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Determinants of success and intensity of livestock feed technologies use in Ethiopia: Evidence from a positive deviance perspective

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A B S T R A C T

This study explores factors associated with success and intensity of livestock feed technologies use among positive deviants in feed technology adoption in Ethiopia. We used a nation-wide dataset of over 603 farm households, which surveyed pockets of successes in using improved livestock feed technologies. Heckman two-stage estimation procedures were used to identify factors associated with success and intensity of livestock feed technology use simultaneously. Results from the first stage of selection equation show that households socioeconomic and institutional factors such as education status of the head, herd size, exercise in feed technology utilization, cooperative membership, distance to district center, and diverse use of technologies have significant effect on success in livestock feed technologies adoption. The second stage demonstrates that intensity of household collaboration or network, membership in livestock related cooperatives, training, access to livestock feed technologies with packages, diverse use of technologies, engagement in livestock enterprises, livestock management system, willingness to invest more in feed technologies, and agro-ecologies significantly influence the intensity of feed technologies use. These results suggest that success and intensified use of improved feed technologies demand different entry strategies for risk factors, enablers, and behaviors, which may differ from the classic agricultural technologies transfer system. These include availability of appropriate biophysical and resource environments, functional linkages between different actors, access to inputs and social capital, and enabling institutional support system. Moreover, this study shows that when there is limited adoption, few pockets of success in improved technologies use, positive deviant approach would be more informative to understand the underlying factors and principles for success and intensified use of technologies than the most commonly reported conventional adoption rate studies.

1. Introduction

In developing countries, where most of the smallholder farmers practice mixed farming system, livestock production is the major source of household food, income, traction power and a means to accumulate assets. Smallholder farmers do not only generate cash income from sale of livestock and livestock products, but they also use livestock as a cash buffer, capital reserve, and hedge against inflation. Despite mixed livestock growth pattern observed in different regions of developing countries, in general, the productivity (output/animal) of different livestock species in developing countries is still the lowest in the world. For instance, in Sub-Saharan Africa, significant decline in milk and beef production per animal have been recorded since 1961, which has made the average contribution of the region to the world milk and beef production among the lowest (Nin et al., 2007). Broadly, this could mainly be attributed to inadequate production inputs, traditional management system, poor enabling environment and associated research and development efforts exerted to generate improved technologies (McDermott et al., 2010; Fuglie and Wang, 2012; Makkar, 2014).

Empirical findings on livestock production and productivity also show that, in most developing countries, lack of adequate quantity and quality of feed remains one of the most important constraints that smallholder livestock farmers face especially during the dry season (Thornton, 2010). Even though well-integrated and comprehensive livestock strategy is necessary to address various constraints and improve the production and productivity of livestock in developing countries, improved livestock feed and feeding system would have significant contribution by dealing with multiple challenges related with livestock nutrition, health, and husbandry system simultaneously. Improved feed technologies have better social, economic, and environmental benefits over the traditional feed types. Their contribution in improving feed supply, enhancing the health and productivity of animals, augmenting land use efficiency, and reclaiming land degradation and others have been well studied and documented in different countries (Peters et al., 2001; Bouton, 2007; Koralagama et al., 2008; White et al., 2013; Yami et al.,

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2013: Franzel et al., 2014; Rao et al., 2015). For instance, Turinawe et al. (2012) shows that farmers who used improved feed technologies had significantly higher gross margins than those using traditional feeding methods. Moreover, using improved feed technologies like forages does not only improve animal nutrition but it also contributes to improve crop productivity by maintaining soil fertility through nitrogen fixation, reduce pressure on natural pastures, reduce soil erosion on marginal lands, and improve carbon sequestration to mitigate climate change (Peters et al., 2001; Entz et al., 2002; Rao et al., 2015).

In Ethiopia, like to other developing countries, due to inadequate feed availability and malnutrition, animals' performance measured by birth weight, growth rate, milk yield, mortality rate, and reproductive performance are below the expected range and different animals in the country are not able to produce at their genetic potential (Shapiro et al., 2015). To address this constraint and improve the production and productivity of animals, so far a plethora research and development efforts have been exerted by national and international research institutes to generate and disseminate improved livestock feed and feeding system in the country. Various exotic and indigenous improved technologies were introduced to smallholder farmers by different strategies. For instance, improved livestock feed technologies such as forage legumes, perennial grasses, and pastures were first introduced by Arsi Rural Development Unit (ARDU) (Davis et al., 2010; Tekalign, 2014). Then through various projects such as Fourth Livestock Development Project (FLDP); Crop Diversification and Marketing Development (CDMD); and Feed Enhancement for Ethiopian Development (FEED); improved forage seeds were disseminated to smallholder farmers in different parts of the country (Tekalign, 2014). Moreover, the role of agricultural research institutes such as International Livestock Research Institute (ILRI), Kulumsa and Melkassa Agricultural Research Centers and others in testing the adaptability and nutritional contents of various exotic and indigenous forages crops for different agro-ecological zones was very significant. As a result different improved forages and fodder crops have been released for different ecological zones and considerable efforts have been made to disseminate these pasture and forage technologies to smallholder farmers.

However, despite a number of efforts that have been exerted to introduce various improved feed technologies and feeding systems, adoption and use of these technologies have been still very limited and insignificant (Gebremedhin et al., 2003, Bassa, 2016). For example, based on 2014/15 livestock survey report only 0.3% of livestock holders practiced using improved feed technologies for their livestock (CSA, 2015). This can be attributed to various socio-economic, institutional and biophysical factors entailing limited household resource endowment, especially labor and land to plant forage; mismatch of farmers need's and technologies; limited market integration and extension services provision including weak information flows and linkages to other inputs providers; and multiple bio-physical stress and shocks (Adugna et al., 2012).

Various researches have been conducted to quantify the level of livestock feed technologies adoption and understand the main reasons behind the limited adoption rate among smallholder farmers in developing countries (Gebremedhin et al., 2003; Adugna et al., 2012; Beshir, 2013). Nevertheless, most of the previous studies have mainly focused on the rate of adoption and factors associated with adoption or non-adoption of technologies for a very specific location and at a point in time. Moreover, most of the reported adoption studies generally assumed widespread use of technologies, which does not hold true in the case of improved livestock feed technologies especially in developing countries. Apart from quantifying and describing the situations on the ground, the contributions of such type of studies to generate proven and practicable solutions that could inform policies and strategies to enhance widespread adoption and use of technologies are minimal. Therefore, using a positive deviance approach, this study tries to explore additional insights on factors associated with success and intensity of improved livestock feed technologies use, where positive deviant farmers have been able to derive economic value from using diverse improved feed technologies.

The main purpose of this study was to assess the common factors, processes, and organizational and institutional arrangements underpinning successful cases in improved livestock feed technologies adoption in Ethiopia, which have paramount implication for promoting widespread adoption and use of improved livestock feed technologies in developing countries or elsewhere in the world. This paper has two major contributions to the existing literature on adoption of agricultural technologies in developing countries. Firstly, since the study used a comprehensive national level data on positive deviants in feed technology adoption, it provides affordable, acceptable, sustainable, and multifaceted possible solutions for challenges and constraints associated with widespread adoption and use of livestock feed technologies in developing countries. Secondly, unlike to most of previous similar studies, which have focused mainly on easily and quickly unchangeable socio-economic characters, this study shows the relative importance of household enabling factors and behaviors such as trainings, collaboration and networks, technology transfer arrangements, engagement in farm enterprises (entry strategies), and attitudinal changes that have strong association with both success and intensity of improved livestock feed technologies use in developing countries.

The rest of this paper is organized as follows. The second section discusses the conceptual framework, the econometric models, and estimation strategy employed. Section three describes sampling procedures and data used in the study. Section four presents the results and discussion, and finally, summary of findings and policy implications are presented.

2. Conceptual framework and econometric estimation model

2.1. Positive deviant analysis in evaluating livestock improved feed technologies use

Studies on livestock feed technologies adoption and use in developing countries show the presence of limited adoption and scattered pocket of success among smallholder farmers in developing countries. As it is indicated above, this could be attributed to socio-economic, institutional, and environment related factors mainly affecting the process of technology generation, dissemination, and use. Most available studies on livestock feed technologies mainly focused on rate of adoption and have rarely made an attempt to scrutinize the processes underlying the observed limited adoption and pocket of successes. As a result, in general there is limited information on fundamental factors that contribute to the observed pockets of success in feed technologies adoption. Consequently, using the concept of positive deviance, this study aims to move one step further from the most commonly reported adoption rate studies by focusing only on the limited adopters and tiny pockets of successes observed among smallholder farmers. This helps to draw feasible lessons from the successful cases on the underlying factors and principles pertinent for success and widespread adoption of improved feed technologies in developing countries.

In academic literatures, individuals that exist in resource-poor communities with uncommon beneficial practices that allow the household to have better livelihood or outcomes as compared to their similarly impoverished neighbours are considered as 'positive deviants' (Lapping et al., 2002; Marsh and Schroeder, 2002). The term positive deviance refers to an inductive approach to determine successful practices of individuals who succeed where most tend to fail (Stuckey et al., 2011). Primarily, the concept of positive deviance originates in the field of epidemiology and biostatistics referring to positive outliers in a frequency distribution of various events. For instance, in disease epidemic outbreak, there were survivors that led researchers to question why these survivors who share the same environmental and socio-economic conditions exposed to the same situations remained healthy while others got sick (Lapping et al., 2002). This encouraged researches to follow new approaches to explore the cases differently focusing only on the survivors and examine the underlying factors related with surviving. Such type of approach helps to scrutinize the practice and behavior of individuals in a community with the same socio-technical context who have achieved better results than their peers (Fowles et al., 2005). According to Pant and Odame (2009),

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positive deviants can challenge existing organizational structures and institutional set-ups, and promote alternative approaches to solve social problems. This gives the opportunity to understand how change originate and progressively disseminate through individuals practices and behavior and results the required outcomes.

Even though its application in agricultural researches is still minimal, the concept of positive deviance could also be applied in technology adoption studies, like improved livestock feed technology use, where there are few exceptions or niches of successful cases in adoption and use of technologies that can be positive examples for the rest of populations constrained by different socio-economic and bio-physical factors. Using positive deviance approach helps to understand the processes, factors and conditions underlying the observed pockets of success and draw out lessons and principles why positive deviants do differently from others. It also helps to examine where and why available improved feed technologies have been put into use by few adopters and generate relevant information to scale out the underlying lessons and principles for wider adoption and use of technologies in developing countries. Lessons and principles obtained from positive deviants can be used to figure out possible strategies on how improved feed technologies can be promoted in ways that are relevant, applicable, and beneficial to smallholder farmers. Moreover, focusing on positive experiences in adoption would also assist to reframe current assumptions and expectations on adoption of improved feed technologies and promote alternative approaches for wider adoption (Pant and Odame, 2009).

2.2. Empirical models used to identify factors associated with technology adoption

In this paper, a model that explains the existence of intense adoption of feed technologies was constructed using different explanatory variables. The main interest here is to estimate the level of adoption activities by their intensity and examine whether there is any variability among positive deviants in feed technologies adoption. Empirical findings in general show that the process of technology adoption involves two main steps: the decision to adopt the technology and the decision on how much to use or intensity of adoption, which are assumed to occur jointly or separately and may be associated with different factors (Sulo et al., 2012).

Factors associated with adoption or intensity of adoption could be identified by using either cross-sectional, panel, or time series econometric models (Besely and Case, 1993). As it was suggested by Greene (2011), researchers who assumed the simultaneous occurrence of these two decisions used either logit or probit models for discrete choice scenarios (Nicholson et al., 1999; Lapar and Ehui, 2003; He et al., 2007; Jera and Ajayi, 2008; Raut et al., 2011; Akudugu et al., 2012). Similarly, for continuous dependent variable others used tobit or ordinary least square (OLS) model (Gebremedhin et al., 2003; Kiggundu, 2007). Nevertheless, mostly farmers first make decision on either using or not using the technologies and then determine how much to use them, which may sometimes involve a series of decisions through time (Sulo et al., 2012). Hence, factors that affect the initial adoption of technologies may be different from those that affect the intensity of using (Gebremedhin and Swinton, 2003). Based on this assumption, running two separate models for each decision could be more informative than using either of the single models (Cragg, 1971). For instance, while Asfaw et al. (2011) used double-hurdle model to identify the determinants of intensity of technology adoption conditional on overcoming seed access constraints, others like Fufa and Hassan (2006) used probit model to determine factors associated with probability of adoption and tobit model to identify factors associated with intensity of adoption. On the other hand, Ibrahim et al. (2012) used Heckman two-stage model to determine factors associated with adoption of technology and intensity of adoption or use simultaneously.

The choices of the above models were mostly based on the nature of the samples, the expected relationships between the two decisions, and the underlying statistical assumptions of the models one would consider. Usually, in adoption studies where the dependent variable is continuous, like this study, there are four possible options to predict the association between the continuous dependent variable and various independent variables. The first and most commonly used option is ordinary least square method, which takes intensity of adoption as dependent variable and household characteristics and socio-economic factors as independent variables. But, especially in a data with sample selection problems, this type of approach could be misleading as there may be observations with zero intensity of adoption that indicate limit in the dependent variable, which might be caused by exogenous factors and possibly destroy the linearity assumption of the model (Dubin and Douglas, 1989). By and large, in situations where the dependent variable to be modeled is limited in its range, using OLS estimation would result in biased and inconsistent parameter estimates (Heckman, 1979).

The second option is to use Tobit model. Different researchers repeatedly used this model to identify factors associated with intensity of adoption. This model assumes that the two decisions (adoption and intensity of adoption) are made jointly and hence the same set of variables and coefficients are used to determine both the probability of adoption and intensity of adoption (Greene, 2011; Tobin, 1958). Hence, this model does not allow generating full theoretical explanation of why some farming households are adopting technologies and other not.

The third option is using sample selection models. Sample selection models help to correct selection bias usually resulted from using nonrandomly selected samples because of self-selection problem in the unit of analysis or created by researchers during the data generation process (Heckman, 1979). These models assist to address the shortcomings of both OLS and Tobit models by modifying the likelihood function and allow to explore the reasons why the selection problem exist. In this particular study, Heckman two-stage estimation procedure is used to find empirical evidence on factors associated with success in adoption and intensity of adoption. Since we are trying to explain intensity of feed adoption as a function of various explanatory variables, where the intensity of adoption is observed only for households that are only successful, it is important to find theoretical reasons why some households are not successful adopter and have zero intensity of adoption. Therefore, compared to either OLS or Tobit models, this model can be the best candidate to estimates parameters in the selection and outcome equations. It helps to use different set of variables and coefficients to determine the probability of success in adoption and intensity of adoption separately. These variables may overlap to a point or may be completely different and allow for greater hypothetical development, as observations may be censored by some other variables. This permits us to take account of the censoring process due to the interdependence of success in adoption and intensity of adoption. Moreover, with Heckman two-stage models, it is possible to have a theory that specifies why households are not successful, which could mainly be due to demographic, socioeconomic, biophysical factors including lack of incentives to continue their adoption activity, lack of required knowledge, limited resources, and others.

The fourth option is a Double-hurdle model. It is considered as the modification of both Tobit and Heckman two-stage model and used to model the selection and outcome decisions sequentially (Akpan et al., 2012; Mal et al., 2013). Cragg (1971) suggested this model to minimize the possible limitations of Tobit and Heckman-two stage models. Both Heckman-two stage and Double hurdle model assume that the selection and outcome decisions are two-step separate decisions. Nevertheless, in Double-hurdle model the possible occurrence of zero outcomes in all sample households (i.e. in our case both successful and unsuccessful households) are acceptable. Moreover, unlike to Heckman-two stage model, the presence of the zero outcomes in the outcome decision are not only considered as the result of selection decision in the first stage but also due to individuals choice and other random circumstances, which may not be valid for the specific dataset used in this study (Aristei and Pieroni, 2008). In contrast to Double-hurdle model, Heckman two-stage model assumes the zero outcomes are the result of the first selection stage or the absence of any zero outcomes in the outcome decision once the first selection decision stage is passed. Notably, according to

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Heckman, only unsuccessful households should have zero intensity of adoption, which is also true in this dataset. Therefore, based on the nature of the data and the expected relationships between success in adoption and intensity of adoption, using Heckman two-stage model is found to be more appropriate than Double-hurdle model. More importantly, as it is clearly indicated in the description of the data, the possible occurrence of selection bias in this study is very high due to the design of the research and nature of positive deviants in feed adoption. Indeed double hurdle model was also run to check the consistency of the result and the estimated parameter coefficients' and their significant level are found consistent with Heckman two-stage model.[1]

Generally, the main points for the choice of Heckman two-stage model in this paper can be summarized as follows: firstly, since the sample comprises only positive deviants in feed technologies adoption and contains only households that are considered as adopters of feed technologies, the presence of selection bias created by researchers is highly likely. Secondly, even among these positive deviants, there are households that stopped using some of the feed technologies and have zero intensity of adoption that suggests the presence of systematic relationship between success and intensity of adoption. Besides, self-selection problem might arise here due to factors that affect the success of adoption on the one hand and the intensity of adoption and use on the other hand are unobservable. In fact as Heckman demonstrated, if the selection decision and outcome decisions are related, estimating the outcome decision without first estimating the selection decision would lead to biased estimates (Heckman, 1979).

2.3. Econometrics framework

As indicated above, the Heckman two-stage model comprises two separate equations namely the selection and outcome equation (Heckman, 1979). In the first stage selection equation, the probability of being selected or included in the sample is estimated using probit or logit model and in second stage outcome equation, using either tobit or OLS, main factors associated with the outcome variable are determined by including the inverse Mills ratio, which is obtained from the first selection equation. The inverse Mills ratio contains information about unobserved factors that determine the selection decision and helps to control the zero-censored data in the outcome equation, selection bias. A statistically significant inverse Mills ratio result in the selection equation reflects the presence of selection bias that suggest the need for considering two separate models for the selection and outcome decisions.

Accordingly, we followed the following two steps to implement the Heckman two-stage models: first, the likelihood of households' success in technology adoption was estimated using probit model, which has given us an estimate of 'λ', inverse Mills ratio or hazard function. Then, in the second step, factors associated with intensity of adoption was estimated using least square regression for different explanatory variables X_i and λ.

The conditional expected value of intensity of feed adoption is given by:

$$E(Y_{1i}|Y_{2i}=1) = x_i'\beta + \rho\sigma\lambda(z_i'\gamma) \quad (1)$$

Where, $\lambda(z_i'\gamma) = \frac{\varphi(z_i'\gamma)}{\Phi(z_i'\gamma)}$, is the inverse Mills ratio.

Given the above equation, the intensity of feed adoption was modeled as a joint process involving the decision to continue feed adoption and the decision to diversify feed adoption activities. Let Y_1 denote the intensity of adoption and Y_2 success in adoption, which is a dummy variable that takes value 1 if the farming household is successful and 0 otherwise.

In Eq. (1), *x* and z *are* vectors of explanatory variables for the intensity of feed adoption and success of adoption equations respectively. Then we can write,

$$Y_{1i} = x_i'\beta + \sigma u_i \quad (2)$$

Y_{1i} Intensity of feed adoption, which is observed only when $Y_{2i} = 1$.
x Vector of explanatory variable.
σ Is a scale factor.

and,

$$Y_{2i} = \begin{cases} 1 \; if \; z_i'\gamma + \varepsilon_i \geq 0 \\ 0 \; if \; z_i'\gamma + \varepsilon_i < 0 \end{cases} \quad (3)$$

Y_{2i} Probability of success
Z Explanatory variables

The joint distribution of (u_i, ε_i) is assumed to be bivariate normal with zero means, variances equal to 1 and correlation 'ρ'. When 'ρ' is equal to zero, OLS regression can provide unbiased estimates and it can be used. But when 'ρ' is not equal to zero, OLS regression can give us biased estimates and using sample selection model like Heckman two-stage model allows us to include information from the selection equation improve the parameter estimates in the intensity of adoption equation. This indicates the possibility of getting consistent and asymptotically efficient estimates for all parameters using sample selection model than the OLS model.

3. Survey design and data description

3.1. Survey Design

The data used for this study is based on a 2006/2007 household survey in Ethiopia that was conducted by the International Livestock Research Institute (ILRI) in Ethiopia. The study was conducted mainly to identify successful cases of improved livestock feed technologies use in the country and assess common factors, processes and organizational arrangements underpinning the successful cases. Before the household survey, desk review, reconnaissance survey, and participatory rural appraisal were used to understand forage innovation system, identify positive deviant households in the country, and design the data collection instrument. Then the survey was designed to collect information on household characteristics, resource endowment, feed technology transfer arrangements, social capital and networks, household behaviors, and other related variables that are hypothesized to influence success and use of livestock feed technologies.

Purposive and stratified sampling techniques were used to select the study samples. Sampling was done based on the result of desk review and reconnaissance survey. Even though desk review and the reconnaissance survey results showed that districts with cases of positive deviance were distributed across the four regional governments, namely, the Oromia, Amhara, South Nations and Nationalities People (SNNP) and Tigray regions, using predefined stratification criteria, variability, and budget considerations, only three regions were included in the study. Following the selection of regions, a stratified three-stage cluster sampling method was adopted to select sample households. At first, sample list of districts were identified using the stratification criteria and variability. Then, sample Kebele Administrations (KAs) were purposively selected by key informants and promoters of improved feed technologies in the districts where positive deviance was identified. Finally, feed technology user households were selected randomly from each KA feed technology users master list developed by KA level key informants and administrative leaders. Totally, six hundred and three (603) households were sampled based on the proportion of positive deviant population size in each region (Kiggundu, 2007). Finally, the data was collected using pre-tested structured questionnaire by trained and experienced enumerators. After data entry and cleaning, the data was analyzed using Stata version 12 statistical package.

[1] The result from the Double-hurdle model is not reported here to save space, but can be made available on request.

3.2. Variable definitions and their description

3.2.1. Improved feed technologies

The term improved feed technologies in this study refers to improved exotic forage crops, improved indigenous forage crops, improved grazing pastures, treated crop residues, and other improved commercially produced livestock feeds. Based on the result of desk review and reconnaissance survey , the following improved feed technologies are considered for the study: (i) Browse trees and shrubs such as Tree Lucerne (*Cytisus proliferus*), Leucaena (*Leucaena leucocephala* (Lam.)), Pigeon pea (*Cajanus cajan*) and *Sesbania sesban; (ii)* Herbaceous plant of the following types:Annual grasses such as oats, Annual legumes such as Vetch, Cowpea and Lablab, Perennial legumes such as Desmodium, alfafa (Lucern), Perennial grasses such as Elephant grass (Napier) and Rhodes grass, and Fodder root crops such fodder beet; (iii) Treated hay, treated crop residues and improved grazing pasture; and (iv) Concentrates (such as those used for dairy ration, mixed locally or at factories)

3.2.2. Dependent variables

Intensity of adoption

Intensity of adoption/use refers to the extent of diverse forage technologies use among successful positive deviants. It is constructed from indicators that show households' status in using improved livestock feed technologies listed above. Specifically it includes planted fodder trees, planted non-fodder tress/grasses, treated crop residues, improved grazing lands, purchased green feeds, and purchased concentrates. These indicators take 1 if the household is using the technology and 0 otherwise. The index was constructed by averaging the total number of households' use of these technologies.

Success in adoption

As it is indicated above, sample farmers in this study composed of households who are considered as positive deviants in improved forage technologies adoption and use in the country. These farmers were identified by community and local administration based on their previous experience on using different improved livestock feed technologies; of course, the length of their experience may also vary from location to location. However, adoption of agricultural technologies is a continuous process that may be affected by change in farmers' social, behavioral, economic, and environmental circumstances (William, 1983; Tura et al., 2010; Pannell et al., 2006). Therefore, based on their technologies use status during the study period, in this particular study, while success in adoption refers to the adoption and continued use of feed technologies, unsuccessful adoption refers to the discontinuation of utilizing technologies after adopting for some time in the past. Hence, those positive deviant farmers who have been continuously using the technologies since they adopted for the first time are considered as successful adopters. On the other hand, those positive deviant farmers who adopted any of the technologies once or several times in the past and then stopped the practice later due to different constraints are considered as unsuccessful adopters. Moreover, positive deviant farmers who planted improved livestock feed in their farms but have stopped utilizing them as livestock feed are also considered as unsuccessful adopters. This definition helps to distinguish farmers who have never tried the technologies, have tried a technology and triggered to stop the practice due to different reasons, and those who are continuously using the technologies for the intended purposes. Nevertheless, in many studies, farmers who have never tried the technologies and those who adopted and stopped the practices are treated as "non-adopters," which may conceal the important difference between these two groups. The variable that indicates success in adoption is dummy, which was constructed from households' response on the utilization status of the identified improved feed technologies.

3.2.3. Independent Variables

Based on theoretical and empirical literatures review, variables that capture individual socio-economic characteristics and spatial differences are identified to find possible explanation for the observed success and intensity of adoption. The description and expected effect of these variables on the success and intensity of adoption is presented Table 1. Accordingly, the expected signs (+ or −) of the coefficients associated with the variables are also given in the third column of Table 1, where it is not possible to set the expected sign of coefficients, it is indicated as 'unknown'.

Table 1
Description of the independent variables and their expected effect on both dependent variables.

Variables	Description and type of measure	Expected sign
Education of household head	The level of household head education: 0 = Illiterate; 1 = Elementary; 2 = Junior Secondary and High School	+
Change in attitude	Change in attitude observed on farmers about feed technologies use: 1 = Yes; 0 = No	+
Agro-ecology	The area where the household reside and undertake farming activities: 1 = Midland; 0 = Highland.	unknown
Distance from district center	The distance of household residence from the nearest district center in Km	−
Livestock herd size	Number of livestock owned by the household measured in TLU based on FAO (Food and Agricultural Organization) estimation procedure	+
Land size	Total amount of private land owned by the household in (Ha)	+
Off-farm income	The household has off-farm income source: 1 = Yes; 0 = No	unknown
Intensity of collaboration in feed technology adoption	A composite[a] indicator constructed from household collaboration with peasant farmers, commercial farmers/private investors, livestock traders, seed companies/seed producing farmers, research institutes, government development agents, village level organizations, credit and financial institutions, and NGOs.	+
Membership in dairy cooperative	The household is member of diary cooperatives: 1 = Yes; 0 = No	+
Active labor force	Total number of family members who can participate in agricultural activities	+
Willing to invest more on feed	The household is willing to invest more on feed technologies in the future 1 = Yes; 0 = No	+
Membership in multipurpose cooperative	The household is member of multi-purpose cooperatives 1 = Yes; 0 = No	+
Access to feed technology with packages	A composite[a] indicator constructed from variables indicating if the household was introduced to feed technologies with different input packages such as credit, training/follow up, enterprise development, traders' connection, and others.	+
Exercise in utilizing feed technology	The household has exercised utilizing feed technologies: 1 = Yes 0 = No	+
Diversify use of fodder trees	A composite[a] indicator constructed from variable showing if the household uses fodder trees for multiple purposes such as fencing, wood, construction material, soil conservation, feed, and sale/income generation.	+
Training	The sum of normalized values of households' participation in livestock feed technologies related training and extension services given by government and nongovernment organizations.	+
Livestock management system	The type of livestock management system practiced by the household: 0 = Open Grazing, 1 = Mixed, 2 = Cut and Carry.	unknown
Engagement in livestock farm enterprises	A composite[a] indicator constructed from variables that indicate households engagement in dairy farming, fattening of cattle, and fattening of sheep and goat.	+

[a] Composite variables are constructed from by averaging the total values of dummy indicators that have values either 1 or 0.

4. Results and discussion

4.1. Descriptive statistics

Table 2 presents the *t*-test for mean of continuous explanatory variables by success of adoption for the sample households. It contains 13% unsuccessful adopters and 87% successful adopters of feed technologies. Significant differences between the mean values of successful and unsuccessful adopters are observed for land size, training, livestock herd size, diversity of feed use, engagement in farm enterprise activities, distance to nearest district center, active labor force, and intensity of collaboration. This suggests the existence of possible association between household success in feed technology adoption and different demographic and socio-economic variables (Table 2). For instance, successful adopters have 36.4% higher land size than unsuccessful adopters and, on average; they took training three times than unsuccessful adopters did. Similarly, successful adopters had five times higher access of feed technologies with packages than unsuccessful adopters and they had 71.4% more intensity of collaboration/network than unsuccessful adopters. Moreover, relatively unsuccessful adopters found further from the district center than successful adopters. In general, higher mean values for indicators such as land size, training, collaboration, and livestock herd size indicate the contribution of these factors for success in adoption (Table 2).

Table 3 presents the chi-square test to compare proportion of categorical variables by success status and chi-square test to assess the presence of significant association between categorical explanatory variables and success status of households. Differences in proportions of categorical variables between successful and unsuccessful positive deviants are observed (Table 3). For example, the proportions of households who are member of dairy or multipurpose cooperatives are higher in successful adopters than unsuccessful adopters. Likewise, the proportions of households that use mixed and cut and carry system are higher in successful adopters than unsuccessful. Higher proportions of attitudinal change and exercise in utilizing improved feed technologies are also observed among successful households than unsuccessful. Statistically significant relationships are also observed between success status of households and membership in dairy cooperatives, membership in multipurpose cooperatives, livestock management systems, attitudinal change, exercise in utilizing feed technologies, and education level of household head (Table 3). Results from the z and chi-square test also suggest the presence of possible relationships between these categorical variables and success status of households.

4.2. Determinants of success in feed technology use

This section presents the results of Heckman first stage probit selection model for identifying factors associated with success in improved feed technologies adoption (Table 4). This model helps to determine the likelihood of success in feed adoption among the positive deviants.

Table 3
Descriptive summary and chi-square test for categorical explanatory variables used in Heckman two-stage model.

Variables	Category	Unsuccessful	Successful	Chi-square
Membership in dairy cooperatives	No	98.7_a	77.8_b	9.214^{***}
	Yes	1.3_a	22.2_b	
Membership in multipurpose cooperatives	No	14.5_a	5.3_b	18.408^{***}
	Yes	85.5_a	94.7_b	
Agro-ecology	Highland	38.7_a	50.5_a	3.662^{*}
	Midland	61.3_a	49.5_a	
Livestock management system	Open grazing	23.7_a	10.2_b	11.496^{***}
	Mixed Type	69.7_a	80.8_b	
	Cut and carry	6.6_a	8.9_a	
Change in attitude	No	69.7_a	17.8_b	97.05^{***}
	Yes	30.3_a	82.2_b	
Exercise in utilizing improved feed technologies	No	90.8_a	26.0_b	123.97^{***}
	Yes	9.2_a	74.0_b	
Willing to invest in feed innovation	No	26.3_a	21.3_a	0.9666
	Yes	73.7_a	78.7_a	
Education: Illiterate	No	77.6_a	87.1_b	4.914^{**}
	Yes	22.4_a	12.9_b	
Elementary & Junior	No	31.6_a	28.1_a	0.398
	Yes	68.4_a	71.9_a	
Secondary	No	90.8_a	84.8_a	1.917
	Yes	9.2_a	15.2_a	
Off-farm income source	No	59.2_a	56.4_a	0.220
	Yes	40.8_a	43.6_a	

Note: Values in the same row and subtable not sharing the same subscript are significantly different at $p < 0.05$ in the two-sided test of equality for column proportions.
*** Significant at 1%.
** Significant at 5%.
* Significant at 10%.

The likelihood function form the Heckman probit model is statistically significant ($p < 0.000$), showing strong explanatory power of the independent variables.

The lambda coefficient from the selection equation has negative value (−3.27) and it is significantly different from zero at 1% significant level, which confirms the presence of selection bias in the sample (Table 4). This indicates that the error terms of the selection model, success in feed adoption and the outcome model, intensity of feed adoption, are negatively correlated suggesting unobserved factors that make success of feed adoption are more likely to be associated with lower intensity in feed adoption. Therefore, using OLS or Tobit method to identify factors associated with intensity of feed adoption would give us biased estimates and the decision to use Heckman two-stage model is appropriate for this particular data. The Marginal effect (dy/dx) reported represents the change in probability of success to a unit change in the continuous independent variables and a change in the probability of success for discrete change of dummy variable from 0 to 1.

Table 2
Descriptive summary and *t*-test for continuous explanatory variables used in Heckman two-stage model.

	Unsuccessful					Successful				
	Mean	St.	Min.	Max.	Med.	Mean.	St.	Min.	Max.	Med.
Land size	1.18_a	0.88	0.00	4.00	1.0	1.61_b	1.26	0.00	8.00	1.50
Training	0.10_a	0.21	0.00	1.33	0.00	0.31_b	0.30	0.00	2.00	0.33
Engagement in farm enterprises	0.19_a	0.19	0.00	0.67	0.33	0.41_b	0.32	0.00	1.00	0.33
Diversity of fodder technology use	0.01_a	0.12	0.00	1.00	0.00	0.45_b	0.35	0.00	1.00	0.50
Intensity of collaboration	0.049_a	0.098	0.00	0.429	0.00	$.084_b$	0.13	0.00	0.71	0.00
Livestock herd size	4.00_a	2.24	0.27	9.50	3.70	6.86_b	5.63	0.20	57.00	5.62
Active labor force	3.00_a	1.00	1.00	6.00	3.00	4.0_b	2.00	1.00	13.00	3.00
Distance to district center	8.37_a	4.86	0.05	20.0	8.00	6.85_b	4.57	0.02	25.00	6.00
Access to feed technology with packages	0.02_a	0.06	0.00	0.40	0.00	0.12_b	0.21	0.00	1.00	0.00

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at $p < 0.05$ in the two-sided test of equality for means. Tests assume equal variances. St. = Standard deviation; Min = Minimum; Max = Maximum; Med. = Median.

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Table 4
Heckman first stage model for determinants of success in feed technologies adoption.

Independent variables	Coef.	Std. Err.	z	Dy/dx
Change in attitude	0.0764	0.2336	0.33	0.0020
Multipurpose cooperative membership	0.6621	0.3025	2.19**	0.0335
Livestock herd size	0.1265	0.0399	3.17***	0.0032
Off-farm income source	−0.1640	0.1911	−0.86	−0.0043
Diversify use of fodder technology	2.9711	0.7136	4.16***	0.0756
Training	0.6200	0.4070	1.52	0.0158
Education: Elementary & Junior	0.4060	0.2393	1.70*	0.0130
Secondary	0.6749	0.3470	1.94*	0.0105
Exercise in utilizing feed technology	0.6847	0.3166	2.16**	0.0244
Distance to district center	−0.0817	0.0207	−3.95**	−0.0021
Agro-Ecology: Midland	−0.0350	0.2275	−0.15	−0.0009
Cons	−0.6709	0.4999	−1.34	
lambda (Mills)	−0.1405	0.0429	−3.27***	

Coef = Coefficient; Std. Err = Standard Error.
*** significant at 1%.
** significant at 5%.
* significant at 10%.

The results of the model indicate that the probability of households' success in feed adoption is positively and significantly affected by membership in multipurpose cooperatives, livestock herd size, diverse use of fodder technologies, education of the head, and exercise in utilizing feed technologies. In most similar studies, cooperative membership is reported as one of the important factors for technology adoption. A review that examined experiences from 21 cases on agricultural innovation in Africa highlights the presence of strong relation between membership in farmers' organizations and adoption of technologies (Adekunle et al., 2012). Moreover, studies by Abebaw and Haile (2013) and Verhofstadt and Maertens (2013) also suggest that cooperative membership has positive impact on the adoption of agricultural technologies. Farmers who are member of cooperatives may have better access to continuous input supply, training and information, loan and other resources that enhance their capability for success in adoption. In addition, farmers' group formation in the form of cooperatives may increase their bargaining power when dealing with input suppliers and output users and allow them to share risks collectively that contribute to their success in using technologies.

Positive and significant relationship is observed between livestock herd size and success in adoption of technologies. This suggests that relatively households who have large size of herds have more likelihood to continue using feed technologies than others mostly to fulfil the amount of feed required for their animals. This can also be attributed to economics of size where households with larger herd size may afford to continue using more capital and labor-intensive technologies relatively with less technical and practical constraints than others can. Other similar studies have also found positive and significant relationship between technology adoption and herd size measured by total livestock units (Asfaw et al., 2011; Kotu et al., 2000; Simtowe et al., 2011; Shikur and Beshah, 2013). Livestock herd size can also indicate the wealth status of households, and hence relatively wealthier households may be more successful adopters than poor households due to better access to fodder crop seeds and other inputs (Jera and Ajayi, 2008). In addition, households who own different livestock species may need different types of feeds that can be grown and managed in various ways to meet the demand of their livestock, as traditional grazing does not provide adequate supply of feed, and consequently improve their likelihood of success in adoption.

Education of household head has positive and significant effect on success of feed technologies adoption. Households whose head have completed elementary or junior and secondary education have more probability of success than those households who had no any education. Farmers who have higher education level have better access to information relevant for adoption of technologies than others do. Education can develop farmers' intellect and improve their analytical power to assess the benefits of technologies and helps to make relatively better decision. Mostly decisions in technology adoption and use are continuous processes that may be changed based on knowledge and information level of the decision maker at different times. Moreover, knowledge and information obtained from different sources decrease farmers risk aversion nature that implicitly increase farmers' success in adoption (John et al., 2003). Similar findings were also reported in studies conducted to identify factors that affect adoption of different agricultural technologies (Gebremedhin et al., 2003; Lapar and Ehui, 2003; Krishna et al., 2008; Uaiene, 2011).

The marginal effect of exercise in utilizing feed technologies, which indicates farmers experience in feed production and provision to livestock, tells us farming households who have experience in using improved feeds for their livestock are more successful adopter than others. Having experience in feed production and utilization improves farmers' agronomic skills for future production and builds their confidence on the expected return. However, unlike to food crops, return from livestock feeds cannot be immediately realized. Mostly it is fully perceived from livestock products after feeding the animals. For resource constrained smallholder farmers, this might be a challenge to continue in adoption as the return from other alternative investments such as crop production could be realized immediately. This suggests the need for raising farmers' awareness about the expected return from adoption of feed technologies, supported by a good economic analysis, to enhance success in adoption. Similarly, although statistically significant relationships are not observed, the effects of attitudinal change and training on success of adoption are positive highlighting the contribution farmers' perception change on success of adoption.

Distance from district center has negative and significant effect on success of feed technologies adoption. Households near to the district centers are more successful adopters than those who are far from the district centers. In most developing countries, because of poor infrastructures and limited access to institutions, pertinent services for production and marketing decisions are mainly available in district centers. Mostly agricultural offices, non-governmental organizations working in input supply and capacity building, and other institutions and service providers involved in agricultural development and support programs are found in the district centers. Therefore, those households who are near to the district centers may have better access to different farming related services and information than others have. Better access to institutions and marketing centers would facilitate transactions of inputs/output and create opportunities for collaboration and networking that contribute continued utilization of technologies. On the other hand, households living very far from the district centers may incur higher transaction cost to access both input and output markets, which may affect their success in adoption. Other researchers have also reported that an increase in distance from demand centers decreases the profitability of feed technologies by increasing the transaction costs, which in turn decreases adoption of feed technologies (Gebremedhin et al., 2003).

4.3. Determinants of intensity of feed technologies use

In the second stage of Heckman estimation procedure, we tried to model the determinants of farming households' intensity of improved feed technology adoption. The inverse Mills ratio, which is estimated from the first stage selection model, is included as explanatory variable in this model to control the effect of possible selection bias while estimating parameters. As noted above, the inverse Mills ratio is statistically significant indicating the presence of strong evidence on unobserved factors that determine success in adoption in the first selection stage would affect the intensity of adoption in the second stage. Therefore, it is possible to conclude that, for this particular data, the two-stage estimation procedures may offer an interesting framework to understand households' intensity of adoption than other candidate estimation procedures. Accordingly, on Table 5 the specification results for the

Table 5
Heckman second stage outcome model for determinant of intensity of feed adoption.

Independent variables	Coef.	Std. Err	Z	Dy/dx
Intensity of collaborations	0.1409	0.0620	2.27***	0.1395
Land size	0.0029	0.0074	0.39	0.0029
Active labor force	0.0002	0.0048	0.04	0.0002
Access to feed technologies with packages	0.2315	0.0396	5.85***	0.2294
Willing to invest more in feed	0.0456	0.0192	2.37**	0.0452
Engagement in livestock farm enterprises	0.1390	0.0258	5.39***	0.1376
Diversify use of fodder technologies	0.0776	0.0307	2.52**	0.1368
Training	0.0763	0.0286	2.67***	0.0881
Livestock management: Cut and carry	0.0809	0.0362	2.24**	0.0802
Mixed	0.0523	0.0254	2.06**	0.0518
Dairy cooperative membership	0.0787	0.0204	3.86***	0.0779
Livestock herd size	0.0022	0.0017	1.32	0.0048
Agro-ecology	−0.0453	0.0175	−2.59**	−0.0456
Cons	0.2263	0.0407	5.56***	0.0016

Coef = Coefficient; Std. Err = Standard Error.
*** significant at 1%
** significant at 5%
* significant at 10%

determinant of intensity of feed technologies adoption are presented. The empirical model results indicate that intensity of adoption could be affected by social, economic, environmental, and behavioral related factors of the households.

Households who have collaboration or network with other stakeholders may tend to grow different types of fodder technologies than others. Intensity of households' collaboration, which indicates their social capital/network, has positive and significant effect on intensity of adoption. Farmers' collaboration with peasant association, peer farmers, village level organization, and development agents has enormous contribution to the adoption of technologies, as it facilitates knowledge and information exchange among groups that have common interest. The marginal estimate for collaboration indicates that a unit increase in collaboration index will increase intensity of adoption by 13.95% (Table 5). This is because mostly farmers who have good collaboration or networks have better access to information, new technologies, inputs, and others services that could ultimately increases their tendency to adopt more technologies. In addition, having wider collaboration with governmental and non-governmental institutions such as seed companies, research institutes, religious institutions, and traders would increase the likelihood of farmers to access technologies and other allied services that may increase their probability to adopt diverse technologies. Moreover, collaboration can help farmers to establish partnerships with different actors for the provision of services such as research, extension, training, credit and savings schemes, and lobbying. Other researchers (Asfaw et al., 2011; Uaiene, 2011; Adekunle et al., 2012; Ayele et al., 2012) have also indicated that widespread adoption of technologies involves higher level of collaboration among all actors, which indicates the need for individual and collective capabilities to create enabling conditions, improving access to diverse resources and ideas for intensified adoption. In general, this implies that successful adoption of improved technologies is not only the result of simple linear transfer of technologies from extension workers/researchers to farmers but also the result of farmers' interaction and network with various actors and their environment (Lapple et al., 2015; Magurie, 2012). In other words, widespread adoption of agricultural technologies are the result of interactions between farmers, researchers, extension workers, development partners, financial institutions, and other stakeholders working in related activities.

Likewise, membership in multipurpose cooperatives in the selection model above, households who are member of dairy cooperatives have 8% more intensity of adoption than others (Table 5). Improved feed technologies are one of the components of dairy technology and, hence, households who are member of dairy cooperative have better access to forage seeds, training related to feed production and management, credit and other inputs that improve their intensified adoption capacity. Moreover, dairy cooperative members may have better access to market for their products that may in turn increases their demand for new technologies and improves adoption capability. Usually farmers who are involved in similar agricultural activities could collaborate with other peer farmers to access information, identify opportunities, and share common visions that improve their intensity adoption. Other similar studies have also reported the positive contribution of dairy cooperative membership for wider adoption of livestock feed technologies (Jera and Ajayi, 2008; Ayele et al., 2012).

Access to improved forage seeds with different packages has positive and significant association with intensity of feed adoption. The marginal effect shows that a unit increase in availability of improved forage seed with different packages increases intensity of adoption by 23% (Table 5). This suggests that the contribution of other allied packages such as credit, follow up, training on related issues like enterprises development, and connection with trades are vital for intensity of feed technology adoption. For instance, experience from India (Mahajan and Vasumathi, 2012) indicates that under Agricultural, Livestock, and Enterprise Development Services, provision of technologies with credit service improved farmers adoption of new technologies in crop, livestock and other non-farm activities. This shows the direct contribution of allied services from different sources on technological change and adoption. As indicated by Sunding and Zilberman (2000), the introduction of new technologies may increase demand for complementary inputs. However, smallholder farmer may not easily access these inputs due to various reasons. Therefore, when farmers have limited access to these inputs, intensified adoption will be constrained. Furthermore, if improved technologies are provided with appropriate training and follow up services, their likelihood of success is usually high.

The roles of agricultural knowledge, information, and skills in supporting innovation are enormous. The result of this study also shows that farmers who have taken more number of trainings from government and non-governmental organizations on feed technologies production and maintenance adopted high number of technologies than others. The marginal effect indicates that a unit increase in intensity of training increases intensity of adoption by 8.8% (Table 5). Similarly, a case study conducted by Kumar et al. (2013) shows that training given to farmers on cattle feed consumption and technology adoption significantly increased adoption of feed technologies in India. Through training, farmers can get information about nature of technologies, their management and expected benefits, which helps to develop their confidence on the validity of the technologies and improves their decision to adopt. Moreover, better access to information through training and formal education can also improves farmers' adoption capacity by creating effective demand for technologies (Ayele et al., 2012). Nevertheless, due to infrastructural and other institutional constraints, mostly smallholder farmers in developing countries have limited access to training on technologies and other related farming activities. This is mainly attributed to market failures and shows the significant contribution of governmental and non-governmental organizations in building farmers capacity through training to enhance intensified adoption of agricultural technologies.

Significant association between type of livestock management system and intensity of feed adoption is found in this study. Households who practice cut and carry system and mixed system are more likely to adopt diverse technologies than those who are using open grazing system. Likewise, relatively to mixed system users, households who use cut and carry system have more likelihood to adopt different feed technologies. The relation between livestock management system and intensity of adoption can be partly explained by the change in smallholder land holding and management system. Due to decrease in amount of land holding resulted from ever-increasing population growth, smallholder farmers in developing countries are being forced to move from free/open grazing system to cut and carry system, where the animals are kept in a shed or pen and feed is given to them based on their requirement. This would create high demand for feeds and require the availability of quality forages and nutritious feed supplements to fulfil the energy and dietary requirement of animals, which in turn encourages farmers to adopt more improved feed technologies than ever.

The profitability livestock enterprises mainly depend on the quality of feed provided to the animals that can be achieved through intensified use improved feed technologies. The result of this study also shows that farming households that are engaging in livestock enterprises such as dairy farming, fattening of cattle, and fattening of sheep or goat have more intensity of adoption than others do. Similarly, other studies in developing countries also show that market oriented livestock farming activities that optimize production help to enhance adoption of forage technologies (Ayele et al., 2012). The reason behind this association is not implicit; to become productive and profitable in a very short period, most of such type of enterprises should be intensive in their nature and need to use high inputs such as improved feed technologies to meet the dietary requirements of animals. For example, a study that assessed the potential role of perennial pasture in mixed crop livestock farming system of Australia shows that *Lucerne* improves the profitability of sheep meat enterprises largely compared to the wool enterprises primarily due to the better matching of supply and demand for animal energy requirements (Byrne et al., 2010). This suggests that farmers' linkage to market oriented production system would improve widespread adoption of forage technologies.

Households who are willing to invest more in feed crops in the future have adopted more technologies than others have. This variable simply indicates farmers' perception about technologies that may be the result of previous training and experience in using technologies and realizing their benefits. Farmers usually decide to adopt more in the future if they believe that the technologies can meet their expectation. For instance, a worldwide assessment on tropical legumes shows that meeting the needs of farmers was the most significant factor leading to successful uptake of tropical forage legume technologies in different countries (Shelton et al., 2005). Of course, once farmers realized the benefits of technologies, it will not be difficult for them to continue using the technologies they have and adopt other new technologies. On the other hand, farmers who have positive attitude on different technologies can contribute for successful technology demonstration and dissemination efforts as they can easily convince their peer farmers on the benefits associated with adoption.

Farmers usually consider their multiple objective when they are making agricultural related decisions. Likewise, in this study also, diversity of fodder use is found to be one of the most important variables that affects both success and intensity of adoption. It is positively and significantly associated with success and intensity of adoption (Table 4 & Table 5). Farming households who are using fodder crops for multiple purposes such as feed, income generation, soil and water conservation, fencing, woods, and construction material are more successful and intensified user of technologies than others are. Previous studies on success and intensity of feed adoption have also examined that multipurpose legume fodder crops were adopted more than other fodder crops (Lapar and Ehui, 2003; Shelton et al., 2005; Tarawali et al., 2005). Because of limited land, labor and other resources, usually farmers prefer to maximize their returns by using multipurpose fodder crops than others. The main implication here is that for successful adoption and diverse use of feed technologies, multiple benefits of technologies can be considers as the source of incentive to enhance adoption especially in the context of resource poor smallholder farming households.

Agro-ecology also plays an important role to intensify adoption of feed technologies in most developing countries. Farming households living in different agro-ecological settings may employ different adoption strategies for various technologies. The marginal effect for change in agro-ecology tells us that being located in midland area has negative and significant relationship with intensity of adoption than being located in the high land area (Table 5). That means, farming households who are living in midland areas have less intensity of using improved feed technologies than those living in the highland areas, which may be associated with either availability of feed, relative moisture stress in midland areas to grow planted forage technologies or shortage of available feed technologies appropriate for midland areas (Franzel et al., 2014). The strong association between agro-ecology and intensity of adoption could also be due to the result of more technology demonstration or dissemination efforts made in the highland areas than midland areas. Other similar research findings have also indicated that agro-ecology is one of the important factors that affect intensity of adoption of agricultural technologies (Nicholson et al., 1999; Jera and Ajayi, 2008). This suggests that adoption of technologies is not only affected by household and socio-economic factors but also by biophysical factors, which indicates the need for considering agro-ecological setting when developing strategies for developing and dissemination of agricultural technologies in the future.

5. Conclusion and policy implication

Factors associated with intensity of livestock feed technologies adoption are assessed using household level data from positive deviants' in improved feed technologies use in Ethiopia. This study shows that when there is limited adoption and few pockets of success in improved technology use, compared to the most commonly reported conventional adoption rate studies, positive deviant approach would help to go one-step further and understand the underlying factors and principles behind the observed successes in adoption. This approach can also reveal the organizing process, possible entry points, and the roles of actors for promoting pro-poor livestock feed technologies adoption especially in developing countries.

Results of the empirical analysis show that adoption and intensified use of improved livestock feed technologies are not the result of simple linear relation between farmers and extension agents but it is an intricate process resulted from the interactions of economic, social, behavioral, and environmental factors. Moreover, intensity of adoption is influenced by success in adoption which in turn mainly affected by nature of technologies, extent of households social capital, households perception on technologies, farming experience, and location of households. Compared to the most commonly reported household farm size indicators such as land size, herd size, and family size, evidences from this study show that households' enabling factors including training, access to technologies and inputs, and farmers' social capital are found to have significant effect on households intensity of use. Unlike to farm size indicators, which may need changes in economic and social structure, these factors could easily enhance intensified use of technologies within short period by improving the capacity of farmers and their access to inputs and technologies. Similarly, households behavior related indicators such as diversity of forage technology use, engagement in livestock related enterprises, livestock management system, and willingness to invest more in feed technologies in the future, which are usually resulted from evidence-based practices, are also found to be the most important factors for intensified adoption. This shows that household enabling and behavioral factors should be exploited in the process of identifying suitable entry strategy for promoting wider use of technologies and toward enhancing the production and productivity of livestock sector in developing countries. Moreover, the strong relation observed between intensity of adoption and farmers' social capital is a good evidence on the importance of building local coalition for intensified use of improved technologies. This also implies that success and intensified use of improved technologies are also the result of social processes that need the contribution of various actors either in the form network or in collaboration. Furthermore, actors involved in promoting improve technologies are expected to reframe their habits and practices and enhance the participation and collaboration of different

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partners. The study would also underline the important roles of appropriate institutional arrangements and support system for promoting multi-stakeholder platforms to enhance learning and innovation in technology adoption.

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