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Livestock and Irrigated Value Chains for Ethiopian Smallholders Project—International Livestock Research Institute, Melkassa Agricultural Research Center (MARC), Holleta Agricultural Research Center (HARC)

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Yared Deribe[1] and Agajie Tesfaye[2]

[1]Livestock and Irrigated Value Chains for Ethiopian Smallholders Project—International Livestock Research Institute (ILRI), P.O. Box 5689, Addis Ababa, Ethiopia

[1]Melkassa Agricultural Research Center (MARC), Adama, Ethiopia

E-mail: yared.deribe@gmail.com

[2]Holleta Agricultural Research Center (HARC), Holleta, Ethiopia

E-mail: agajie@yahoo.co.uk

Abstract— *The low productivity of the Ethiopian dairy sector has been explained by the genetic potentials and management practices. Milk production and consumption largely rely on the indigenous cows. To enhance the contribution of dairy to household food security, nutrition, and income, adoption of improved dairy breeds together with the component practices is indispensable. To study the adoption of the dairy technologies and the factors stimulating the choices, a cross-sectional household survey was conducted in the central and eastern Ethiopia. Results declare that the rate of adoption of improved breeds, artificial insemination, and improved forage remained to be limited. The uptake of concentrate feeding is found to be relatively better. As the joint multivariate probit estimation confirmed, there is complementarity and interdependence in the uptake of improved breeds, artificial insemination, concentrate feeds, and improved forages. Utilization of forage lagged behind to complement adoption of improved cows. Tobit model determination confirmed that the same factors are affecting the adoption decisions. The factors responsible for the joint adoptions, the number of cows owned and intensity of adoption include education status, household wealth, access to markets and district centers, contacts with extension and gender roles. Both the joint and individual analyses highlighted the need for strategies that could overcome the constraints and ensure better uptake of the technologies.*

Keywords: productivity; adoption; joint estimation; complementarity; adoption intensity; responsible factors

1. Introduction

Despite Ethiopia has high potentials for dairy development, farm productivity, and consumption of milk lags behind the World and African average. Recent estimates showed that the national average daily milk yield of the indigenous cows is 1.32 liter with a lactation period of 180 days. While improved cows yield 7 liters with a lactation period of 242 days (Gebremedhin et al., 2014). Reasons of poor genetics, insufficient animal feeding, and poor management practices explain the low productivity levels. Availability of feed both in quantity and quality remain to be the major impediment for livestock production and also specifically to the dairy sector. The size of land allocated for livestock grazing is minimal compared to land devoted to crop productions (Ahmed et al., 2004; Gebremedhin et al., 2009; Ayele et al., 2012). Moreover, limited availability of land and water resources and climate variability are important challenges (Godfray et al., 2010; Smith, 2013; Alemayehu et al., 2012).

Current studies indicated that there is a high supply and demand gap for fresh milk and milk products. Population growth, rising income, and urbanization justify the recent growing trend of the demand for livestock products in the domestic and export markets (Delgado, 2003; Smith, 2013; Dunkan et al., 2013). Keeping pace with an increasing demand for livestock products, improving household income, and reducing poverty requires revolutionizing productivity through adoption and diffusions of dairy technologies. Literatures emphasized that adoption of new technologies is promising path way to agricultural development (Baltenweck et al., 2006) or to accelerate economic growth and ensuring food security in Africa (Hazell, 2013).

Notwithstanding the availability of agricultural technologies, adoption rates in Sub-Saharan agriculture remained low (Gollin et al., 2005; Kondylis et al, 2017). In Ethiopia, several technologies of improved breeds of dairy cattle, artificial insemination, improved forages and veterinary health care have been promoted to the users (Staal et al., 2008; Ahmed et al., 2004; Spielman et al., 2010). However, the uptake of the technologies by the stallholder farmers proved to be minimal (Ayele et al., 2012; Duncan et al., 2013). Several scholars have tried to find out the reasons for the lower rate of adoption of technologies. Some farmers have better acceptance towards the disseminated technologies while others are reluctant and they maintain their status quo positions. Determination of the complementarity, extent, intensity and the factors explaining smallholders' adoption decision is therefore crucial to suggest research and extension policies to design mechanisms that facilitate adoption of technologies.

2. The Study Approach and Data

2.1 Design and Data Source

With an aim to address the adoption study and impacts of adoption of dairy technologies, a household survey was conducted in 2015. The dataset used for this literature was generated through cross-sectional survey held at country level, considering diverse agro-ecologies and administrative regions. In the Oromia region, eight zones were targeted to document the extent of adoption and impacts of adoption of dairy technology packages. As part of the national survey, the analysis comprises East Shewa and West Hararge zones, situated in the central and eastern part of the country. The main survey included a total of 1630 households among which 401 households were considered.

The selection of the next administrative units or districts was based on their access to markets and services, which could further give options to target more accessible and less accessible villages. Furthermore, the cow population potential of the districts was used as the selection criteria. Two districts, Boset and Ada'a were included in East Shewa zone. From the West Hararge zone, Chiro and Habro districts were studied. Subsequently, two villages from each districts were considered based on their proximity to the district center, i.e., within 10 km distance from the district for the more accessible and greater than 10 km for the less accessible PAs. Based on the nationally adjusted and determined samples, proportionate samples of households were taken from the respective villages while taking into account the number of households residing in those villages. The same survey instrument was used embracing gender disaggregated information towards dairy technology adoptions and services.

2.2 Characterization of the Study Areas

In Ethiopia, the dairy system is characterized by subsistent production, low use of technologies, underdeveloped markets, and services (Ahmed et al., 2004; Staal et al., 2008). The share of the indigenous cows constitutes 81% of the total annual milk productions (FAOSTAT, 2014). In the rural areas, much of the production is used for household consumptions (CSA, 2015; Duncan et al., 2013; Staal et al., 2008).

Feed constitutes the largest share of the expenditure in dairy farming system in Ethiopia. To come up with the existing feed shortages, improved forage technologies, feed conservation technologies and the use of agro-industrial by-products have been promoted (Lenné and Wood, 2004; Ergano, 2015). Studies indicated that there is an increased demand for concentrate feeds, which could be explained by the replacement of indigenous cows with crossbred cows. Grazing remains to be an important source of feed for dairy animals comprising nearly half of the overall nutritional sources. Estimations showed that the contribution of crop residues, green fodder, and concentrate constitute 60%, 25% and 15%, respectively (Duncan et al., 2013).

So far, several development programs in the country have targeted on introduction of high yielding exotic cattle in the highlands and distribution to smallholder farmers (Ahmed et al., 2004; Staal, 1995; Ergano, 2015). Artificial insemination (AI) technologies have been widely promoted as an effective technique for dissemination of genetic gain to producers at a relatively low cost. The dysfunctional nature of the Ethiopian AI system has also been emphasized. The involvement of the private sector for the provision of AI services is also minimal (Duncan et al., 2013; Ergano, 2015).

The importance of market access for dairy development, adoption of breeds, utilization of inputs and marketing links has been mentioned. Organized dairy cooperatives enable to overcome the existing dairy marketing constraints in rural areas (Jaleta et al., 2013). The recent emergence of private processing industries and marketing units likely stimulate producers in the peri urban areas and rural production systems, offering new market outlets for dairy products (Ahmed, 2004). Past studies defined market quality sites by associating with the availability of dairy cooperatives and privates operating with necessary dairy processing facilities (Duncan et al., 2013).

The center for East Shewa zone, named as Adama is found some 100 kilometers away from Addis Ababa. It is a business hub for the surrounding zones and neighborhoods. The site is characterized by its proximity to better markets and services of institutions that are disseminating dairy technologies. The major market outlets for dairy products and institutions such as cooperatives, milk collectors, small and medium processors are available. Feed milers/mixers, flour mills, and food industries are also supplying compound and concentrate feeds.

Bishoftu is the center for Ada's district and located at about 44 kilometers distance from Addis Ababa. The district has access to markets at Bishoftu where milk collectors and processing units of the private owned, Holland Dairy and Ada'a Dairy Cooperative are in operation. Among the industrial feed manufacturers, Alema Feed PLC is the largest supplier of compound feed for different livestock. Boset district is found in the neighborhood to the zonal center. Urban and peri-urban dairy producers supply fresh milk for the city and milk processors, such as Yakla PLC. Some of the selected villages have access to the district and market at Adama while others have poor access. Adama is the major supplier of wheat bran, wheat middling, and seed cakes to the neighborhoods and distant markets.

Chiro is the administrative center for the West Hararge and had a distance of 325 kilometers from Addis Ababa. The area could be described by the limited access to large markets, services, and feed suppliers as compared to East Shewa. The formal dairy marketing outlets both private and dairy farmer groups are not common. Though better participation in milk marketing in the West Hararge, the informal marketing channel remains the dominant option. The district of Chiro is found very closer to zonal center and expected to have better market access. Habro district is found 70-75 kilometers away from the zonal center.

Table1. Household and dairy related information about the survey sites

Household and farm characteristics	East Shewa	West Hararge	Total	Std. Dev
Family members	6.19	6.08	6.14	2.33
Age of the head(years)	45.65	38.89	42.20	12.01
Completed education (years)	2.35	2.17	2.26	3.32
Land holding (ha)	2.09	0.66	1.36	1.26
Land for perennials (ha)	0.11	0.23	0.17	0.36
Non-agricultural income (ETB)*	6211.8	2262.4	4192.8	16547.2
Total livestock ownership (TLU)	8.12	3.61	5.82	4.19
Oxen ownership (No)	2.82	0.88	1.83	1.80
Cow ownership (local)	1.47	1.26	1.37	0.87
Lactation length (months)**	7.0	5.6	6.0	-
Daily milk production (liters)**	1.38	1.83	1.60	-
Local breed cows(liters)				
Early lactation			2.64	3.12
Mid lactation			1.65	1.29
Late lactation			1.07	1.10
Improved cows(liters)				
Early lactation			9.27	5.68
Mid lactation			6.76	4.09
Late lactation			4.71	3.29

Source: Own Survey (2015) **1$=22.63 ETB* *** Central Statistical Agency (2015).*

Table 2. Major dairy feed sources and composition (percentages)

Feed Source	East Shewa	West Hararge	Total
Grazing	79.08	75.61	77.31
Crop residue	92.35	98.05	95.26
Green feeding	78.57	94.15	86.53
Hay	22.96	54.15	38.90
Concentrate feeds	52.04	49.27	50.62
Improved forage	10.2	29.27	19.95
Beverage by-products	80.61	6.83	42.89

Source: Own Survey (2015).

3. Theoretical and Analytical Context

3.1 Theories of Technology Adoption and Empirical Models

The pioneer scholars elucidated that technology adoption commonly refers to the decision to use a new technology or best course of action available by economic units on a regular basis. The terminology of diffusion often refers to spatial and temporal spread of the new technology among different economic units (Rogers and Shoemaker, 1971). According to Feder et al. (1985), individual or farm level adoption refers the degree of use of a new technology in a long-run equilibrium when the farmer has full information about the new technology and potentials. Aggregate adoption (diffusion) was defined as the process of spread of a technology within a region. Similarly, Thirtle and Ruttan (1987) defined aggregate adoption as the spread of a new technique within a population.

In the literatures of agricultural technology adoption, two commonly known approaches often have been raised. Because of the fact that agricultural extension programs in developing countries promote technologies as a package, simultaneous adoption of whole package is expected (Beyene, 2008). One of the first models related with a technological package was developed by incorporating technological complementarity and adoption under uncertainty. The potential output would rather be higher if both technologies are adopted than when the single one is adopted. Thus, the model implies a situation whereby initially larger farms adopt both technologies, while adoption of the divisible technologies by smaller farms will be limited (Feder and Umali, 1993). Others debated the whole package approach and emphasized that farmers do not adopt technologies as packages, rather they are opting for a single component or a few suitable technologies (Byerlee and Hesse de Polanco, 1986). Leathers and Smale (1991) explained step-wise or sequential adoption despite risk neutrality and unconstrained expenditures because uncertainty is reduced through experience, the farmer may choose to adopt a component of the package (Foster and Rosenzweig, 1995).

Empirical studies by Pitt and Sumodiningrat (1991) modeled the simultaneous decisions involved in the adoption of new technologies under risk and uncertainty using the meta profit function. Hayami and Ruttan (1985) defined the meta profit function as dual to the meta production function (cited in Feder and Umali, 1993). Others stated that due to this fact, it is important to account for the relationships between the components of the innovation package (Mara et. al, 2002). The interactions between technological components possibly have influences on adoption (Byerlee and Hesse de Polanco, 1986). In connection to this, the simultaneous pattern of adoption was not found to be the case in drought-prone areas of Ethiopia (Kebede et al., 1990).

Both economic and sociological factors are responsible for the disparity in farm decisions and heterogeneity among adopters and non-adopters. From the sociological perspective of adoption, Rogers (2003) explained five main factors that are important in innovation, viz.: relative advantage, compatibility, complexity, trialability, and observability (Marra et al., 2003). Relative advantage refers the degree to which a measure is assumed to outmatch another one, for instance, costs and associated risks with new technologies (Smit and Smitters, 1992; Sattler and Nagel, 2006).

3.2 Factors Explaining Adoption Decisions

Analysis of agricultural technology adoption tempted in the effects of imperfect information, risk, uncertainty, institutional constraints, human capital, input availability and infrastructures (Feder et al., 1985; Foster and Rosenzweig 1995; Feder and Umali, 1993; Semgalawe and Folmer, 2000). Differences in technology uptake among smallholders could arise due access to farm endowments and product markets (Jayne et al., 2013). Feder et al. (1985) indicated that farm size, risk and uncertainty, human capital, availability of labor, credit constraints, and tenure security were the most explaining factors (Marenya and Barret, 2007). Furthermore, profitability, perceptions, attributes of the technology and information were discussed (Ervin and Ervin, 1982; Norris and Batie, 1987; Pagiola, 1996; Shiferaw and Holden, 1998; Hassan et al., 1998a; Hassan et al., 1998b; Lapar and Pandey, 1999; Kazianga and Masters, 2001 cited in Yigezu et al., 2015).

The conclusion by Just and Zilberman (1983) is that the magnitude of the effect of farm size on adoption decision relates to the household‘s risk behavior and farm returns. The larger farms are relatively are in better position to fulfill the high capital expenditures required with the adoption of new technologies. The Study by (Kebede et al., 1990) showed that in Ethiopia, adoption of crop inputs is positively associated with land ownership. Dynamic study approaches to adoption also confirmed that large land size is needed for continuous uptake of grade cattle in Kenya. When it comes to use of concentrates, owning of more land tend to be associated with continued use of concentrate feeding. Whereas, farmers who started growing fodder are the owners of less land implying the tendency for intensification of dairy production (Baltenweck et al., 2006).

Among the human capital variables, Weir and Knight (2004) found that education leads to higher probability of technology adoptions in Ethiopia. Wozniak (1987) and Kebede et al. (1990) also found that higher levels of education and access to information reduce the uncertainty associated with technology adoption and thus, led to better adoption behavior. Panel data tells that household education has positive effect for the continued uptakes of grade cattle. Unexpectedly, more educated farmers abandoned concentrate feeding while it positively affected established use of concentrates (Baltenweck et al., 2006). Availability of more family labor encouraged establishment of dairy farming, which implies that feeding concentrates is labor intensive. Furthermore, younger households who started keeping improved cattle in the past, but while aging they abandoned keeping them. In Ethiopia, similar conclusions have been drawn by studies on the adoption of improved breeds in the areas of Selale and Ada’a. It is indicated that the experience of the farmer has positive impact on adoptions of improved breeds while size of the family was negative (Kebede et al., 1993).

Possession of more wealth leads to decreased absolute risk aversion (Marra et al., 2003). Empirical studies concluded that poor households are risk adverse so that they fail to invest in the most profitable opportunities. Conversely, they are involved with low return and low risk activities (Dercon, 2008; Schindler, 2009). M. Rosenzweig and H. Binswanger found that the wealth of the household encourages allocation of productive assets to the more risky portfolio (Dercon, 1996). According to (Semgalawe and Folmer, 2000), household wealth did not have significant roles for adoption of conservation technologies. In Ethiopia, higher wealth of the household positively affected adoptions of crossbreeds in North Shewa (Selale) area while it was negative in Ada’a (Kebede et al., 1993). The finding by (Diiro and Sam, 2015) concluded that values of the household assets did not have significant impact on technology adoptions.

Technology adoption decision as a function of learning process from the past experiences has been emphasized. Through learning-by-doing households accumulate knowledge (Semgalawe and Folmer, 2000; Kondylis et al., 2017) and past adopters are more likely to continue to adopt new technologies. The role of experimentation and experience is related to more ability to mitigate risks and making better farm decisions. Acquisition of information favors agricultural technology adoption (Lindner, 1987). Lack of experience leads to risk aversion and has discouraging effect on adoptions. Most adoption studies use specifications of proxy variables to address the access. Proxy variables are commonly used and include for both the cost of acquiring information and proxies for the incentive to acquire. Education status, distance to nearest current adopter, and availability of extension services refer to the costs to acquire while farm size for the incentive to acquire (Marra et al., 2003).

With the prevalence of imperfect credit markets, non-farm income sources are substitutes for borrowed capital (Reardon, 1997; Ellis and Freeman, 2004) and translate into increased availability of resources to invest in improved technologies. Findings tell that studies investigating the effect of non-farm income on technology adoption in Africa have proved mixed effects. Dynamic programming techniques evidence reduced farmer incentives to invest in conservation despite the access to better non-farm income opportunities (Diiro and Sam, 2015). On the contrary, (Marenya and Barrett, 2007) found a positive and significant effect of non-farm income on the use of inorganic fertilizers.

The implication of transport infrastructure, markets for the supply of inputs and services, and distribution of outputs on adoption decision have been discussed (Fafchamps, 2004; Jayne et al., 2010). Studies conducted in Kenya indicated that low access to formal milk market outlets are more likely not to keep grade cattle and feeding concentrates. They concluded that for permanent adoption of dairy technologies, market access is found to be crucial. Growing of planted fodder is positively related to market access (Baltenweck et al., 2006).

To come up with the constraints in dairy marketing in Ethiopia, dairy cooperatives and dairy hub models have been targeted (Bernard and Spielman, 2009; Jaleta et al., 2013). Empirical research further highlighted that access to markets favors market orientation of the smallholders than isolated households who consume the larger portion of their produce (Stifel and Minten, 2004). Farmers' intention to adopt advanced technologies increases when they reside closer to markets. Study conducted by (Demeke et al., 1998) proved that better road infrastructures encouraged the use of crop inputs. It is evidenced that high quality markets impacted positively for the ownership of cross breeds in Ethiopia. The availability of formal markets for dairy products favors adoption of crossbreed animals. The market quality encourages stall-feeding and more use of concentrate feeding. The use of AI among the indigenous cows has positive relation with the market quality but for the crossbred cows, it was insensitive to market quality (Duncan et al., 2013). Similarly, as the farmers became further from the livestock markets, the tendency of growing improved fodder increased (Gebremedhin et al., 2003).

3.3 Modelling Technology Adoption and Estimations

Modeling of farm level decisions involves estimations of the likelihood of adoption of a given technology by the farmer. Dichotomous logit or probit are used in determining whether or not a farmer adopts a complete package or a few components (Feder and Umali, 1993; Koundouri et al., 2006). From the extension point of view, improved breed cows have been promoted inclusive of the necessary packages for dairy production. To overcome the numerous agricultural production constraints, farmers are also adopting a mix of technologies. The issues draw the attention to use models capturing the sort of correlations in adopting complementary or substitutable technologies. Studies by (Maregna and Barret, 2007; Teklewold et al., 2012) applied multivariate probit to analyze adoption decisions towards multiple technologies. Therefore, the joint multivariate probit (MVP) model was used to determine whether the farmers adopt improved dairy breeds together with the desired technological packages.

The MVP approach simultaneously determines the influence of the set of independent variables on the probability of adopting multiple technological choices. The model at the same time allows for potential correlations among unobserved disturbances and relationships between the adoptions of different packages (Belderbos et al., 2004). Otherwise, disregarding the prospective correlations and independent estimation of the single equations will lead to biased and inconsistent parameters estimates (Greene, 2003)

The joint estimation of farmers' adoption of improved forage (F), concentrate feeds (C), artificial insemination (A) and improved cows (I) according to (Poirier and Kapadia, 2012) given by,

$$y_{ij}^{*} = \left(I_j \otimes x_{ij}'\right)\beta_j + \varepsilon_{ij}, \qquad \varepsilon_{ij}|X_i \sim N_j\left(0_j \Omega\right) \qquad (1)$$

Where, y_{ij}^{*} is the latent for the joint adoptions, x_{ij} is a K×1 vector of covariates, $X_i\left(I_j \otimes x_{ij}'\right)$ is a J×JK matrix and Ω denote a J×J covariance matrix. In the latent four dimensional MVP model, y_{ij}^{*} are not observed but only their component signs,

$$y_{ij} = \begin{cases} 1, & \text{if } y_{ij}^{*} > 0 \\ 0, & \text{if } y_{ij}^{*} \leq 0 \end{cases} \qquad (2)$$

The adjustment of the off-diagonal elements prior to imposing the diagonal restrictions, the joint-multivariate probit choice probability,

$$\pi_{ij\psi_1\psi_j} = \text{prob}\left(y_{ij} = \psi \middle| \beta_j, \Omega\right) = \int_{\Psi(\psi)} \phi_j \left(y_{ij}^{*} \middle| \left(I_j \otimes x_{ij}'\right)\beta_j, \Omega\right) dy_{ij}^{*} \qquad (3)$$

Where $\phi_j(.)$ is the four dimension multivariate normal density and $\Psi(\psi) = (\Psi(\psi_1) \times \ldots \times \Psi\left(\psi_j\right)$,

$$\Psi(\psi_j) = \begin{cases} (-\infty, 0) & if\ \psi_j = 0 \\ (0, \infty) & if\ \psi_j = 1 \end{cases} \qquad (4)$$

The likelihood function for the joint-MVP,

$$L\left(\beta_j, \Omega\,; y_{ij}\right) = \prod_{n=1}^{N} \pi_{ij\psi_1\psi_j} \qquad (5)$$

Restriction on the diagonal elements of the matrix, Ω and correlations of adoption decisions,

$$\begin{bmatrix} 1 & \rho FC & \rho FA & \rho FI \\ \rho CF & 1 & \rho CA & \rho CI \\ \rho AF & \rho AC & 1 & \rho AI \\ \rho IF & \rho IC & \rho IA & 1 \end{bmatrix} \qquad (6)$$

Decision by the farmer also involve how much to adopt a given technology. In making a choice of whether to adopt and how much to adopt, it might take place as joint or separate decisions. When the decision includes the intensity of utilization conditional on the first step choice of adoption, the tobit model also known as the censored normal regression model is appropriate (Greene, 1990). Thus, the farmer makes a decision on the number of improved dairy cows to adopt or intensity of adoption of the technology (t), the distribution of t_i given that it is positive as denoted in (Verbeek, 2008),

$$E\{t_i|t_i > 0\} = x_i'\beta + \sigma \frac{\phi(x_i'\beta\,/\sigma)}{\Phi\,(x_i'\beta\,/\sigma)} \qquad (7)$$

The distribution given that it is censored,

$$E\{t_i\} = x_i'\beta\Phi\left(\frac{x_i'\beta}{\sigma}\right) + \sigma\phi(x_i'/\sigma) \qquad (8)$$

The log likelihood function for the tobit model,

$$\text{LogL}_1(\beta,\sigma^2) = \sum_{i\in I_0} \text{Log}\left[1-\Phi\left(\frac{x_i'\beta}{\sigma}\right)\right] + \sum_{i\in I_1} \text{Log}\left[\frac{1}{\sqrt{2\pi\sigma^2}} exp\left\{-\frac{1}{2}\frac{t_i-x_i'\beta)^2}{\sigma^2}\right\}\right] \quad (9)$$

3.4 Factor Analysis

Households were classified into four wealth quantiles and the computation of the scores was obtained through principal component analysis (Legese et al., 2010). In many of the literatures, livestock and land ownership are commonly used as proxies for household wealth. For the analysis, the amount of total land owned, number of oxen, income from off-farm labor, petty trade and participation in perennial crop production was taken into account. West Hararge is characterized by ownership of small land sizes and less number of livestock compared to East Shewa. Production of perennial cash crops, such as Chat & Coffee is important to explain the specific situations. After the principal component analysis, three factors were finally retained based on the Eigen values and total variances captured. Checking the appropriateness of the grouping with Kaiser-Meyer-Olkin test, the value of 0.72 (middling) implies that the variables have in common to warrant principal component analysis. The predicted scores then were standardized by the respective means and standard deviations of the variables for each of the households before the wealth quantiles have been created.

4. Description and Econometric Estimation Results

4.1 Adoption of Dairy Technologies

The rate of adoption of improved dairy cows was found to be only 11.47 % over the two study areas. The results proved that there is low level of uptake of the cross breeding technology. Comparatively, East Shewa has got higher adoption rate of 16.84% while West Hararge underperformed by scoring merely 6.34%. Unlike improved breeds, pooled data confirms that the adoption of concentrate feeding was better, almost half (50.62%) of the households utilized concentrate feeds. Specifically, adopters in East Shewa constituted 52.04% and in West Hararge, 49.27% of the households had adopted the practices. When it comes to improved forage adoptions, 19.95% of the households had the practice of feeding forages to dairy cows. East Shewa is described by lower utilizations of forage with a rate of 10.20% while it was relatively higher (29.27%) for West Hararge. Despite the lower adoption of improved dairy cows in West Hararge, improved feeding of the indigenous dairy cows was comparable to East Shewa where purchased feed is readily available. The adoption rate of artificial insemination services is equivalent to 23.19 percent. The two areas proved slight differences towards the uptake of the technology.

The primary reason for the households to stay with their status quo or fail to adopt improved cows was the expensiveness for acquiring them as quoted by 46.91 percent of the households. The availability issue and lack of sources for improved cows is the second important limitation for 36.66 percent who would like to adopt them. In spite of the two major bottlenecks, other reasons have contributions, for instance, 14.04 percent declared lack of feeding material among the hindering factors. Inadequate awareness and the complicated management of improved cows remain to be less favoring for 13.76 and 7.02 percent, respectively.

4.2 The Joint Adoptions of Multiple Dairy Technologies

The estimation results of the joint multivariate probit analysis evidence that adoption of improved dairy cows is significantly determined by the education status of the household head. This means that an increase of the household head's education leads to an increase in probability of adoptions. Several studies confirmed the positive associations of education with the likelihood of uptake of technologies that it favors assimilation of information, learning, understanding of techniques, and making better farm decisions. Age of the household head and size of the household have shown no significant impacts for the decision. The household being in the highest wealth quantile (better-off households) leads to higher propensity of adoption of the technology. As empirical studies concluded, the poor less likely adopts technologies due to lack of resources and risk aversion behavior. The recent trend shows that improved dairy cows are so expensive and it requires higher initial investment. Imperfect financial markets and prerequisite of collaterals limit the participation of the poor. Lack of dependable AI services that prevailed so far also was not encouraging for acquiring at lower costs. The situation less favors the poor and the results are in consistent to theories and earlier findings.

Frequency of extension visit with farmers significantly affects adoption decisions. Extension contacts enhance knowledge about the technology, information on dairy management practices and AI services. Farmers who possess earlier awareness about improved breeds have higher tendency for adoption. This could be explained by their dairying experience, contacts with extension and networks. In contrast to areas with better accessibility to markets and services, the less accessible sites proved limited levels of adoption. Furthermore, better accessible areas in East Shewa have significant adoptions than better accessible localities in West Hararge where the earlier has got advantages of the services of breeding and market outlets to Addis Ababa, Bishoftu and Adama. Better access to zonal and district centers provides incentives of extension services, market opportunities for dairy products and reduced transaction costs. Past studies highlighted the existing dairy marketing constraints and the sought development interventions. Introduction of the formal marketing outlets through private and farmer owned collection points possibly pledged adoptions mainly in the urban and peri urban areas. Districts or villages with less proximity to the centers proved very limited adoptions. Distance to market centers often used as proxy for market access is a limiting factor for adoption decisions.

Gender disparity in terms of access to information, services, and resources has encouraging or discouraging basics for farmers' technology adoption decision. Differing settings of gender roles embedded in the households' headship positions have significant implications for farm decision making and adoptions. Compared to households with equal participation in decision-making, households' decision dominated by male heads leads to less likelihood of adoption of improved cows. If the decision is exclusively made by the wife or else the female head, positive association was evidenced. While comparing the household headship status, male headship did not lead to significant adoption of improved breeds. The results explain the important roles of women in adoption decisions.

The study on adoption of concentrate feeding considered purchased industrial by-products and own produced feed types. The industrial by-products such as oil seed cakes, wheat bran, wheat middling, spent grain, and grain produce were included. The analysis result concluded that concentrate feeds adoption is positively and significantly explained by the education of the head. The household being in the highest wealth quantiles had no significant explanation for the utilization of concentrate feeds. The adoption of concentrate feeds comprises feeds that are own produced by the farmer and owners of more land may rely on grazing could be possible reasons for the weak influences. More frequent contacts with extension impacts positively for the adoption decision. More accessible areas significantly use concentrate feeds obviously related with the more availability of feed materials in the nearby market centers and less transaction costs. Equal participation in the household encouraged the use of concentrate feeds in contrast to decisions made exclusively either by male or female.

Table 3. Multivariate probit joint estimation on adoption of dairy technologies

Variables	Improved cows (I)		Artificial insemination (A)		Concentrate feed (C)		Improved forage (F)	
	Coeff [1]	SE	Coeff	SE	Coeff	SE	Coeff	SE
Household head							0.4422	0.2827
Household size	0.0397	0.0429	0.0236	0.0347	-0.0372	0.0320	-0.0086	0.0361
Age of the head	-0.0003	0.0082	-0.0067	0.0077	-0.0025	0.0063	0.0118	0.0073
Formal education	0.1080**	0.0433	0.1114***	0.0376	0.0943***	0.0338	0.0785**	0.0380
Formal education square	-0.0073	0.0075	-0.0065	0.0065	-0.0083	0.0061	-0.0010	0.0060
Second[2]	0.2600	0.2899	0.1336	0.2258	0.1558	0.1916	-0.1397	0.2285
Middle[2]	0.0695	0.3143	0.1390	0.2182	0.0023	0.1887	-0.3174	0.2272
Highest[2]	0.6765**	0.2758	0.3035	0.2185	-0.1455	0.1924	0.1840	0.2166
Productive safety net	-0.0595	0.0698	-0.0208	0.0484	0.0252	0.0392	0.0018	0.0461
Less access to district (East Shewa)[3]	-0.7710***	0.2577	-1.4108***	0.2320	-0.4406**	0.2009	-0.1405	0.2696
Access to district (West Hararge)[3]	-0.7680***	0.2771	-0.6248***	0.2197	-0.1944	0.2071	1.2080***	0.2527
Less access to district (West Harage)[3]	-0.7452***	0.2636	-0.8674***	0.2298	-0.8240***	0.2346	0.4568*	0.2686
Frequency of extension contact	0.2269***	0.0757	0.2112***	0.0639	0.3183***	0.0700	0.1777***	0.0612
Decision of male headed[4]	-0.5327**	0.2313	0.0127	0.1810	-0.2212	0.1565		
Decision of female headed/ wife[4]	0.2405	0.3164	0.6855***	0.2492	-0.3171	0.2130		
Time aware of improved breeds	0.0567***	0.0193	0.0181	0.0147				
Constant	-1.6670***	0.3193	-0.7728***	0.2484	0.1100	0.2174	-2.0782***	0.3488
ρCF	0.2072**	0.0949	ρAC	0.2664***	0.0965			
ρAF	0.0579	0.1101	ρIC	0.2608**	0.1257			
ρIF	0.1009	0.1324	ρIA	0.4737***	0.1052			

Number of observations = 401 Wald chi2 (57)= 271.2***

Log pseudo likelihood = -675.953 Likelihood ratio test of ρCF = ρAF = ρIF = ρAC = ρIC = ρIA = 0

chi2(6) = 28.2821***

*1 *, **, *** significant at 10% 5% and 1%, respectively* *2 Reference category is lowest wealth quantile*
3 Reference category is access to district capital (East Shewa) *4 Reference category decision is equally by male & female*

For successful improved dairy breeds production, the availability and use of improved high quality forages is crucial. There is limited use of improved forages in East Shewa though relatively higher breeds adoption. Oat-vetch is among the adopted type by some farmers in East Shewa while elephant grass has better acceptance in West Hararge. The results showed that male-headed households are better users of forage crops. Similarly, educated farmers have better utilizations than the less educated farmers. Possession of high wealth is positive but not very determinant for the adoption of forages. Study conducted with regard to forage adoption concluded that wealth did not sufficiently explain the decisions (Gebremedhin et al., 2003). Frequency of extension contact positively affects the probability of adoptions. There is association between more accessibility and adoption of forage, however, the evidence is not sufficiently large. Rather, both accessible and less accessible areas in West Hararge have higher adoption than more accessible in East Shewa. The study by (Gebremedhin et al., 2003) indicated that distance from crop and feed markets encourages forage adoption.

The adoption of Artificial Insemination (AI) technology importantly and positively associated with the education status of the household head. Households in the highest wealth quantile have higher tendency for utilization of AI services, however, the evidences do not support significant impact as in the case of breed adoptions. Frequent extension contacts and access to districts found to be limiting for adoption of AI. Proximity to district centers determines the access to AI and propensity of adoptions. In the same way to breeds, recent status evidences that better accessible areas in West Hararge have shown slow rate of adoption and is negative compared to the reference location. In contrast, better accessible areas in west Hararge have low tendency to use AI could also be connected to lack of better market opportunities and services for dairy products. Consequently, if decisions are dominantly made by the female head or the wife, higher adoptions of AI was concluded.

The joint multivariate probit analysis confirmed the correlation of the error terms and interdependence in the dairy technological choices. The likelihood ratio test declared significant complementary relations among the four adoption equations at 1% probability levels. The adoption of artificial insemination is simultaneous to that of improved breeds and concentrate feeding. Concentrate feeding is suggestively correlated with improved cow adoption. Among all combinations, adoption of improved cows was not with adequate forages implying the low adopted bundle. To conclude, with MVP model we benefit from both estimation of unbiased parameters and testing of the simultaneous adoption of desirable technological components.

Conditional probabilities in (Table 4) imply the likelihood of adoption of the technology given that the other technology has already been adopted. As shown, there is a change in the conditional probabilities compared with the marginal probabilities, confirmed the dependency and complementarity of the actions. In contrast to all pair-wise matches, the probabilities for improved forage, concentrate, and artificial insemination is higher when it was conditional on the adoption of improved cows. Concentrate feeds and artificial insemination proved higher complementarity in conformity to the significance test of correlations of the disturbance terms in MVP model. Adoption of improved cows is highly interdependent with the use of artificial inseminations. For the conditionality of a single practice given three technologies are adopted, the same holds that the probability changes are higher for concentrate and artificial inseminations.

Table 4. Marginal and conditional probabilities of dairy technologies adoption

Probabilities	Improved Forage	Concentrate	Artificial Insemination (AI)	Improved Cows
$P_M = 1$	0.199	0.507	0.235	0.115
$P_M = 1/P_F = 1$	1	0.687	0.300	0.175
$P_M = 1/P_C = 1$	0.271	1	0.315	0.167
$P_M = 1/P_A = 1$	0.258	0.688	1	0.344
$P_M = 1/P_I = 1$	0.304	0.739	0.696	1
$P_M = 1/P_F = 1, P_C = 1$	1	1	0.364	0.218
$P_M = 1/P_F = 1, P_A = 1$	1	0.833	1	0.542
$P_M = 1/P_F = 1, P_I = 1$	1	0.857	0.928	1
$P_M = 1/P_C = 1, P_I = 1$	0.353	1	0.823	1
$P_M = 1/P_C = 1, P_A = 1$	0.312	1	1	0.437
$P_M = 1/P_A = 1, P_I = 1$	0.406	0.875	1	1
$P_M = 1/P_C = 1, P_A = 1, P_I = 1$	0.428	1	1	1
$P_M = 1/P_F = 1, P_A = 1, P_I = 1$	1	0.923	1	1
$P_M = 1/P_F = 1, P_C = 1, P_I = 1$	1	1	0.917	1
$P_M = 1/P_F = 1, P_C = 1, P_A = 1$	1	1	1	0.600

P_M is the probability of adoption of a given technology component m, representing improved forage (F), concentrate feeds(C), artificial insemination (A) and improved cows (I).

4.3 Number of Improved Cows Adopted and Intensity of Adoption

The decision on the number of improved cows owned is affected by education status of the head. In the same way to the decision of whether to adopt or not to adopt, more education leads to possession of more number of improved cows. Adoption intensity measured as the ratio of cross breed cows to total cows also was positively determined by education. The conditional and unconditional marginal effects in (Table 5) attest that an increase in education favors the adoption of more number of improved cows or higher probability of increased intensities. Though not very strong evidences, household size has positive while age of the head has negative relations with both the dependent variables.

High wealth has positive impact both for acquiring more number of improved cows and the intensities. Again, this is related to the liquidity constraints with the poor households. Prevalence of imperfect credit markets and increased absolute risk aversion explain the heterogeneity among the households. Contacts with extension and time of awareness significantly influence the decisions of how many improved cows to keep or replacement of the local breeds. Significant differences exist among more accessible and less accessible areas. Moreover, more accessible areas in East Shewa have higher adoption than more accessible areas in West Hararage. In the household, if decision is made exclusively by the male heads, the likelihood of acquiring more number of cows will be low. The conditional and unconditional marginal effects as shown indicate changes in the number of improved cows owned, intensities, and probabilities due to changes in the explaining variables.

Table 5. Tobit regression results on the number of cows owned and intensity of adoption

Variables	Number of improved cows					Intensity of adoption				
	Coeff[1]	SE	Total change	Change E(t>0)	Probability Change (t>0)	Coeff	SE	Total change	Change E(t>0)	Probability Change (t>0)
Household Size	0.0940	0.0821	0.0109	0.0159	0.0064	0.0381	0.0415	0.0109	0.0159	0.0064
Age of the head	-0.0043	0.0167	-0.0005	-0.0007	-0.0003	-0.0024	0.0078	-0.0005	-0.0007	-0.0003
Formal education	0.2878***	0.0947	0.0335	0.0486	0.0195	0.1091***	0.0397	0.0335	0.0486	0.0195
Formal education square	-0.0272*	0.0150	-0.0032	-0.0046	-0.0018	-0.0088	0.0068	-0.0032	-0.0046	-0.0018
Second[2]	0.6553	0.5729	0.0762	0.1106	0.0444	0.3184	0.2696	0.0762	0.1106	0.0444
Middle[2]	0.1762	0.5985	0.0205	0.0297	0.0119	0.0736	0.2776	0.0205	0.0297	0.0119
Highest[2]	1.3213**	0.5414	0.1537	0.2229	0.0894	0.5817**	0.2350	0.1537	0.2229	0.0894
Productive safety net	-0.1118	0.1354	-0.0130	-0.0189	-0.0076	-0.0406	0.0687	-0.0130	-0.0189	-0.0076
Less access to district [3] (East Shewa)	-1.6300***	0.5432	-0.1896	-0.2750	-0.1103	-0.7624***	0.2404	-0.1896	-0.2750	-0.1103
Access to district (West Hararge)[3]	-1.7422***	0.5838	-0.2027	-0.2939	-0.1179	-0.7781***	0.2572	-0.2027	-0.2939	-0.1179
Less access to district (West Harage)[3]	-2.0259***	0.6063	-0.2357	-0.3418	-0.1371	-0.8526***	0.2694	-0.2357	-0.3418	-0.1371
Frequency of extension contact	0.4499***	0.1400	0.0523	0.0759	0.0304	0.1983***	0.0654	0.0523	0.0759	0.0304
Time aware of improved breeds	0.0830**	0.0329	0.0097	0.0140	0.0056	0.0372**	0.0157	0.0097	0.0140	0.0056
Decision of male headed[4]	-0.9280*	0.5285	-0.1080	-0.1566	-0.0628	-0.5138**	0.2475	-0.1080	-0.1566	-0.0628
Decision of female headed/ wife [4]	0.6168	0.5717	0.0718	0.1041	0.0417	0.2301	0.2672	0.0718	0.1041	0.0417
Constant	-3.2261***	0.7024				-1.4812***	0.3084			
Sigma	2.1372	0.2319				1.0283	0.0841			
F(15, 386) = 4.24***						F(15, 386) = 8.63***				
Log pseudo likelihood = -164.732						Log pseudo likelihood = -132.992				
Pseudo R2= 0.2055						Pseudo R2= 0.2214				

*1 *, **, *** significant at 10% 5% and 1%, respectively* *2 Reference category is lowest wealth quantile*
3 Reference category is access to district capital (East Shewa) *4 Reference category decision is equally by male & female*

For successful dairy production crossbreeds, improved feeding and artificial insemination are not the complete packages. Extension advises more and several component practices so that determination of the issues would be useful to gain feedback for future research and extension approaches. Furthermore, intensity of use of the recommended component practices are explaining successful adoptions of the technologies. Notwithstanding the analysis on the adoption of breeds, parity and blood levels are important for enhancing efficiency of the dairy production. The effort did not attribute towards those concerns.

5. Conclusion and Implications

Due to subsistence nature of the diary system in the country, there is limited surplus production of dairy products. High dependence on local breeds, poor feeding and health management practices contribute for low productivity of dairy cows. The source of feed for dairy is dominated by crop residues and grazing. The poor quality of crop residue and need for improvement options has been mentioned. Lack of adoption of improved forage limits the potential productivity gains of both improved and local breeds. The presence of the informal market channel in many rural areas and lack of dairy processing facilities constrained the incentives for market orientation, utilization of inputs and technologies. It hampers the potential income and livelihood prospects from the sector.

Most of farmers raised the high cost of improved cow breeds as the major restriction and lack of supply is the second reason for not adopting improved dairy breeds. The adoption of improved cows requires high capital so that more wealthy households more likely own them. Sequential and package adoption approaches are debatable in many of the literatures. Recent efforts in the study of technology adoption emphasized the complementarity and substitutability of farm practices and adoption decisions. Analysis on the joint dairy adoption decision proved the existing complementarity in the uptake of the technologies. The availability of concentrate feeds and AI services have association with the adoption of improved breed cows. The adoption of forage is not satisfactory though positive association and long established dissemination efforts by extension. The responsible factors for the adoptions include education position of the household, wealth status, extension contacts, number of years become aware of improved cows, access to the markets and district centers, and women's involvement in decision making. However, household wealth did not sufficiently explain the adoption of improved forages and concentrate feeds.

The market constraints are important for adoption decision that high transaction costs reduce the incentives for farmers' participation and they will have less preference to invest in high return dairy technologies. In support of this, it is concluded that milk market participation is limiting for adoption of the dairy improved breeds. Strategies that ensure improved market access for dairy products through linkages to formal market channels, farmer institutions, dairy infrastructure, enhancing awareness, and lessening the financial burden of the poor are indispensable. Interventions need to consider specific realities for improving adoptions of dairy technologies.

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