Adoption Probability and Intensity Determinants of Crossbred Cows Technologies in Oromia National Regional State

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ABSTRACT

Modern dairy production technologies dated back to 1950s in Ethiopia. Efforts have been made by governmental and non-governmental organizations to expand the use of crossbred cows to boost yield. However, adequate empirical information on adoption of crossbred cows in Ethiopia is lacking. This study investigated the determinants of crossbred cows adoption in Oromia National Regional State using large dataset collected from eight zones. Multistage sampling procedure was used to select the study zones, districts, kebeles and households. Using a standard formula to determine sample size, a total of 1630 samples were selected using systematic random sampling technique. The data collection procedure was implemented using a structured questionnaire designed to collect better quality data. Both descriptive and econometric models were used to analyze the data. Heckman's two-steps selection model was used to investigate the determinants of adoption probability in the first stage and determinants of adoption intensity (number of crossbred cows) in the second stage. Result shows that the adoption level of crossbred cows in Oromia Region was 28%. The probability of adoption was positively influenced by education and age of household head, grazing, perceived feed cost, knowledge on improved feed, milk selling experience, and milk market distance but negatively influenced by price of crossbred cows. The intensity of adoption was positively influenced by farm size, dairy related training, milk production and experience in milk selling, but negatively influenced by gender (male) and age of household head, perceived high price and unavailability of crossbred cows, high feed cost and distance from big cities. Therefore, socio-demographic, institutional and dairy related attributes should be taken into consideration in designing policies that target crossbred dairy cow expansion in Oromia and other regions that share similar characteristics of dairy development with Oromia. Formal heifer rearing centers should also be established and strengthened not only in Oromia but also other regions of the country to ensure adequate suppliers of dairy cows as affordable prices.

Keywords: crossbred cows, Heckman two-steps, adoption

INTRODUCTION

Introduction of modern dairy production in Ethiopia dated back to 1950s which started by importing 300 exotic cows (Staal and Shapiro, 1996). Since then, various research and developmental activities such as generating and disseminating crossbred heifers along with improved feed, management and husbandry practices were implemented for smallholders (Ahmed, 2004). Starting from 1974, the research approach changed to upgrading the local indigenous cows, especially boran breed by Ethiopian Institute of Agricultural Research (EIAR) using semen from Holstein Friesian bull to obtain 50% crossbred heifers (Gojam *et al*., 2017). Considering the social and economic context of smallholder farmers, the exotic blood level of crossbred cows was set at affordable level of 50% (Kebede, 1992; Shapiro *et al*., 2015). On the other hand, up to 62.5% of exotic blood level of crossbred cows was recommended for urban and peri-urban market oriented dairy producers (Shapiro *et al*., 2015).

The reason for maintaining this level of exotic blood was mainly to ensure adaptability and create affordable management levels for smallholder farmers. According to the research results of Kebede (1992), crossbred dairy cows with higher levels of exotic blood are not able to express their potential productivity with minimum management levels provided by smallholder farmers. This was the reason why research fixed manageable and affordable level of exotic blood of crossbred cows for smallholder farming and production settings.

With an objective of supplying crossbred heifers in different parts of the country, parastatal ranches such as Chilalo Agricultural Development Unit (CADU) which was part of the Arsi Rural Development Unit (ARDU), Wolaita Agricultural Development Unit (WADU), Abernossa ranch, and Gobe ranch were established in different parts of the country in the 1970-80s (Haile *et al*., 2011; MoA, 1986). In addition, with the aim of conserving indigenous breeds of Fogera, Andassa and Metekel ranches, and to conserve the Begait indigenous breeds, Humera ranch were established under the ministry of agriculture (MoA) in the northern and north western parts of the country. Currently, most of the influential farms including Abernossa and Gobe were privatized whereas Andassa was included under the regional research system (Alemneh, 2015), Wolaita Sodo state farm is currently running under regional government (Lemma *et al*., 2010), Metekel and Humera are still under the MoA ownership. Most of the privatized dairy farms have shifted to other businesses and no longer serve as heifer multiplication center. This made access of improved heifers difficult.

Despite the breeding improvement efforts made by the government, the proportion of improved breed of female cattle is only 2.5%, of which 2.1 and 0.4% are crossbred and exotic breeds, respectively (CSA, 2020). This can be partly attributed to the policy constraints in dairy sector (Ergano *et al*., 2015) and weak livestock extension system (MoA and ILRI, 2013).

Dairy production technologies developed and generated through research were promoted and disseminated to smallholder farmers through various routes of technology transfers including technology verification, demonstration of proven technologies, popularization of selected technologies, providing tailor-made trainings, experience sharing visits and field days, preparation and dissemination of production manuals, fliers and pamphlets (Kuma *et al*., 2006; Abebe and Ponnusamy, 2015). Various programs have also been striving to enhance dairy technology dissemination and use through incorporating in the national development initiatives, such as the growth and transformation plans of the country (NPC, 2016).

Despite several efforts made to modernize the dairy sector, there is no adequate information on the rate and intensity of adoption of dairy production technologies. Public, private and non-governmental organizations have made investments over years in the generation, dissemination and promotion of dairy production technologies. However, these technologies are not impacting the dairy sector to the level expected. To help design appropriate policy, institutional, research and developmental measures, there is a strong need to generate information on the status and intensity of adoption of dairy production technologies. Apart from patchy and inadequate availability of information, past studies conducted in Ethiopia have methodological limitations. The studies conducted on crossbred dairy adoption by Asres *et al*. (2012), Gezie *et al*. (2014), Fita *et al*. (2012), Mekonnen *et al*. (2010) and Tadese (2020) explored the factors affecting the probability of adoption by using either a binary logit, probit or correlation between factors and descriptive analysis. The binary logit and probit analyses, however, can only analyze the probability of adoption without consideration of the intensity of adoption.

Even though the work of Gezie *et al*. (2014) has applied Heckman's selection model to understand the factors affecting adoption probability and intensity of crossbred dairy cows, the methodology used to select the sample rarely fits for adoption study. The authors selected 192 adopters and 192 non-adopter sample households purposively, the methodology which fails to determine the actual adoption rate. To determine the adoption rate of a technology, the sample should be drawn randomly out of the identified sampling frame. The current study adds to the existing dairy adoption literature in three ways: First, it generates up-to-date information on the status of adoption rate and intensity along with determining factors which would help policy makers, private sectors and development practitioners make informed decisions. Second, it draws sample households randomly from the sampling frame of households who own either local or crossbred cows or both. This study also draws relatively large size of sample covering eight zones, 16 districts and 32 kebeles of Oromia National Regional State. Third, Heckman's two step econometric model which is appropriate to analyze factors affecting both the probability and intensity of adoption was engaged. Apart from this, the model takes care of the sample selection problem. The study also fills the gaps of earlier studies with the objective of investigating factors affecting the probability and intensity of adoption of crossbred cows technology.

METHODOLOGY

The Study Area

Multistage sampling technique was adopted to select the region, zones, woredas and kebeles. The study was conducted in Oromia National Regional State which has over 24 million cattle, accounting for 41% of cattle population in Ethiopia (CSA, 2015). Eight zones that are believed to represent the region in dairy production were selected for the study including North Shewa, West Shewa, South West Shewa, East Shewa, West Hararghe, Arsi, Bale and West Arsi. Two districts were again selected from each of the zones based on representativeness of the zones in dairy production, making a total of 16 districts embraced in the study. From each of the districts, two kebeles were selected again based on representativeness in dairy production practices and this makes a total of 32 kebeles.

Data Collection Approaches

The required dataset and information were collected by employing stages of standard data collection methodologies. In the first stage, extensive desk review was made from electronic and print media including published and unpublished materials. Information obtained from desk reviews has helped to design survey instruments, such as checklists and structured questionnaire. In the second stage, qualitative information was collected on specific parameters through qualitative techniques, such as focus group discussions and key informant interviews. Information collected through this technique helped to describe and narrate quantitative findings. The third stage was devoted to collection of quantifiable data through quantitative survey approaches. This stage was fundamental to collect concrete and measurable data from randomly selected households using a structured and pre-tested questionnaire.

Sampling Frame and Sample Selection Techniques

The sampling frame of the study was the population of households who owned cows either local or crossbred. The complete list of households from where samples were drawn randomly was obtained from records of Office of Agriculture. After securing the list, data was collected on the cow ownership status of each of the households along with kebele and village representatives. With this process, the sampling frame of the population of households who own cows was established. Out of this sampling frame, the sample of households was drawn randomly using systematic probabilistic sampling procedure. To obtain a representative sample size for the study, the sample size determination formula by Kothari (2004) was used:

$$N = \frac{Z^2 pq}{e^2} = \frac{(1.96)^2\ (0.5)(0.5)}{(0.025)^2} = 1537 \quad (1)$$

Where N is the sample size needed, Z is the inverse of the standard cumulative distribution that corresponds to the level of confidence, e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q = 1-p. The value of Z is found from the statistical table which contains the area under the normal curve of 95% confidence level. In the determination of sample size, setting the value of p=0.5 and hence q=0.5 yields the maximum optimum sample size while any other combination of the values of p and q yields less sample size using the Kothari formula. Therefore, using 0.5 for the values of p and q and e =0.025, the Kothari formula gives a total of 1537 samples to sufficiently represent the population in the selected study areas assuming a 95% confidence level and ±5% precision. However, assuming a response rate of 94%, additional 93 samples were added to have a total of 1630 samples (Table 1).

Table 1. Sample size selected from each of the study zones in Oromia region

Zones	Male	Female	Overall
North Shewa	167	57	224
West Shewa	175	60	235
South West Shewa	155	42	197
Arsi	130	42	172
Bale	140	60	200
West Arsi	138	61	199
East Shewa	140	58	198
West Hararghe	125	80	205
Overall average	1170	460	1630

Theoretical Framework and Analytical Model

This study was theoretically framed on the random utility theory (McFadden, 1974) with a bounded rationality framework. The original random utility model assumes that a decision maker (dairy producer in this case) is rational which is also termed as 'an economic man' with perfect information to make a decision that gives him/her maximum utility. However, these assumptions are criticized arguing that human beings are limited with cognitive capacity, information asymmetry and limited time availability to make a decision to reach global maximum utility (Simon, 1955). As a result, there is an increasing trend to shift from rationality assumption to bounded rationality theory developed by Simon (1955). Based on this theory, a decision maker cannot make utility maximizing decision but a nearly optimal decision that is sufficient to compare alternatives (Simon, 1955).

To put this theory in analytical form, an individual dairy producer, i, who has two options either to adopt or not to adopt crossbred cow/heifer, chooses option one say, j, if and only if the expected utility (profit or milk yield), U_{ij} derived from adopting crossbred, is greater than the expected utility say, U_{ik} that can be obtained from not adopting, k, in the choice set. In the bounded rationality assumption, the utility, U_{ij} was obtained not at profit maximizing point but sufficient to choose the best alternative. However, the utility is not directly observed while only the action of the decision-maker is observed through the choice he/she made (adopt/not adopt). According to Greene (2012), the linear random utility model for the two choices can be specified as:

$$U_{ij} = \beta_j' X_j + \varepsilon_j \text{ and } U_{ik} = \beta_k' X_k + \varepsilon_k \qquad \forall j \neq k \tag{2}$$

Where β_j and β_k are vectors of parameters to be estimated, ε_j and ε_k are the error terms assumed to be independently and identically distributed, and X_j and X_k are vectors of explanatory variables that affect the perceived utility obtained by adopting crossbred cow j and not adopting k, respectively.

The perceived utility for the i^{th} dairy farmer obtained from adopting crossbred cow, j is greater than the utility from not adopting the option k which is represented as:

$$U_{ij}(\beta_j' X_j + \varepsilon_j) > U_{ik}(\beta_k' X_k + \varepsilon_k), \qquad \forall j \neq k \tag{3}$$

Assume that Y is the decision to adopt j so that Y takes the value of 1 if j is chosen and 0 otherwise, the probability that a dairy farmer adopts crossbred cow conditional on X can be expressed as:

$$\begin{aligned}(Y = 1|X) &= P\left(U_{ij} > U_{ik}\right) \\ &= P(\beta_j' X_i + \varepsilon_j - \beta_k' X_i - \varepsilon_k > 0|X) \\ &= \mathrm{P}(\beta_j' \mathrm{X_i} - \beta_k' \mathrm{X_i} + \varepsilon_j - \varepsilon_k > 0|\mathrm{X}) \\ &= P(\beta^* X_i + \varepsilon^* > 0|X) = F(\beta^* X_i)\end{aligned} \tag{4}$$

where P is a probability function, U_{ij}, U_{ik} and X_{ik} are as defined above, $\varepsilon^* = \varepsilon_j - \varepsilon_k$ is a random error term, $\beta^* = \beta_j' - \beta_k'$ is a vector of unknown parameters to be estimated and can be interpreted as the net influence of the vector of explanatory variables affecting adoption, and $F(\beta^* X_i)$ is the cumulative distribution function of ε^* evaluated at $\beta^* X_i$. The distribution of F depends on the distribution of ε^*.

Analytical Model

Dairy producing farmers make two types of decisions in the crossbred cows adoption process. First, they make a decision on whether or not to participate in adopting crossbred cows. Depending on their first decision, those who decided to participate make the second decision on the number of crossbred cows to hold. Potential empirical models to handle such kinds of decision are Tobit (Tobin, 1958), Heckman two-stage (Heckman, 1979) and

Craggit double hurdle (Cragg, 1971). However, the Tobit model is criticized for two shortcomings. First, it cannot separate the participation and intensity of participation decisions and assumes factors affecting participation also affect the intensity decision in the same way. However, these decisions are separate in reality and participation and intensity can be influenced either by the same factors or not with different direction and magnitude of influence. Second, it assumes the zero values in the intensity equation as a corner solution. Nevertheless, the zero value of the intensity of participation equation may not be necessarily the corner solution but can be due to a discrete choice of not to participate in the adoption decision. Therefore, Heckman two-stage and Craggit double hurdle models are the two better alternatives of the Tobit model.

The difference between the Heckman and the Craggit double hurdle models is that the former assumes there is no zero observation in the dependent variable of the second stage once the first stage is passed whereas the later still considers that there might be a possibility of zero observation. In this study, once the dairy farmers decided to participate in adopting the crossbred cows, there is no possibility that the number of crossbred cows adopted can be zero. That is, as the number of cows cannot be a decimal number, there is no possibility that it can be rounded to zero. Another difference between the two is that the Heckman two stage model assumes the dependence of the hurdles whereas the Craggit double hurdle model assumes the independence of the hurdles (Rufino, 2016). If this holds true, the Heckman is better than Craggit double hurdle model for it corrects the sample selectivity bias.

Rufino (2016) also suggested the way to undertake the empirical comparison of the Craggit and the Heckman two stage models by evaluating the phenomenon of dependence/independence of the hurdles. According to Rufino (2016), the likelihood-ratio test reported at the bottom of the Heckman two stage model output is an equivalent test for Ho: $\rho = 0$. It is computationally the comparison of the joint likelihood of an independent probit model for the selection equation (first hurdle) and a truncated regression model of the intensity equation (second hurdle). If a p-value is less than 0.05, the use of Heckman sample selection model instead of the Craggit model is justifiable.

Heckman's two-steps selection model was used on conditions where there is selectivity bias especially for dependent variables. Therefore, Heckman model was employed here to correct for selectivity bias. Selection bias problems are endemic to applied econometric problems, which make Heckman's original technique and subsequent refinements by both himself and others, indispensable to applied econometricians. Heckman's sample selection model is based on two latent dependent variable models and has developed a two steps estimation procedures model that corrects for sample selectivity bias (Heckman, 1979). Moreover, Heckman's two steps estimation procedures are appropriate in that there are two decisions involved, such as participation in adoption of crossbred cows and the intensity of adoption. The first step of Heckman two steps model, 'the participation equation', attempts to capture factors affecting participation decision.

The selectivity term called 'inverse Mills ratio' (which is added to the second step outcome equation that explains factors affecting the level or intensity) is constructed from the first equation. The inverse Mill's ratio is a variable for controlling bias due to sample selection (Heckman, 1979). The second step involves the Mills ratio to the intensity (level of participation) equation and estimating the equation using Ordinary Least Square (OLS). If the coefficient of the mill's ratio (lambda) is significant, then the hypothesis of the unobserved selection bias is confirmed. Moreover, with the inclusion of extra term (Mill's ratio), the coefficient in the second step selectivity corrected equation is unbiased (Zaman, 2001).

Specification of the Heckman two steps procedures, which is written in terms of the probability of participation and intensity, is:

The participation/the binary probit equation

$$Y_{1i} = X_{1i}\beta_1 + U_{1i} \qquad U_{1i} \sim N(0, 1) \qquad (5)$$

$$Y^* = 1 \text{ if } Y_{1i} > 0 \qquad (5.1)$$

$$Y^* = 0 \text{ if } Y_{1i} \leq 0 \qquad (5.2)$$

Where Y_{1i} is the latent dependent variable which is not observed,

X_{1i} is vectors that are assumed to affect the probability of participation,

β_1 is vectors of unknown parameter in the participation equation, and

U_{1i} are residuals that are independently and normally distributed with zero mean and constant variance

The observation equation/the intensity equation

$$Y_{2i} = X_{2i}\beta_2 + U_{2i} \qquad U_{2i} \sim N(0, 1) \qquad (6)$$

Y_{2i} is observed if and only if $Y^* = 1$. The variance of U_{1i} is normalized to one because only Y^*, not Y_{1i} is observed. The error terms U_{1i} and U_{2i} are assumed to be bivariate, normally distributed with correlation coefficient ρ, β_1 and β_2 are the parameter vectors.

Y_{2i} is regressed on explanatory variables, X_{2i}, and the vector of inverse Mill's ratio (λ_i) from the selection equation by Ordinary Least Square (OLS).

Where, Y_{2i} is the observed dependent variable

X_{2i} is factors assumed to affect intensity equation

β_2 is vector of unknown parameter in the intensity equation

U_{2i} is residuals in the intensity equation that are independently and normally distributed with mean zero and constant variance.

$$\lambda_i = \frac{f(XB)}{1 - F(XB)} \qquad (7)$$

f (Xβ) is density function and 1- F (Xβ) is distribution function.

Hypothesis and Definition of Variables

Several studies have often been considering household and farm characteristics, attributes of the technologies, institutional factors such as access to markets, information, credit and extension services. Regarding the dairy technology adoption, previous findings indicated that household background such as age (Gezie *et al*., 2014; Quddus, 2012), education (Asres *et al*., 2012, Fita *et al*., 2012; Mekonnen *et al*., 2010; Quddus, 2012), gender (Tadese, 2020), and family size (Gezie *et al*., 2014; Mekonnen *et al*., 2010) were the key factors included in the model for affecting dairy technology adoption.

Variables such as farm size (Gezie *et al*., 2014), income (Gezie *et al*., 2014; Quddus, 2012), credit (Quddus, 2012), extension services (Gezie *et al*., 2014; Quddus, 2012; Tadese, 2020), training (Gezie *et al*., 2014; Fita *et al*., 2012), cooperative membership (Tadese, 2020), distance to market (Mekonnen *et al.*, 2010), experience in dairy farming (Fita *et al*., 2012), availability of source of crossbred heifers (Gezie *et al*., 2014), and other context specific variables were also reported to be the determinant factors of dairy technology adoption. Based on economic theories and past findings, the hypothesized explanatory variables along with their expected signs are presented in Table 2.

Table 2. Variables hypothesized to influence adoption of crossbred cows

Variable code	Description	Values	Expected sign
Age of HH	Age of household head	years	-/+
Education of HH	Elementary, secondary and above	1=yes, 0=no	+
Family size	Number of family members	number	-/+
Household type	Gender of household head	1=male	-/+
Farm size	Total area of land operated	Hectare (ha)	+
Income	Total household income	Birr	+
Crossbred price	Perceived price of crossbred cows	1=expensive	-
No source cows	No source of crossbred cows	1=Yes	-
Feed cost	Perceived feed cost is expensive	1=Yes	-
Source of feed	Main source of feed is grazing	1=Yes	+
Improved feed knowledge	Household head's knowledge on improved feeding practices	1=Yes	+
Trainings	Trainings received on dairy	1=Yes	+
Credit	Access to credit services for feed and crossbred cows purchase	1=Yes	+
Extension	Access to extension services on improved dairy management	1=Yes	+
Member-coops	Member of dairy cooperatives	1=Yes	+
Milk production	Quantity of cow milk produced	Liters	+
Sale experience	Has milk selling experience	1=Yes	+
Market distance	Distance to milk selling center	km	-
Proximity to big cities	Proximity to big consumer centers, (within 100km radius)	1=Yes	+

Note: HH refers to household head

RESULTS AND DISCUSSION

Descriptive results

Household characteristics

Tables 3 and 4 present descriptions of continuous and discrete variables of the sample households, respectively. The average age of adopters and non-adopters of crossbred cows was 44 and 42 years, respectively, with a significant mean difference between them. Similarly, the average family size of adopters and non-adopters was 7.2 and 6.8 persons, respectively, with a significant mean difference. Age of the household head is believed to be associated with farming experiences which is hypothesized to have either positive or negative influences on the adoption of technologies. Assuming that the household heads started farming at their ages of 20 years, they have accumulated more than 20 years of faming experiences. Family size is also an essential resource for farming households because, farming activities mainly depend on family labor for operations related to livestock management, such as feeding, feed collection, herding, milking and cleaning.

Educational level and sex of the household head are also important demographic factors for crossbred cows adoption process. In this study, 85% of the overall sample households was headed by male with no significant difference between the adopters and non-adopters. Regarding educational status, 44.2 and 27.7% of the overall sample households attended elementary and above levels, respectively. While there is no significant difference between the elementary level of education for adopter and non-adopter sample households, the proportion of adopters above elementary levels was significantly higher for adopters than non-adopters. The results also indicated that the proportion of households with access to dairy related trainings, milk selling experiences and knowledge of improved feeding practices was significantly higher for adopters than non-adopters.

Farm and economic characteristics

The average farm size, milk production per day and annual income of adopter households were significantly higher than non-adopters (Table 3). Land is a crucial input to adopt crossbred cows for it is used for grazing, producing improved forages/hay and staple crops that in turn help to obtain crop residue which is one of the essential animal feeds in Ethiopia. Household income and milk production are also vital to expand the adoption of crossbred cows as they can be used to purchase the required inputs for dairy production.

As the findings indicate, the proportion of households who reported grazing as the main source of feed was significantly higher for adopters (94%) than non-adopters (88%). In the rural setting, grazing is a vital source of feed for dairy production. Moreover, dairy producers depend on purchased feed, especially concentrate feeds, to boost milk yield. The major concern of households on purchased feeds is the cost which they noticed it to be not only high but also increasing over time. As witnessed in this study, the proportion of households who perceived that feed cost is expensive was significantly higher for adopters (78.5%) than non-adopters (71%) (Table 4). It was also revealed that the ever-increasing feed cost could affect further adoption of dairy technologies and productivity.

Table 3. Mean difference of continuous variables between adopters and non-adopters of crossbred cows

Variables	Adopters (n=460)	Non-adopters (n=1170)	Total sample (n=1630)	t-test
Age of HH head*	44.3 (13.0)	42.1 (12.6)	42.7 (12.8)	3.2***
Family size	7.2 (3.3)	6.8 (2.9)	6.9 (3.0)	2.5***
Land size	3.1 (2.6)	2.0 (1.8)	2.3 (2.1)	9.8***
Milk production	7.7 (7.3)	0.7 (2.2)	2.7 (5.3)	29.6***
Income (1000ETB)	34.9 (58.9)	23.0 (32.5)	26.4 (41.9)	5.2***
Distance to market	2.3 (2.5)	1.7 (3.2)	1.8 (3.0)	3.4***

*HH=Household Head, Figures in parentheses indicate standard deviations
*** means significant at 1% level of significance.

Access to sources and affordability of crossbred cows

In the context of Ethiopia, sources of crossbred heifers/cows is one of the fundamental factors affecting adoption of crossbred cows technologies. As presented in Table 4, 24% of non-adopters reported unavailability of sources of crossbred cows/heifers. While the supply of crossbred cows is limited on one side, the demand is growing on the other. This has consequently contributed to the high price which is apparently unaffordable especially by smallholder farmers. This was witnessed by 49% of non-adopters who reported the expensive purchase price of crossbred cows/heifers while this proportion was 12% for adopters. These results suggest that improving the sources of crossbred heifers/cows at affordable price would motivate the non-adopters to adopt crossbred cows technologies. Adopters would also increase the number of crossbred cows/heifers once they find sustainable sources at affordable prices.

Institutional characteristics and market access

Increased access to credit and extension services, membership in dairy cooperatives, milk market and close proximity to consumers in big cities are believed to be contributing factors for the adoption of improved dairy technologies. The findings revealed that the average proportion of overall sample households who had access to credit services for dairy production was low (6.6%) with a significant difference between adopters (8.7%) and non-adopters (6%). However, 45% of the overall sample households on average had access to dairy related extension services with statistically significant differences between adopters (54%) and non-adopters (41%).

Membership in dairy cooperative was also another crucial variable affecting adoption of dairy production technologies. Cooperatives usually play dual roles of input supply for dairy production and source of market purchasing milk and other dairy products from households. According to the findings, less than 10% of the overall sample households were members of dairy cooperatives with a statistically significant differences between adopters (17%) and non-adopters (4%). Encouraging the farmers to be members of dairy cooperatives is believed to be helpful to enhance adoption of dairy production technologies.

Overall adoption rates and intensity of adoption of crossbred cows

The overall adoption rate of crossbred cows in Oromia National Regional State was 28% (Table 5). Among the study zones, crossbred cows were most adopted in North Shewa zone (74%) followed by Arsi (51%) and Bale (33%) zones. In contrast, West Hararghe was the least adopter of crossbred cows (3%) among all the study zones. The reason for higher adoption in North Shewa, Arsi, and Bale zones are due to the fact that dairy development efforts by Addis Ababa dairy development project for the North Shewa and CADA/ARDU, Gode ranch for the Arsi and Bale zones.

In the context of this study, intensity of crossbred cows adoption is defined as the number of crossbred cows owned by the sample households. The findings revealed that the adopters owned nearly two (1.78) crossbred cows on average. It was also noted that there was significant variation among the study zones with the highest intensity of adoption in North Shewa zone (2.02) followed by Bale (1.89) and Arsi (1.76) zones. On the contrary, adoption intensity was the least in Hararghe and East Shewa zones where the adopters owned 1.29 crossbred cows each on average. This was because of the fact that most of the dairy development programs and projects have been implemented in the Selale (North Shewa zone), Arsi and Bale areas since long time ago.

Determinants of the adoption of crossbred cows

In view of the nature of dataset and sampling procedures, Heckman's two-steps selection model was employed to take care of sample selection bias for dependent variable. The first step of Heckman procedure captures factors affecting participation decisions in the adoption of crossbred cows while the second step explains factors affecting the intensity of adoption. The intensity of adoption was attributed to the number of crossbred cows owned by adopters. The mills ratio or lambda of the model reveals a statistically significant value ($P<0.001$). In addition, LR test of independence of the two equations is 5.65 ($P=0.0175$) implying the assumption of Craggit model which states the independence of the two hurdles was rejected but the dependence assumption of Heckman was not rejected. Both the mills ratio and LR test value implied appropriateness of the choice of Heckman model for the analysis.

Table 4. Percentage difference between adopters and non-adopters of crossbred cows (discrete variables)

	Adopter (n=460)		Non-adopter (n=1170)		Overall (N=1630)		Chi2 value
	Freq.	%	Freq.	%	Freq.	%	
Elementary education (Yes=1)	210	45.7	510	43.6	720	44.2	0.57
Above elementary education (Yes=1)	148	32.2	304	26.0	452	27.7	6.3**
Household type (Male=1)	387	84.1	995	85.0	1382	84.8	0.21
Trainings received on improved crossbred cows (Yes=1)	213	46.3	336	28.7	549	33.7	45.7***
Has knowledge of improved feed practices (Yes=1)	229	49.8	521	44.5	750	46.0	3.7*
Milk selling experience (Yes=1)	286	62.2	101	8.6	387	23.7	522.8***
Main feed source is grazing (Yes=1)	430	93.7	1022	87.7	1452	89.4	12.6***
Feed cost is expensive (Yes=1)	361	78.5	835	71.4	1196	73.4	8.5***
Perceived source of crossbred cows (Not available=1)	2	0.90	269	24.3	271	20.4	62.2***
Perceived price of crossbred cows (Expensive=1)	26	11.8	518	46.9	544	41.0	93.8***
Dairy related credit (Yes=1)	40	8.7	70	6.0	110	6.6	3.9**
Dairy extension (Yes=1)	249	54.1	484	41.4	733	45.0	21.7***
Member of dairy coops (Yes=1)	79	17.2	46	3.9	125	7.7	81.8***

Table 5. Adoption rate and intensity of crossbred cows in the study zones of Oromia Region

The study zones	N	Adoption rate		Adoption intensity
		Freq.	%	Mean number of crossbred cows
North Shewa	224	165	73.66	2.02 (1.26)
West Shewa	235	37	15.74	1.54 (0.87)
South West Shewa	197	21	10.66	1.48 (0.75)
Arsi	172	87	50.58	1.76 (0.95)
Bale	200	65	32.50	1.89 (1.08)
West Arsi	199	50	25.13	1.56 (0.95)
East Shewa	198	28	14.14	1.29 (0.6)
West Hararghe	205	7	3.41	1.29 (0.49)
Total	1630	460	28.22	1.78 (1.07)
		X^2=403.23, df=7, P<0.001		F=3.23, df=7, P<0.01

Note: Figures in parentheses indicate standard deviation, Freq.=frequency

According to the Heckman two-steps analysis results illustrated in Table 6, the coefficient estimates for the factors affecting participation of households in the adoption of crossbred cows were provided along with marginal probabilities while the intensity of crossbred cows adoption has been provided along with corresponding marginal effects. In both cases, most of the coefficient estimates are statistically significant with the expected sign. The Wald Chi-square test for the Heckman model was highly significant (P<0.001) confirming a strong explanatory power while the significant value of mill's ratio confirms the appropriateness of using Heckman's two-steps model due to the presence of selectivity bias.

It was hypothesized that the level of education of the household head positively contributes to adoption of crossbred cows and the findings have also supported this. Both elementary and junior secondary levels of education for the household head have positively and significantly (P<0.001) influenced the likelihood of adoption of crossbred cows. The likelihood of owning crossbred cows would be higher by 13.3% for a household with primary level of education while it is 18% for the household with junior level of education. Access to education contributes for increased knowledge and informed decision making. Consequently, enhancing educational access to households is believed to enhance adoption of crossbred cows technologies. This result is in line with a number of previous findings which reported a positive association between educational level and dairy technology adoption (Asres *et al*., 2012, Fita *et al*., 2012; Mekonnen *et al*., 2010; Quddus, 2012). It was, however, noted that education did not have significant influence on the intensity of adoption. This might be because, once the household is an adopter, the number of crossbred cows to be purchased is not determined by the level of education, but rather by some other factors such as price and economic capacity.

The findings also indicated that male headed households had high probability of adoption but negatively associated with the intensity equation. Male headed households perceived that keeping increased numbers of dairy cows would demand more time and affect other farming activities, such as crop production. For female headed households, the probability of adopting crossbred cows was lower by 17.8% while the intensity of owning crossbred cows was higher by 3.7% as compared to male headed households. This is mainly because crossbred cows are often herded around homesteads where women are the ones who have close attachments to look after and manage. Similar findings on the negative relationship between male headed households and the intensity of dairy technology adoption were also reported by Tadese (2020) in Ethiopia.

Age of the household head was observed to have a positive association with the probability of adoption of crossbred cows, but negative association with the adoption intensity. The positive association between age and improved dairy technology adoption was also observed by Quddus (2012) in Pakistan. As the age of the household head increases by a year the probability of adoption increased by 0.8% while the number of crossbred cows to be owned decreased by 0.2%. This might be because of labor shortage to manage more crossbred cows at the later ages. Even though farming households often depend on family labor, the family size declines at later ages of the household head due to engagement of youths and girls in marriage, employment, and various other issues. Moreover, the income of the household declines at later ages due to sharing away of part of the properties and assets for adult children to support them start their own life. The adoption equation disagrees while the intensity equation agrees with the findings of Gezie *et al.* (2014) who reported that age is negatively associated with both the likelihood and intensity of adoption of improved dairy technologies in Ethiopia.

Farm size was found to have insignificant effect on the probability of adoption of crossbred cows but a significant and positive effect on the intensity equation. According to the marginal effect, a one hectare increase in farmland would enhance the number of crossbred cows to be owned by 1.2%. This is because, the farmers are supposed to allocate a certain proportion of land for grazing and production of improved forage crops. Moreover, a farmer with large farm size can produce more crop residues that are still essential sources of animal feed in rural areas.

Table 6. Parameter estimates of the Heckman Two-step model.

	Adoption equation		Intensity equation	
	Coef. (SE)	ME	Coef. (SE)	ME
Elementary level	0.14*** (0.031)	0.133	0.12 (0.16)	0.009
Junior/secondary level	0.18*** (0.031)	0.180	-0.072 (0.17)	-0.005
Household type	0.16*** (0.03)	0.178	-0.4** (0.16)	-0.037
Age of household head	0.01*** (0.001)	0.008	-0.03*** (0.01)	-0.002
Family size	0.002 (0.003)	0.003	-0.004 (0.02)	-0.000
Farm size	-0.001 (0.005)	-0.010	0.17*** (0.03)	0.012
High price of crossbreds	-0.053* (0.031)	-0.017	-0.69*** (0.16)	-0.045
No crossbred cow source	-0.09 (0.11)	0.048	-2.59*** (0.55)	-0.092
Participation in trainings	0.017 (0.02)	0.004	0.22* (0.13)	0.019
Grazing is main feed	0.3*** (0.04)	0.286	0.035 (0.18)	0.002
High feed cost	0.035* (0.021)	0.049	-0.26** (0.13)	-0.021
Improve feed knowledge	0.04** (0.02)	0.034	0.19 (0.12)	0.013
Access to credit services	-0.013 (0.03)	-0.030	0.33 (0.23)	0.031
Access to extension	0.03 (0.02)	0.037	-0.09 (0.13)	-0.006
Member of dairy coops.	-0.01 (0.03)	-0.020	0.24 (0.22)	0.021
Household income	0.001 (0.001)	0.000	0.001 (0.001)	-0.000
Milk production	-	-	0.2*** (0.012)	0.014
Milk selling experiences	0.057** (0.023)	0.023	0.65*** (0.15)	0.071
Distance to milk market	0.012*** (0.003)	0.012	0.002 (0.022)	0.000
Distance to Addis Ababa	0.102*** (0.04)	0.142	-0.78*** (0.19)	-0.053
Lambda			0.06** (0.02)	

Rho = 0.487, Sigma = 0.147

Number of obs.=946, Censored obs.=218, Uncensored obs. = 728

Wald chi2 (19) = 3975.6, Prob > chi2=0.000

LR test of indep. eqns. (rho = 0): chi2(1) = 5.65 Prob > chi2 = 0.0175

Mean dependent var. = 0.396, SD dependent var. = 0.86

****p<0.01, **p<0.05, *<0.1*

The results also revealed that the high price of crossbred cows had a significant negative effect on both the probability and the intensity of adopting crossbred cows. As the price of crossbred cows becomes unaffordable for smallholder farmers the likelihood and the intensity of adopting crossbred cows decrease by 1.7 and 4.5%, respectively. Unavailability of formal sources of crossbred cows/heifers had also insignificant impact on the likelihood of adopting but a significant negative impact on the intensity of adopting crossbred cows. There are almost no formal rearing centers of crossbred heifers in the country unlike the case of seeds for improved crop varieties. With persisting unavailability of crossbred cows the likelihood of having a crossbred cow decreased by

9.2%, ceteris paribus. This result is in line with the previous finding by Gezie *et al*. (2014) who observed a positive association between the availability of crossbred cows and the likelihood and intensity of adoption in Ethiopia.

Participation in training had insignificant impact on the likelihood of adoption but a significant positive impact on the intensity of crossbred dairy adoption. The marginal effect of the intensity of adoption equation indicates that households who participated in training would increase the intensity of having a crossbred cow by 1.9% as compared to those who did not get the training. This suggests that in addition to expanding formal education, arranging practical training for farmers would have a positive impact on technology adoption. This result is consistent with previous findings by Gezie *et al*. (2014) and Fita *et al*. (2012) who found a positive impact of training on dairy technology adoption in Ethiopia.

Grazing is believed to be one of the major sources of livestock feed in the farming community illustrating a highly significant (P<0.001) and positive association with the likelihood of adoption of crossbred cows. As the farmers strengthen the choice of grazing as the main source of feed, the likelihood of adoption of crossbred cows increased by 28.6%. Even though crossbred cows are not supposed to depend on grazing as a source of feed, farmers are still practicing it and that is one of the reasons why grazing is positively and significantly associated with the adoption of crossbred cows. However, this variable did not have a significant impact on the intensity equation which suggests that having more grazing land is not a guaranty for having more crossbred cows.

The knowledge of improved feeding practices has also imposed a significant and positive influence on the likelihood of adopting but an insignificant impact on the intensity of adopting crossbred cows. As the farmers acquire more knowledge and experience in improved feeding techniques the likelihood of adopting crossbred cows increased by 3.4%, ceteris paribus. This result is in conformity with the findings of Fita *et al*. (2012) who reported a positive association between knowledge on improved dairy husbandry practices and improved dairy technology adoption in Ethiopia.

The main product in dairy farming is milk which is meant mainly for sale. The quantity of milk produced is an important variable for those who already adopted crossbred cows and it is usually higher for the adopters than non-adopters. Hence, it was included only in the intensity equation. The result shows that the quantity of milk produced was significantly and positively associated with the intensity of crossbred cows adoption while selling experience of households was significantly and positively associated with both the likelihood and intensity of adopting crossbred cows. A liter increase in milk production would increase the number of crossbred cows by 1.4%, holding all other variables constant. Likewise, as the experience of selling milk increases by one year, the likelihood of further adoption of crossbred cow increases by 2.3% while the number of cows owned increases by 7.1%, ceteris paribus. A previous finding by Fita *et al*. (2012) has also attested that experience in dairy farming plays a positive role in dairy technology adoption in Ethiopia.

The result further shows that households who have proximity to big cities had a 14.2% higher likelihood of adoption but 5.3% less likelihood to own additional crossbred cows. The explanation for this could be dairy farming requires larger farm size for its operation, but farmers near the capital city usually keep productive but small number of dairy cows. Surprisingly, institutional variables such as access to credit and extension services, and membership in dairy cooperatives had a significant impact neither on the likelihood of adoption nor on the intensity equation although more roles are expected from such institutes to modernize the dairy sector in the country. The implication is that the government and development partners have to redesign the service provision system of these institutes to bring the intended objectives.

CONCLUSION

This paper investigated the adoption of crossbred cows in Oromia National Regional State. The adoption rate of crossbred cows in the Oromia region was 28%, which is perceived to be an encouraging progress. Various factors have positively and significanlty influenced adoption of crossbred cows. These included increased education levels, male headed households, older household heads, using of grazing as a main feed source, perception of high feed cost, knowledge of improved feed practices and milk selling experiences had a higher probability of adopting crossbred cows. On the other hand, households who perceived that the price of crossbred cows is high had less likelihood of adopting crossbred cows. Furthermore, farm size, dairy related practical training, milk production and experiences in milk selling had positive influence on the intensity of crossbred cows adoption while gender (male) and age of household head, perceived price and unavailability of crossbred cow sources, high feed cost and distance from big cities had negative impact on the intensity of adoption of crossbred cows.

The finding of this research has a nummber of policy implications. First, strengthening access to training on improved dairy is important. Dairy related trainings were observed to have a positive influence on crossbred cows adoption. Strengthening the capacity of farmers' training centers and provision of skill based trainings on improved dairy production and management practices will enhance adoption rates and intensity of improved dairy technologies. Exposing dairy farmers to experience sharing visits to successful and exemplary smallholder dairy farms would largely help to facilitate adoption of crossbred cows technologies. Preparation of an easily understandable production manuals in all aspects of dairy production in local languages will be useful to increase crossbred dairy adoption.

Second, gender focused intervention is crucial. Dairy management fundamentally requires the involvement of women for various operations, such as feeding, milking, cleaning, and health care. Despite this, the participation of women in training, experience sharing visits and other capacity-building initiatives are very limited as compared to men. Mostly men are given priority advantages in training and expereicne sharing programs. Therefore, there should be fair consideration of men and women in capacity building programs, technology promotion and demonstration initiatives. Targeting of either men or women shall depend based on the type of task they are mainly responsible for dairy management. This could be identified through a gender analysis study disaggregating the various practices and activities as managed by men, women, and youths. Based on this, it is essential to design gender-responsive programs and development initiatives that eventually contribute to the enhancement of the dairy sector.

Third, the need to have formal and reliable sources of crossbred heifers at affordable prices is important. One of the problems fundamentally recognized during the study was the unavailability of reliable sources of crossbred cows and heifers at affordable prices. There are no formal heifer rearing centers in the country as there are seed multiplication enterprises for crops. Only limited private enterprises have started the initiative of crossbred heifers rearing even though they are not still able to meet the growing demands. As a result, the farmers tend to depend on markets to acquire crossbred cows, a source where they cannot get reliable information about reproductive and production traits of the cows, such as their parity, milk yield potential, age, and other essential merits. In addition, the price of crossbred cows is very high and unaffordable for smallholder farmers. Even those households who can afford could not get crossbred cows in the required supply with known records of reproductive traits. Therefore, addressing these problems requires not only development but also policy intervention to establish heifer rearing centers at regional levels to create easy and reliable access to farmers with affordable prices. Moreover, private enterprises need to be supported and strengthened to invest in this business venture. In the short term, additional options can be taken to produce crossbred calves from local cows through effective promotion of AI and purebred bull services including synchronization techniques. All other possible options need to be exhausted to ensure a reliable supply of crossbred heifers for the farming community. Beyond policy and institutional issues, enhancing the supply of crossbred heifers also requires a serious engagement in technical back up by harnessing the state of the art of reproductive biotechnology (multiple ovulation and embryo transfer, sexed semen technology, and *in vitro* fertilization).

ACKNOWLEDGEMENT

This work was funded by Ethiopian Institute of Agricultural Research. We would like to thank the sample dairy producing households for their time and information. We also extend our appreciation to development agents for their guidance to access the selected sample households. The authors are thankful to editors of this manuscript for the helpful comments.

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