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Determinants of farm-gate marketed milk output volumes in Kericho County, Kenya

Elijah Kiplang'at Ng'eno *

Department of Applied Economics, University of Eldoret, Eldoret, Kenya

Abstract

In response to structural transformations and the continuous growth in the Kenyan dairy sector value chain, this article examined the factors affecting farm-gate marketed milk volume by dairy farmer households in Kericho County, Kenya. Multistage cluster sampling technique was employed in data collection from a sample of 432 dairy farmers. Survey data were analyzed using descriptive and Heckman two-stage selection model. Maximum restricted or residual likelihood was used to estimate the regression models. Results show that the average age of household head was 48.4 years and owned on average, three dairy milking cows that produced 6.3 liters of milk per cow per day. Second-stage Heckman selection estimates showed an increase in age by one year led to a 6.3% increase in milk output, thereby increasing the probability of more milk produced per day. A unit increase in household size, off-farm employment, milking cows, price, access to extension services and market information lead to a positive increase in daily marketed milk output by 6.5%, 198%, 13.7%, 11.6%, 40.3%, and 34.3%, respectively. To improve on dairy farmers' milk output, the exchange of dairy farming experiences should be supported. Farmers should be encouraged to improve their dairy cow herd quality by upgrading the existing herd. Thus, national and county governments should come up with policies that pay more attention to access to market information and financial investments. The policy should strengthen dairy extension services through redesigning, reforming and improving implementation strategies and importantly, strengthen and improve infrastructure facilities of existing milk processing plants.

Keywords: Determinants; Farm-Gate; Milk Output; Heckman Selection Model; Dairy Farmer Households; Milk Market

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* Corresponding author. *E-mail address:* engeno489@gmail.com

1. Introduction

Livestock milk marketing is a favorite sector, where most African governments have chosen to intervene in a variety of ways (Beneberu and Girma, 2011). These interventions range from outright fixing of wholesale and retail milk prices to monopolizing the export market, yet in many instances, policy decisions on livestock milk marketing are often taken in the absence of vital information on how they affect small-scale livestock producers, traders, and consumers.

In Kenya, milk marketing is composed of many agents that are either formal or informal. Informal milk markets continue to dominate over the formal markets by absorbing most of the milk from smallholder farmers, and they account for over 80 percent of the total milk sold (Karanja, 2003). Market-oriented smallholder dairy production normally offers a significant source of income for smallholder farmers, and the profitability of dairy production depends on market prices upon which a good marketing system is thus very crucial. However, one of the most controversial issues in international development is that of the rise in modern milk marketing chains, especially under private ownership, which could have negative effects on the producer's income distribution (Elizabeth et al., 2000). Several research findings have opined that poor farmers will continue to suffer from this process. Projected dairy farm margins will also continue to edge lower to near or below break-even for most producers.

The dairy sector is the single largest agricultural subsector in Kenya, contributing about 14 percent of agricultural Gross Domestic Product (GDP) and 3.5 percent of the total GDP (Kenya National Bureau of Statistics (KNBS), 2014). However, in 2016, the quantity of milk output produced, marketed, and processed increased by 5.6 percent and 3.2 percent to 650.3 million liters and 451.7 million liters, respectively, (KNBS, 2017). The volume of milk deliveries to processors rose by 4.6 percent from 153.3 million liters in the third quarter of 2017 to 160.4 million liters in the third quarter of 2018 (KNBS, 2018).

Much of the milk produced in Kenya is by smallholder dairy farmers who account for 80 percent of the total national milk production (Wambugu et al., 2011). Out of this, it is estimated that 36 percent is consumed on-farm and 64 percent offered for sale to milk markets, individual milk consumers and institutions dealing with milk and milk products. Kenya has one of the highest levels of per capita milk consumption in sub-Saharan Africa. There are wide discrepancies in milk consumption in rural and urban populations and across income groups. However, consumption at the household level is higher in urban than in rural regions. Statistics also indicate that the annual per capita consumption of milk in rural areas was 45 liters for "milk-producing" households and 19 liters for "milk-purchasing" households, while the urban per capita milk consumption was estimated at 125 liters (KNBS, 2014).

Smallholder dairy production systems range from stall-fed cut-and-carry systems, supplemented with commercial concentrate, to free grazing on unimproved natural pastures in the more marginal areas. Upgraded (crossbred) dairy cow breeds are kept under the zero-grazing system or the semi-zero-grazing systems (Wambugu et al., 2011). Dairy production improves household nutrition and provides extra income. In addition to family labor, dairy farming generates jobs in wage labor and mobile milk trading for further 365,000 people. These jobs benefit the poorest people in urban and rural areas (IFAD, 2013).

According to Kericho County Second Generation Integrated Development Plan, 2018 – 2022, (CIDP, 2018), agriculture and livestock production are the major activities in the county. The majority of the people in the county depend directly or indirectly on agriculture for their livelihoods. Over 70 percent of the labor force is engaged in either livestock or agricultural activities. Farmers grow both food and cash crops to earn income. The greater part of the county's income comes from this sector, which accounts for about 70 percent of the household income. The county is one of the potential milk and milk products producing and marketing counties in Kenya. In the county, it is common to see the majority of the households participating in milk production and marketing.

Table 1 shows some basic data on dairying in Kericho County. The total dairy cattle population is about 100,047 with average daily milk production of 11.4 liters per farm.

Table 1. Smallholder Dairying in Kericho County, 2018

Sub – County	Human Population	Number of households	No. of Dairy Farmers	Dairy Cattle Population	Average No. of Dairy Cows/Farmer	Average Daily farm Milk output	Average Farm Size (Acres)
Ainamoi	180,391	27,700	8,150	10,498.8	3	12	2
Belgut	168,329	31,394	17,111	26,007	2	15	1
Bureti	209,561	30,977	28,304	11,400	2	12	3
Kipkelion East	146,435	27,791	13,996	20,666	5	15	6
Kipkelion West	111,803	14,615	11,725	18,667	4	10	10.5
Sigowet/ Soin	131,405	20,940	15,141	12,808	2	4.5	2.5
Total	947,924	153,417	94,427	100,047	3	11.4	4.1

Source: Kenya Dairy Board (KDB), 2018

The predominance of smallholder crop-dairy farms in the highland areas as the major suppliers of marketed milk in the county reflects the strong historical linkages between cash crop co-operative marketing systems especially tea and coffee, but also pyrethrum, and dairy production and marketing. The competitiveness of these systems in comparison with marketed milk from the intensive smallholder crop-dairy farms depends on the costs of milk collection and transport, particularly where distance-sensitive informal markets predominate. The cooperative sub-sector plays a key role in mobilizing resources for small-scale farmers while also availing marketing channels for their products (CIDP, 2018). The county has over 330 dairy co-operative societies and other farmer groups such as self-help groups (SHG) that have been formed to assist farmers in acquiring credit and inputs.

Farm-gate milk production significantly varies from one sub-county to the other with Kipkelion West and Ainamoi sub-counties being the highest milk producing sub-counties in the county. These variations in milk production are between the sub-counties, between seasons and also between the dairy farmers themselves. Table 2 shows the quantities of dairy milk output volume produced and milk sales to the various milk marketing channels used in the county. According to the CIDP, 2018 – 2022 (CIDP, 2018), available milk marketing channels in the county include milk vendors (hawkers), final consumers, milk cooperative societies and self-help groups and milk processors. Smallholder dairy farmer households in the County produced an average of 503,957 liters of milk per day against the county's potential of 1,500,705liters per day (CIDP, 2018). The table also reveals that out of the 503,957 liters of milk produced per day, 110,643 liters sold to cooperative

societies and self-help groups, 311,344 liters sold to traditional informal traders and final consumers and 44,209 liters of milk sold to formal milk processors like New KCC, Brookside limited and Kabianga Dairies. The balance of 37,761 liters was fed to calves, and some were spillage.

Table 2. Dairy Milk Production and Sale to Marketing Systems, 2018

Sub – County	Milk production per day (liters)	Milk sales to cooperatives societies per day (liters)	Milk sales to milk vendors (hawkers) per day (liters)	Volume sold to processors per day (liters)
Ainamoi	84,600	16,240	67,680	0
Bureti	68,400	16,416	23,940	23,940
Belgut	197,653	51,333	146,320	1,200
Kipkelion East	54,192	16,258	25,284	11,250
Kipkelion West	70,089	7,496	22,003	7,819
Sigowet/ Soin	29,023	2,900	26,117	0
County Total	503,957	110,643	311,344	44,209

Source: KDB and KDPA, 2018

Kenya's population has continued to increase both in the rural and urban areas, with the latest population estimates showing that Kenya's population is now over 45 million people (KNBS, 2018). The high population creates a market and price incentive for dairy production. This increased demand should trigger a corresponding increase in production. However, gaps exist about supply and demand for raw milk in Kericho County, Kenya. Although dairy farming in the county is largely subsistence, the trend has been gravitating towards full commercialization. According to the CIDP, (2018), the majority of the dairy cattle farmers produce on average 11.4 liters of milk per day against the county's potential of 15 liters. However, surplus milk is still available for direct sale and further processing into other milk derivatives. Additionally, the report revealed that most dairy farmer households are unable to sell their milk during milk glut periods, particularly in March to May and July to October. In the other periods of the year, the market is characterized by milk shortage, which prompts milk 'import' from other neighboring counties. However, in the county and the country at large, farm-gate raw milk output volumes have been fluctuating periodically to levels too low to cover farmers' costs of production. These seasonal variations in milk output volumes and the exploitation of small-scale dairy farmers by the major processors have elicited a lot of debate in Kenya. In response to farmers' calls, KDB initiated consultations with dairy farmers across the country to plan on how to regulate milk product prices and on how to implement the policy shift to iron out these seasonal variations in milk production and protect farmers from exploitation by processors (Business Daily, 2014).

Despite these difficulties that smallholder dairy farmer households face in milk production and marketing, they continue to produce and survive in the face of these unfavorable conditions (Jari, 2009). Farmers need to maximize their returns on their dairy investment and production through value addition, which should complement their produce from other sources, as well as offering diversified milk products from the same material inputs. When selling their milk outputs, it is expected that such farmers would make use of milk marketing channels that will enable their products to reach the market at least cost per unit of output. By pooling skilled workforce, dairy farmers who are the chain actors would be able to minimize the transaction costs, access market information, and adhere to government regulations more easily. However, cooperative

dairy societies, which used to be an integral part of the formal milk collection and marketing in the county, have been relegated by dairy farmers to buyers of the last resort due to the low raw milk purchase prices that they offer. With sizeable milk output volumes, dairy farmers would be able to take collective action by securing new milk markets, bargaining for better prices for their milk and milk products and be able to use the most effective milk marketing channels. Though, most of the dairy farmers' milk output produced depends mostly on the milk price received in environments of minimal agricultural policy support, the absence of social safety nets, and a weak non-farm rural economy which limits agricultural diversification (Sauer et al., 2012). These features characterize much of Kericho County, where rural poverty has been widespread. Farm-gate milk output volumes produced by the dairy farmer households have been of considerable concern.

Most studies have sought to establish dominance premised on the proportion of the populace that uses a certain marketing channel as opposed to using the net returns (Kumar and Staal, 2011; Kumar, 2010; Wambugu et al., 2011). Other previous research interventions to promote the dairy industry have focused on opportunities in dairy sector factors affecting dairy productivity (Ahaibwe, et al. 2013), the competitiveness of milk processing firms and intensification of dairy farming (Kabunga 2014), while others have focused on productivity, genetics, nutrition, and value chain development (Wambugu et al., 2011; Ahaibwe, et al., 2013; Kabunga, 2014; Kavoi, Hoag and Pritchett 2010; Murage and Ilatsia, 2011). However, the knowledge gap still exists in the literature on determinants of farm-gate marketed milk output volume by dairy farmer households in Kericho County, Kenya.

Given that Kericho County has the potential for milk production; processing, marketing and consumption, the results of the study will become essential to providing vital and valid information for effective research, planning, and policy formulation. Therefore, the study provides an empirical basis for identifying options for increasing farm-gate marketed milk output volumes by dairy farmer households. In doing so, the study attempts to contribute to filling the knowledge gap by assessing factors determining the volume of marketed milk output supply in the county.

2. Methodology

2.1. Research design

This study was conducted in Kericho County, Kenya, using a cross-sectional survey research design. A total of 432 dairy farmer households were sampled and used in the study.

2.2. Sampling Procedure and Sample Size

The study used a multistage cluster sampling procedure to select the total population and representative dairy farmer households from the study area. In the first stage, Kericho County purposively selected since it is one of the potential milk-producing, consuming, and marketing county in the country. The county was clustered into six sub-counties, namely Ainamoi, Belgut, Bureti, Kericho East, Kericho West, and Sigowet/Soin. Therefore, to achieve a representative sample size, the six sub-counties then formed the first-stage cluster. Within the six sub-counties, a second-stage cluster sample of wards and villages with a high concentration of

small scale dairy farmers was then selected purposively based on milk production potential and choice of milk marketing channels. The sample selection of dairy farmer households from the clustered wards was then made using random sampling. An effort was also made to include statistically significant sub-samples of dairy milk producers representing the different milk marketing channels and the different sizes of each of the sub-counties.

The sampled milk-producing n^{th} smallholder dairy farmer household was determined by the proportionate size sampling methodology, as shown in equation 1 and as adopted from Anderson et al. (2007).

$$N_0 = \frac{Z^2 pq}{e^2} \quad (1)$$

Where N_0 is the sample size, z is the standard normal value of 1.96 significant at 5 percent confidence level, e is the margin of error, p is the estimated population proportion of dairy farmer household with the characteristics of interest, q = 1-p, Z = 1.96, and e = degree of precision. The sample units were calculated proportionately based on the number of dairy farmer households in each sub-county and as a proportion of the total dairy farmer households in the county against the desired sample size of 504 as shown in table 3. Out of the 94,427 dairy farmer households, 504 households, based on the proportionate size sample, were then selected using a simple random sampling technique. However, after data cleaning, 72 dairy farmer households with an incorrectly filled questionnaire and missing data were dropped, and the data set for only 432 dairy farmer households were analyzed.

Table 3. Proportionate Distributions of Dairy Farmer Households, 2019

Sub – County	Number of Households	Number of Dairy Farmers	Percentage	Total Proportion (N_0)
Ainamoi	27,700	8,150	9	44
Belgut	31,394	17,111	18	91
Bureti	30,977	28,304	30	150
Kipkelion East	27,791	13,996	15	75
Kipkelion West	14,615	11,725	12	63
Sigowet/ Soin	20,940	15,141	16	81
Total	153,417	94,427	100	504

2.3. Methods of data collection

Both primary and secondary data sources were used in the study. Primary data was collected through the household formal survey. The major data collection methods used included discussions and observations. Survey questions were prepared and pre-tested using 20 dairy farmer households in the neighboring Bomet County, a county with striking characteristics with the study county. Secondary sources included reports from economic surveys, economic journals, statistical abstracts, conference reviews, books, the official government of Kenya reports and documents such as statistical abstracts and bulletins, national and county development and strategic plans, the Kenya National Bureau of Statistics publications and Kenya Dairy Board reports. Livestock production and marketing, regional level, and consultants' reports were also reviewed. Desktop

literature and internet were used to access credible information, published and unpublished reports, books, and agricultural journals. Farm records from a few select dairy farmer households were also used to supplement secondary data sources. Trained and experienced enumerators collected the data from dairy farmer households.

2.4. Data sources and types

To analyze the determinants of farm-gate marketed milk output volume by dairy farmer households in Kericho County, Kenya, the population of interest was defined as the primary dairy cow farmer households' who produced raw dairy cow's milk at the farm-gate to be consumed by the final consumers or sold to another milk supply chain actor. For that reason, dairy farmer households without a dairy cow were excluded from the study.

Interviews using questionnaires were conducted to gather data on the dairy farmers' socio-economic characteristics, actual milk production, milk market competitiveness, and other related obligations with the milk supply actors. The socio-economic data collected comprised the farmer's age, education level, household size, gender, and farm ownership, off-farm income, access to credit, access to extension service, membership to milk cooperative society and access to other milk marketing channels. The data types used also encompassed a representative sample of dairy farmer households representing the various categories of households, types of commercial and non-commercial dairy cow milk producers in the county dairy sector. The other data type was farm production data. Farm production data consisted of land size under dairy production, the average raw milk produced per day, the number of livestock inputs, farm-gate milk prices, and prices of other livestock outputs. Respondents were also expected to provide information regarding market competitiveness and the estimated total number of potential commercial milk buyers in their respective areas. This information on market competitiveness would assist in capturing the degree of switching power of each of the dairy farmer households.

2.5. Analytical frameworks

Two types of data analysis were used to analyze data collected from dairy farmer households. These were descriptive statistics and econometric models. Descriptive statistics involved the use of percentages, means, and standard deviations in the process of comparing the socioeconomic, demographic, and institutional characteristics of households. To analyze factors affecting marketing channels and volume of output supply, Heckman's two-stage selection econometric model was used. The specification of the empirical models used to identify these factors follows selectivity models widely discussed in the literature (Goetz, 1992; Key et al., 2000; Heltberg and Tarp, 2002; Holloway et al., 2001; Bellemare and Barret, 2006).

2.5.1. Econometric Analysis

The outcome equation was used to explain the factors affecting the volume of marketed milk output supply in this study. If a data set used for a regression suffers from selectivity bias, then the regression analysis, for

example, Ordinary Least Squares (OLS), which compute the effects of characteristics of this population on other characteristics, will be biased (Sauer et al., 2012). Therefore, if two decisions are involved, choice of a milk marketing channel and volume of supply in the milk market, then a two-step procedure was appropriate, which was adopted in this study to correct for sample selectivity bias.

Using the Heckman sample selection model, the first stage was the 'choice decision of a milk marketing channel equation,' which helped to identify the factors affecting the choice decision for a marketing channel. Then in the second stage, OLS regression was fitted along with the Probit estimate of the inverse Mill's ratio, a selectivity term that was added to the outcome equation that explained the factors affecting the marketed farm-gate milk output volume by the dairy farmer households in Kericho County, Kenya. The inverse Mill's ratio was then used as a variable for controlling the bias due to sample selection.

Inverse Mill's ratio was used in the milk supply equation, and then the equation was estimated using OLS. With the inclusion of an extra term, the Heckman two-step procedure was written in terms of the probability of choice of a milk marketing channel and marketed milk output volume, as shown in equation 3.

$$Y_{2i} = \alpha_{2i}\beta_{2j} + u_{2,}u_{2i} \sim N\left(0, \delta^2\right) \quad (3)$$

Where, Y_{2i} is the latent dependent variable (milk marketed output), which was not observed. However, it was observed only when the dairy milk farmer household sold milk to commercial milk buyers = 1. Y_{2i} was a dependent variable that was not directly observed but was rather inferred, through a mathematical model, from other variables that were observed or measured directly. α_{2i} is the vector that was assumed to affect the probability of dairy farmer household selling to a commercial milk marketing channel, β_{2j} is the vector of an unknown parameter in milk marketing channels equation, and μ_2, μ_{2i} are the residuals that are independent and normally distributed with zero mean and were assumed to be bivariate.

From the analysis of the determinants of marketed farm-gate milk output volume by the dairy farmer households, it was expected that several explanatory variables would influence a farmer's decision to use a commercial milk marketing channel (Y_i). These factors were the important factors affecting the marketed farm-gate milk output volume sold by dairy farmer households in Kericho County.

2.6. Model estimation

Both Heckman two-step and maximum restricted or residual likelihood (REML) were used to estimate the regression models as adopted from Harville, (1977). In the two-stage estimation procedure, correlation of the error terms inferred in equation three was assumed. Multivariate probit was used first to estimate the choice equation in the first stage. The estimations that were obtained in the first analysis were then used to generate the inverse Mill's ratio (IMR) that was used in the second milk output equation analysis. The inverse Mill's ratio was needed to account for sample selection bias in the second stage of the model (Greene, 2003) in Sauer et al. (2012). The IMRs would then be included in equations 3, where the ratios were treated as missing variables. Therefore, the principal focus was the analyzed results of the two stages, the choice, and the outcome equations.

The unobservable characteristics that affected the decision to sell milk only to commercial milk buyers were correlated with the milk output volume. According to Sauer et al. (2012), selectivity bias for such an analysis would be present. Therefore, the two-stage sample selection model coped with such a selection problem, and hence, the study was based on the two hidden dependent variable models. The system of equation 4 as adopted from Ngeno and Ngeno V., (2018) would then be estimated for the average marginal effects estimates using a multivariate probit model. The coefficients α and β_1-β_5 in the milk marketing choice equation measures the marginal effects of independent variables on milk marketing channel choice.

$$Y_{1i} = \begin{cases} 1 \ if \alpha + \sum_{J=1}^{4} \beta_1 X_1 + \sum_{K=1}^{5} \beta_2 X_2 + \sum_{L=1}^{5} \beta_3 X_3 + \sum_{M=1}^{4} \beta_4 X_4 + \sum_{N=1}^{2} \beta_5 X_5 + u > 0 \\ 0 \ otherwise \end{cases} \quad (4)$$

Where; Y_{1i} is a binary variable, which took the value one if the farmer sold to commercial milk buyers only and zero if the farmer decided to sell also to final consumers of milk. That is, the dependent variable is the farmers' choice for a given marketing channel; X_i is a vector (X_1-X_5) of observable control covariates; α and β are the parameters that were estimated, and u is the random error term, which included unobserved individual effects. In this case, an individual is assumed to have preferences defined over a set of alternatives.

The Inverse Mills ratio (λ) was also used to correct the error terms in the mixed effects and outcome equations to achieve consistent and unbiased estimates. The coefficients of IMR provided estimates of covariance σ^2_{u1}, σ^2_{u2} and σ^3_{u12} in the milk marketed output volume in equation 3. However, the parameter estimates of a two-stage approach are consistent but inefficient, especially if the coefficient, λ, is non-zero.

2.7. Diagnostics tests

Diagnostic tests were conducted from the regression results of STATA output. All assumptions were tested and corrected accordingly. Potential multicollinearity among explanatory variables was tested in a preliminary analysis. They were found to have no potential influence on estimates from the model. The highest pair-wise correlation was 0.4, whereas multicollinearity is a serious problem if the pair-wise correlation among regressors is more than 0.5 (Akerlof, 1970).

An analysis of the variance inflation factor (VIF) did not show any problem since none of the VIF of a variable exceeded 8 (McFadden, 2001). Besides, the likelihood chi-square ratio test statistic of 48.89 with a p-value of 0.001 indicated that the model that was used in the study as a whole was statistically significant.

3. Results and discussion

3.1. Socioeconomic characteristics of dairy farm households

Out of the 432 sampled dairy farmer households, 55% sold their milk at farm-gate to commercial milk buyer(s), 40.06% sold to final consumers while 4.86% marketed their milk output to both final consumers and

commercial buyers respectively. From the results, most of the dairy farmer households sold their farm-gate raw milk to more than one milk marketing outlet depending on the unit price offered, the volume of milk produced, and the need for urgent cash. The mean values of the socioeconomic characteristics of the dairy farmer households are as shown in table 4. Results show that the average family size of the surveyed dairy farmer households was six members per household and did not vary significantly across the six sub-counties. According to the findings by Berhanu et al. (2014), households with smaller family size have higher marketable milk surplus as compared to households with larger family size. Family size is postulated to influence household milk market participation indirectly.

The age structure of smallholder dairy farmer households shows that the average age of household head was 48.4 years, and this did not vary across the six sub-counties. This was a clear indication of the preference that energetic dairy farmers have for milk production activity. About half of the entire sampled respondents were 40 years and above. The selected households had fairly long experience in dairy farming. Farmers had, on average 18.6 years of experience in dairy production. More than one-third of the dairy farmers had less than ten years of experience. These smallholder dairy farmers seemed to have been driven by the demand-side market dynamics such as the increased demand for milk in urban areas, better marketing opportunities, and easy access to resources for dairy production. Results further show that the majority of the dairy farmer households owned on average, three dairy milking cows producing on average 6.3 liters of milk per cow per day. The minimum milk production was 0.46 liters, while the maximum was 16 liters per cow per day. There was also the existence of significant differences in the distribution of dairy farmers across the six sub-counties.

The average size of land holdings was 4.98 acres. It ranged from about 0.2 acres in the case of smallholder farms mostly in Kericho East and West where tea growing predominates, to about 70 acres in the case of large farms in Kipkelion East and Kipkelion West, respectively. In the latter two sub-counties, dairy cow and maize production were the two major agricultural enterprises being practiced as compared to the other sub-counties. This shows that dairy farming households that participated in the production of milk had a smaller mean acre of landholding. This could be a clear indicator that marketed farm-gate milk output does not necessarily need large landholdings.

Table 4. Mean Socioeconomic Characteristics of Dairy Farmer Households, 2019

Indicator	Minimum	Max	Mean	Std. Dev.
Age (years)	23	80	48.4	11.7
Family size (number)	1	15	6.2	2.3
Farming experience (years)	1	45	18.6	10.6
Herd size (number)	1	54	6.4	5.5
Land size (acres)	0.2	70	4.98	6.8
Milking cows (number)	1	50	2.6	3.15
Milk yield per cow per day (liters)	0.46	16	6.3	8.6

On average, the sampled smallholder dairy farmer households had three milking cows with the minimum being one and the maximum being 50 dairy cows, respectively. However, the number of milking cows varied with the size of the farmers' farm holding. The quantity of daily milk produced by the dairy farmer household did not depend on the total number of the dairy herd, but the number of dairy cows in milk. Incidentally, about

66.90 percent of the households owned less than the average number of dairy cows, while 33.10 percent owned more than the average number of dairy cows, as shown in table 5.

Table 5. Average Dairy Cows Owned per Household, 2019

Households with	Herd size	Percent
Less than or equal to six	489	66.90
Greater than six	143	33.10
Total	632	100

Table 6 presents milk price summary statistics for those dairy farmer households that sold milk to commercial milk buyers and final consumers, respectively at farm-gate. In 2016, 2017 and 2018, the average actual farm-gate milk price per liter received by all the farmers selling exclusively to commercial milk buyers in the study area was Kenya Shillings (KES) 29.91, 32.71 and 35.51 respectively. For the final consumers, the average farm-gate milk price for the three years was KES 33.03, 37.31, and 41.65, respectively.

Table 6. Dairy Farmer Household's Farm Gate Milk Price Statistics, 2019

Year	t-test	Significance			
2018	8.3000	0.0000			
2017	6.8790	0.0000			
2016	5.1459	0.0000			
All counties	Mean selling to commercial (Ksh. per liter)	Standard Deviation	N	Mean selling to Final consumers (Ksh. per liter)	Standard deviation
Average milk price (2018)	35.51	6.93	194	41.65	8.44
Average milk price (2017)	32.71	5.88	194	37.31	8.01
Average milk price (2016)	29.91	5.55	194	33.03	7.03

3.2. Econometric analysis

3.2.1. Estimates of factors affecting volume of milk marketed output

Table 7 presents the results of the estimates of factors affecting marketed milk output per day per dairy farmer obtained through equation 3. The study used the Heckman selection model (two-step estimates), a regression model with sample selection. The first model was the choice model – whether the dairy milk farmers were selling to commercial milk buyers or not. The second analysis was the examination of the effects of the independent variables on the volume of milk output per day sold only to commercial milk buyers by the dairy farmer households. Inverse Mill's Ratio (λ) was calculated and included in the second stage Heckman selection model to estimate marketed milk output volume as given in Table 7. The overall joint goodness of fit for the second stage Heckman selection estimates was assessed based on the maximum likelihood method. The model chi-square test, while applying appropriate degrees of freedom, shows that the overall goodness of fit for the second stage Heckman selection model was statistically significant at a probability level of less than 5%. Therefore, the predictors included in the selection model explained the marketed milk output volume. Further,

from the results, rho (ρ) is positive, an indication that the unobservable factors are positively correlated with each other. Therefore, the standard interpretation of the estimates in the regression analysis is that a unit change in the predictor, while all the factors affecting milk marketed output are held constant, results in the respective regression coefficient to change the estimated value of the milk output volume produced. In the second stage selection model, seven predictor variables: Age, household size, formal employment, number of milking cows, number of calves, milk price per liter, access to extension services, and access to milk market information were all significantly different from zero and hence found to positively affect the marketed milk output per day per dairy farmer household. Therefore, the null hypothesis was thus rejected.

It was hypothesized that the age of the household head could determine their willingness to market their milk output per day positively. This was from the point of view that household heads could have acquired dairy farming experience over time. Results confirmed this and showed that the age of household head was statistically significant and had a positive effect on the proportion of the volume of milk that was produced by dairy farmer households per day that was eventually sold to commercial milk buyers. A one year increase in age, which represented a general increase in experience of the household head, increased the marginal value of time by 6.3% on milk output, thereby increasing the probability of more dairy milk in liters being produced per day. The current results are in convergence with the findings of Tshiunza et al. (2001) who identified the age of a household head as a major household characteristic that significantly affected the proportion of cooking banana plant for markets. However, the current finding is in divergence with the findings of Tesfaw, (2013), who found out that the age of household head negatively influenced the market participation decision of households. The reason was that when households get older and older, they shift to the production of the lesser labor-intensive farming alternatives like production of grain crops or they tend to rent out their land. This had, in turn, reduced their market participation.

Table 7. Heckman Two-Step Estimates for Factors Affecting Milk Marketed Output, 2019

	Coefficient	Standard Error	Z	P>|z|
Age	0.063	0.139	0.45	0.002*
Gender	-2.53	3.838	-0.66	0.010**
Household size	0.065	0.626	0.10	0.017**
Education Level	-2.160	0.930	-2.32	0.020**
Farming experience	-0.005	0.172	-0.03	0.976
Formal Employment	1.988	1.862	1.07	0.006*
Number of calves	-0.184	0.757	-0.24	0.008*
Number of milking cows	0.137	0.761	0.18	0.007*
Milk Price per liter	0.116	0.223	0.52	0.002*
Distance to Milk Market	-0.081	0.337	-0.24	0.009*
Access to Extension Service	4.026	1.924	2.09	0.036**
Access to credit	-2.346	2.575	-0.91	0.062
Access to market information	3.429	2.356	1.46	0.046**
Milk market participation	-0.461	2.818	-0.16	0.870
Constant	4.634	12.482	0.37	0.010**
Inverse Mill's Ratio (Lambda)	3.784	17.222	0.22	0.826
Rho (ρ)	0.290			
Sigma	13.034			
LR chi2(15)	33.22			
Log-likelihood	0.004			

Pseudo R2	0.056
Wald chi2(14)	20.90
Prob>chi2	0.004
Legend: * = 1 percent and ** = 5 percent levels of significance respectively. p-value of Likelihood Ratio Test (Pr>x2)	
Number of Observations	432

Source: Authors' Analytical Computation from Survey Data, 2019

Household size (total household members) had a significant positive effect on the milk volume produced. One additional member of the household results in a 6.5% increase in marketed milk output volume per day. In the context of agriculture being subsistence, and off-farm income opportunities being limited in rural areas of Kenya, the positive association of household size and increased milk productivity per day was expected. There was the possibility that large family size provides more family labor at the farm level, thereby increasing the family's chances of more benefits in terms of more milk production. Therefore, the bigger the household size, the higher the possibility of improved benefits from the increased volume of milk output produced by households. However, large household size can be a risk or a benefit to the household in terms of food security (Ng'eno, 2016; Karna, 2015; and Lapar, et al. 2003) found out a negative relationship between household size and market participation of households. Families with more household members tend to consume more milk, which in turn decreases milk market participation and marketed milk surplus. Hence, controlling for labor supply, larger households are expected to have lower market participation, a finding which is in convergence with the current study finding.

Formal employment of household head exerted a positive and significant effect on the daily volume of milk output produced by the dairy farmer at a one percent probability level. This means that a unit increase in the number of family members in formal employment results in a 198% increase in milk output volume produced per day. Productivity increases as a result of an increase in household income from formal employment are associated with increases in dairy cow milk production per day. Any additional monetary income from off-farm employment enables dairy farmer households to purchase more improved dairy cows and more feeds, which can contribute to increased milk production and increased milk market participation decision, respectively. This finding implies that although an increased number of family members in formal employment simulates increased milk production, the volume of milk output would rise steadily at an increasing rate as the household members in formal employment increases. According to Owusu et al. (2014), off-farm activities, besides being a valuable source of income for rural households in developing countries, also helps in smoothing incomes, which in turn smoothens consumption over long periods. The finding is in convergence with the current study finding. Therefore, formal employment (off-farm work) of household members head exerts a positive and robust effect on milk marketed volume and hence leads to increased household income.

The number of milking cows per day has a positive and significant influence on the marketed milk output volume per day per dairy farmer household. A unit increase in the number of dairy cows on milk, while holding other factors constant, leads to a 13.7% increase in the daily marketed milk output volume. The positive and significant relationship between the two variables shows that the number of dairy cows milked per day per household is an important variable affecting the household's volume of marketed milk output. The finding is consistent with the findings of Kuma et al. (2013), who found that milk yield per day has a positive and significant influence on the volume of milk supply per day per household.

The coefficients for milk price received per liter per day by the dairy farmer households had a positive and significant impact on the volume of milk output produced per day at a one percent significance level. Results reveal that for every one Kenyan shilling increase in milk price, there was a probability that farmers would increase the proportion of milk output volume produced per day by 11.6 percent. The variable was hypothesized to affect daily milk marketed output volume positively. The significant positive relationship shows that as the milk price increases, the decision by households to increase the volume of milk output also increases. However, the increase in income from milk sales would stimulate more household demand. This result was in agreement with past findings by Kuma et al. (2013) who found out that the better the price offered by the milk marketing channel, the more a household would prefer that outlet for accessing and selling milk.

Access to dairy extension services was a dummy independent variable that took the value one if a household had access to dairy extension services and 0 otherwise. From the results of this study, access to dairy extension services was statistically significant at 5 percent level of probability with a positive influence on the daily marketed milk output. From the results, access to dairy extension services led to increased daily milk output volume by 400 percent. Access to extension service widens a dairy farmer household's knowledge of the use of improved dairy technologies and consequently leads to increased milk productivity. According to Lerman, (2004), agricultural extension services are expected to enhance households' skills and knowledge and link households with technology and markets. The number of extension agent visits improves the household's intellectual capitals and helps in improving dairy production and impacts milk market outlet choices. Past studies revealed that extension agent visits had a direct relationship with market outlet choices (Holloway et al., 2000; Rehima and Dawit, 2012). Thus, these past research findings are in concurrence with the current study findings, and therefore access to dairy extension service by dairy farmer households affects positively daily milk marketed output volume.

Milk market information was a dummy independent variable that took the value one if a household had access to milk market information services and 0 otherwise. According to the study results, access to milk market information was statistically significant at the 5 percent probability level and positively impacted on the volume of milk output sold by the dairy farmer household. From the results, a unit increase in access to milk market information led to a 34.3 percent increase in the daily milk marketed output volume by the dairy farmer households. According to Goetz, (1992), poorly integrated markets may convey inaccurate price information leading to inefficient product movement. He further showed that better market information significantly raised the probability of market participation of households. Households marketing decision is based on market price information. A study conducted by Goetz, (1992) on food marketing behavior showed that better market information significantly raised the likelihood of market participation of households. These earlier results are in convergence with the current study finding, and therefore, the variable was correctly hypothesized to affect daily milk marketed output volume of supply positively.

According to the study results, the Lambda (Inverse Mill's Ratio) or selectivity bias correction factor had a positive and statistically significant influence on dairy household milk produced per day. This result suggests that there were unobserved factors that might have affected both the probability of dairy household engagement in dairy cow production and consequently, marketable milk output volume decisions. The

Heckman results suggest that the overall influence of the commercial milk buyer on milk output volume produced per day is driven in part by an endogenous selection process.

4. Conclusions and recommendations

The results showed that the majority of the dairy farmer households owned on average, two dairy milking cows producing on average 6.3 liters of milk per cow per day. There were also significant differences in the distribution of dairy farmers across the six sub-counties. In 2016, 2017 and 2018, the average farm-gate milk price per liter received by all the farmers selling exclusively to commercial milk buyers was Kenya Shillings (KES) 29.91, 32.71 and 35.51, respectively. The second-stage Heckman selection model estimates showed that age, household size, formal employment, number of milking cows, number of calves, milk price per liter, access to extension services, and access to milk market information were all significantly different from zero and hence found to positively influence the marketed milk output volume per day per dairy farmer household at farm-gate. Policy implications arising from the study results is that to improve on dairy farmers' milk production per day, exchange of farming experiences should be supported. Additionally, off-farm income, milk market information access, and better milk price seems to be the precise and essential elements for dairy productivity. Milk yield per day has a significant positive impact on the total daily milk marketed output volumes. Thus, the national and county governments could pay more attention to enhance access to financial investment and information access to milk markets. The smallholder dairy farmers should also be encouraged to improve their financial capability, to improve their dairy cow herd quality and quantity for added improvement. Dairy extension services should also be strengthened through redesigning or reforming implementation strategies or improving/strengthening the existing policy. It should be strengthened to enable farmers to produce surplus milk for external milk markets. Moreover, both levels of government should strengthen existing milk processing plants and improve their infrastructure facilities.

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