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IMPACT OF CONTRACT FARMING ON THE INCOME OF SMALLHOLDER DAIRY FARMERS FROM NYAGATARE DISTRICT IN THE EASTERN PROVINCE OF RWANDA

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ABSTRACT

The demand for dairy milk and its products is projected to increase significantly in the developing countries by the year 2030. Globally, close to 6 billion people consume milk and other dairy products due to rising earnings, population expansion, urbanization, and dietary changes. The projected increase in demand for dairy milk and its products thus requires enhanced productivity by the dairy farmers. However, dairy farming is relatively capital intensive which requires dairy farmers to have disposal income to run the venture. Contract farming is gradually being embraced in Rwanda as a viable option to help farmers increase dairy productivity. The impact of contract farming on dairy farmers' incomes is however not well documented in the Rwandan context. Thus, the purpose of this study was to assess the impact of contract farming on smallholder dairy farmers' income in Rwanda among smallholders' dairy farmers in Nyagatare District. Following the stratification and purposive sampling of two sectors, random sampling of two villages from each of those sectors allowed for the systematic and purposive sampling of representative households and farmers. Data from 214 smallholder dairy farmers were collected using structured interviews and document reviews. The multivariate logistic analysis and propensity score matching was used for data analysis in Stata Version 15. The findings showed that smallholder dairy farmers adopting contract farming earned on average 135,000 RWF (135$) more than their non-adopter counterparts. Further, contract farming was found to have a significant positive impact on income among smallholder dairy farmers in Nyagatare district. However, the impact of contract farming on farmer incomes could be further augmented by increasing the heads of cattle owned per farmer, to at least more than 30. Government intervention is one way to achieve this. The government, in collaboration with businesses like Heifer International, can give heifers to small-scale dairy farmers.

Key words: Contract farming, Income, Smallholder dairy farmers, Impact, Rwanda

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INTRODUCTION

Millions of individuals in the dairy industry depend on milk and other dairy products for their livelihood. In Rwanda, the dairy industry is important for enhancing nutrition and generating income primarily to rural households. The demand for dairy and its dairy product is projected to increase significantly in the developing countries by the year 2030 with more than 6 billion people consuming milk and its products globally due to rising earnings, population expansion, urbanization, and dietary changes [1]. With the projected decrease in cultivatable land [2-5], exponential increase in global population [6], coupled with the projected increase in the number of countries that will be in need of food assistance [7], significant increase in agricultural productivity has become the single most important global goal. Thus, to meet these increasing demand dairy farmers should be willing and ready to take up modern technologies as well as improve on their management practices to increase milk productivity. Enhanced productivity is generally determined by a number of factors among which are farmers' incomes and access to agricultural credit are perhaps the most paramount [8-10].

Dairy farming remains relatively more capital intensive due to costs of breeding, feeds, treatment, and waste management [11-13]. In essence, any shortage in farm income among dairy farmers has several implications on milk production per cow with the major one being low milk productivity. The most immediate effect of low dairy productivity is a vicious loop that results in low farm income, low milk production, and shorter farm longevity due to the resulting low ability to care for the animals. Access to credit is hampered by low dairy yields, which have a ripple effect on global milk availability. Although globally, the milk industry was valued at US$ 827.4 billion in 2020 and projected to increase to US$ 1,128 billion by 2026 [14, 15], its value stands to be affected most by the level of incomes among individual dairy farmers. Thus, enhancing dairy productivity requires that dairy farmers have disposal income to augment their production.

Innovations such as contract farming are gradually being embraced in Rwanda and provide a viable option to help farmers increase dairy productivity. Contract farming refers to a formal pre-harvest /farm yield agreement between a buying entity (company or individual) and a farmer [16, 17, 18, 19]. Contract farming engagement requires that a buyer sets the terms of the product in this case the volume of milk they need from the dairy farmer and at what cost. In so doing, a dairy farmer gets to carry out their farming activities with a ready market in mind through investing in the dairy enterprise in order to meet part of their bargain with the buyer. Thus, contract farming provides a good opportunity to dairy farmers to

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adopt new technologies and even benefit from pre-financing, in addition to having a higher access to dairy markets [20, 21].

Contract farming has therefore become highly advocated by policy makers and is becoming more widely adopted in developed countries although it has gained popularity in developing countries as well where dairy farming is commonly practiced [22]. Although contract farming is still essential and important to the enhanced productivity of the dairy industry, the majority of smallholder dairy farmers currently use it insufficiently or not at all. For contact farming to be adopted by dairy producers, it is essential to comprehend how it affects their incomes. This is taking into account the fact that a lot of research has been done on the adoption of contract farming, particularly in the horticulture business, with very few studies looking at the dairy industry and more specifically its effects on farmers' incomes. There is evidence that contract farming has elevated incomes among smallholder farmers engaged in crop husbandry [23-26]. However, there is a dearth of information on the impact of contract farming on farmers' incomes especially in the Rwanda [27, 28], although contract farming is being promoted by policy makers as one of the most viable options to increase dairy productivity. Nyagatare District has numerous dairy farmers, some of whom have taken up dairy farming and yet anecdotally claim to have had little income benefits. Although some studies exist that examine the impact of contract farming, majority have focused on crops such as broccoli, cassava and maize [29, 30]. The impact of contract farming on dairy farmers' incomes is not documented in the existing literature in the Rwandan context. This study thus sought to investigate the impact of contract farming on farmers' incomes among smallholder dairy farmers in Nyagatare District, Rwanda.

MATERIALS AND METHODS

Study design

The study adopted a cross-sectional survey design to investigate the impact of contract farming on smallholder dairy farmer incomes. A crossectional survey was preferred since it allow data collection at a given point in time and compare the population of farmers utilizing contract farming and those not [31].

Study area

The study was conducted in Nyagatare district, located in the Eastern province of Rwanda during December 2021 to February 2022. This district lies between latitude 1° 18' 00" (-1.3) South and longitudes 30° 19' 18" (30.3) East of the Equator. The district has an elevation of 1513.5m above sea level. The district experiences an average tempearture of 19^{o}C to 22^{o}C with an average annual

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rainfall of about 827mm. Ngagatare district is bordered to the North by Uganda, to the East by Tanzania, and to the South by Gatsibo district. The district is the largest in Rwanda, with a population exceeding 466,944, distributed within 14 sectors (Figure 1), 106 cells and up to 630 villages. Nyagatare district is renowned for dairy farming and cereal production especially maize and rice and has the largest mean land size for dairy farms per farmer, averaging 7.3ha [29]. The sectors in Nyagatare include; Nyagatare, Rwimiyaga, Kiyombe, Rwempasha, Tabagwe, Karama, Gatunda, Karangazi, Mimuli, Katabagemu, Musheli, Matimba, Rukomo, and Mukama. However, the study was conducted in two of the sectors (Nyagatare and Rwimiyaga) which were purposely sampled premised on having substantial numbers of dairy farmers who had benefited from contract farming.

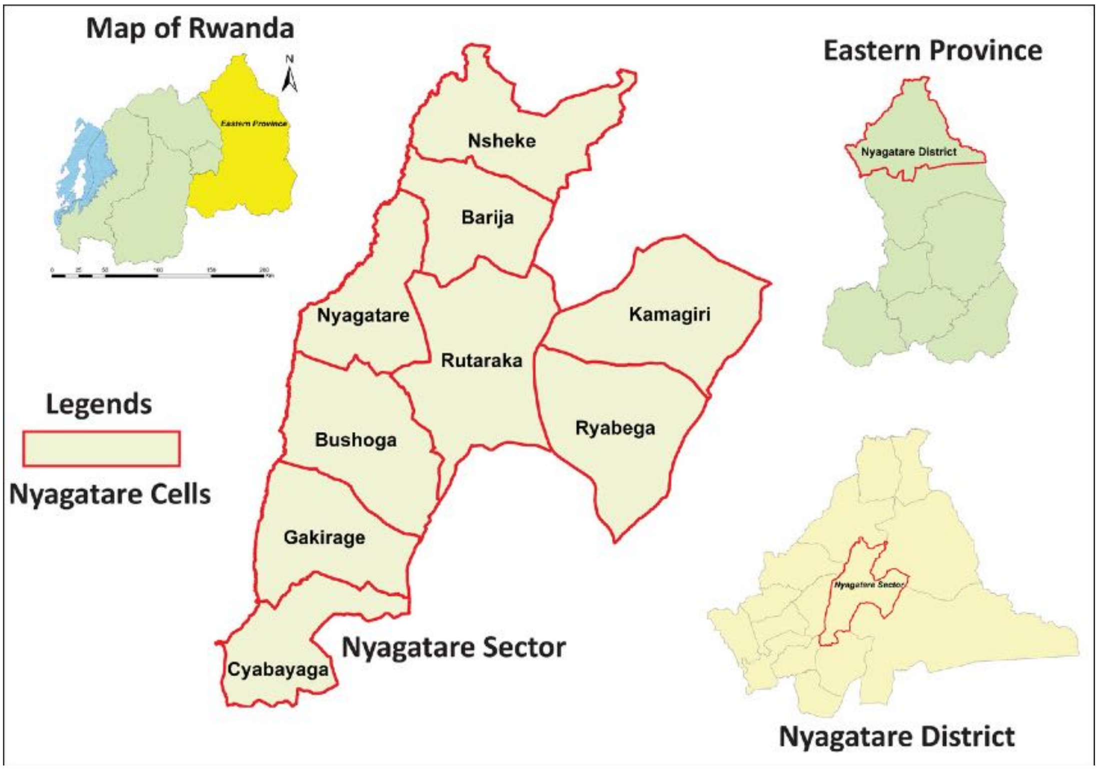

Figure 1: Map of Nyagatare District showing Sectors
Source: https://onlinelibrary.wiley.com/doi/full/10.1002/vms3.787

Study population and size

The study population was smallholder dairy farmers in Nyagatare District. The target population was smallholder dairy farmers practicing dairy farming on pieces of land that were equal to or less than 2.5ha in Nyagatare district. The sample was drawn from dairy farmers who had been engaged in commercial dairy farming for at least a period of one year at the time of the study. The sample of the smallholder dairy farmers that was engaged in contract farming were considered as the

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"treatment group", while those who were not engaged in contract farming were considered as the control group in the study.

The required sample of smallholder dairy farmers was determined using a formula by Krejcie and Morgan [32] for sample size for categorical data, since there were no single proportions required and the population size of smallholder dairy farmers in Nyagatare was known. Sample size was computed using Equation 1 as follows:

$$s = X^2.NP\ (1\text{-}P)\ /\ d^2\,(N\text{-}1) + X.\ P\ (1\text{-}P) \qquad (1)$$

where:
s = required sample size.
X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841).
N = the population size = number of dairy farmers in Nyagatare and Rwimiyaga sectors = 445
P = the population proportion (assumed to be 0.50 since this would provide the maximum sample size).
d = the degree of accuracy expressed as a proportion (0.05)
therefore,
$s = 1.96^2 \times 445 \times 0.5\ (1\text{-}0.5)\ /\ 0.05^2\,(445\text{-}1) + 1.96^2 \times 0.5\ (1\text{-}0.5)$
s = 427 / 0.0025 (444) + 0.9604
s = 427 / 2.0
s = 214 smallholder dairy farmers

Sampling procedures

The study purposively sampled Nyagatare and Rwimiyaga sectors of Nyagatare District. Simple random sampling was used to sample two villages from each of the two stratified sectors. Simple random sampling was done using the lottery approach so as to minimize sampling bias. The villages sampled were Nyagatare and Barija from the Nyagatare stratum and Bwera and Kirebe from the Rwimiyaga stratum. Systematic random sampling was used to sample the households from each the sampled villages through a preliminary survey that involved a convenient identification of households that had eligible dairy farmers per village. Such households were labeled and a list of their identification numbers made per village, and it is those lists that constituted the sampling frame that was used to conduct the systematic random sampling. The sampling was done following calculation of a sampling interval that was specific to a given village. The number of dairy farmers that were required from each village was calculated proportionately in line with the area population size (Table 1).

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Data collection techniques

The data collection exercise adopted survey methodology. The use of survey adopted structured interviews to collect the data. Structured interviews were preferred because they are simple to administer, simple to repeat because a predetermined set of closed questions is employed, and easy to generate quantifiable responses [31]. Structured interviews were used because the study, despite being an impact evaluation for contract farming. The responses were captured using structured questionnaire which was designed with close ended questions distributed within 5 sections.

Measurement of milk yield and income

Incomes were assessed based on the presumption that on average, each respondent had 17 heads of dairy cattle, with the mean milk yield per day of 17 liters. Therefore, each day, the mean number of liters collected per average farmers was 289, implying that in a month an average farmer collected about 8,959 liters of milk. Since each liter is sold at an average of 1,000 RWF (1 US$), an average farmer was expected to earn 8,959,000 RWF (8,969 US$). An upward adjustment of 10% was made in order to cater for factors such as higher milk price and number of cattle exceeding 30, leading to the setting of a minimum of 10,000,000 RWF (10,000 US$) as optimal income that had to be earned by a farmer.

Data analysis

Data were analyzed using STATA 15. The analysis first generated the descriptive results of all the variables used in the study. This was followed by bivariate analysis using a log-binomial model since the outcome was common. The alpha level was set at 5%, implying that all variables that had p-values less than 0.05 were considered significant. It is those variables that were fitted in a multivariable log-binomial model in which adjustment for confounders was made. Findings obtained at the bivariate level were reported in terms of crude prevalence ratios (cPR) with their corresponding confidence intervals, while those at multivariable level were reported in terms of adjusted prevalence ratios (aPR) at 95% confidence. Variables that remained significant at the multivariable analysis were considered to be the determinants of farmers' income and hence, were taken to be confounders during the next step of the analysis. That step was propensity score matching which was used to evaluate the impact of contract farming on farmer incomes.

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For a farmer i, (where i=1…I, and I denotes the population of farmers), the evaluation of the impact consists of separating the impact of participating in contract farming (Di=1) on a certain outcome Yi (Di) from what is happening to the farmers without participation in contract farming program (Di=0), that is, the counterfactual scenario.

Equation (2) summarizes the above scenario, the observed outcome for a contracting farmer I and the counterfactual potential outcome without/before contracting farmer as follows:

$$\pi_i Y_i(1) - Y_i(0) \qquad (2)$$

The impact πi cannot be observed, since in an ex- post setting, a farmer is either a contracting farmer or non-contracting farmer, but not both. It is anticipated that farmers select a contracting farming type that will maximize their utility. Consider a latent model that describes the behavior of the ith dairy farmer in selecting types of contract farming set ($\pi = 1, 2$,.....n). This situation shifts attention to the average population effect specified in Equation 3

$$\pi_I = E|\pi|D = 1 = E[|Y(1)|D = 1] - E|Y(0)|D = 1 \qquad (3)$$

Where E represents the average E (Y0 | D =1) the average outcome of treated individuals in the absence of treatment; which is not observed. However, term E (Y0 | D = 0) which is the Y0 for value for untreated individuals is observed. Since E [Y0/D=1] is not observed, the technique consisted of subtracting the unobserved effect of participating group of farmers in respect to the group of farmers who did not participate in contract farming program. See Equation 4:

$$E[Y(1)|D = 1] - E[Y(0)|D = 0] = \pi_{ATT} + E[Y(0)|D = 1] - E[Y(0)|D = 0] \qquad (4)$$

The equation right-hand side represents the impact to investigate; the two last terms stand for selection bias. Hence, the identification of the true impact is specified in Equation 5:

$$E[Y(0)D = 1] - E[Y(0)D = 0] = 0 \qquad (5)$$

For solving the selection bias, the problem identification assumes that farmers with same characteristics (X) that are not affected by contract farming will observe alike

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outcomes without partaking in contract farming. The PSM method permits to reduce this matching problem to a single dimension as indicated in Equation 6:

$$\Pr(X) = \Pr(D = 1 / X) \tag{6}$$

The balancing assumption in equation (5) ensures that farmers with alike propensity score share same unobservable characteristics, irrespective of their participation in contract farming outcome. See Equation 7:

$$D \perp X | \Pr(X) \tag{7}$$

Assuming that partaking in contract farming is not confounded, the Conditional Independence Assumption (CIA) in equation (6) implies that partaking in contract farming is as good as random after controlling for farmers' characteristics (X) as indicated in Equation 8:

$$Y(0), Y(1) \perp D | X, \forall X \tag{8}$$

The common support assumption in equation (7) ensures that the probability of partaking in contract farming for each value of vector X is strictly within the unit interval so that there is sufficient overlap in the characteristics of contracting and non-contracting farmers to find adequate matches as indicated in Equation 9:

$$0 < \left[\Pr(X) = \Pr(D = 1 | X\right] < 1 \tag{9}$$

Considering the CIA assumption, the following generalization of Propensity Score Matching estimator for Average Treatment effect on the Treated (ATT) was applied as specified in Equation 10:

$$\pi_{ATT}^{psm} = \Pr(X) | D = 11 \{ E[Y(1) | D = 1, \Pr(X)] - E[Y(0) | D = 0, \Pr(X)] \} \tag{10}$$

Empirical estimation

To investigate contract farming determinants among small scale dairy farmers, a probit model was estimated. For the estimation of the model, the farmer's decision to partake in contract farming program is a dependent and binary variable taking the value of 1 if a farmer partook in contract farming program and 0 otherwise. The model estimates the probability that a farmer i with particular characteristics Xi does fall under a contracting farmers group is specified as Equation 11:

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$$P(Di) = 1/xi) = \phi(Xi, \beta) \quad (11)$$

Where ф symbolizes the cumulative distribution function of the standard normal distribution.

Matching methods

To examine the contract farming effects on income level, Nearest Neighbor Matching (NNM), Radius Matching (RM) and Kernel Based Matching (KBM) methods were used. These methods permit to numerically search for neighbors that have a propensity score for non-treated individuals that is very close to the propensity score of treated individuals.

The NNM algorithm calculates the absolute difference between propensity scores as specified in Equation 12:

$$\left|\Pr_i - \Pr_j\right| = \min_{K\varepsilon L=0}\left\{\Pr_i - \Pr_k\right\} \quad (12)$$

The KBM method uses the weighted average of the outcome variable for all individuals in the group of non-participants, giving more importance to those observations that provide a better match. For a contracting farmer i, the associated matching outcome is given by Equation 13:

$$\frac{\check{Y}i = \sum_{j\varepsilon I=0}^{n} K[Pri - Prj]/h]yi}{\check{Y}i = \sum_{j\varepsilon I=0}^{n} K[Pri - Prj]/h]yi} \quad (13)$$

Where k is a kernel function and h, is a bandwidth parameter.

The RM is a variant caliper done by comparing group that is a matching partner for a participant individual that lies within the caliper ('propensity range'). The RM basic idea consists of using not only the nearest neighbor within each caliper but all of the comparison members with in the caliper.

Ethical considerations

Approval to conduct the study was granted by the Ethical Review committee of the University of Rwanda. Moreover, the study was done in line with ethical considerations required when dealing with human subjects such as the right to consent, self-determination, privacy, voluntary participation, protection from harm, anonymity and confidentiality of information.

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RESULTS AND DISCUSSION

Socio -demographic characteristics

Findings in Table 2 show the socio-demographic characteristics of the dairy farmers who participated in this study. Nearly two thirds were male 134(62.6%). Slightly more than a third of the farmers were aged between 41 and 50 years. Almost all the farmers 203(94.9%) had received formal education, and more than two thirds of them were married 146 (68.2%). Nearly two thirds of the farmers had been in dairy farming for more than 5 years 138 (64.5%).

Dairy farmer income

Figure 2 shows that nearly two thirds of the sampled dairy farmers (63.6%) had earned more than 10 million Rwandan Francs from dairy alone, over the previous 12 months.

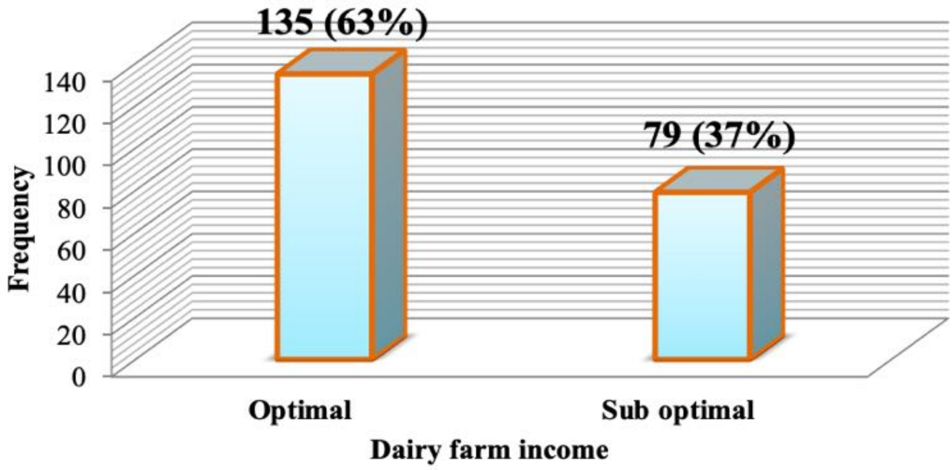

Figure 2: Distribution of dairy farmer incomes

Contract farming assessment

Figure 3 shows that slightly more than a third of the sampled dairy farmers (34%) had benefited from contract farming over the previous 12 months.

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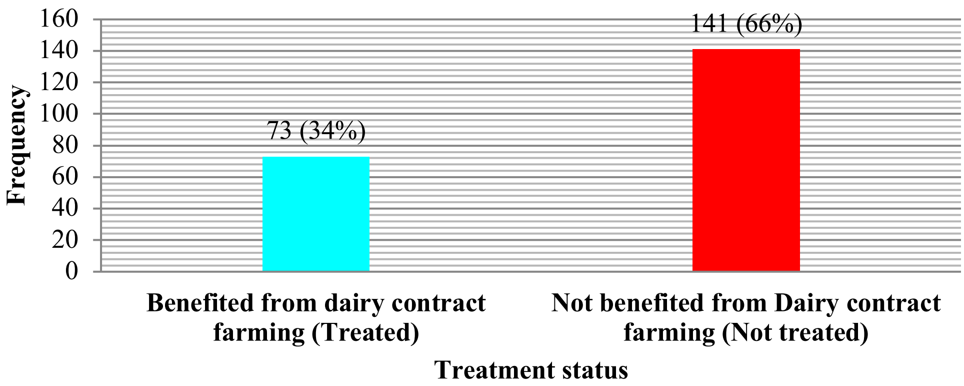

Figure 3: Proportion of farmers who have benefited from dairy contract farming

Bivariate analysis between the dairy farmers' characteristics and dairy farm income

This section presents findings of the bivariate analysis between the dairy farmers' characteristics and dairy farm income. This was done in order to determine the characteristics that were significantly related to farmer income, and could therefore be considered for multivariable analysis, upon further significance would make the characteristics be considered as confounders in propensity score matching. Of all the variables considered in the bivariate analysis, formal education and marital status variables had null integers in their cross tabulation, hence, could not have their p-values computed (Table 3).

The bivariate results indicated that three variables had a significant association with income. They included duration in dairy farming for which smallholder dairy farmers who had practiced dairy farming for less than 5 years had a 41% higher prevalence of having optimal income from their dairy farms (cPR = 1.410 [CI =1.162 - 1.710], P = 0.001) compared to those who had been practicing smallholder dairy farming for more than 5 years. The prevalence of optimal dairy farm income was less by a margin of 49% among smallholder dairy farmers who sold their milk to Inyange Company (cPR = 0.514 [CI = 0.355 - 0.744], p = 0.000) compared to those who sold their milk to traders only. The prevalence of optimal dairy farm income for farmers who had refrigerators was less by a margin of 23% a (cPR = 0.777 [CI = 0.606 - 0.995], P = 0.046) compared to those farmers who did not have refrigerators.

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Multivariate analysis between the dairy farmers' characteristics and dairy farm income after adjustment of confounders

After adjustment for confounders, the multivariate results as shown in Table 3b indicated that three variables that were significant at bivariate level still remained significant at this stage. They included duration in dairy farming for which smallholder dairy farmers who had practiced dairy farming for less than 5 years had a 40% higher prevalence of optimal farm incomes from dairy farming (aPR = 1.397 [CI = 1.152 - 1.694], p= 0.001) compared to those who had practiced dairy farming for more than 5 years. The prevalence of optimal dairy farm income was less by a margin of 49% for smallholder dairy farmers who sold their milk to Inyange Company (cPR = 0.514 [CI = 0.355 - 0.744], p = 0.000) compared to those who sold their milk to traders only, and 28% less among farmers who had refrigerators (aPR = 0.775 [CI = 0.604 -0.994], p = 0.045) compared to those who did not refrigerators. Thus, the above three variables were considered as confounders in the subsequent propensity score matching analysis.

Propensity score matching

The propensity Score Matching (PSM) findings provided in Table 4 showed that contract dairy farming had a statistically significant impact on farmer incomes (p = 0.004) (Table 5). The findings showed that smallholder dairy farmers who had benefited from contract farming earned 186,000 RWF (186 US$) more than those who had not benefited from contract dairy farming. The Nearest Neighbor matching statistics however showed that farmers who had benefited from contract dairy farming had earned 135,000 RWF (135 US$) more than those who had not benefited from contract farming (Table 5). This finding is consistent with finding from other previous studies evaluating the impact of contract farming on farmer incomes [31, 32, 33, 34, 35]. This finding was expected, given the merits of contract farming such as guaranteed/assured market of farmer's produce in this case which is dairy milk. Once a farmer is guaranteed of a market for their produce it can lead to a comparatively higher motivation of the farmer to invest more time, labor, and personal funds in the farm, so as to meet the targets of the company, person or institution that has contracted them to produce for them a given quantity of milk.

The quantity of milk supplied to the contracted agency certainly increases the income of the dairy farmer. Contract farming increases the farmer's income security since the farmer gets to be insured against any risks that may incur during the contracted period. In other words, a contracted farmer can include any foreseen income losses during agricultural production, beforehand, during contract

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agreement making. As such, contracted farmers are thus shielded from any potential losses, which also increase their ultimate incomes, in comparison to non-contracted farmers who may not enjoy such kind of benefits.

This study notes that the difference in income between contracted and non-contracted smallholder dairy farmers ranged between 135,000 RWF and 180,000 RWF (Tables 4 and 5), which translates to about 147.2$, going by the exchange rate of November 2022. This clearly implies that contract significant has a significant positive impact on incomes of the dairy farmers in the study area. The difference of 147.2$ in income among contracted and non-contracted dairy farmers is not static but remains highly elastic depending on a number of factors, one of which is the number of cows a farmer owned. Findings in Table 2 indicate that the majority of the farmers had less than 30 cows on average which limits a dairy farmer from being contracted to supply milk to a given agency. With a limited number of cows, dairy farmers earn less income from the sale of milk compared to those contracted farmers that had more cows.

On the contrary some studies reported inconsistent findings, indicating that contract farming had a negative impact on farmer incomes [33, 34]. The difference in finding between those studies and the current study is that the focus of the study was on crops notably rice, malt barley farmers and avocado [35-38], while this study focused on smallholder dairy farmers. There are huge differences in market dynamics between the crop and dairy enterprises since crop enterprises do not have the leverage that dairy farmers' have in terms of market price stability. Compared to avocado prices, for instance, milk and milk product prices are more stable and have actually been on the increase, and are projected to increase. Secondly, avocado yields are less predictable than dairy yields; avocado tree yields fluctuate more even with biological or chemical inputs [37], yet for dairy farming, high yields are almost always certain depending on the level of inputs. Therefore, despite the general confounders of agribusiness that cut across the dairy sector as well, dairy farming can be more profitable in comparison to crop farming despite the level of investment in the two enterprises [39]. This implies that contract farming generally have a positive impact on dairy farmer incomes in comparison with the crop enterprises with contracted dairy farmers and likely benefitted more in terms of farm income, compared to avocado farmers.

CONCLUSION

Contract farming has a significant positive impact on farm income among smallholder dairy farmers in Nyagatare district. However, the impact of contract

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farming on farmer incomes could be further augmented by increasing the heads of cattle owned per farmer, to at least more than 30. Thus, to aid in increased milk productivity, the Rwandan government, in collaboration with private sector organizations like Heifer International, can offer heifers to smallholder dairy farmers at subsidized costs.

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Table 1: Sample size

Sector	Village sampled	Number of dairy farmers available	Total number of dairy farmers available in the four sampled villages	Sample size	Number sampled from each village
Nyagatare	Nyagatare	120	455	214	57
	Barija	94	455	214	45
Rwimiyaga	Bwera	86	455	214	41
	Kirebe	155	455	214	74

Table 2: Socio-demographic characteristics of participants

Variable	Category	Frequency	%
Sex	Female	80	37.4
	Male	134	62.6
Age	20 - 30 years	14	6.5
	31 - 40 years	74	34.6
	41 - 50 years	75	35.0
	More than 50 years	51	23.8
Formal education	Yes	203	94.9
	No	11	5.1
Marital status	Married	146	68.2
	Single	56	26.2
	Cohabiting	8	3.7
	Widowed	4	1.9
Duration in dairy farming	Less than 5 years	76	35.5
	More than 5 years	138	64.5

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Table 3a: Bivariate analysis between dairy farmers' characteristics and income

Variable	Frequency (n)	%	Income Optimal >10 million RWF	Income Sub Optimal <10 million RWF	cPR (95% CI)	P value
Sex						
Female	80	37.4	46(57.5%)	34(42.5%)	0.866 (0.692 - 1.083)	0.206
Male	134	62.6	89(66.4%)	45(33.6%)	1.000	
Age						
20 - 30 years	14	6.5	11(78.6%)	3(21.4%)	1.252 (0.886 - 1.770)	0.202
31 - 40 years	74	34.6	47(63.5%)	27(36.5%)	1.012 (0.770 - 1.330)	0.930
41 - 50 years	75	35.0	45(60.0%)	30(40.0%)	0.956 (0.722 - 1.266)	0.755
More than 50 years	51	23.8	32(62.7%)	19(37.3%)	1.000	
Formal education						
Yes	203	94.9	124(61.1%)	79(38.9%)		n.a
No	11	5.1	11(100.0%)	0(0.0%)		
Marital status						
Married	146	68.2	96(65.8%)	50(34.2%)	1.510(0.354 - 0.736)	
Single	56	26.2	31(55.4%)	25(44.6%)	2.735 (0.560 - 0.965)	n.a
Cohabiting	8	3.7	4(50.0%)	4(50.0%)	0.185 (0.680 - 1.083)	
Widowed	4	1.9	4(100.0%)	0(0.0%)	1.000	
Duration in dairy farming						
Less than 5 years	76	35.5	59(77.6%)	17(22.4%)	1.410 (1.162 - 1.710)	0.001
More than 5 years	138	64.5	76(55.1%)	62(44.9%)	1.000	
Where milk is usually sold						
Inyange industry	49	22.9	21(42.9%)	28(57.1%)	0.514 (0.355 - 0.744)	0.000
People in the community	61	28.5	37(60.7%)	24(39.3%)	0.728 (0.556 - .0953)	0.021
Community people, Inyange Industry and traders	80	37.4	57(71.3%)	23(28.7%)	0.855 (0.682 - 1.073)	0.176
Traders only	24	11.2	20(83.3%)	4(16.7%)	1.000	
Off farm employment						
Yes	194	90.7	121(62.4%)	73(37.6%)	1.237 (0.691 - 2.863)	0.548
No	20	9.3	14(70.0%)	6(30.0%)	1.000	

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Variable	Frequency (n)	%	Income Optimal >10 million RWF	Income Sub Optimal <10 million RWF	cPR (95% CI)	P value
Number of cows						
Less than 10 cows	38	17.8	30(78.9%)	8(21.1%)	0.632 (0.255 - 1.660)	0.316
10 - 20 cows	46	21.5	23(50.0%)	23(50.0%)	1.500 (0.801 - 3.506)	0.266
21 - 30 cows	69	32.2	51(73.9%)	18(26.1%)	0.783 (0.389 - 1.891)	0.530
31 - 40 cows	20	9.3	7(35.0%)	13(65.0%)	1.950 (1.002 - 4.585)	0.072
40 - 5 cows	23	10.7	12(52.2%)	11(47.8%)	1.304 (0.599 - 3.213)	0.516
More than 50 cows	18	8.4	12(66.7%)	6(33.3%)	1.000	
Breed of cows						
Cross breed	103	48.1	59(57.3%)	44(42.7%)	2.563 (0.746 - 41.584)	0.306
Friesian	72	33.6	51(70.8%)	21(29.2%)	1.750 (0.483 - 28.665)	0.548
Local Ankole	33	15.4	20(60.6%)	13(39.4%)	2.182 (0.571 - 36.046)	0.407
Jersey	6	2.8	5(83.3%)	1(16.7%)	1.000	
Farm labor						
Hired only	46	21.5	26(56.5%)	20(43.5%)	1.081 (0.696 - 1.612)	0.711
Family labor only	76	35.5	54(71.1%)	22(28.9%)	0.687 (0.432 - 1.054)	0.095
Both hired and family labor	92	43.0	55(59.8%)	37(40.2%)	1.000	
Average price per liter						
Less 1000 RWF	50	23.4	34(68.0%)	16(32.0%)	0.600 (0.327 - 1.154)	0.100
1, 000 RWF	144	67.3	91(63.2%)	53(36.8%)	0.736 (0.480 - 1.307)	0.218
More than 1000 RWF	20	9.3	10(50.0%)	10(50.0%)	1.000	
Have refrigerators						
Yes	70	32.7	37(52.9%)	33(47.1%)	0.777 (0.606 - 0.995)	0.046
No	144	67.3	98(68.1%)	46(31.9%)	1.000	
Type of milking						
By hand	129	60.3	81(62.8%)	48(37.2%)	0.960 (0.757 - 1.219)	0.739
Milking machine	33	15.4	20(60.6%)	13(39.4%)	0.927 (0.661 - 1.301)	0.661
Both hand and milking machine	52	24.3	34(65.4%)	18(34.6%)	1.000	
Milk yield per day						
10 - 50 liters	20	9.3	14(70.0%)	6(30.0%)	0.800 (0.343 - 1.454)	0.534
60 - 100 liters per day	58	27.1	37(63.8%)	21(36.2%)	0.966 (0.626 - 1.419)	0.865
More than 100 liters per day	136	63.6	84(61.8%)	52(38.2%)	1.000	

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Table 3b: Multivariate analysis between dairy farmers' characteristics and income after adjusting for confounders

Variable	cPR (95% CI)	P value	aPR (95% CI)	P value
Duration in dairy farming				
Less than 5 years	1.410 (1.162 - 1.710)	0.001	1.397 (1.152 - 1.694)	0.001
More than 5 years	1.000		1.000	
Where milk is usually sold				
Inyange industry	0.514 (0.355 - 0.744)	0.000	0.510 (0.354 - 0.736)	0.000
People in the community	0.728 (0.556 - .0953)	0.021	0.735 (0.560 - 0.965)	0.027
Community people, Inyange industry and traders	0.855 (0.682 - 1.073)	0.176	0.858 (0.680 - 1.083)	0.199
Traders only	1.000		1.000	
Have refrigerators				
Yes	0.777 (0.606 - 0.995)	0.046	0.775 (0.604 (0.994)	0.045
No	1.000		1.000	

Table 4: Propensity score matching

Dairy farm income ATE	Coef.	AI Robust Std. Err.	Z	P>|z|	[95% Conf. Interval]	
Contract farming (No vs Yes)	0.1861037	.0640046	2.91	0.004	.060657	.3115504

Table 5: Nearest Neighbor matching

Dairy farm income ATE	Coef.	AI Robust Std. Err.	z	P>|z|	[95% Conf. Interval]	
Contract farming (No vs Yes)	0.1352397	0.0665165	2.03	0.042	.0048697	.2656098

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