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

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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.

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 (Habiyaremye et al., 2021). 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 (Habiyaremye et al., 2021).

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

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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, andaccess 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[1] 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 our study as we seek to estimate the effect 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, 2017). 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 Nacul and 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, 2017). 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 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, our 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

[1] 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.

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 our 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.

2. Methodology

2.1. Model specification

Our model is 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:

$$C_i^* = \beta X_i + \varepsilon_i \tag{1}$$

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:

$$C_i = \begin{cases} 1 \ if \ C_i^* > 0 \\ 0 \ otherwise \end{cases} \tag{2}$$

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

$$\Pr(C_i = 1) = \Pr\left(C_i^* > 0\right) = \Pr(C_i > -\beta X_i) = 1 - F(-\beta X_i) \tag{3}$$

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

2.2. Estimation strategy

Our interest is to estimate the effect of cooperative membership on the choice of milk marketing channel. We group milk marketing channels in Rwanda into three major categories 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 farmers 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.

We assume 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 effect of dairy cooperative membership on milk producers' choice of marketing channels, we 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, we use an endogenous switching probit (ESP) model, 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:

$$Y_{ij}^* = \alpha Z_i + \varphi C_i^* + u_i, Y_{ij} = \begin{cases} 1 \ if Y_{ij}^* > 0 \\ 0 \ otherwise \end{cases} (J = Y_1, Y_2, Y_3) \tag{4}$$

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. The potential endogeneity of membership is modelled using a shared random effect as discussed above to induce the dependence between the error terms of equations (1) and (4) (Miranda and Rabe-Hesketh, 2006),

$$\varepsilon_i = \theta \mu_i + \gamma_i \tag{5}$$

$$u_i = \mu_i + \omega_i \tag{6}$$

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 ν_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 (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 our sample are selling to 2 marketing channels which complicate the error structure not only between equations (1) and (4) but also the error terms within the equation (4). Following Hao et al. (2018), wemade our outcome variables dummies for each of the marketing channels used by farmers. Furthermore, we performed a multivariate probit regression (MVPM) to verify whether this cross-correlation bias our analysis. The results of MVPM (Appendix A) support the impact of cooperative membership on the choice of milk marketing channels, but the model has few parameters that are statistically significant compared to the ESP model while its parameters are less efficient than a FIML approach. Despite this caveat, we preferred an ESP model[2] 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 & 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, we use the number of trainings attended on dairy farm management in 2019 and whether any household member is in local administration 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. We performed a simple falsification test following Di Falco et al. (2011) to establish the admissibility of these two instruments (Appendix C). We find that our 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).

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 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. We also estimate the average treatment effect (*ATE*) of cooperative membership for a milk producer with observed characteristics (x) randomly selected from the population of milk producers. 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 ($\overline{\varepsilon_i}$). These effects are estimated following Lokshin and Sajaia (2011), thus:

$$ATT = E(Y_{1i}|C_i = 1, X = x) - E(Y_{0i}|C_i = 1, X = x) \quad (7)$$

$$ATU = E(Y_{1i}|C_i = 0, X = x) - E(Y_{0i}|C_i = 0, X = x) \quad (8)$$

$$ATE = E(C_i = 1, X = x) - E(C_i = 0, X = x) \quad (9)$$

$$MTE = E(C_i = 1|X = x, \varepsilon_i = \overline{\varepsilon_i}) - E(C_i = 0|X = x, \varepsilon_i = \overline{\varepsilon_i}) \quad (10)$$

2.4. Study area and data collection

We conducted a household survey between January and March 2020 in Nyabihu and Ruhango districts of Rwanda, two of the country's main milk-producing districts (Fig. 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.

3. Variables and descriptive statistics

3.1. Selection and outcome variables

Our selection variable (the dairy cooperative membership) is 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?". We found zero dropping in cooperative membership where all 99 households representing 27% of our 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 measures participation on the extensive margin without considering the quantity of milk sold to different channels.

We find that the main marketing channels for milk producers in Rwanda are milk traders, MCCs, direct consumers, and restaurants (Table 1). However, due to a small share of direct consumers (15.5%) and restaurants (14.3%), we combine these two marketing channels to form one marketing channel named "other buyers" channel as explained in Section 2.2 above. Hence, we grouped the outcome variable into 3 dummy variables namely, milk traders equals 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.

[2] We performed the analysis in Stata 16 using the "switch_probit" command.

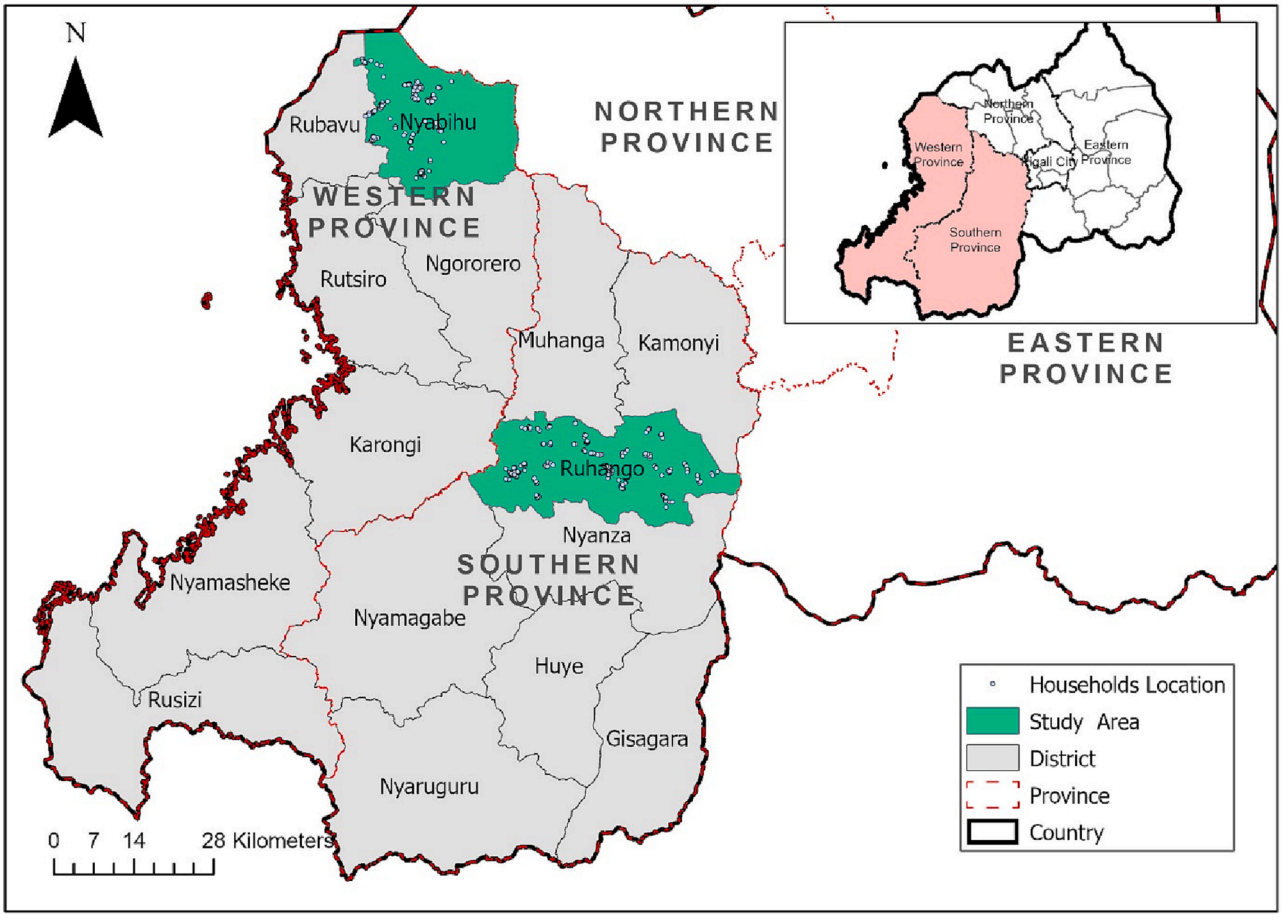

Fig. 1. Map of the study area. We used a two-stage random sampling procedure where the first stage is the selection of Nyabihu and Ruhango districts due to the pre-determined sites of the project (This is one of the Feed the Future Livestock Systems Innovations Lab projects on "Enhancing milk quality and consumption for improved income and nutrition in Rwanda" which was led by the International Livestock Research Institute (ILRI)). The second stage is 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, we collected information on farmer and farm characteristics, dairy cooperative membership, milk production, and marketing, which enabled us to establish the determinants of the choice of milk marketing channels in Rwanda.

Table 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%)

3.2. Explanatory variables and expected effects

Table 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 is 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; Verhofstadt & Maertens, 2015). We hypothesise 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 is 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. Verhofstadt and Maertens (2014) found a positive relationship between the quantity of produce sold and cooperative membership. In this study, we use the commercialization index which is the ratio of the total quantity of milk sold to the total milk produced, and expect it 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, we include this variable and expect it to either positively or negatively influence the cooperative membership. Furthermore, this variable is 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.

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; Verhofstadt & Maertens, 2015) are positively associated with cooperative participation. Thus, we expect similar effects of these variables on the probability of farmers joining cooperatives in this study, but with an unclear effect on the choice of marketing channel. Likewise, we expect a cooperative membership to be positively related to off-farm income as found by (Abebaw & Haile, 2013; Fischer & Qaim,

Table 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.

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. In this study, we include two dummies for keeping crossbreeds and pure breed lactating cows and expect them 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 is 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, we base our expectation 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, we expect the price of milk received by farmers to have a positive effect on the choice of MCCs and conversely on the choice of both milk traders and other buyers. The selling season is 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 are expected to join cooperatives more than those in Ruhango because Nyabihu has many active dairy cooperatives.

3.3. Descriptive statistics

Table 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 our 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.

In Table 3, we also present the results of a mean difference test that we conducted to differentiate between cooperative members and non-members. Out of 370 farmers, 99 farmers are dairy cooperative members with a mean membership fee of 32,167 Rwf. Non-cooperative members are 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 attend 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 (Habiyaremye et al. 2021). In addition, 33% of cooperative members are into local government administration compared to 20% of non-members, they have 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 sell milk at a higher price than non-members ($p < 0.01$). This can be attributed to the fact thatthe members mostly sell to MCCs, which offer them higher prices because standard quality tests are 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

Table 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 (proportion of milk sold to milk produced)	0.611 (0.173)	0.598 (0.174)	0.647 (0.163)	−0.049 **
Distance (distance from farm to nearest milk selling point in Km)	1.342 (1.804)	1.108 (1.724)	1.984 (1.871)	−0.876 ***
Experience (dairy farming experience in years)	12.042 (10.882)	10.876 (10.395)	15.232 (11.584)	−4.356 ***
Sex of the household head (=1 if male, 0 otherwise)	0.865 (0.342)	0.863 (0.344)	0.869 (0.339)	−0.005
Age (age of the household head in years)	51.965 (14.135)	50.089 (14.048)	57.101 (13.124)	−7.012 ***
Education level of the household head (number of years of formal education)	4.911 (3.708)	5.221 (3.717)	4.061 (3.565)	1.161 ***
Off-farm income (=1 if the household has an off-farming income, 0 otherwise)	0.465 (0.499)	0.472 (0.500)	0.444 (0.499)	0.028
Crossbreed lactating cows (=1 if the household has a crossbreed lactating cow)	0.843 (0.364)	0.838 (0.369)	0.859 (0.350)	−0.021
Pure breed lactating cows (=1 if the household has a pure breed lactating cow)	0.192 (0.194)	0.125 (0.122)	0.374 (0.286)	−0.248 ***
Membership fee (the amount of money paid to become a cooperative member in Rwf[1])	8,606.757 (22,754.44)	0.00 (0.00)	32,166.67 (34,408.78)	−32166.67 ***
Local administration (=1 if any HH member is in local administration, 0 otherwise)	0.235 (0.425)	0.199 (0.400)	0.333 (0.473)	−0.134 ***
Training (number of trainings attended on dairy farm management in 2019)	1.449 (1.673)	1.148 (1.568)	2.272 (1.683)	−1.125 ***
Adherence to DBP (=1 if the household adheres to DBP, 0 otherwise)	0.527 (0.50)	0.406 (0.492)	0.858 (0.350)	−0.453 ***
Selling price (milk price in Rwf per litre)	156.882 (40.625)	151.611 (43.159)	171.313 (28.199)	−19.702 ***
Selling season (=1 if milk is sold in rainy season, 0 in dry season)	0.538 (0.499)	0.513 (0.501)	0.606 (0.491)	−0.093
Location (=1 or 0 if the household resides in Nyabihu or Ruhango district respectively)	0.538 (0.489)	0.472 (0.500)	0.717 (0.453)	−0.241 ***

Note: Standard deviations are in parentheses and *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
[1]1 USD = 920 Rwf when the data was collected in February 2020.

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, we cannot draw that inference based on these results as other observable and unobservable confounding factors are not controlled for. Hence, we present the results of the models that control for these confounding in the subsequent section.

4. Results and discussions

4.1. Treatment effects results

Table 4 presents the average treatment effects for actual and counterfactual situations. The results show that cooperative membership increases 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 increases the likelihood of selling to MCCs by 18 percentage points. This implies that households who are members of dairy cooperatives are more likely to sell to MCCs than the counterfactual scenario of non-members (12 percentage points). We further find that cooperative membership decreases 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.

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 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 variables 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), we find 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 has 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

Table 4
Treatment effects.

Outcomes	Treatment effects			
	ATT	ATU	ATE	MTE
Milk traders	0.032 *** (0.166)	0.204 *** (0.289)	0.238 *** (0.299)	−0.690 (0.465)
MCCs	0.183 *** (0.361)	0.122 *** (0.325)	0.311 *** (0.428)	0.940 *** (0.239)
Other buyers	−0.052 *** (0.0.141)	0.115 *** (0.270)	0.065 *** (0.302)	−0.047 *** (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; *** $p < 0.01$.

Table 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 index	−0.427 (0.607)	−0.461 (1.367)	−0.565 (0.738)	−13.826 ** (6.988)	−0.187 (0.727)	−0.437 (1.011)
Distance to nearest milk selling point in Km	0.146 *** (0.053)	0.238 ** (0.122)	0.175 *** (0.059)	−0.233 (0.220)	0.153 *** (0.055)	0.090 (0.095)
Dairy farming experience in years	−0.002 (0.012)	−0.059 * (0.031)	−0.013 (0.012)	−0.057 (0.051)	−0.007 (0.013)	0.010 (0.019)
Sex of the household head	0.198 (0.373)	−2.111 ** (1.026)	0.252 (0.392)	0.144 (1.748)	0.450 (0.430)	−0.036 (0.571)
Age of the household head in years	0.010 (0.010)	0.095 * (0.051)	0.020 ** (0.009)	−0.112 ** (0.057)	0.018 (0.011)	−0.023 (0.018)
Education level of the household head	−0.017 (0.033)	0.067 (0.103)	−0.023 (0.037)	−0.168 (0.147)	−0.015 (0.038)	−0.184 ** (0.077)
Off-farm income	−0.323 (0.285)	1.279 (1.077)	−0.186 (0.302)	−0.215 (0.828)	0.374 (0.299)	−0.062 (0.407)
Crossbreed lactating cows	1.512 *** (0.561)	1.034 (1.292)	0.963 ** (0.507)	1.455 (2.906)	1.346 ** (0.626)	−0.140 (0.719)
Pure breed lactating cows	2.184 *** (0.533)	−0.039 (1.061)	1.889 *** (0.473)	2.048 (2.823)	2.002 *** (0.576)	−0.460 (0.622)
Membership fee[2]	0.288 *** (0.029)	−0.264 *** (0.080)	0.302 *** (0.032)	−0.197 (0.133)	0.290 *** (0.031)	0.050 (0.113)
Local administration	0.919 *** (0.257)		0.784 ** (0.341)		0.971 *** (0.321)	
Training	0.259 *** (0.074)		0.233 *** (0.068)		0.254 *** (0.075)	
Adherence to DBP		−0.698 (0.679)		8.259 ** (4.038)		−2.287 *** (0.752)
Selling price in Rwf per litre	–	−0.063 ** (0.031)	–	0.111 ** (0.052)	–	−0.009 (0.006)
Selling season	–	−0.509 (0.716)	–	−1.019 (1.267)	–	0.095 (0.414)
Location	−0.080 (0.261)	−3.967 ** (1.694)	−0.253 (0.274)	6.577 ** (2.889)	−0.190 (0.270)	−0.847 * (0.473)
Constant	−4.260 *** (0.952)	13.514 ** (5.214)	−3.871 *** (0.898)	−16.474 (10.297)	−4.655 *** (1.068)	5.936 ** (2.327)
Wald χ2	–	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.
[2] 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).

older farmers understand the importance of cooperatives well due to their farming experience and connections in society.

While membership fee was expected to have a negative association[3] on cooperative membership, we find 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 co-operatives 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, our 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. Our 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, we find a positive significant effect of keeping crossbreeds and pure-breed lactating cows on cooperative membership 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 co-operatives 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.

4.3. Outcome model: Choice of marketing channels

The estimated correlation coefficients[4] (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. Converselyary, 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;

[3] As highlighted by one of the reviewers, since the fee is not determining the sign of the association, but other unobservables which are not measured, then it is more of an association/correlation rather than an effect.

[4] 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).

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. We present the results for cooperative members and attach the results for non-members in Appendix B. The third, fifth and seventh columns of Table 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 study results show that adherence to DBP standards has a significant positive effect on the probability that members of dairy cooperatives will 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 handmilk from other outlets (restaurants, milk bars, roadside vendors, and shops/kiosks) exceed 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 (Habiyaremye et al. 2021). 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 headloading 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. Conclusions and policy implications

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, we estimate the effect of cooperative membership on the choice of milk marketing channels and assess other factors that influence the farmers' choice of marketing channels. Using data collected from 370 milk producers in Rwanda, we employ an endogenous switching probit model to control for the selection bias of cooperative membership.

Our model allows us to first establish the determinants of cooperative membership and then estimate the effect of membership on the choice of marketing channel. We find 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 our 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 hasits 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.

We also find 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 thechoice of other buyers. Furthermore, we find that 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.

5.2. Policy implications

Based on our findings, we suggest four key policy recommendations. 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 many 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, we recommend a strong-public–private partnership that supports the establishment of new MCCs 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, our findings give an insight into farmers' choice of marketing channels and the role of dairy cooperatives, however, we recommend further studies that expand the scope of our analysis. The limitation of this study is that we only limit the analysis 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, we did not have data on the characteristics of dairy cooperatives. 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.

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Naphtal Habiyaremye: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Nadhem Mtimet:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Emily Awuor Ouma:** Conceptualization, Methodology, Writing – original draft, Supervision, Project administration, Funding acquisition. **Gideon Aiko Obare:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Multivariate probit model (MVPM) results

Variables	Membership	Milk traders	Membership	MCCs	Membership	Other buyers
Commercial index	−0.218 (0.734)	−0.683 (0.512)	−0.171 (0.734)	0.231 (0.508)	−0.237 (0.735)	−0.088 (0.454)
Distance to nearest milk selling point in Km	0.146 *** (0.054)	−0.042 (0.048)	0.145 *** (0.054)	0.027 (0.045)	0.147 *** (0.054)	0.003 (0.046)
Dairy farming experience in years	−0.004 (0.012)	−0.001 (0.010)	−0.003 (0.013)	−0.007 (0.010)	−0.003 (0.013)	0.005 (0.009)
Sex of the household head	0.317 (0.402)	−0.163 (0.249)	0.296 (0.340)	−0.163 (0.254)	0.311 (0.401)	−0.232 (0.233)
Age of the household head in years	0.016 (0.011)	−0.010 (0.007)	0.016 (0.011)	0.007 (0.008)	0.015 (0.011)	−0.001 (0.007)
Education level of the household head	−0.020 (0.038)	−0.054 ** (0.026)	−0.021 (0.038)	0.045 * (0.026)	−0.020 (0.038)	−0.024 (0.023)

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Variables	Membership	Milk traders	Membership	MCCs	Membership	Other buyers
Off-farm income	−0.379 (0.309)	0.446 ** (0.177)	−0.363 (0.307)	−0.209 (0.180)	−0.374 (0.309)	0.019 (0.159)
Crossbreed lactating cows	1.554 *** (0.583)	0.266 (0.389)	1.611 *** (0.591)	−0.297 (0.335)	1.570 *** (0.586)	−0.107 (0.307)
Pure breed lactating cows	2.194 *** (0.546)	0.190 (0.394)	2.217 *** (0.553)	−0.200 (0.331)	2.203 *** (0.550)	−0.146 (0.303)
Membership fee	0.286 *** (0.030)	−0.044 * (0.025)	0.287 *** (0.030)	0.023 (0.023)	0.287 *** (0.030)	0.030 (0.023)
Local administration	0.983 *** (328)	–	0.981 *** (0.324)	–	0.982 *** (0.327)	–
Training	0.235 *** (0.072)	–	0.231 *** (0.072)	–	0.230 *** (0.073)	–
Adherence to DBP	–	−0.188 (0.194)	–	1.633 *** (0.217)	–	−1.607 *** (0.198)
Selling price in Rwf per litre	–	−0.036 *** (0.004)	–	0.018 *** (0.003)	–	0.006 *** (0.002)
Selling season	–	−0.096 (0.175)	–	0.037 (0.177)	–	0.065 (0.160)
Location	−0.187 (0.271)	−1.839 *** (0.283)	−0.166 (0.270)	1.761 *** (0.237)	−0.175 (0.270)	−0.514 ** (0.199)
Constant	−4.582 *** (1.079)	8.724 *** (1.144)	−4.669 *** (1.084)	−6.976 *** (0.966)	−4.580 *** (1.078)	0.463 (0.835)
Wald $\chi 2$	–	220.48 ***	–	232.40 ***	–	211.34 ***
ρ	–	0.038 (0.156)	–	0.128 (0.162)	–	−0.077 (0.143)

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

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

Variables	Milk traders Non-member	MCCs Non-member	Other buyers 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 become a cooperative member in Rwf)	−0.042	−0.220 ***	0.051
	(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 C. Falsification test on the validity of the selection instruments

Variables	(1) Coop membership	(2) Milk traders	(3) MCCs	(4) 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 we only report the estimates of the instruments to reduce space.

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