit ***(codes C_4)***	Price/unit		

Table of codes

(E_3) **1**= Commercial dairy meal, **2**= Mineral blocks/salt blocks/lick, **3=** Bran (Maize, wheat), **4=** Maize germ, **5=** Oilseed by-product (Sesame seed, cotton seed, copra, sunflower etc.), **6=** Agro industrial by-products (vegetable waste, brewer's waste etc.), **7=** Other (specify)	**(C_3)** **1=** All **2**= Lactating cows only **3=** Calves only **4=** Bulls only **5**= Other (specify)	**(C_4)** **1=** Kgs **2**= Tones **3=** Bales 4= Handcart/Wheelbarrow **5=** Standard sac **6**= Bundle **7**= Other (specify)	**(C_5)** **1**= Agrovet shops **2=** Other farmers **3**= Market, traders **4=** Supplier affiliated to farmer group **5**= Other fodder supplier **6=** Other (specify)
(C_6) **1=** January **2=** February **3=** March	**4=** April **5**= May **6**= June	**7=** July **8=** August **9=** September	**10=** October **11=**November **12=**December

F) Watering for cows

1. No	2. Water for cows	3. Codes	4. Rainy season	5. Dry season
1	How often do you water your cows? ***(Frequency)***	***See F_1 codes below***		
2	Main water source	***See F_2 codes below***		

3	Distance to the watering point (source) (Km)	0= if available within homestead		
5	Do you pay for the water for your cows?	1= Yes 0= No		
6	On average, how much do you pay water for cows per month? (Frw)	899=N/A		
7	Which strategies do you use when water is not available in your main water source, (e.g during draught)	***See F_7 codes below***	N/A	

Table of codes

(F_1)	**(F_2)**	**7**= Rain water	**(F_7)**
1= Once a day	**1=** Piped into house	**8**= River/streams	**0=** Never occurs (there is water all the time),
2= Twice a day	**2**= piped into homestead	**9**= tankers-truck/vendor	**1**= Reduce watering frequency,
3=Thrice a day	**3**= Public tap	**10**= Unprotected dug well/springs	**2=** Fetch water from other sources,
4= throughout the day	**4**= borehole with pump	**11**= Other (specify)	**3**= Move cattle to different location**,**
5= other (Specify)	**5**= protected dug well	**12**= N/A	**4=** Other (Specify)
	6= protected spring		

1.2. Labor costs

A) Monthly paid laborers

A_1. Did you employ a monthly paid laborer for your cattle enterprise in the last 12 months (Feb 2019-Jan 2020)? [__] **(**0=No 1=Yes). ***If yes, enter the following details:***

	Name of labourer	**Gender 0= Female 1=Male**	**Average working hours per day**	**Number of days worked**	**Monthly Wage (Frw)**	**Activities engaged in (*See A_1 codes)***	**Hours of a working day dedicated to activity**
1							
2							
3							

Table of codes

(A_1)	**4=** Watering	**7**= All inclusive
1= Cow management (Other than grazing or watering)	**5**= milking	**8**= Cleaning utensils
2= Fodder/feed related	**6**= selling/delivering milk	**9**= Cow fattening
3= Grazing		**10**= Other (Specify)

B) Casual labor

B_1. Have you employed any casual laborer(s) in cattle enterprise in the last one 12 months (Feb 2019-Jan 2020)? (0=No, 1=Yes).

B_2. If yes, enter the following details:

Type of Activity	Non-Household		Frequency
	Hired Females	Hired Males	***(See B_1 codes)***

	No. people	Hrs/person	No. people	Hrs/person	
1. Grazing					
2. Feeding (+ cutting, collecting & preparation)					
3. Fodder/feed production on farm					
4. Providing water to the cows					
5. Cleaning of cows and their shed/shelter					
6. Collection of Farm Yard Manure (FYM)					
7. Milking and milk processing					
8. Selling milk					
9. Cleaning utensils					
10. Selling cows/ cow products (except milk)					
11. Cow housing construction/improvement/ repairs					
12. Other (specify)					
Average wage/day (Frw/day)					
Average working hours/day					

Table of codes

(B_1)	**4=** fortnightly	**7=** once in six months
1= per day	**5**= per month	**8**= per year
2= per week	**6=** per quarter	**9=** other (specify)
3= twice per week		

C) Household labor

C_1. Has any household member been involved in cattle related activities in the last 12 months (Feb 2019-Jan 2020)? (0=No, 1=Yes).

C_2. If yes, enter the following details:

Type of Activity	Household							Frequency ***(See B_1 codes)***
	Adult Males		Adult Females		Children (< 15 yrs)			
	No. people	Hrs/person/day	No. people	Hrs/person/day	No. people	Gender 0=Female 1= Male	Hrs/person/day	
1. Grazing								
2. Feeding (+ cutting, collecting & preparation)								
3. Fodder/feed production on farm								

4. Providing water to the cows								
5. Cleaning of cows and their shed/shelter								
6. Collection of Farm Yard Manure (FYM)								
7. Milking and milk processing								
8. Selling milk								
9. Cleaning utensils								
10. Selling cows/ cow products (except milk)								
11. Cow housing construction/improvement/ repairs								
12. Other (specify)								

Table of codes

(B_1)	**4=** fortnightly	**7=** once in six months
1= per day	**5**= per month	**8**= per year
2= per week	**6=** per quarter	**9=** other (specify)
3= twice per week		

1.3.Veterinary services and costs

A) Costs of animal health services

	Anthelmintic (deworming)	Tick control (spraying/dipping)	Vaccination	Curative treatment	Mastitis	Other (specify)
Can you access and use this service? (0= NO; 1=YES)						
How many times have used this service in last one year?						
Type of cow treated/given the service in last one year ***(C_3 codes)***						
Total expenditure for treatment for last one year						
Who provided the service? List a maximum of **three** providers ***(A_2 codes)***	[__] [__] [__]	[__] [__] [__]	[__] [__] [__]	[__] [__] [__]	[__] [__] [__]	[__] [__] [__]

Table of codes

(C_3)	**(A_2)**	**5=** Project/NGO staff
1= All	**1**= Self/neighbor with professional advices	**6=** MCC/group staff (including vet)
2= Lactating cows only	**2**= Self/neighbor without professional advices	**7**= Agro-vet shop
3= Calves only	**3**= Animal health service provider/para-vet	**8**= Community dip
4= Bulls only	**4**= Government veterinarian	**9**= Other (specify)
5= Other (specify)		

B) Cost of breeding services

	Own bull service	Other bull service	A.I service
Which breeding methods can you find and use when your cow is on heat? (0= NO; 1=YES)			
Which methods do you usually use when your cow is on heat? (0= NO; 1=YES)			
How many times have you used this service in the last 12 months?			
Three (3) main reasons for use of method ***(B_2 codes)***	[___] [___] [___]	[___] [___] [___]	[___] [___] [___]
Three (3) main reasons for non-use of method ***if you didn't use any (B_4 codes)***	[___] [___] [___]	[___] [___] [___]	[___] [___] [___]
What is the average cost per service? ***(Frw)***			
How many different service providers can you access for this type of service			
What types of providers can you access? ***(B_5 codes)***		Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]
What is the distance (Km) from your farm to the service providers/bull owner?		Provider 1. [__] Provider 2. [__] Provider 3. [__]	Provider 1. [__] Provider 2. [__] Provider 3. [__]

Table of codes

(B_2)	**(B_4)**	**(B_5)**
1= Cheap	**1=** Expensive	**1**= Other farmers
2= Easily accessible (provider can easily be reached)	**2**= Not easily accessible	**2**= Community bull (bull scheme)
3= Readily available when cow is on heat	**3**= Not readily available	**3**= Private AI provider
4= Higher success rate	**4**= Low success rate	**4**= Government/public AI provider
5= Offers calf with desirable traits	**5**= Produces poor quality calf	**5**= Project/NGO AI provider
6= Offers access to wide variety of breeds	**6**= Limited access to variety of reeds	**6**= MCC/AI provider
7= Frequently gives female calves	**7**= Frequently gives male calves	**7=** Other (specify)
8= Offers access to sires with known history	**8=** Unknown sire history	
9= Helps to avoid inbreeding	**9**= Encourages inbreeding	
10=Other (specify)	**10**= Other (specify)	

1.4. Cow shelter and milk utensils costs

i. Do your cows have a shelter/cowshed? [__] (0=No, 1=Yes)

ii. If Yes, when did you built it? [__] (***Give the year of construction)***

iii. How much did it cost you to build it? [__] (***in Frw***)

iv. How much does it cost you to repair it per year? [__] (***in Frw***)

v. Did you buy stainless steel cans for collecting your milk? [__] (0=No, 1=Yes)

vi. If Yes, when did you buy them? [__] *Give the year you bought them*

vii. How much did they cost you? [__] (in Frw)

viii. How much do you spend/have you spent on following activities? (***0 if no cost or if the activity is not carried)***

Activities	**Amount in Frw**

Soaps for milker and utensils cleaning (per year)	
Buying towels for udder cleaning	
Buying appropriate coat for the milker	
Other (specify)	

MODULE E: SECTION 1: AWARENESS ABOUT MCC/ DAIRY COOPERATIVE AND GROUP MEMBERSHIP DETAILS

1	Have you ever heard about MCC?			0=No (***skip to Q7***) 1=Yes
2	Is there any MCC around your location?			0=No (***skip to Q4***) 1=Yes
3	How far is the MCC to your farm? (Km)			
4	Are you a member of any MCC?			0=No 1=Yes (***skip to Q6***)
5	**If NO in Q4 above,**			
	5.1	What are your reasons?		**See codes (5.a)**
	5.2	Which services do you receive from an MCC as a non-member?		
	5.3	Have you been a member of any MCC before but not anymore currently?		0=No (***skip to Q7***) 1=Yes
		5.3.1	If YES, how long since you stopped to be a member? (in years)	
		5.3.2	If YES, why did your membership stop?	**See codes (5.b)**
6	**If YES in Q4 above,**			
	6.1	How long have you been a member? (years)		
	6.2	How often do you pay your membership fee?		**See codes (6.a)**
	6.3	How much is your membership fee? (***Frw)***		
	6.4	Based on your experience, how likely are you to recommend the MCC to a friend or a colleague?		**See codes (6.b)**
	6.5	What are the two key reasons behind the ratings you provided?		1…….. 2……..
	6.6	Have you ever recommended someone to the MCC?		0=No 1=Yes
7	Are you a member of any other dairy group or dairy cooperative?			0=No 1=Yes
8	**If YES in Q7**, how long have you been a member? (years)			
9	Are you supplying milk to MCC?			0=No 1=Yes

10	**If NO in Q9**, why are you not supplying your milk to MCC?	**See codes (10.a)**

Table of codes

(5.a)
1= Located far from HH
2= Selling milk elsewhere at a higher price
3= Delayed payments
4= poor management of MCCs
5= Lack of membership fees
6= MCCs are not beneficial
7= Insufficient/irregular milk production
8= Other (Specify)

(5.b)
1=Located far from HH
2= Lower buying price
3= Poor management of the group
4= Lack of membership fees
5= No benefits gained from membership
6= Other (specify)

(6.a)
1= Monthly
2= Quarterly
3= Twice a year
4= Once a year,
5= Once only (at the beginning)
6= Other (Specify)

(6.b)
1 = Extremely likely to recommend AGAINST
2 = Slightly likely to recommend AGAINST
3 = NEITHER likely to recommend nor recommend against
4 = Slightly likely to RECOMMEND
5 = Extremely likely to RECOMMEND

(10.a)
0= Immature cows,
1= Selling milk elsewhere at a higher price,
2= delayed payments, 3= dry cows,
4= Insufficient/irregular milk production,
5= consuming all the milk/no excess milk to sell,
6= the co-op not taking milk anymore/ collapsed,
7= Other (specify)

SECTION 2: A) SERVICES OFFERED BY THE MCC (*To be answered by members of MCCs only*) (*to be merged with section 1 above in ODK*)

1.S no	**2.** Services	**3**. Does MCC offers these services? 0= No ***(skip)*** 1= Yes	**4**. Did you use the services in the last 12 months? 0=No (***skip to Q10***) 1=Yes	**5.F**requency of usage ***(Number of times used in the last 12 months)***	**6. Unit** 1=Day 2=Total	**7.**Why did you use this service from MCC other than others? **(*See codes 7.b)***	**8.**Who makes decision to use the services? (***See codes 8.b)***	**9.**Are you satisfied with the service? **(*See codes 9.a)***	**10.**Any challenges OR If not used, why? **(*See codes 10.b)***
1	Milk marketing								
2	Agrovet (Feeds inclusive)								
3	Veterinary services								
4	Artificial Insemination (A.I)								
5	Extension services/Training (milk handling)								
6	Milk transportation								
7	Monetary advances								
8	Savings and credits								
9	Food provision (maize floor, rice)								

10	Other (specify)								

Table of codes

(7.b) 1= Good prices (high for milk or low for services) **2**= Good quality services **3=** Accessible	**4=** The only source of service available **5=** Service on credit **6=** Availability of check-off payment system **7=** Other (specify)	**(8.b)** **1=** Head **2=** Spouse **3=** Joint head and spouse **4=** Another male **5=** Another female **6=** Other (specify) **7=** Don't know
(9.a) **1=** Very satisfied **2=** Satisfied **3=** Neutral **4=** Dissatisfied **5=** Very dissatisfied	**(10.b)** **1=** Not able to pay for the service, **2=** Service located far from the HH, **3=** Poor quality of services, **4=** the service is not beneficial,	**5=** Limited range of services offered (A.I, feed, etc), **6=** Cheaper services/higher milk prices from elsewhere, **7=** Insufficient/irregular milk production, **8=** Other (Specify)

B)	What are the **three** main things that the MCC is not providing but you would like them to provide to increase the value of their service to you?	1…….. 2…….. 3……..
C)	What are the disadvantages of being a member of an MCC? (everyone)	1…….. 2…….. 3……..

MODULE F: HOUSEHOLD ASSETS

SECTION 1: CATTLE ASSETS (*Heads of cattle kept on the farm including those kept but not owned)*

1.No	**2.**Cattle type ***(See codes 2.a)***	**3.**Breed ***(See codes 3.b)***	**4.**Source ***(See codes 4.a)***	**5.**Total number owned by the HH and kept on the farm	**6.**Total number owned by household and kept elsewhere	**7.**Total number owned by Male	**8.**Total number owned by female	**9.**Total number owned jointly	**10.**Total number owned by children <16 years	**11.**Total number kept on farm but not owned
1										
2										
3										
4										
5										
6										
7										

Table of codes

(2.a)	**4=** Cows (calved at least once)	**6=** pre-weaning females (< 8 weeks)
1= Mature males (>3 years)	**5=** Heifers (female ≥1 year but have not calved)	**7=** Male calves (between 8weeks &<1year)
2= Immature males (<3 years)		**8=** Female calves (between 8weeks &<1year)
3= Pre-weaning males (< 8 weeks)		
(3.b)	**(4.a)**	**3=** Gifted**,**
1= Local/indigenous	**1=** purchased,	**4=** Born on farm**,**
2= Cross breed	**2=** Girinka**,**	**5=** Kept for others,
3= Exotic		**5**= Others (specify)

SECTION 2: OTHER LIVESTOCK ASSETS (***Heads of livestock other than cows kept on the farm including those kept but not owned)***

1. No	**2**.Livestock type	**5.**Total number owned by the HH and kept on the farm	**6.**Total number owned by household and kept elsewhere	**7.**Total number owned by Male	**8.**Total number owned by female	**9.**Total number owned jointly	**10.**Total number owned by children <16 years	**11.**Total number kept on farm but not owned
1	Goats							
2	Sheep							
3	Pigs							
4	Chicken/pigeon							
5	Oxes							
6	Other (specify)							

SECTION 3: Land for cropping

i. How much owned land have you used for cropping in the last season? [__] ***(in hectares)***
ii. How much rented land have you used for cropping in the last season? [__] ***(in hectares)***

SECTION 4: HOUSEHOLD AND FARM ASSETS IN USABLE OR REPAIRABLE FORM

	A. Household assets	**1. Does the household own?** **1**=Yes, **0**=No ***skip next asset***	**2. No. owned now (*in usable or repairable condition*)**	**3. When acquired (*Year, most current)***	**4. Who owns (*See codes 8.b)***
1	Radio				
2	Television				
3	Mobile phone				
4	Vehicle (cars)				
5	Motorcycle				
6	Bicycle				

7	Refrigerator				
8	Solar panels				
9	Car battery				
10	Elec./ gas cooker				
11	Sofa set				
12	Water tanks				
13	Water pumps				
14	Sewing machine				
15	Other (specify)				
16	Other (specify)				
	B. Farm assets				
17	Hand/ ox/ donkey cart				
18	Draft animals Oxen)				
19	Shovel				
20	Axe				
21	Bush knife (panga)				
22	Hand hoe				
23	Plough				
24	Harrow				
25	Wheelbarrow				
26	Tractor/ trailer/ pickup				
27	Spray pump				
28	Chaff cutter				
29	Pulveriser machine				
30	Milking cans (aluminium)/mazzican				

31	Milking cans (other)				
32	Other (specify)				

Table of codes

(8.b)	
1= Head	**4=** Another male
2= Spouse	**5=** Another female
3= Joint head and spouse	**6=** Other (specify)
	7= Don't know

MODULE G: EXTENSION SERVICES

SECTION1: Dairy extension services

1. Livestock extension service providers	**2.** Accessible in your area**?** **1**=Yes, **0**=No, **88** = Don't know. ***0 or 88 skip next line***	**3.** No. of contacts in last 12 months **(***includes visiting and visits by the extension staff, and attending trainings carried out by extension staff)*	**4.** Total Cost between Feb 2019 and Jan 2020 **(Frw)**	**5**. Skills trained on ***(G_1 codes)***		
				1	2	3
Government (MINAGRI, RAB, RALIS, etc)						
Project or NGO's						
Private practitioners						
MCC / farmer group						
Lead farmers/ volunteer farmer trainers						
Community Facilitators (CFs) and Community Agro-veterinary entrepreneurs (CAVES)						

Table of codes

(G_1)		
1= Animal health	**3**= Feeding	**6**= Milk handling and cleanness
2= Milk quality	**4**= Breeding	**7=** Business/ entrepreneurs
	5= Other animal husbandry skills	**8**= Other (specify)

SECTION 2: Training attendance

Besides Extension, have you or someone else from your household attended any training in business and animal husbandry/ dairy? 1= Yes, 0= No (skip to Module H)

Type of skills trained	Was anyone in your HH trained on this skill in the last one year?	Who was trained? ***(8.b codes)***	Number of trainings	Who Offered the training?	Did you pay for the training?	How much? (***Frw***)

	0= No (***skip to next***) 1=Yes			***(G_2 codes)***	0= No 1=Yes	
1. Milk quality and value addition						
2. Livestock feeds, feeding and nutritional skills						
3. Breeding						
4. Animal health skills						
5. milk handling and cleanness						
6. Business skills						
7. Other animal husbandry practices						
8. Savings and credits						
9. Other (specify)						

Table of codes

(8.b)		**(G_2)**
1= Head	**4=** Another male	**1**= Government extensionist
2= Spouse	**5=** Another female	**2**= Project/NGO staff (RDCPII, RDDP, Technoserve, etc)
3= Joint head and spouse	**6=** Other (specify)	**3**= MCC/group staff (include vet)
		4= Government veterinarian
		5= Other (specify)

MODULE H: HOUSEHOLD INCOME

Instruction: ***Income sources and levels should include all members of the household***

	i. Off-farm income sources	Did your HH receive any cash income from these sources in the last 12 months? (Feb 2019-Jan 2020) ***1=Yes, 0=No***	If Yes, how frequently did you receive cash income from these sources? (***H_1 codes)***	On average how much did you receive each time from the indicated source between Feb 2019-Jan 2020	Who in the household received the income and decided on how it was used? ***(8.b codes)***
1	Wages or salary from regular job				
2	Wages from casual work				
3	Running business				
4	Pension/grants				
5	Remittances of any sort				
6	Renting out your own land				

7	Rented out property such as house, tractors, shops				
8	Others (specify)				
	ii. On-farm income sources			**Total received in 12 months *(H_2 codes) in Frw***	
9	Sale of crops				
10	Sale of cattle				
11	Sale of other livestock (e.g. shoats, sheep, pigs, other cattle, poultry, etc)				
12	Sale of other livestock products such as eggs (excluding products from cattle)				
13	Farm labor				
14	Sale of farm produced animal feeds, pasture or fodder				
15	Sale of cattle manure				
16	Sale of other livestock manure				
17	Other (specify)				

Table of codes

(8.b)	**4=** Another male	**(H_1)**	**5**= Quarterly	**(H_2)**	**6=** 250000 – 300000
1= Head	**5=** Another	**1**= Daily	**6**= twice a year	**1=** 0 – 50000	**7=** 300000 – 350000
2= Spouse	female	**2**= Weekly	**7**= Annually	**2**= 50000–100000	**8=** 350000 – 400000
3= Joint head	**6=** Other	**3**= fortnightly	**8**= other (specify)	**3=** 100000–150000	**9=** 400000 – 450000
and spouse	(specify)	**4**= monthly		**4=** 150000–200000	**10**= 450000–500000
				5= 200000–250000	**11**= Above 500000

MODULE I: ACCESS TO CREDIT AND INFORMATION
SECTION 1: ACCESS TO CREDIT

1	Did you need/desire any credit for farm operations ***between Feb 2019-Jan 2020***?	[_____]	**1= Yes**, **0= No**
2	If No, why didn't you need credit?	[_____] [_____]	Use ***I_1 codes*** below
3	Did anyone in the household access credit for dairy activities ***between Feb 2019-Jan 2020?***	[_____]	**1= Yes**, **0= No (*if No skip to 1_5*)**
4	What is the source of credit?	[_____][_____]	**(*I_3 codes)***
5	If no credit was accessed, why not?	[_____] [_____]	Use ***I_1 codes*** below

Table of codes

(I_1)	**4**= Lack of collateral	**7**= Never taught of it
1= credit required but didn't get	**5**= Fear of being unable to pay	**8**= Not aware (didn't know)
2= credit not available (Lack of lenders)	**6**= Self-sufficiency (does not need credit)	**9**= Other (specify)
3= High interest rate (credit was too costly)		

(I_3)	**3**= Microfinance institutions (SACOOs, etc)	**5**= Family/friends
1= Commercial banks	**4**= Informal lenders (Lambert)	**6**= Government bank/agency
2=MCCs/Cooperatives/Groups		**7**= project/NGO
		9= Other (specify)

SECTION 2: INFORMATION AND SOURCE OF INFORMATION

	Information (other than extension and training)	Did you search for the information on these ***between Feb 2019-Jan 2020?*** **1**= yes, **0**= no ***Skip next line***	If yes, from which sources did you search for this information? **(*1.10 codes)***	How many times in the last **one (1) month** have you used this information source?
1	Information on markets and prices of milk and milk products		**[_____] [_____] [_____]**	
2	Quality of milk		**[_____] [_____] [_____]**	
3	Dairy best practice (DBP)/Seal of Quality (SoQ) standards		**[_____] [_____] [_____]**	
4	Livestock Husbandry (Health, and management)		**[_____] [_____] [_____]**	
5	Cow feed production and formulation		**[_____] [_____] [_____]**	
6	Other (Specify)		**[_____] [_____] [_____]**	

Table of codes

(1.10)	**3**= Radio/TV programs/ gazette	**6**= MCC
1= Friends/ neighbors	**4**= Mobile phone /internet	**7**=Trainings/extensionists
2= Local opinion leader/model farmers	**5**= Print media	**8**=Other (specify)

SECTION 3: FARM RECORD KEEPING

i. Do you keep farm records? ☐ 1=Yes, 0=No (If No, conclude the interview)

ii. If Yes, what type of farm records? ☐ ☐ ☐ ***(I_5 Codes)(Enumerator to check the book where possible)***

Table of codes

(I_5)	**3**= Production, farm produce, AI, calving
1= Sales (prices and quantities, market outlets)	**4**= Purchase of inputs and assets
2= Milk production and sales	**5**= Other (specify)

***[END]*(Please DO NOT forget to thank the farmer)Ensure you also answer questions in the next SECTION**

To be answered privately by the enumerator immediately following the interview			
In your opinion, how did you establish rapport with this respondent?	**[_____]**	**1** = with ease	**2** = with some persuasion
		3 = with difficulty	**4** = it was impossible
Overall, how did the respondent	**[_____]**	**1** = willingly	**2** = reluctantly

give answers to your questions?		**3** = with persuasion	**4** = it was hard to get answers
How often do you think the respondent was telling the truth?	**[_____]**	**1** = rarely	**2** = sometimes
		3 = most of the times	**4** = all the time

Appendix C: Consumer Questionnaire

3.1. Informed Consent to Participate in Experimental Auction

Participants:

Participants are milk consumers from urban centres of Musanze and Ruhango districts of Rwanda who make the milk buying decision in their households.

Title of Study: Economic analysis of milk quality certification in Rwanda: assessing consumer demand and willingness to pay for quality milk that meets the dairy best practice standards

The student: Naphtal Habiyaremye, ILRI/ Egerton University

Contact Phone number: +254741095455

Contact email: habiyaremyen@gmail.com

Funding Source or Sponsor: United States Agency for International Development (USAID) through University of California Davis

What are some general things you should know about this experimental auction?

You are being asked to take part in this experimental auction on assessing consumer demand and willingness to pay for quality milk that meets the dairy best practice standards in Kigali city of Rwanda. To join the experiment is voluntary. You may refuse to join, or you may withdraw your consent to be in the experiment, for any reason.

I am using experimental auction to estimate consumer demand and willingness to pay for quality milk that meets the dairy best practice standards. Your participation in the experiment will be rewarded with some amount of money. This money is yours to use as you wish. I will also give you the opportunity to buy some milk products during the auctions that are about to follow. You should know that if you are the highest bidder in an auction you will have to pay for the product you bid. Because I am trying to find out the value for three milk products, I ask you not to communicate with each other. If you have any question at any point, please raise your hand and someone will come for your help. No communication is allowed with any participant for no reason. Since I will conduct this survey with other participants, I ask you not to discuss about any part of the survey with other people.

Details about this experiment are discussed below. It is important that you understand this information so that you can make an informed choice about participating in this experimental auction. Your bids will be noted down and the collected data will be safely stored. The content of the consent form will be read to you. If you agree to participate in the experiment,

you will be asked to sign the consent form. You should ask the researchers named above, or staff members who may assist them, any questions you have about this experiment at any time.

What is the purpose of this study?

The purpose of the experiment is to assess consumer demand and willingness to pay for quality milk that meets the dairy best practice standards. Furthermore, I would like to assess the effects of information on willingness to pay for quality milk that meets the dairy best practice standards.

How long will your part in this experiment last?

One session is composed of eight people who will bid simultaneously with you for the same products and the session will take a maximum of 2 hours.

What are the possible benefits from being in this experiment?

This research in the long run will benefit milk value chains actors by estimating the willingness to pay for quality certified milk.

What are the possible risks or discomforts involved with being in this experiment?

There are no sensitive questions, but if you feel uncomfortable answering a specific question, you may remain silent and you will not be penalized in any way.

How will your privacy be protected?

I will make every effort to protect your privacy and confidentiality. No study participant will be identified in any report or publication about this experiment. Every effort will be made to keep collected data private. In some cases, however, your information (names and contact) in this research study could be reviewed by the national institutional review board/ethics committees, other government agencies, or project collaborators (ILRI, University of Rwanda, or University of California).

What if you want to stop before your part in the experiment is complete?

You can withdraw from this study at any time, without penalty.

Will you receive anything for being in this study?

Yes, you will be rewarded with some amount of money as your participation fee

Who is sponsoring this study?

This research is funded by the United States Agency for International Development (USAID). The researchers working on this project do not have a direct financial interest in the final results of the study.

What if you have questions about this experiment?

You have the right to ask, and have answered, any questions you may have about this experiment. If you have questions, complaints, or concerns, you should contact the researchers listed on the first page of this form.

Title of Study: Economic analysis of milk quality certification in Rwanda: assessing consumer demand and willingness to pay for quality milk that meets the dairy best practice standards

Main supervisor: Naphtal Habiyaremye, ILRI/ Egerton University

Participant's Agreement:

If you have read this consent form, or had it read and explained to you, and you understand the information, and you voluntarily agree to participate, please sign your name or make your mark below.

PART A: LITERATE PARTICIPANT

Participant is literate: ☐

_____	_____	_____
Participant Name (print)	Participant Signature	Date
_____	_____	_____
Study enumerator (print)	Enumerator Signature	Date

PART B: ILLITERATE PARTICIPANT

Participant is illiterate: ☐

The enumerator must complete this section. This form can ONLY be completed in the case of an illiterate participant if an impartial witness is available.

_____	_____	_____
Participant Name (print)	Participant thumbprint	Date
_____	_____	_____
Study enumerator (print)	Study Staff Signature	Date
_____	_____	_____
Impartial Witness Name	Impartial Witness Signature	Date

3.2. Consumers' Willingness To Pay Questionnaire

SECTION 1: Respondent´s Characteristics

1. ID	**2.** Name of respondent (***one name)***	**3.**Received information **0**= No **1**= Yes	4.Relationship to HH head ***(codes 1.4***	**5.** Sex **0**=Female **1**= Male	**6.** Age (in years)	**7.**Education (***number of years***)	**8.** HH size	**9**.Marital status (***codes 1.9)***	**10.**monthly income ***(Frw)***	**11.**Number of children between **6-59** months	**12.**Time of day **1**= Morning **2**= Afternoon	**13.** District **1**=Musanze **2**=Muhanga

Table of codes

(1.4)			**(1.9)**
1= Head	**4**= Grandchild	**8**=Son/daughter-in-law	**1**=Married/living together
2= Wife/husband	**5**= Nephew/Nice	**9=** Parent-in-law	**2=** Divorced/separated
3= Daughter/Son	**6**= Parent	**10=** House maid	**3=** Widowed
	7= Sister/Brother	**11=** Not related	**4=** single

SECTION 2: Milk Purchase and Consumption Habits

2.1 What type of milk do you mainly (frequently) **buy**? ***(Codes 2.1 below)***

2.2 Where do you normally **buy** your fresh milk from? ***(Codes 2.2 below)***

Table of codes

(2.1)		**(2.2)**	
1= Raw Milk (non-DBP)	**4=** Pasteurized Milk (packaged)	**1**= From producer	**5**= Kiosk
2= Raw Milk (DBP)	**5=** Fermented milk (Ikivuguto)	**2**= Shop	**6**= Milk collection center
3= Pasteurized Milk (unpackaged)	**6=** Other (specify)	**3**= milk trader	**7**= Alimentation
	7= I don't know	**4**= Milk Bar	**8**= Supermarket/hypermarket
			9= Other (specify)

2.3 Please state the amount and price of your recently purchased fresh milk?
Size (litres): _____ Price: _____ [__] I don´t remember

2.4 What is the distance between your house and the place where you usually buy fresh milk?
In Km _____

2.5 Are there other nearer fresh milk sellers to you than the place you usually buy fresh milk?
1= Yes, 0= No

2.6 If yes, why do you prefer the place where you usually buy your fresh milk? ***(Codes 2.5 below)***

2.7 How often (frequently) do you usually **buy** fresh milk for yourself or your household? ***(Codes 2.6 below)***

Table of codes

(2.5)	**(2.6)**	
1= Good prices (cheaper)	**1**= More than once a day	**5**= Once/week
2= I trust the quality	**2**= Once a day	**6**= Once/2 weeks
3= I can buy on credit	**3**= 4-6 times/week	**7**= Occasionally
4= Other (specify)	**4**= 2-3 times/week	**8**= Other (specify)

2.8 Do you know who has produced the fresh milk you generally buy? 1= Yes, 0= No

2.9 If yes, to what extent do you trust the producer to provide hygienic produced fresh milk? ***(Codes 2.9 below)***

2.10 What do you consider when buying fresh milk? ***(Codes 2.10 below)***

Table of codes

(2.9)	**3**= I don´t really know	**(2.10)**	**4**= Taste
1= I extremely trust	**4**= I slightly don´t trust	**1**= price	**5**= Packaging
2= I slightly trust	**5**= I extremely don't trust	**2**=Smell	**6**= brand of the seller
		3= Colour	**7**= Other (specify)

SECTION 3: Awareness of Dairy best practice (DBP)/ Seal of quality (SOQ) and Milk collection canters (MCCs)

3.1 Have you ever heard about MCC? [__] 1= Yes, 0= No

3.2 Have you ever heard about Seal of quality (SoQ)/dairy best practice (DBP)? [__] 1= Yes, 0= No

3.3 If yes, how much do you consider DBP information before you buy fresh milk? ***(Codes 3.3 below)***

3.4 If yes in 2.3 above, to what extent do you know if the fresh milk that you usually buy has met DBP standards? ***(Codes 3.4 below)***

Table of codes

(3.3)	**3**= I don´t really consider	**(3.4)**	**3**= I am not sure
1= I fully consider	**4**= I don't consider at all	**1**= I completely know	**4**= I don´t really know
2= I slightly consider		**2**= I know a little	**5**= I completely don't know

SECTION 4: Attitudinal Issues

4.1 What is your opinion on certified food/food quality labels? ***(Codes 4.1 below)***

4.2 What is your opinion of information given on food product packaging labels and commercial advertisements? ***(Codes 4.2 below)***

4.3 What is your main source of information to stay current? ***(Codes 4.3 below)***

4.4 How much does milk quality influence your purchase decisions? ***(Codes 4.4 below)***

Table of codes

(4.1)	**(4.2)**	**(4.3)**	**4**= Friends	**(4.4)**
1= I fully trust	**1**= I fully rely	**1**= TV	**5**= Internet	**1**= A lot
2= I slightly trust	**2**= I slightly rely	**2**= Radio	**6**= Work (colleagues)	**2**= A bit
3= I don´t really trust	**3**= I don´t really rely	**3**= Newspaper	**7**= Other (specify)	**3**= Not at all
4= I don't trust at all	**4**= I don't at all rely			

Appendix D: Publications and Presentation

frontiers in Veterinary Science

POLICY AND PRACTICE REVIEWS
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A Review of the Evolution of Dairy Policies and Regulations in Rwanda and Its Implications on Inputs and Services Delivery

Naphtal Habiyaremye[1,2*], *Emily Awuor Ouma*[3], *Nadhem Mtimet*[4] *and Gideon Aiko Obare*[2]

[1] *Policies, Institutions, and Livelihoods, International Livestock Research Institute, Nairobi, Kenya,* [2] *Department of Agricultural Economics and Agribusiness Management, Egerton University, Nakuru, Kenya,* [3] *Policies, Institutions, and Livelihoods, International Livestock Research Institute, Kampala, Uganda,* [4] *Strategy and Knowledge Department, International Fund for Agricultural Development, Cairo, Egypt*

The dairy sector in Rwanda plays a key role in improving nutrition and generating income mostly for rural households. Despite the Rwandan 1994 genocide that left around 80% of dairy cows decimated, the dairy sector has experienced significant growth in the past two decades through government, development organisations, and donor programs, and through the nascent vibrant public–private partnership. In this paper, we reviewed and documented the evolution of the dairy policies, programs, and regulations in Rwanda and how they have contributed to the development of the dairy sector. The policy change has impacted the provision and use of inputs and services that have shaped the sector's milk production and productivity, milk quality, and demand. The results suggest that various policy- and program-level interventions have positively contributed to the growth of the dairy sector and improved the livelihoods of low-income households. This has been achieved through increased access to inputs and services, enhanced capacities of the public and private sector to deliver services, strengthened dairy cooperatives' governance, and increased value proposition to members of various farmer groups and promotion of milk consumption. We find that some of the implemented policies and programs, such as the "Girinka" (one cow per poor family) program, Rwanda Dairy Competitiveness Program II, and Rwanda Dairy Development Project, have resulted in improved farmer access to improved cow breeds and improved milk quality and cow productivity through enhanced health inputs and other services. While the dairy policies, programs, and regulations in Rwanda have paved the way for the development of the dairy sector and contributed to the provision and use of inputs and services, there are still challenges that need to be addressed. Accessibility and use of veterinary and artificial insemination services are limited by the quality of veterinary products, while the inadequate quality of feeds leads to low productivity of improved cow breeds. Consequently, farmers' uptake and use of inputs and services can be enhanced through a strengthened capacity of milk collection centres and health and animal feed policies that guide and control the quality of veterinary products and feeds sold in the markets.

Keywords: dairy, policies, regulations, inputs, services, Rwanda

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***Correspondence:**
Naphtal Habiyaremye
n.habiyaremye@cgiar.org;
habiyaremyen@gmail.com

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Cooperative membership effects on farmers' choice of milk marketing channels in Rwanda

Naphtal Habiyaremye [a,b,*], Nadhem Mtimet [c], Emily Awuor Ouma [d], Gideon Aiko Obare [b]

[a] Policies, Institutions, and Livelihoods (PIL), International Livestock Research Institute (ILRI), Nairobi, Kenya
[b] Department of Agricultural Economics and Agribusiness Management, Egerton University, Nakuru, Kenya
[c] Strategy and Knowledge Department, International Fund for Agricultural Development (IFAD), Cairo, Egypt
[d] Policies, Institutions, and Livelihoods (PIL), International Livestock Research Institute (ILRI), Kampala, Uganda

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Keywords:
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ABSTRACT

Although cooperatives play a critical role in reducing transaction costs and enhancing farmers' adoption of better farming practices, little is known on the effects of dairy cooperative membership on the choice of milk marketing channels. This paper employs an endogenous switching probit model to estimate the determinants of farmers' choice of milk marketing channels while controlling for the potential selection bias of cooperative membership. We find that cooperative membership has positive and significant effects on the choice of both MCCs and milk traders as marketing channels along with a negative effect on the choice of other buyers (direct consumers and restaurants). The varying effect of cooperative membership on choice of different marketing channels holds also for non-members had they been cooperative members. Furthermore, we find that the selling price positively affects farmers' choice of MCCs, but the longer distance to MCCs may make farmers (including cooperative members) to choose milk traders who offer lower prices than MCCs. Since the MCCs are managed by dairy cooperatives and they are the only marketing channels that conduct basic milk quality tests while offering higher prices to farmers, we recommend policies that support easy access to MCCs and enhance dairy cooperatives' governance. This will facilitate dairy farmers' access to a better marketing channel while meeting an already growing consumer demand for products safety and quality in the food industry.

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RESEARCH ARTICLE

Agribusiness WILEY

Consumers' willingness to pay for safe and quality milk: Evidence from experimental auctions in Rwanda

Naphtal Habiyaremye[1,2] | Nadhem Mtimet[3] | Emily A. Ouma[4] | Gideon A. Obare[2]

[1]Policies, Institutions, and Livelihoods (PIL), International Livestock Research Institute (ILRI), Nairobi, Kenya

[2]Department of Agricultural Economics and Agribusiness Management, Egerton University, Nakuru, Kenya

[3]Strategy and Knowledge Department (SKD), International Fund for Agricultural Development (IFAD), Cairo, Egypt

[4]Policies, Institutions, and Livelihoods (PIL), International Livestock Research Institute (ILRI), Kampala, Uganda

Correspondence
Naphtal Habiyaremye, Policies, Institutions, and Livelihoods (PIL), International Livestock Research Institute (ILRI), Nairobi, Kenya.
Email: habiyaremyen@gmail.com

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Abstract

A major concern of the Rwandan government and other dairy stakeholders is the safety and quality of milk that goes through informal delivery systems until it gets to the consumers. Although the government introduced the dairy best practices scheme that stipulates standards and practices for proper handling of raw milk, consumers' willingness to pay (WTP) for such milk has not yet been assessed. It is also unclear whether consumers are aware of and/or value the safety- and quality-related information on types of milk sold in different marketing channels. In this study, we use the second price auction mechanism to elicit consumers' WTP for pasteurized but unpackaged milk in Rwanda and we estimate the effect of providing safety- and quality-related information on WTP using the random-effect Tobit model. Our results show that consumers are willing to pay a price premium for safe and quality milk, implying that there is an opportunity for market transformation in the dairy sector. Furthermore, we find a positive and significant effect of providing information to consumers on WTP for safe and quality milk. Based on our results, we recommend policies that promote private sector investments in upscaling of milk zones and the establishment of milk-dispensing machines selling this type of milk. There is also a need for information campaigns that increase consumers' knowledge and awareness of the quality of milk consumed. [EconLit Citations: C34, C91, D12, D44, M31].

KEYWORDS
consumers' willingness to pay, experimental auctions, random-effect Tobit model, safe and quality milk, second price mechanism

Appendix E: Robusteness Models for Estimating the Effects of Cooperative Membership

Appendix E.1. Multivariate probit model (MVPM) results

Variables	Membership	Milk traders	Membership	MCCs	Membership	Other buyers
Commercial index	-0.218	-0.683	-0.171	0.231	-0.237	-0.088
	(0.734)	(0.512)	(0.734)	(0.508)	(0.735)	(0.454)
Distance to nearest milk selling point in Km	0.146 ***	-0.042	0.145 ***	0.027	0.147 ***	0.003
	(0.054)	(0.048)	(0.054)	(0.045)	(0.054)	(0.046)
Dairy farming experience in years	-0.004	-0.001	-0.003	-0.007	-0.003	0.005
	(0.012)	(0.010)	(0.013)	(0.010)	(0.013)	(0.009)
Sex of the household head	0.317	-0.163	0.296	-0.163	0.311	-0.232
	(0.402)	(0.249)	(0.340)	(0.254)	(0.401)	(0.233)
Age of the household head in years	0.016	-0.010	0.016	0.007	0.015	-0.001
	(0.011)	(0.007)	(0.011)	(0.008)	(0.011)	(0.007)
Education level of the household head	-0.020	-0.054 **	-0.021	0.045 *	-0.020	-0.024
	(0.038)	(0.026)	(0.038)	(0.026)	(0.038)	(0.023)
Off-farm income	-0.379	0.446 **	-0.363	-0.209	-0.374	0.019
	(0.309)	(0.177)	(0.307)	(0.180)	(0.309)	(0.159)
Crossbreed lactating cows	1.554 ***	0.266	1.611 ***	-0.297	1.570 ***	-0.107
	(0.583)	(0.389)	(0.591)	(0.335)	(0.586)	(0.307)
Pure breed lactating cows	2.194 ***	0.190	2.217 ***	-0.200	2.203 ***	-0.146
	(0.546)	(0.394)	(0.553)	(0.331)	(0.550)	(0.303)
Membership fee	0.286 ***	-0.044 *	0.287 ***	0.023	0.287 ***	0.030
	(0.030)	(0.025)	(0.030)	(0.023)	(0.030)	(0.023)
Local administration	0.983 ***	–	0.981 ***	–	0.982 ***	–
	(328)		(0.324)		(0.327)	
Training	0.235 ***	–	0.231 ***	–	0.230 ***	–
	(0.072)		(0.072)		(0.073)	
Adherence to DBP	–	-0.188	–	1.633 ***	–	-1.607 ***
		(0.194)		(0.217)		(0.198)
Selling price in Rwf per litre	–	-0.036 ***	–	0.018 ***	–	0.006 ***
		(0.004)		(0.003)		(0.002)
Selling season	–	-0.096	–	0.037	–	0.065
		(0.175)		(0.177)		(0.160)
Location	-0.187	-1.839 ***	-0.166	1.761 ***	-0.175	-0.514 **
	(0.271)	(0.283)	(0.270)	(0.237)	(0.270)	(0.199)
Constant	-4.582 ***	8.724 ***	-4.669 ***	-6.976 ***	-4.580 ***	0.463
	(1.079)	(1.144)	(1.084)	(0.966)	(1.078)	(0.835)
Wald $\chi 2$	–	220.48 ***	–	232.40 ***	–	211.34 ***
		0.038		0.128	–	-0.077
ρ	–	(0.156)	–	(0.162)		(0.143)

Note: Standard errors clustered at the household level are in parentheses and *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix E.2. Falsification test on the validity of the selection instruments

Variables	(1)	(2)	(3)	(4)
	Coop membership	**Milk traders**	**MCCs**	**Other buyers**
Local administration	0.981 ***	0.148	-0.026	0.088
	(0.326)	(0.255)	(0.273)	(0.250)
Training	0.236 ***	0.023	0.093	-0.061
	(0.072)	(0.058)	(0.062)	(0.060)
Other control variables	Included	Included	Included	Included
Constant	-4.593 ***	9.049 ***	-7.421 ***	-0.572
	(1.078)	(1.385)	(1.201)	(1.039)
Observations	370	271	271	271

Note: (1) is a probit model for selection equation; (2), (3), and (4) are probit models for outcome equations for non-cooperative members; Standard errors are in parentheses; *** p<0.01. All other control variables are included in the models, but I only report the estimates of the instruments to reduce space.

Appendix E.3. Endogenous switch probit (ESP) model results of three main milk marketing channels for non-cooperative members

Variables	Milk traders	MCCs	Other buyers
	Non-member	**Non-member**	**Non-member**
Commercial index	-0.508	0.793	0.048
	(0.534)	(0.568)	(0.534)
Distance to nearest milk selling point in Km	-0.111 **	0.005	-0.034
	(0.051)	(0.054)	(0.065)
Dairy farming experience in years	-0.001	-0.017	0.006
	(0.012)	(0.013)	(0.011)
Sex of the household head (=1 if male)	0.063	-0.120	-0.251
	(0.271)	(0.286)	(0.282)
Age of the household head in years	-0.014 *	0.008	0.002
	(0.008)	(0.008)	(0.008)
Education level of the household head	-0.055 **	0.045 *	-0.011
	(0.027)	(0.027)	(0.025)
Off-farm income (=1 if there is)	0.284	-0.206	0.080
	(0.186)	(0.198)	(0.183)
Crossbreed lactating cows	-0.121	-0.729 **	0.299
	(0.487)	(0.370)	(0.423)

Pure breed lactating cows	-0.430	-0.888 **	0.365
	(0.536)	(0.399)	(0.501)
Membership fee (the amount of money paid to	-0.042	-0.220 ***	0.051
become a cooperative member in Rwf)	(0.054)	(0.048)	(0.098)
Adherence to DBP (=1 if the household adheres)	0.327 *	1.412 ***	-1.536 ***
	(0.192)	(0.224)	(0.231)
Selling price in Rwf per litre	-0.033 ***	0.015 ***	0.009 ***
	(0.004)	(0.003)	(0.003)
Selling season (=1 if milk is sold in rainy season)	-0.097	0.095	0.035
	(0.180)	(0.192)	(0.184)
Location (=1 if Nyabihu district)	-1.671 ***	1.479 ***	-0.403 *
	(0.303)	(0.261)	(0.242)
Constant	8.553 ***	-5.928 ***	-0.769
	(1.237)	(1.050)	(1.054)

Note: Standard errors clustered at the household level are in parentheses and *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix F: Experimentl Auction Procedure and Robusteness of WTP Model

Appendix F.1. The WTP script: Auction procedure and instruction card

- Thank you for choosing to participate in an experiment on how people make decisions regarding choices of fresh milk for consumption. Please read carefully all the instructions written on this paper. There is no right or wrong answer in any question, I just want to know about your opinion.
- It is very important to follow instructions carefully. It is also **very important not to communicate with any other participant**. Any attempt to communicate with each other will result in the failure of this experiment and biased results.
- Today, I will auction different types of fresh milk. In a while you will receive details on how an auction works.
- Your transport fees of Rwf 2,000 to participate in the experiment will be reimbursed at the end of experiment. I will also give you the opportunity to buy some types of milk during the auctions that are about to follow.
- You should know that if you are the highest bidder in an auction you **will have to pay for the milk you bid**.
- Because I am trying to find out the value for various milk types, I ask you not to communicate with each other. If you have any questions, at any point, please raise your hand and someone from our team will come for your help. No communication is allowed with any participant for any reason.
- Since I will conduct this experiment with other milk consumers in this town, I ask you not to discuss about any part of the experiment with other consumers.
- Thank you for your understanding and abiding to the rules.

How the auction works:

Today, I will use what is known as «2nd price auction». It has 5 basic steps:

- **Step1.** You will first examine the fresh milk types I am about to offer for auction
- **Step2.** Each one of you, will submit a bid for each milk type in the appropriate field on the paper and put the paper in an envelope and seal
- **Step3.** We will randomly select a number which identifies the binding product to auction
- **Step4.** I will open the envelope and rank your bids from the highest to the lowest

- **Step5.** The person that submits the highest bid wins the auction but will pay the price of the second highest bidder. In case of ties, we will decide about the winner randomly.

Conduct 2 rounds of trial auctions to familiarize participants with auction

The experiment today is on milk:

- Milk essentially comes from a sterile environment within the animal. From the moment the animal is milked, the potential for contamination begins with the udder, skin, milking equipment, handling and storage. Contamination of milk with germs and poisons (such as drug residues) is often not detected by smell, taste or appearance of milk.
- Now I want present to you three different types of fresh milk for you to bid

Appendix F.2. The simple quiz to participants (English version)

1. The highest bidder will buy the auctioned product and will have to pay the price he/she bided.
   A. True B. False
2. If you have the second highest bid, you win the auction.
   A. True B. False
3. In this type of auction, it is always in your best interest to bid the exact amount that you are willing to pay.
   A. True B. False
4. It does not make sense to bid 0 Rwf.
   A. True B. False
5. Suppose that 8 people (person 1, person 2, person 3, person 4, person 5, person 6, person 7, and person 8) submit bids to buy a goat. The submitted bids are:

PERSON 1	**24,500 Rwf**
PERSON 2	**80,000 Rwf**
PERSON 3	**85,000 Rwf**
PERSON 4	**12,000 Rwf**
PERSON 5	**65,000 Rwf**
PERSON 6	**0 Rwf**
PERSON 7	**67,000 Rwf**
PERSON 8	**34,500 Rwf**

a. Which person wins the auction?

b. How much does he/she pay?

Appendix F.3. Pictures of bottles with milk type A, B, and C labelled in Kinyarwanda

The three types of milk are milk A (raw milk bought directly from the farmer), milk B (raw milk bought from the milk collection center (MCC)), and milk C (pasteurised but unpackaged milk bought from the milk processor). Each milk type was in a clear one litre bottle labelled in Kinyarwanda (the label indicates the type and source of the milk) with a picture showing the source of the milk. Milk A was symbolised with a picture of a farmer milking a cow, milk B was represented by a picture of a cooling tank and milk cans used at the MCC, and milk C was symbolised with big cooling tanks used by milk processors.

Source: Pictures taken during the experiment

Photo credit: The author

Appendix F.4. Parameter estimates of Random Effect GLS Model estimating determinants of WTP for one litre of safe and quality milk

Dependent variable: WTP for milk in hundreds of Rwf/litre	Coefficients	Std. Err.
Milk B (Yes=1, 0 otherwise)	0.78 ***	0.10
Milk C (Yes=1, 0 otherwise)	2.03 ***	0.10
Safety and quality-related information (=1 if received)	0.77 **	0.35
Prior safety information (=1 if heard about DBP before)	0.44 **	0.24
Safety and quality-related information x Prior safety information	-0.75 **	0.38
Safety and quality-related information x Milk B	0.22	0.15

Safety and quality-related information x Milk C	0.79 ***	0.15
Sex of the participant (=1 if male)	-0.172	0.125
Age of the participant in years	0.01	0.01
Education level of the participant[a]		
=1 if the participant has primary education level	0.44 *	0.26
=1 if the participant has higher than primary level	0.25	0.26
Marital status of the participant[b]		
=1 if the participant is divorced or separated	0.03	0.18
=1 if the participant is widowed	-0.38 *	0.20
=1 if the participant is single	0.58 **	0.24
Number of children below 5 years in the household	0.10	0.08
Household monthly income in hundreds of Rwf	-0.0001	0.0001
Price of milk purchased recently (in hundreds of Rwf/litre)	0.31 ***	0.08
Amount of milk purchased recently in litres	-0.03	0.06
Type of milk mainly purchased (=1 if milk B)	-0.61 ***	0.19
Distance from the household to source of milk in km	0.15 ***	0.05
Time of day (=1 if in the afternoon)	0.19 **	0.10
Trust in food safety and quality labels[c]		
=1 if the participant slightly trusts	-0.07	0.13
=1 if the participant doesn't really trust	-0.26 *	0.15
=1 if the participant doesn't trust at all	-0.07	0.30
Quality influence on milk purchase decision[d]		
=1 if quality highly influences	0.08	0.21
=1 if quality slightly influences	-0.001	0.21
=1 if quality doesn't really influence	-0.06	0.27
Location (=1 if in Musanze district)	0.10	0.12
Constant	0.21	0.51
Sigma_u	0.85	
Sigma_e	1.03	
Log-likelihood	1,199.41	
Number of observations	1,158	

[a] No formal education serves as reference, and [b] married serves as a reference, [c] fully trusts serves as reference, and [d] doesn't influence at all serves as reference. ***, **, * denote the level of significance at 1%, 5%, and 10% respectively.