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Analysis of determinants of improved dairy technologies adoption in Woliso District, Ethiopia.

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Abstract: *Ethiopian economy is highly depending on agriculture, which is characterized by low production and productivity. The country holds the largest livestock population in Africa whereas; the output of the livestock (milk and meat) is the lowest, which shows low productivity of dairy sub-sector. Thus, the objective of this study was to analyze the determinant of the adoption of dairy technologies in Woliso Districts of South West Shoa Zone. The study uses data from a random sample of 288 households of which, 144 were IDT adopters and 144 were non-adopters. The study tests the hypothesis that the factors affecting farmers' decision to adopt IDT are not necessarily the same as those affecting their extent of adoption. Results from the double hurdle model indicates that age of the household head, household size, membership to social group, access to extension services and perception towards IDT adoption were found to influence the decision to adopt IDT. And, household size, access to extension services and perception towards IDT adoption influenced the extent the farmer is willing to adopt. The result concludes with policy implications aimed at renewing the focus on IDT adoption and transfer in Woliso and other areas with similar conditions.*
Key words: *Adoption, double-hurdle model, improved dairy technology (IDT), Woliso.*

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I. Introduction

Ethiopian economy is highly depending on agriculture that accounts 43.2% of gross domestic product, 60% of exports, and 80% of total employment. The country has largest livestock producer in Africa (CSA, 2017). In spite of the large livestock population, the contribution of the Ethiopian livestock sector in general and the dairy sector in particular is below its potential at both the national and household level (Behnkle, 2010).

Study done by Quddus (2012) indicates dairy development in developing countries has played a major role in increasing milk production, improving income level in rural areas, generating employment opportunities and improving the nutritional standards of the people, especially for small and marginal farmers. According Agajie *et al* (2016) in Ethiopia, Oromia region showed that adopter of crossbred cows technology generated 44% more income than non-adopters. Low and unreliable income from cash crops suggest that alternative farming activities should be developed. This is in spite of indications that there is a potential for dairy development, and dairy can reduce the level of poverty. However, smallholder dairy production is becoming increasingly important and it contributes magnificently to the improvement of the livelihoods of rural people.

Dehinenet *et a.l*, 2014 point out that the dissemination of improved dairy technologies to farmers, there is no adequate information on the rates and extent of adoption of improved dairy production technologies among smallholder farmers. Therefore such information is limited in Woliso Districts. Thus, the extent to which farmers have adopted these technologies has not been studied recently and factors affecting the adoption of dairy production technologies were not yet known in these study areas. This suggests that there is a need to bridge this information gap through further research on the adoption of improved dairy technologies. This necessitated studying the determinant of improved dairy technologies adoption in Woliso Districts.

1. Hypothesis

1.1. Theoretical model and empirical specifications

Adoption is a mental process through which an individual passes from hearing about an innovation to its adoption that follows awareness, interest, evaluation, trial, and adoption stages (Samuel *et al*.,2016). There is a large literature on the adoption of agricultural technology (Rogers, 2003). They viewed through a broad cross-disciplinary lens, there is agreement that the adoption of agricultural technology depends on a range of personal, social, cultural and economic factors, as well as on the characteristics of the innovation itself (Adesina and Zinnah, 1993).

In particular, the relative complexity, risk and investment characteristics of technologies significantly affect their adoption and diffusion (Batz et al, 1999). When there is a change in economic parameters associated to improved dairy technology, the central question is related to how much compensation, whether paid or received, would make the decision maker indifferent about the change. Thus the change in welfare associated with this development was used as the basis for economic valuation process. When an individual farmer faces a change in a measurable attribute, for example higher control for new improved dairy technology (q), then q changes from $q0$ to $q1$ (with $q1 > q0$). The indirect utility function u after the change becomes higher than the status quo. Now the status quo can be represented econometrically as follows:

$u1j = ui\ (yi, zj\ , q°, \varepsilon 0j\ )$

On the other hand, the changed or final state due to the introduction of improved dairy technology is shown by:

$u2j = ui\ (yi, zj\ , q1, \varepsilon ij)$

Where, yi, refers to the farmer's income, Zj is a vector of the farmer's socio-economic variables and attributes of choice, and εj is the stochastic error term representing other unobserved utility components,

The farmer would opt, pay and adopt improved dairy technology if the following condition holds:

$ui\ (yi - Pi, zj\ , \varepsilon ij\ ) > u0\ (yi\ , zj\ , \varepsilon 0j\ )$

Where: Pi is the monetary investment associated with the new variety.

Since the random components of the preferences are not known with certainty; it is only possible to make probabilistic statements about expected outcomes. Thus, the decision by the farmer to adopt improved dairy technology is the probability that he/she will be better off if this improved technology is used. This is represented as follows:

$Prob\ (Yesi) = Prob\ [ui\ (yi - Pi, zj, \varepsilon ij\ ) > u0\ (yi, zj, \varepsilon ij\ )]$

Since the afore-mentioned utility functions are expressed generally, it becomes critical to specify the utility function as additively separable in deterministic and stochastic preferences. Using, this argument, the function becomes:

$ui\ (yi\ , zj\ , \varepsilon ij\ ) = ui\ (yi, zj\ ) + \varepsilon ij$

Where: The first part of the right hand side is the deterministic part and the second part is the stochastic part. The assumptions that εij are independently and identically distributed with mean zero describes most widely used distributions.

Two widely used distributions are the normal (probit) and logistic regression models. In this study, the statistical dichotomous choice data is modeled by superimposing a probability function. The dependent variable takes the value 1 if the smallholder-farming households are willing to adopt improved dairy technology or 0 if they are not willing to adopt. And if the farming households adopt, how much could they adopt? The observed adoption of improved dairy technology is hypothesized to be the end result of combined effects of a number of factors related to the farmer's goals and means of achieving them. Several hypotheses can be derived from these two sets of decision; factors that affect adoption and factors that affect intensity of improved dairy technology adoption. The following variables in the models were hypothesized to influence the adoption of improved dairy technology adoption in different directions. External influences include institutional support systems such as marketing facilities, credit and extension services which are important in affecting adoption (Feder, 1980). Credit was not included as factor influencing the improved dairy technology adoption because very few households in the study area used credit to purchase farm inputs. Also access of the introduced improved dairy technology adoption was not included as determinant explaining adoption because access of the improved technology in the study area was mainly done through extension services and farmer's social groups (cooperative) which were already hypothesized to influence improved dairy technology adoption.

Table 1: Variable Specification and Hypothesis

	Variable	Variable type	Measurement	Expected effect
1	Age of the HHH	Continuous	Year	-/+
2	Gender of HHH (male=1)	Dummy	1 or 0	+/-
3	HHH education 1-4 years (yes=1)	Dummy	1 or 0	+
4	HHH education 5-8 years (yes=1)	Dummy	1 or 0	+
5	HHH education greater than 8 years (yes=1)	Dummy	1 or 0	+
6	HH size	Continuous	Number	+
7	Farm size	Continuous	Ha	+/-
8	Membership to social group (yes-1)	Dummy	1 or 0	+
9	Access to extension services (yes=1)	Dummy	1 or 0	+
10	Perception towards IDT control	Dummy	1 or 0	+/-

II. Materials and Methods

2.1 Description of the study area

The study was undertaken in Woliso District, South West Shoa Zone of Oromia National Regional State. Woliso Districts is located in the southern which is 114 KM far from Addis Ababa. The District has a total population of 23,354 households (South West Shoa Administrative Office, 2018). Agriculture is the major source of livelihood for the Districts. An available literature clearly shows that agriculture employees about 88% of population in the study area (CSA, 2011).

2.2 Sampling techniques and data collection

Woliso Districts was selected purposely based on potential of dairy production in the zone and sample of households were selected by systematic random sampling procedure. The required sample number of farmers was determined based on the formula suggested by Yamane (1967). Accordingly, 288 (144 of adopters and 144 of no-adopters) sample farmers were randomly selected from selected kebeles of Woliso out of the total number of dairy technology adopters household was 1,867.

$$\mathbf{n = \frac{N}{1 + N(e)^2}}$$

Where n is the sample size, N is the population size (total improved dairy technology user households), and e is the level of precision with 95% confidence level and 8% level of precision. Hence, the desired sample size is 144 households for adopters and 144 households for non-adopters which were taken based on proportion of adopter households and selection of proportioned household head was obtained proportionally to kebeles population size. Generally, total of 288 household heads (144 adopters and 144 non adopters) would be sample size for this study.

2.3 Econometric specification: The double-hurdle model

While other studies have approached a similar problem using the logistic analysis (Kavia et al., 2007), Heckman procedure (Adeoti, 2009); this paper compares the results from a joint Tobit and a Double-Hurdle (DH) models because I believe that factors that affect farmers' choice of an option should not necessarily be the same as those that affect the intensity of use. This is because the decision to choose a particular dairy technology option is obviously associated with some threshold effects. In terms of policy relevance, my analysis clearly shows that adoption and intensity may be different decisions and that estimation of intensity on the basis of factors affecting adoption, as implied by other approaches, may be liable to error.

The DH model, originally proposed by Cragg (1971) has been extensively applied in several studies (Martínez-Espiñeira, 2006; Newman et al., 2001; Burton et al., 1996). However, it has not been much used in the area of adoption of agricultural technologies; an exception would be Berhanu and Swinton (2003).

Double-hurdle model was used in this case to determine the factors that influence the decision to adopt and the extent of adoption of improved dairy technology in order to identify areas of intervention. The underlying assumption in the DH approach is that farmers make two decisions with regard to their decision to improved dairy technology adoption. The first decision is whether they will adopt improved dairy technology. The second decision is about the amount of land that they will allocate, conditional on the first decision. The two decisions are, therefore, whether to adopt improved dairy technology and how much to hold dairy. The importance of treating the two decisions independently lies in the fact that factors that affect one's decision to adopt may be different from those that affect the decision on how much to adopt. This implies that households must cross two hurdles in order to adopt. The first hurdle needs to be crossed in order to be a potential adopter. Given that the households is a potential adopter, their current circumstances then dictate whether or not they do in fact adopt: this is the second hurdle (Moffatt, 2003). The DH model allows for the possibility that these two decisions are affected by a different set of variables.

The advantage with this approach is that it allows us to understand characteristics of a class of households that would never adopt improved dairy technology. Thus the probability of a household to belong to a particular class depends on a set of household characteristics. The DH model is a parametric generalization of the Tobit model, in which two separate stochastic processes determine the decision to adopt and the level of adoption of technology. The first equation in the DH model relates to the decision to adopt (y) can be expressed as follows:

yi = 1 if $y_i^* > 0$ and 0 if $y_i^* \leq 0$ (1)

$$y_i^* = x_i'\alpha + \varepsilon_i$$

Where: y^* is latent adoption variable that takes the value of 1 if a household adopt improved dairy technology and 0 otherwise, x is a vector of household characteristics and α is a vector of parameters.

The second hurdle, which closely resembles the Tobit model, is expressed as:

ti = $t_i^* > 0$ and $y_i^* > 0$

ti = 0 otherwise

$$t_i^* = z_i'\beta + u_i \quad (2)$$

Where: *ti* is the observed response on how much land one allocated for dairy production *z* is a vector of the household characteristics and β is a vector of parameters.
The decision of whether or not to adopt IDT and about how much land to allocate to dairy can be jointly modeled, if they are made simultaneously by the household; independently, if they are made separately; or sequentially, if one is made first and affects the other one as in the dominance model (Martínez-Espiñeira, 2006). If the independence model applies, the error terms are distributed as follows:

$$\varepsilon_i \sim N(0, 1) \text{ and } u_i \sim N(0,\delta^2).$$

If both decisions are made jointly (the Dependent DH) the error term can be defined as:

$$(\varepsilon_i \ u_i) \sim BV\,N(0,Y)$$

$$\text{Where } Y = \begin{bmatrix} 1 & \rho\delta \\ \rho\delta & \delta^2 \end{bmatrix}$$

The model is said to be a dependent model if there is a relationship between the decision to adopt and the intensity of adoption. This relationship can be expressed as follows:

$$\rho = \frac{\operatorname{cov}(\varepsilon_i u_i)}{\sqrt{\operatorname{var}(\varepsilon_i)\operatorname{var}(u_i)}}$$

If r =*0* and there is dominance (the zeros are only associated to non-participation, not standard corner solutions) then the model decomposes into a probit for participation and standard OLS for Y.
Following Smith (2003) we assume that the error terms and ε_i and *ui* are independently and normally distributed and thus we have the following expression:

$$\begin{pmatrix} \varepsilon_i \\ u_i \end{pmatrix} N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & \delta^2 \end{pmatrix}\right]$$

And finally, the observed variable in a DH model is $t_i = y_i\, t_i^x$ and the log-likelihood function for the DH model is:

$$LogL = \sum_0 \ln\left[1 - \Phi(x_i'\alpha)\Phi\left(\frac{z_i'\beta}{\delta}\right)\right] + \sum_+ \ln\left[\Phi(z_i'\alpha)\frac{1}{\delta}\phi\left(\frac{y_i - x_i'\beta}{\delta}\right)\right]$$

Where: Ø(·) refer to the standard normal probability and Ø (·) refer to density functions.
Thus in this study I estimate the decision to adopt and the extent of adoption using a DH model.

III. Results and Discussion

3.1 Household characteristics

Household characteristics of respondents in the study area are shown in Table 2. Most respondents in the present study were male (88.9%) as they were head of the family. Education is an important factor especially in access and use of information and technologies (Akzar et al., 2016). The respondents in the study area had different educational status with majorities being read and write (76.38%).

Table 2: Household Characteristics (N= 288)

Household characteristics	Male (N=256)		Female (N=32)	
	Frequency	%	Frequency	%
Sex of household head	256	88.9	32	11.1
Marital status				
Married	250	86.83	14	4.87
Single	0	0	3	1
Divorced	4	1.4	2	0.7
Widowed	2	0.7	13	4.5
Able to read and write				
Yes	202	70.13	18	6.25
No	54	18.75	14	4.86

Source: Field survey, 2019

Table 3 presents the t-test and chi-square comparison of means of selected variables by adoption status for the surveyed households. The analysis of the data shows that there is a significant (P < 0.01) mean difference between age of adopters and non-adopters. Average age of sample household head is about 49 years with non-adopters. No significant difference is observable in the gender of the household head although the groups vary significantly in terms of their education level. Primary and junior levels of education (1 to 8 years) are lower for adopters however adopters have higher proportion of household heads with secondary education.

This suggests that education might be correlated with decision to adopt. The household size is 6.22 persons for adopters and 5.28 for non-adopters and the difference is statistically significant suggesting the importance of family size for adoption of new technologies. There is significant difference in terms of household membership in different rural institutions such as cooperatives. The result also depicts that the adopter categories are distinguishable in terms of their access to extension services and perception towards adoption of improved dairy technology (IDT). This simple comparison of the two groups of smallholders suggests that adopters and non-adopters differ significantly in some proxies of socio-economic characteristics.

Table 3: Descriptive summary of variables used in estimations (N= 288)

Variable	Unit	Adopters (N= 144)	Non-adopters (N= 144)	t-start(chi-square)
Dependent variable				
Land kept for dairy	Ha	0.23	0.00	0.23***
Adoption	1/0	1.00	0.00	-
Independent variable				
Age of the HHH	Years	48.92	45.19	3.73***
Gender of HHH(male -1)	1/0	0.71	0.75	-0.04
HHH education 1-4 years(yes-1)	1/0	0.09	0.27	-0.17***
HHH education 5-8 years(yes-1)	1/0	0.36	0.48	-0.12***
HHH education <8 years(yes-1)	1/0	0.54	0.25	0.29***
HH size	count	6.22	5.28	0.94***
Farm size	Ha	0.85	0.41	0.44
Membership to cooperative(yes-1)	1/0	0.75	0.58	0.17***
Access to extension services(yes-1)	1/0	0.70	0.39	0.32***
Perception toward improved dairy technology	1/0	0.96	0.72	0.25***

Statistical significance at the 99% (***), 95% (**) and 90% (*) confidence levels.

3.2 Econometric results

The results from the study showed that the coefficients of most of the variables hypothesized to influence the decision and extent of adoption of IDT have the expected signs. The Probit results on the decision to adopt IDT and truncated regression analysis results on the extent of adoption are presented in Table 4.

3.2.1 Determinants of IDT adoption

To identify the factors influencing the decision to adopt IDT, the Probit model was estimated (first hurdle). The results shown in Table 4 reveal that five factors are significant in influencing farmers' decision to adopt IDT of whose four at 1% namely: age of household head, household size, access to extension services and perception towards IDT. Membership to any rural association is significant at 5%. The log likelihood for the fitted model was -231.29402 and the $\chi2$ value of 232.48 indicates that all parameters are jointly significant at 5%. Age has been found to have a positive relationship with the decision to adopt IDT implying that old farmers are more willing to adopt IDT than young farmers as a result of age based knowledge gained and probably experiences accumulated over years' differences. However these results were inconsistent with (Lapple et al., 2015; Ndunda & Mungatana, 2013) that indicated that age had a negative effect and not significant in innovation performance of the farmers.

The effect of household size was found to be positive and significant suggesting that the larger in number of persons in the household the more likely the farmer is willing to accept IDT. The results of Berhanuet al. (2011) is against this finding while the result of Tadele et al. (2014) supports.

Membership to a social group which assessed whether the farmer or household is part of a community organization or cooperative was found to be positively and significantly associated with a higher probability of adopting IDT. These results agrees with (Klerkx et al., 2014) who states that innovations takes place through social interaction and in the process individuals build, learn from each other and strategically adapt to new tools and techniques to suit their particular circumstances. Therefore, it is important to promote and strengthen effective networking by improving the farmers network sizes, connectedness and frequent interactions (Meijer et al., 2014) for more benefits in smallholder farming innovation performance. These results underscore the importance of social capital in accessing new technologies by the poor smallholder farmers.

Access to extension services was found positively significant, which implies that the contact with an extension agent is necessary to enhance the rate of adoption. As extension services popularize the innovation by providing necessary information, appropriate knowledge and special skills, they enable farmers to apply innovation. This finding is in line with the results of Tadele et al. (2014). Perception towards IDT is positively and significantly associated with a great likelihood of adopting IDT having in mind the yield performance that will be generated from IDT. Farmers who perceived the technology as beneficial to them would adopt it more than those whose perception is negative or indifferent.

Table 4. Maximum likelihood estimates for the joint Tobit and Hurdle models.

¤ Model specification	Joint		Double- hurdle
	Tobit	Probit	Truncated
Dependent variable	**Land for IDT**	**Dummy=1 if IDT adopted**	**Land for IDT**
Variable	**Coefficient**	**Coefficient**	**Coefficient**
Age of the HHH	0.0129***	0.0635***	0.0005
Gender of HHH (male=1)	-0.0741**	-0.2380	-0.0120
HHH education 1-4 years (yes=1)	-0.1118	-0.9284	0.2132
HHH education 5-8 years (yes=1)	0.1361	0.1802	0.2366
HHH education greater than 8 years (yes=1)	0.4140**	1.5767	0.2544
HH size	0.0377***	0.0901***	0.0380***
Farm size	-0.0010	-0.0052	0.0160
Membership to social group (yes-1)	0.0769**	0.3545**	0.0035
Access to extension services (yes=1)	0.1017***	0.4486***	0.0602***
Perception towards IDT	0.2715***	1.3262***	-0.0908**
Constant	-1.4336***	-6.0134***	-0.2328
Model summary			
Number of observations	288	288	85
Log-likelihood	-141.54089	-231.29402	196.83067
LR chi2(11),Wald chi2 (11)	233.21	232.48	364.27
Prob > chi2	0.0000	0.0000	0.0000
AIC (-LOG-L + k/N)	0.27		-1.09
LR test for Tobit vs. Truncated regression			214.16 (0.0000)

*, **, *** Coefficients are significantly different from zero at the 99% (***), 95% (**) and 90% (*) confidence levels, respectively.

3.2.2 Determinants of extent of adoption

The estimated results for DH and Tobit models on adoption of IDT in Woliso Districts were presented in Table 4. The Tobit model results have been presented for comparison. The results from the two models were comparable which show the robustness of our results to model specification. All the statistically significant variables except the perception towards IDT had the same directional effects in all of the two models. The likelihood ratio test statistic specified in Table 4 favored the DH model over the Tobit. Three variables were found to have significant effects in explaining the level of adoption of IDT by households, measured in term of area or land covered for IDT. These included household size, access to extension services and perception towards IDT adoption. As argued by Asfaw et al. (2010) awareness in technology transfer is very important. Farmers' awareness about the available improved varieties is therefore critical in the adoption programme. Access to extension services was statistically significant in explaining the level of adoption. Access to extension services enables farmers to get exposed and more familiar with a new variety. Extension service is one of the most prearranged conditions for creating awareness and building the necessary knowledge for using the innovation following the approach which is most convenient for farmers.

Farmers' perception towards IDT adoption was negative and significant in explaining the extent of IDT adoption. The negative sign of the perception variable is unexpected and may be explained by the possibility that farmers' positive perception about IDT has been distorted by other perceptions/attitudes or due to negative correlation between this variable and other varietal characteristics not included in the model.

The significance of household size suggests that large households are more likely to invest in new technologies as they can guarantee an adequate supply of farm labour necessary for the expansion of farm enterprises. This may suggest that encouraging them to operate in large number could be regarded as a policy relatively likely to increase productivity.

IV. Conclusion and Recommendations

This study provides an analysis of the determinants of adoption of improved dairy technology using a DH model due to a hypothesis that factors that affect the decision to adopt IDT may be different from those that influence the extent of adoption.

The findings from this study indicate that although in general there is a positive correlation between probability of adoption and intensity of IDT use, I note some differences with regard to the factors that influence the two decisions. Results reveal that age had a positive effect on the decision to adopt while it had no effect on the extent of adoption. The effect of farmers' perception towards IDT adoption decision is another example of variable with an opposite effect between the two stages of adoption.

Results indicated that while perception leads to increased probability of adoption, it has a negative effect on the extent of adoption. The results indicate also that although membership to any social group increases the likelihood of adoption, it does not influence the extent of land reserved for IDT. These results have a number of implications in terms of sustaining smallholder agriculture which are critical for improving the life of poor households.

An interesting lesson from this study is that it is important to consider the two stages of adoption in order to improve farmers' ability to adopt, and increase intensity of IDT use because factors that affect the decision to adopt are not necessarily the same factors that affect the decision on the extent of adoption. Factors such as age, household size, extension services, membership to social group, and perception may enhance or limit adoption and diffusion of improved dairy technology. To develop a successful improved dairy technology package in the study area, these factors have to be taken into consideration focusing first on factors that affect households' decision of adoption. Policy makers and stakeholders of the dairy sector are hereby called upon to develop the sector thereby finding strategies regard to the key determinants in order to encourage households in Woliso Districts to be more decisive in their choice to adopt and intensify improved dairy technology which is vital to reduce poverty.

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Conflict of interest

The author declares there is no conflict of interest.

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