DETERMINANTS OF ARTIFICIAL INSEMINATION USE BY SMALLHOLDER DAIRY FARMERS IN LEMU-BILBILO DISTRICT, ETHIOPIA

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A Thesis Submitted to the Graduate School in Fulfilment for the Requirements of the Master of Science Degree in Agricultural and Applied Economics of Egerton University

EGERTON UNIVERSITY

NOVEMBER, 2013

DECLARATION AND APPROVAL

Declaration

I declare that this thesis is my original work and has not been presented in any other university for the award of a Degree, Diploma or a Certificate.

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Recommendation

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DEDICATION

I dedicate this work to my beloved wife Mebrat Beyecha and my daughter Meklit Sime.

ACKNOWLEDGEMENT

Above all, honour and thanks go to the Almighty GOD for his mercy, care, strength and guidance during the entire period of my study. I wish to acknowledge the staff of the Department of Agricultural Economics and Agribusiness Management, Egerton University for their support since I enrolled for my study. Special thanks go to my University supervisors Prof. Job. K. Lagat and Dr. Hillary. K. Bett for their unreserved effort to reconstruct this thesis work starting from the proposal. I would also like to extend my appreciation to Collaborative Masters of Agricultural and Applied Economics (CMAAE) and German Academic Exchange Service (DAAD) through African Economic Research Consortium (AERC) for providing me the opportunity to undergo specialised and rigorous training both in Egerton and Pretoria Universities by covering the school fees, stipend and research fund. I also extend my honest thanks to Mr. Endale Nigussie, all the respondent farmers, enumerators and Lemu-Bilbilo district agricultural office staffs for their invaluable support during data collection process. I do not forget to express the love I have to my daughter Meklit Sime who was born when I was doing the first year coursework. Last but not least, I would like to express my heartiest love and respect to my wife Mebrat Beyecha for her unlimited care and positive ideas throughout my stay abroad.

ABSTRACT

Despite Ethiopia possessing the highest number of livestock in Africa, its benefit to the country and smallholder farmers is small. This is to a large extent attributed to the dominance of low producing local cattle breeds. Though the government introduced Artificial Insemination (AI) technology to improve this condition, the adoption rate by smallholder farmers is still low. The main objective of this study was, therefore, to examine the adoption of AI technology by smallholder dairy farmers in Lemu-Bilbilo district, Ethiopia. The specific objectives were to characterize adopters and non-adopters of AI, to determine factors affecting adoption of AI and to determine the extent of adoption and factors affecting the extent of adoption. Purposive selection of the area and random sampling procedures were employed to select a sample of 196 smallholder dairy farmers. Data was collected using interview schedule via semi-structured questionnaires. The data was analyzed using Statistical Package for Social Sciences and STATA. Adopter and non-adopter farmers were significantly different with respect to education level, off-farm income, membership in dairy cooperatives, extension contacts, experience with crossbreeds, feeding concentrates to cows, access to credit, income from milk products sales and distance from AI station. The double-hurdle model was used for econometric analysis whereby the two stages were run separately as Probit and truncated regression, respectively. Contacts with extension agents, access to credit, income from milk sales, feeding concentrate to cows and family size influenced the probability of adoption without affecting the extent of adoption. While membership in dairy cooperatives and off-farm income positively affected the probability and extent of AI adoption, distance from AI station and access to crossbred bull services influenced both variables negatively. A further walking distance of one hour to the AI station was associated with 27% and 14.4% reduction in the probability and extent of adoption, respectively. Membership in dairy cooperatives and off-farm income can be instrumental in AI adoption due to milk market guarantee and the strengthening of financial capacity from off-farm income. Farmers located at farther distances from AI station and those with access to crossbred bulls preferred to use bulls than AI. Access to AI should be improved by expanding AI stations throughout the district along with training more AI technicians. Awareness creation especially on the difference between using AI and bull service must be done. Deploying adequate number of extension workers, educating farmers in farmers' training centres and field day visits can be the way forward. Dairy cooperatives and microfinance institutions must be established and strengthened. Ways of milk marketing at farm-gate should be designed, infrastructural development (especially road) should be considered.

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LIST OF ABBREVIATIONS AND ACRONYMS

AEASA	Agricultural Economics Association of South Africa
AESE	Agricultural Economics Society of Ethiopia
AAAE	African Association of Agricultural Economists
AI	Artificial Insemination
ARDU	Arsi Rural Development Unit
AZADD	Arsi Zone Agricultural Development Department
CSA	Central Statistics Agency
EASE	Ethiopian Agricultural Sample Enumeration
ESAP	Ethiopian Society of Animal Production
FDRE	Federal Democratic Republic of Ethiopia
GDP	Gross Domestic Product
GTP	Growth and Transformation Plan
ILRI	International Livestock Research Institute
IPMS	Improving Productivity and Market Success
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
NAIC	National Artificial Insemination Centre
NBE	National Bank of Ethiopia
NGO	Non Governmental Organization
OBPED	Oromiya Bureau of Planning and Economic Development
VIF	Variance Inflation Factor
WRI	World Resources Institute

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Ethiopia is an agrarian economy located in the horn of Africa. Agriculture sector employs more than 80 percent of the population and contributes about 43 percent to the total GDP and 90 percent to the foreign exchange earnings (MoARD, 2010). With its 49.33 million heads of cattle, Ethiopia is the leading country in cattle population in Africa and ninth on the world (CSA, 2008). The contribution of livestock and livestock products to the agricultural GDP of Ethiopia accounts for 40 percent, excluding the values of draught power, transport and manure. Smallholder farming is considered one of the most important in the agricultural sector in Ethiopia. It is a source of income, food security and indicates prestige and social status in the rural community (Kedija *et al*., 2008). More than 99 percent of Ethiopia's cattle have been reported to be indigenous breeds and small Zebu types that are poor in major economically important traits. Crossbreeds and pure exotic breeds constitute only 0.5 and 0.1 percent of the total cattle population, respectively (EASE, 2003).

In the previous decades, the productivity of livestock sector dominated by traditional practices failed to satisfy the food security needs of the country's population at times resulting in severe food scarcity. The development strategy of the Ethiopian government recognizes the leading role of agriculture in the economy and stipulates that for the country to register rapid economic prosperity, it should follow the path of Agricultural Development Led Industrialization (FDRE, 2002; Abraham, 2009).

The per capita milk consumption of Ethiopia estimated at 19 kg per year; is lower than African and world per capita averages, which are 27 kg and 100 kg per year, respectively (ESAP, 2004). In Ethiopia, one of the leading causes of infant mortality is malnutrition. Although milk is considered nature's perfect food for the growing infant, the ever rising scarcity and high cost of milk and dairying has made it impossible to meet the demand. Reports also showed that there is increasing trend in import of milk and dairy products and a considerable amount of foreign exchange is spent on the import of dairy products (Felleke, 2003). The value of imports of milk products in the first half year increased from 48 billion Birr in 2005 to over 114 billion Birr in 2010. The price of milk in Ethiopia is more than tripled in 10 years. This clearly depicts the presence of a wide gap between the supply and demand of milk and milk products (Land O'Lakes, 2010; NBE, 2011).

In order to improve the low productivity of the indigenous Zebu cattle, selection of the most promising breeds and crossbreeding of these indigenous breeds with high producing exotic cattle has been considered as a practical solution (Mekonnen, T. *et al*., 2010). Selection and controlled breeding of superior animals has been found to increase productivity. The development and use of Artificial Insemination technique has also revolutionized cattle production and genetic improvement, particularly in the dairy sector in developed countries (Henning *et al*., 2010). Artificial insemination is the single most important technique ever devised for genetic improvement of animals in all aspects including milk and beef production (Kaaya *et al*., 2005).

While more than 70 percent of animals are bred using AI in the developed world, the technology is almost practically not available in 25 developing countries 16 of which are found in Africa (Kaaya *et al*., 2005). In Ethiopia, AI technology was introduced 5 decades ago through Chilalo Agricultural Development Unit (CADU) project which was importing semen. But later on, because of the importance of the technology, National Artificial Insemination Centre (NAIC) was established in Addis Ababa in the year 1981 (ESAP, 2008; Abraham, 2009). In Arsi zone, where Lemu-Bilbilo district is located, cattle rearing along with land cultivation is the most common economic activity as 99.6 percent of the households in the zone own cattle (MoARD, 2007). Artificial insemination was started in the Lemu-Bilbilo district in 1971 soon as the technology was introduced in to the country.

Although Ethiopia has the largest livestock population in Africa, productivity and production have remained low. Unlike other African countries such as the neighbour Kenya, the large cattle population of Ethiopia has relatively limited numbers of exotic dairy cattle and their crosses. Less than 1 percent of the dairy cattle population of Ethiopia is exotic or crossbred cows (EASE, 2003). According to the Tegegne and Hoekstra (2011), Kenya has more than 100 times crossbred cows than Ethiopia. Consequently, milk productivity in Ethiopia is low. According to CSA (2008) report, the total annual milk production from about 10 million milking cows in

Ethiopia is estimated at about 3.2 billion litres, which is translated into 1.54 litres per cow per day (Kedija *et al*., 2008).

1.2 Statement of the Problem

The majority of farmers in Ethiopia who depend on rearing local cattle breeds along with growing grains, as their main source of food and income are unable to meet their basic household demands. This is due to the increasing cost of production and price fluctuations of grain crops; and the minimum amount of milk yield they obtain from the Zebu breeds. To mitigate the increasing inability of keeping indigenous breeds to support livelihoods of farmers, the Government of Ethiopia has introduced AI technology as a means to improve the production and productivity of the domestic cattle breeds by crossing them with exotic ones. However, despite the dominance of low yielding local breeds and the government's effort to provide AI at low price; the utilization rate of AI in the country in general and in Lemu-Bilbilo district in particular is very low. The result of a study conducted in Fogera district of northern Ethiopia, showed that 90.6 percent of the farmers use natural mating (Anteneh *et al*., 2010). The situation in Lemu-Bilbilo is also not different (Haji, 2003). Hence, there is urgent need to identify the factors responsible for the low utilization of AI service in Lemu-Bilbilo district.

1.3 Objectives of the Study

General Objective

The general objective of this study was to contribute to the improvement in the livestock sector which helps to alleviate food insecurity and poverty in Lemu-Bilbilo district of Ethiopia.

Specific Objectives

i. To characterize adopters and non-adopters of Artificial Insemination in Lemu-Bilbilo district
ii. To determine factors affecting adoption of AI technology by smallholder dairy farmers
iii. To determine the extent of adoption and factors affecting the extent of adoption of AI

1.4 Hypotheses of the Study

i. There is no significant difference between the demographic and socio-economic characteristics of adopters and non-adopters of AI
ii. The socio-economic and institutional factors have no significant effects on adoption of AI
iii. The socio-economic and institutional factors have no significant effects on the extent of AI utilization

1.5 Justification of the Study

Meeting the demand for dairy products of rapidly growing Ethiopian population especially of those residing in urban areas with the low producing indigenous cattle has been difficult. Unless improvements are made; with the current situation in Ethiopia, estimates have shown that in the year 2020 there will be an increase of 148 percent over current consumption of milk by urban dwellers (Land O'Lakes, 2010). In response to that, the government of Ethiopia is allocating a lot of its budget to provide the farmers with many modern agricultural technologies which can improve production and productivity. One of these is AI technology which is being provided at a much lower price. However, the response rate by the farmers is not as expected. There has not been any study undertaken as to why the utilization of AI service by rural farmers of Ethiopia and Lemu-Bilbilo district is low.

This study, therefore, targeted to identify the factors affecting adoption and the extent of using AI technology which will help the policy makers and extension staff to address the technical and economic constraints and enhance production and productivity through active participation of farmers. This study can contribute to improving the efficiency of agricultural research, technology transfer, and agricultural policy formulation. In addition, the finding from this study adds to the body of knowledge regarding the causes of low utilization of AI by farmers in Ethiopia.

1.6 Scope of the Study

This study was limited to assessing factors affecting the adoption and extent of utilization of AI technology by smallholder dairy farmers. The study was conducted on smallholder dairy farmers in Lemu-Bilbilo district in Arsi zone of the Oromiya regional state in Ethiopia. The data was collected for one month in May 2013.

1.7 Definition of Terms

Kebele is the smallest administrative unit in Ethiopia

Smallholder dairy farmer is operationally defined as farmer who has been keeping maximum of ten cows, and whose primary occupation is subsistence agriculture.

Zebu is a word used to represent different local cattle breeds in Ethiopia.

Birr is the currency used in Ethiopia and 1 US dollar equals 18.8 Birr as of August 2013.

CHAPTER TWO

LITERATURE REVIEW

2.1 Livestock Production and its Importance in Ethiopia

In the last years, the average growth rate of the agricultural GDP has been about 10 percent per annum. The Government of Ethiopia has shown a strong interest and commitment in the support to the agricultural sector, considering it as a key driver of the economic and human development of the country. The central role held by agriculture is highlighted in the current Five Year Growth and Transformation Plan (GTP) 2010-2015 and Agricultural Sector Policy and Investment Framework 2010-2020 (MoARD, 2010; MoFED, 2010; NBE, 2011).

The contribution of livestock and livestock products to the agricultural economy of the country is significant as its share in total foreign exchange earnings is about 15 percent. Among the main livestock product exports are hides and skins, live animals and meat (Desta, 2002; NBE, 2011). The contribution of livestock sector can equally well be expressed at household level in the mixed crop-livestock systems in the highlands of the country. Livestock provide food in the form of meat and milk, and non-food items such as draft power, manure and transport services, and fuel for cooking. Livestock are also a source of cash income through sales of the above items, and animal hides and skins. In addition, they act as a store of wealth and determine social status within the community (Benin *et al*., 2003). Livestock also serve as means of saving and capital in rural areas where banking and insurance services are non-existent (Anteneh *et al*., 2010).

The livestock sector of Ethiopia has great potential in supporting the country's effort to escape from poverty. Though the current contribution of the sector to the national economy is high, it is not utilized to its full capacity. About 99.5 percent of the cattle population in the country are indigenous breeds which are poor in major economic traits (EASE, 2003). Improvements in genetic makeup of the herd could be considered as one of the strategies to increase the overall production and productivity in the country.

2.1.1 Dairy Production in Ethiopia

Dairy production is an important part of the livestock production systems in Ethiopia. Cattle, camel and goats are the main livestock species that supply milk, with cows contributing 81.2 percent of the total milk output (Felleke, 2003). Ethiopia has a huge potential to be one of the key countries in dairy production for various reasons. These include a large population of milk cows in the country estimated at 9.9 million (CSA, 2008), a conducive and relatively disease free agro-ecology, particularly the mixed crop-livestock systems in the highlands that can support crossbred and pure dairy breeds of cows, a huge potential for production of high quality feeds under rain-fed and irrigated conditions, existence of a relatively large human population with a long tradition of consumption of milk and milk products and hence a potentially large domestic market, existence of a large and relatively cheap labour force and opportunities for export to neighbouring countries and beyond (Ahmed *et al*., 2003; Anteneh *et al*., 2010).

Different researchers have used different classification to describe the dairy production system of Ethiopia. However, the mostly identified and used ones are smallholder dairy farming system in the crop-livestock mixed farming system in the highlands, urban and peri-urban dairy system found around and inside big cities/towns, pastoral and agro-pastoral system in the lowlands, and intensive (large-scale commercial) dairy farms (Felleke and Geda , 2001; Kebede, 2004; Anteneh *et al*., 2010).

Kebede (2004) concluded that the production of milk in East African countries in general and in Ethiopia in particular is dominated by smallholder dairy production system. In the highlands where the subsistence smallholder farmers are predominant, crop and livestock production are an integral part of their livelihood. As reported by Felleke and Geda (2001), the highland area can be regarded as a mixed farming system, in which crop and livestock are interdependent. The highland smallholder milk production using indigenous cattle is the predominant milk production system with very few cross bred or exotic breed. There is high potential of increasing the cash income a farmer earns through rearing high yielding cattle breeds via utilization of new technology. The results of a study by Haji (2003) showed that keeping crossbred dairy cattle assures food security in a family by increasing the milk yield and raising genetic potential.

2.2 Artificial Insemination

Artificial Insemination is a breeding process in which sperm collected from the male are processed , stored and artificially introduced in to the female (Khanal, 2010). The first scientific research in AI of domestic animals was performed by L. Spallanzani in 1780. He deposited fresh dog semen in the uterus of a bitch utilizing a pointed syringe. Sixty- two days later the bitch whelped, and all three pups resembled the bitch and the sire (Dalton, 1999). However, the technology was widely introduced in 1940s and gained a rapid initial diffusion. Considering its positive influence on genetic improvement and profitability, AI is one of the farmer-friendly and widely adopted breeding technologies (Johnson and Ruttan, 1997).

Studies have shown that AI is without doubt economically advantageous compared to natural service because the need to keep a bull and the costs associated with it are avoided, it is cheaper than natural service, increased efficiency of bull usage, it makes it possible for farmers to have access to high quality germ-plasm and thus make permanent improvement of their stock faster and more efficiently, and the spread of venereal diseases is easily controlled (Vashist and Pathania, 2000; Khanal, 2010; Shehu *et al*., 2010). But AI has also few disadvantages which can be overcome through proper management. These are: proper implementation requires special skill and practice, it requires more labour and facilities, preservation and transportation of semen is difficult under severe climatic conditions (Khanal, 2010; Shehu *et al*., 2010).

2.2.1 Artificial Insemination in Ethiopia

The history of Artificial Insemination in Ethiopia goes back to the time of Italian invasion when they introduced the technology to the country through Asmara. But the utilization by farmers started in 1960s when Chilalo Agricultural Development Unit (CADU) project provided the service by importing semen and liquid nitrogen. In 1973 the project established liquid nitrogen production laboratory in Arsi zone, Asella town. However, because of the high importance of the technology to the farmers and the economy; the government established National Artificial Insemination Centre (NAIC) in Kaliti Addis Ababa in 1981(ESAP, 2008; Abraham, 2009).

NAIC is responsible for the production and distribution of semen to all regions in the country. According to a report in 2010; the centre produces 170, 000 units of bull semen per year with a goal of doubling this amount within five years. In addition to producing bull semen, NAIC serves as a training centre for AI technicians and provider of liquid nitrogen for freezing bull semen. There are 10 liquid nitrogen centres throughout Ethiopia; these centres also serve as the distribution point of bull semen (Abraham, 2009; Land O'Lakes, 2010). The government AI system is heavily subsidized; with the AI service and semen costing 6 Ethiopian Birr (ETB). The actual cost of the service and semen is 22 ETB. Private sector involvement in providing the service is quite recent and is limited to the intensive dairy farms in and around Addis Ababa (Land O'Lakes, 2010).

2.3 Adoption of Technology

Adoption process is the change that takes place within individual with regard to an innovation from the moment that they first become aware of the innovation to the final decision to use it or not (Ray, 2001). Adoption is a mental process through which an individual passes from first knowledge of an innovation to the decision to adopt or reject. According to Feder *et al*. (1985), adoption refers to the decision to use a new technology, method and practice by a farmer or consumer. Adoption of technology involves a process in which awareness created, attitudes are changed and favourable conditions for adoption are provided (Ghosh *et al*., 2008). The last two decades have seen user adoption models being proposed, tested, refined, extended and unified. These models have contributed to our understanding the factors of user technology adoption and their relationships. Many studies have been conducted on the issue of technology adoption based on these models (Mwangi *et al*., 2004; Kaaya *et al*., 2005; Rezaei and Bagheri, 2011; Howley *et al*., 2012).

In this study, for a farmer to be considered as adopter; he/she has to witness owning at least one calf which was born using AI technology. The extent of adoption is described as the level or intensity of use of a given technology. The number of hectares planted with improved seed, the amount of input applied per hectare and the proportion of animals born using a breeding technique are referred to as the intensity of adoption of the respective technologies (Nkonya *et al*., 1997).

2.3.1 Role of Adoption of AI Technology

New technology is always a critical factor in changing the structure of the industry. Johnson and Ruttan (1997) found breeding technologies as the most significant factor contributing to farm productivity in the livestock sector since 1940s. According to Rees *et al*. (2010), the use of breeding technologies like AI can increase the production efficiency of the herd and enhance the genetic characteristics of the herd, while the study by Gillespie *et al*. (2004) states that the usage of breeding technologies allow for the timely production of greater number of quality animals with a given set of resources. The development and use of AI techniques have revolutionized cattle production and genetic improvement, especially in the dairy sector, in developed countries (Henning *et al*., 2010).

A study in Himachal Pradash state of India indicated that with the increase in AI facilities and AI centres there was an increase in the number of crossbred cattle population and a decline in the indigenous cattle population. The percentage of crossbred cattle increased due to the positive impact of cross-breeding with AI program in the state. The share of milk from the crossbred cows to the total milk registered an increase from 11 to 17 percent, indicating the beneficial effects of cross-breeding program (Vashist and Pathania, 2000).

A paper in Kenya showed the major role AI plays in elevating poor peasant livestock keepers to commercial small scale dairy farmers' level. Most of the zebu cattle owners are poorer members of the farming community who cannot afford to purchase grade or pure dairy cattle breeds in order to begin commercial dairy enterprises in the high agricultural potential areas. The adoption of AI technology, especially through the upgrading, has enabled about 80 percent of current suppliers of milk in Kenya to enter into commercial dairying within reasonably short period than would have been if direct importation of dairy cows had been adopted (Oluoch *et al*., 1999).

2.3.2 Factors Affecting Adoption of Technology

In many areas of African countries, technologies are becoming available, but adoption has been slow or has not been sustained. According to Feder *et al*. (1985), immediate and uniform adoption of innovations in agriculture is quite rare as adoption behaviour differs across socio-economic groups, overtime and geographical location. Some technologies have been well adopted, while others have been adopted by only very small groups of farmers. Studies have found that farmers' technology adoption decisions are generally affected by a number of demographic, socio-economic and institutional factors. In an economic sense, farmers adopt technology if the utility associated with adopting it is greater than the utility associated with not adopting (Beshir *et al*., 2012; Asfaw *et al*., 2011; Kassie *et al*., 2012).

According to Feder *et al*. (1985), the different factors that influence technology adoption in developing countries can be grouped in to three main categories. Firstly, factors related to the characteristics of farmers which include age, gender, education level, experience in the activity, farm size, labour availability, level of wealth, and risk-aversion behaviour influence technology adoption. Second group of factors are those related to the characteristics and relative performance of the technology. These include food and economic functions of the product, the perception by individuals about the characteristics, complexity and performance of the innovation, its availability and that of complementary inputs, the relative profitability of its adoption compared to substitute technologies, the period of recovery of investment and the susceptibility of the technology to environmental hazards. Third group of factors consist of institutional factors; which include availability and quality of information on the technologies, availability of credit, the land tenure system, accessibility of markets for products and input factors and the availability of adequate infrastructure (Dandedjrohoun *et al*., 2012).

The findings of research paper by Rees *et al*. (2010), indicated that the adoption of artificial insemination technology is influenced by human capital, measured by age and information usage, as well as natural capital. The present study differs from previous studies in that: First, this study addresses the adoption of AI technology, which is an important factor in influencing dairy productivity and, ultimately industry structural change. Second, the adoption decisions are modelled using double hurdle model that allows for estimation of the extent of the technology adoption.

2.4 Theoretical and Conceptual Framework

2.4.1 Theoretical Framework

From a theoretical perspective, the decision to adopt a technology can be viewed as being driven by how much utility a household gains from its choice. Utility is viewed as an observable index determined by a set of explanatory variables that an individual uses to rank a set of decision alternatives. Because it is unobserved, utility can be treated as a random variable (Ngugi *et al.*, 2003).

The theory of utility maximization is generally used to explain the response of the farmer to a new technique, in this case AI technology. According to utility theory, the farmer will adopt a new technique if the utility obtained from it exceeds that of the old one. The individual effort is an endogenous process that involves comparing the costs and benefits of adopting a technology. It is reasonable to expect that when an individual considers investigating a technology, he will take into account the current expenditure in terms of time and other goods as evaluated against immediate and future returns. Whether or not a household adopts a technology depends on the costs and benefits of the technology (Shiferaw and Holden, 2001).

The assumption made in this study is that a household maximizes utility when choosing AI technology. However, we do not observe its utility, but only its choice of technology. The utility of each alternative is in turn determined by a set of exogenous variables, Z_i and an error term. The exogenous variables are household characteristics and institutional factors. Adoption is assumed to occur if the utility of using AI is higher than the utility of other alternatives.

Let U_{ij} be the utility the farmer obtains from using AI technology with j = {0,1} indicating the adoption or non-adoption of AI technology and i = {1,2,…,n}indicating the farmers characteristics. These characteristics are not all observed, but a linear relationship is postulated for the i^{th} farmer between the utility derived from the j^{th} technology and a vector of observed farmer's characteristics Z_i.

$$U_{ij} = Z_i\beta_j + \varepsilon_j \text{ ; } j = 0{,}1 \text{ } and \text{ } i = \{1,2,\dots,n\} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (1)$$

The decision of the farmer is a process of two mutually exclusive alternatives: either he adopts $j = 1$ or does not $j = 0$. The assumption is that a farmer chooses the option that gives him the largest utility. The i^{th} farmer will adopt the technique j if $U_{i1}>U_{i0}$ and the qualitative variable D_i indexes the adoption decision:

If $U_{i1} > U_{i0}$, then $D_i^* = 1 \text{ } and \text{ } 0 \text{ } otherwise$

$$P_i = P_r(D_i^* = 1) = P_r(U_{i1} > U_{i0}) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Where, P_i is the probability of i[th] household adopting AI.

This can be further expressed as a function of independent variables, that is,

$$P_i = P_r(Z_i\beta_1 + \varepsilon_1 > Z_i\beta_0 + \varepsilon_0) \ldots \ldots (3)$$

$$= P_r(Z_i\beta_1 - Z_i\beta_0 > \varepsilon_0 - \varepsilon_1)$$

$$= P_r(\beta_1 - \beta_0)Z_i > u_i)$$

$$= P_r(\alpha Z_i > u_i)$$

$$P_i = F\left(\alpha Z_i'\right) \ldots \ldots (4)$$

Where,

$u_i = \varepsilon_0 - \varepsilon_1$ is the random error term

$\alpha = \beta_1 - \beta_0$ is vector of parameters to be estimated

$F\left(\alpha Z_i'\right)$ is the cumulative distribution function (cdf) of the error term u_i

Thus, the probability of the i[th] farmer to adopt the new technology is the probability that the utility of the new technology is larger than the utility of the old one or the cumulative distribution F evaluated at $\alpha Z_i'$ (Ngugi *et al*., 2003).

2.4.2 Conceptual Framework

If farmers are consumers of agricultural technology, then according to random utility theory, they will choose to adopt the alternative technology package that gives them highest utility. Farmers are faced with a variety of factors which influence their decision making in view of maximizing utility. Adoption is conceptualized as a function of farmers' characteristics, technology attributes, institutional factors and resource factors. Further, the decision to adopt a technology is a behavioural response arising from a set of alternatives and constraints facing the decision maker (Wanjiku *et al*., 2003).

Smallholder farmers have different personal characteristics which affect their decision making. Socio-economic and institutional factors play great role in affecting the probability of adoption and extent of technology utilization. Based on hypothesized factors which influence AI use in the study area, the conceptual framework for this study is given as follows.

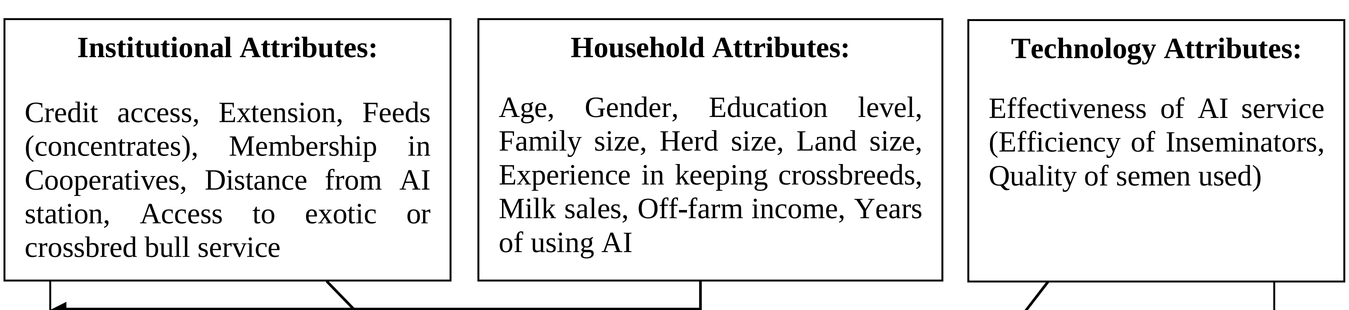

Figure 1: Conceptual Framework

Source: Adopted from Kibet *et al*. (2011)

CHAPTER THREE

METHODOLOGY

3.1 Description of the Study Area

Arsi zone is one of the 17 zones of the Oromiya Regional State, which lies between 6° 45'- 8° 58'N latitude and 38° 32'- 40° 50'E longitude. Arsi zone shares boundaries with East Shewa, West Hararghe, Bale zones and the Regional State of Nations, Nationalities and People of Southern Ethiopia. The zone has an average altitude of 1500 to more than 4000 meters above sea level (OBPED, 2011). Based on 2007 national census, the total population of Arsi zone was 2, 635,515. The zone has 26 districts with a total land area of 23,881km^2 (CSA, 2008; OBPED, 2011). Crop production is carried out mainly during the long rainy season. The zone is also known for its livestock production. According to OBPED (2011), there were about 2.74 million cattle, 1.33 million sheep and goats, 476,721 equines, 1.3 million poultry, and 112,557 beehives in this zone.

3.1.1 Description of Lemu-Bilbilo District

This study was conducted in Lemu-Bilbilo district, which is located between 7°10'14"- 7°40'20"N latitudes and 39°4'59"- 39°38'56"E longitudes. Lemu-Bilbilo district with its capital at Bekoji town is situated 235km southeast of the capital Addis Ababa. The district has a total area of 1212.5km^2 and is divided in to 25 *kebeles*. The altitude of the district ranges from 1500 meters above sea level around Wabe-Shebelle River to 4195 meters above sea level at mount Kaka. The area receives an average annual rainfall of around 1100mm and has an average annual temperature ranging from 6 to 26°C (AZADD, 2000).

According to CSA (2008), the district has a total population of 180,695 out of which 12.92 percent were urban dwellers. Mixed farming system is the main economic activity practiced in Lemu-Bilbilo district. The most important crops grown are barley, wheat, linseed, field-pea, faba-bean and lentil. This district is rich in livestock resources possessing 309,383 cattle, 64,347goats, 301, 917 sheep, 66,373 horses, 52,743 donkeys, 4232 mules, 70,744 poultry and 16, 991 bee colonies (OBPED, 2011). AZADD (2000) indicated that the average livestock holding per household in Lemu-Bilbilo district was 10 cattle, 10 sheep and 3 equines.

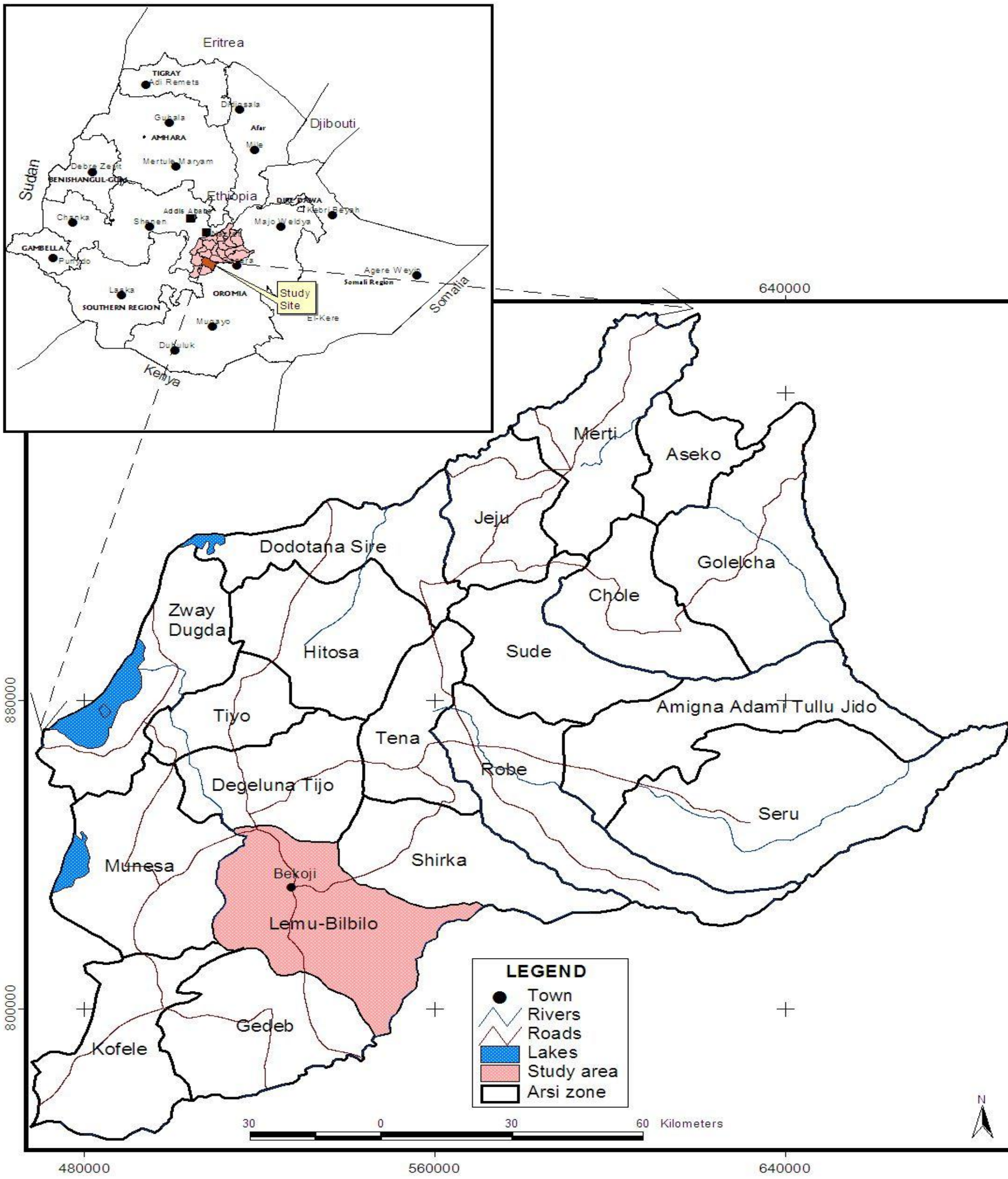

Figure 2: Map of Arsi zone, showing Lemu-Bilbilo district

Source: Central Statistics Agency of Ethiopia (2004)

3.2 Sample Size Determination

The sample size was estimated using Cochran (1963) formula.

$$n = \frac{(p)(q)Z^2}{(e)^2} \quad \text{(5)}$$

Where, n = sample size

p = proportion of the population containing the major interest

q=1-p

e = acceptable/allowable error = 0.07

p=0.5 and q=1-p = 1-0.5= 0.5,

Z = 1.96

$$n = \frac{0.5 \times 0.5 \times (1.96)^2}{(0.07)^2}$$

n=196

The study used 95 percent of confidence level (Z=1.96). Since the variability between the two groups of farmers is not known, the maximum variability principle suggested by Cochran (1963) was used. Therefore, p = 0.5, and q = 0.5. Using an allowable error of 7 percent, the total sample size was 196.

3.3 Data Sources and Method of Data Collection

Primary and secondary data were collected for the study. The sources of primary data were the smallholder dairy farmers residing in Lemu-Bilbilo district. The primary data from the selected farmers was collected through interviews using semi-structured questionnaire. Data on respondents' demographic, social, institutional and economic variables that are useful for this study were collected. In addition to administering the semi-structured questionnaires, secondary data on the history of AI in Lemu-Bilbilo district was obtained from the district agricultural offices to supplement the primary data. Eight trained enumerators were involved in the data collection.

Multistage sampling design was employed to select the sample. First, Arsi zone was selected purposively because it is among the richest zones in cattle population in the country and AI was initially introduced in Ethiopia to this zone. Second, Lemu-Bilbilo district was selected purposively because 96.7 percent of the people in this district keep cattle as part of the mixed farming system (Haji, 2003). This district was also selected because of its cattle population and livestock extension activities that have been carried out since the advent of Chilalo Agricultural Development Unit (CADU) and Arsi Rural Development Unit (ARDU) projects and it is among the districts where AI practices were undertaken initially by these projects. Then, out of the 25 *kebeles* in the district, 4 *kebeles* (Bekoji-Negesso, Chiba-Mikael, Dawa-Bursa and Tamegn-Aware) were selected purposively based on the availability and access of the AI technology. Farmers in each *kebele* were stratified in to two groups: those who adopted AI and not adopted. The list of adopters of AI was obtained from the records at the district animal health and artificial insemination office; whereas the list of non-adopters was obtained from the list at *kebele* administration office. From the two groups (adopters and non-adopters), simple random sampling was applied to select 98 adopters and 98 non-adopters as indicated in Table 1.

Table 1: Distribution of sample farm household heads by *kebele*

Name of Kebele	**Total household head***		**Sample Farm household heads**				
	Male	Female	Adopter		Non-adopter		Total
			Male Number	Female Number	Male Number	Female Number	Number
Bekoji-Negesso	702	101	22	3	22	2	49
Chiba-Mikael	500	60	24	0	21	4	49
Dawa-Bursa	692	112	23	1	24	1	49
Tamegn-Aware	550	26	24	1	24	0	49
Total	2444	299	93	5	91	7	196

Source: **Kebele* Administration Office

3.4 Method of Data Analysis

The study utilized both descriptive statistics and econometric models to analyze the collected data.

3.4.1 Descriptive Statistics

Descriptive statistics was used to explain the different socio-economic and institutional characteristics of sampled households. These include mean, standard deviation and percentages for the adopter and non-adopter farmers in AI technology. The statistical significance of the variables was tested for both dummy and continuous variables using *chi*-square and *t*-tests.

3.4.2 Empirical Models

The variable representing adoption of AI technology is a dummy variable that takes a value of 1 for adopter or 0 for non-adopter depending on whether or not a sample farmer has cattle bred with AI. This binary variable is related to several sets of factors (either continuous or dummies) that were believed to influence adoption decision of the technology.

Limited dependent variables models are often used to evaluate farmers' decision-making process concerning adoption of agricultural technologies (Olwande *et al*., 2009). Those models assume that farmers are faced with two alternatives (adoption or no adoption) and the choice depends upon identifiable characteristics (Pindyck and Rubinfeld, 1997). In adopting new agricultural technologies, the farmer is also assumed to maximize expected utility from using a new technology subject to some constraints (Feder *et al*., 1985). In several studies (Mignouna *et al*., 2011; Rezaei and Bagheri, 2011; Howley *et al*., 2012), a Probit or Logit model is specified to explain whether or not farmers adopt a given technology without considering the intensity of use of the technology. The Probit or Logit models cannot handle the case of adoption choices that have a continuous value range (Kaliba *et al*., 2000).

Tobit model has been used to identify factors influencing adoption and the extent/intensity of technology adoption. This model as employed by different researchers (Kaaya *et al*., 2005; Foti *et al*., 2008; Fikru, 2009) has advantage over Logit and Probit in that it reveals both the probability of adoption and extent of technology adoption. Tobit, also called a censored regression, is used when a dependent variable has a zero value for a significant fraction of the observations. Since there are non-adopters in a technology application, the value given for these is zero and using standard OLS results provide biased and inconsistent parameter estimates (Greene, 2007).

The Tobit model of Tobin (1958) has been used to analyze data under the assumption that the two decisions (adoption and extent of adoption) are affected by the same set of factors (Greene, 2007; Fikru 2009). However, in principle, the decisions on whether to adopt and how much to adopt can be made jointly or separately. When the decisions are made jointly, the Tobit model is appropriate for analyzing the factors affecting the joint decision (Greene, 2007; Teklewold *et al*., 2006). This assumption has been the norm in previous research into the determinants of the intensity of technology adoption (Pender and Kerr, 1998; Kaaya *et al*., 2005). However, adoption and intensity of use decisions are not necessarily made jointly. The decision to adopt may precede the decision on the intensity of use, and the factors affecting each decision may be different (Gebremedhin and Swinton, 2003), as assumed in this research. In this case, it is more suitable to apply a 'double-hurdle' model in which a Probit regression on adoption (using all observations) is followed by a truncated regression on the non-zero observations (Cragg, 1971). The other problem with Tobit model is that it attributes the censoring to a standard corner solution thereby imposing the assumption that non-adoption is attributable to economic factors alone (Cragg, 1971).

The double-hurdle model can overcome these shortfalls of Tobit. The double-hurdle 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 the technology (Greene, 2007; Gebremedhin and Swinton, 2003). The double-hurdle model is applied in such a way that, both hurdles (the decision for adoption and extent of adoption) have equations associated with them, incorporating the effects of farmer's characteristics and circumstances. Such explanatory variables may appear in both equations or in either of the two. Most importantly, a variable appearing in both equations may have opposite effects in the two equations (Moffat, 2005). The double-hurdle model allows for the possibility that the two decisions are affected by a different set of variables.

Whether a Tobit or a Double-Hurdle model is more appropriate, can be determined by separately running the Tobit and the Double-Hurdle models and then conducting a likelihood ratio test that compares the Tobit with the sum of the log likelihood functions of the Probit and truncated regression models (Greene, 2007). This test has been done by several researchers (Gebremedhin and Swinton, 2003; Moffat, 2005; Espineira, 2006; Teklewold *et al*., 2006), and the test results revealed the superiority of the Double-hurdle model over the Tobit. Similarly in this study, the likelihood ratio test favoured the double-hurdle model over Tobit (Appendix III). Hence, double-hurdle model was used to estimate the decision of farmers to adopt AI technology and the extent of adoption.

The double-hurdle, originally by Cragg (1971), assumes that households make two sequential decisions with regard to adopting and extent of use of a technology. Each hurdle is conditioned by the household's socio-economic characteristics. In the double-hurdle model, a different latent variable is used to model each decision process (Olwande *et al*., 2009).

3.4.3 Data Analysis

Objective 1

This objective was analyzed using descriptive statistics. This involved the use of percentages, means and standard deviations. Standard *t*-test and *chi*-square test were used to compare differences in characteristics between adopters and non-adopters.

Objective 2

The first hurdle is an adoption equation estimated with a Probit model. The Probit model represents the probability of a limit observation, which is given by the following equation (Olwande *et al*., 2009).

$$\left.\begin{aligned} D_i &= 1 \; if \; D_i^* > 0, \\ D_i &= 0 \; if \; D_i^* \leq 0 \end{aligned}\right\} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (\mathbf{6})$$

$$D_i^* = \alpha' Z_i + u_i$$

Where,

D_i^* = The latent variable that takes the value of 1 if the farmer adopts AI technology and 0 otherwise

Z_i= Vector of household characteristics that affect the adoption of AI technology

α = Vector of parameters

u_i = The standard error term *i*= 1, 2…n. (n is the number of observation)

The dependent variable of the econometric model for this objective was farmers' decision to adopt AI technology. Its value is either 0 or 1; that is those farmers who used the technology were given value of 1, and 0 otherwise. Based on literature reviews and the discussions held with stakeholders, the explanatory variables selected for this study were broadly categorized under demographic, socio-economic and institutional factors. A brief description of the explanatory variables selected for this study and their likely influence on adoption of AI are presented in Table 2.

Table 2: Variables and their measurement as used in the Probit model

Variables	Type of variable	Measurement of the Variables	Expected Sign
Dependent Variable			
Decision to Adopt AI or not (ADAI)	Dummy	1 for those who have used AI 0 otherwise	
Independent Variables			
Distance from AI station (DISTAS)	Continuous	Walking hours from home	-
Access to credit (ACRDT)	Dummy	1 for those who have access 0 otherwise	+
Extension visits (EXTN)	Continuous	Number of extension visits per year	+
Age of the household head (AGHHH)	Continuous	Number of years	+/-
Education level of household head (EDUC)	Continuous	Number of years spent in school	+
Gender of household head (GEND)	Dummy	1 for male and 0 otherwise	+/-
Family size (FMSZ)	Continuous	Number of family members living together	+
Experience with exotic/cross breeds (EXPCRS)	Continuous	Number of years	+
Livestock owned (TLU)	Continuous	Tropical livestock units	+
Land size (LNDS)	Continuous	Land owned in hectares	+
Feeding concentrate-feeds to cattle (CONCFD)	Dummy	1 for those who feed concentrates 0 otherwise	+
Income from milk and its product sales (INCMLK)	Continuous	Monthly income from milk product sales in Birr	+
Off-farm income (OFRM)	Dummy	1 for those with additional income 0 otherwise	+
Access to exotic/crossbred bull (ACBUL)	Dummy	1 for those with access 0 otherwise	-
Membership in Dairy Cooperatives (MDCOP)	Dummy	1 for members 0 otherwise	+

Objective 3

The second hurdle of double-hurdle model involves an outcome equation, which uses a truncated model to determine the extent of adoption of the technology in question (Olwande *et al*., 2009). This second hurdle uses observations only from those respondents who indicated a positive value of use of AI. The truncated model, which closely resembles the Tobit model, is expressed as:

$$\left.\begin{array}{c} Y_i = Y_i^* \; if \; Y_i^* > 0 \; and \; D_i^* > 0 \\ Y_i = 0 \;\; otherwise \\ Y_i^* = \beta' X_i + v_i \end{array}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where,

Y_i = the observed response on the proportion of calves born using AI technology

X_i= is vector of explanatory variables hypothesized to influence the extent of AI use

β is a vector of parameter and

v_i is the standard error term

The error terms, are distributed as follows:

$$\left\{\begin{array}{l} u_i \backsim N(0,1) \\ v_i \;\backsim N(0,\sigma^2) \end{array}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The error terms u_i and v_i are usually assumed to be independently and normally distributed. It is assumed that for each respondent the decision whether to adopt the technology and the decision about the adoption level are made independently.

And, finally, the observed variable in a double-hurdle model is:

$$Y_i = D_i Y_i^* \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The Log likelihood function for the Double-Hurdle model is given by:

$$Log\ L = \sum_{0} ln\left[1 - \Phi\alpha \mathrm{Z_i}\left(\frac{\beta X_i'}{\sigma}\right)\right] + \sum_{+} ln\left[\Phi\alpha Z_i \frac{1}{\sigma}\phi\left(\frac{Y_i - \beta X_i'}{\sigma}\right)\right] \ldots\ldots\ldots\ldots\ldots (10)$$

Where **Φ** denotes the standard normal CDF (Univariate or Multivariate) and ϕ is the univariate standard normal PDF. Z_i, X_i, β, α, σ as defined earlier (Moffat, 2005).

The dependent variable of the econometric model for this objective was the extent of use of AI technology; which was measured as the proportion of calves born using AI out of the total calves born within the past two years. The explanatory variables selected for this objective were broadly categorized under demographic, socio-economic and institutional factors. A brief description of the explanatory variables selected for this study and their likely influence on the extent of adoption of AI are presented in Table 3.

Table 3: Variables and their measurement as used in truncated regression model

Variables	Type of variable	Measurement of the Variables	Expected Sign
Dependent Variable			
Proportion of cattle bred with AI (PCAI)	Continuous	Number of calves born using AI out of total calves	
Independent Variables			
Distance from AI station (DISTAS)	Continuous	Walking hours from home	-
Access to credit (ACRDT)	Dummy	1 for those who have access 0 otherwise	+
Extension visits (EXTN)	Continuous	Number of extension visits per year	+
Age of household head (AGHHH)	Continuous	Number of years	+/-
Education level of household head (EDUC)	Continuous	Number of years spent in school	+
Gender of household head (GEND)	Dummy	1 for male and 0 otherwise	+/-
Family size (FMSZ)	Continuous	Number of family members living together	+
Experience with exotic/cross breeds (EXPCRS)	Continuous	Number of years	+
Livestock owned (TLU)	Continuous	Tropical livestock units	+/-
Land size (LNDS)	Continuous	Land owned in hectares	+
Feeding concentrate-feeds to cattle (CONCFD)	Dummy	1 for those who feed concentrates 0 otherwise	+
Income from milk and its product sales (INCMLK)	Continuous	Monthly income from milk product sales Birr	+
Off-farm income (OFRM)	Dummy	1 for those with additional income 0 otherwise	+/-
Access to exotic/crossbred bull (ACBUL)	Dummy	1 for those with access	-
Membership in Dairy Cooperatives (MDCOP)	Dummy	1 for members 0 otherwise	+
Effectiveness of the AI service (AIQLTY)	Dummy	1 if effective 0 otherwise	+
Years of using AI (YRADPT)	Dummy	Number of years since the farmer adopted AI	+

3.5 Definition of Variables included in Models and their Expected Effects

Based on the literature review and the discussions held with stakeholders, the explanatory variables selected for this study and their hypothesized influence on probability and extent of adoption of Artificial Insemination technology are presented as follows.

Age of the household head (AGHHH): This is a continuous variable measured in years. It was expected to affect the probability and extent of AI adoption either positively or negatively. Through time, household heads acquire experience in farming and/or technology use. Moreover, older farmers may accumulate more wealth than younger ones and therefore, influence the dependent variables positively. In contrast, older farmers are more risk averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies. Hence, farmer's age may negatively influence both the decision to adopt and extent of adoption. Therefore, the effect of age of household head on adoption and extent of adoption of AI may be indeterminate *a priori*.

Total family size (FMSZ): This is a continuous variable measured by the number of family members and was expected to affect the decision to adopt and extent of adoption of AI technology positively. Total household size is the source of labour in the rural households; more family member means that proportionally, the number of active working group in that household is expected to be high and therefore, there is a possibility of having more alternative sources of income to use the technology in question.

Education level (EDUC): This is a continuous variable measured by the number of years the household head has spent in formal schooling at the time the survey was completed. Education augments one's ability to receive, decode, and understand information relevant to making innovative decisions (Wozniak, 1984). Therefore, education level of a household head was expected to influence adoption and use of AI positively.

Gender of the household head (GEND): This is a dummy variable in the model, which takes a value of 1 if the household head is male and 0, if the household head is female. Gender differentials can be related to access and utilization of a technology and indeed, one may expect that female-headed households are less experienced and hence will not use AI technology intensively because they know little about the consequences of this technology. The opposite expectation may be that, female-headed households tend to be more concerned for the family than male-headed ones. This may arise from the fact that females are more responsible for child care and home management, and are more concerned about the possible desirable consequences arising from using technology. Therefore, it was expected that the gender of the household head would have either a positive or a negative impact on the adoption and intensity of adoption of AI technology.

Total landholdings (LNDS): It is a continuous variable expressed in terms of hectares of total land owned including both cultivated and grassland. Land ownership is an indicator of wealth and social status within a community. It was expected to have a positive effect on farmers' decision to use AI and extent of utilization. As the size of the land owned increases, the likelihood of the household to produce more and get high income would increase and this in turn enhances the chances of adopting new technology. Possession of large land size helps the farmers to allocate some part the land for growing different grasses for their livestock. In addition, farmers with large land size are likely to cultivate more and collect more crop residues which can be used as feed for their livestock.

Livestock ownership (TLU): This refers to the total number of livestock measured in Tropical Livestock Unit. Based on Makeham and Malcolm (1986) standard conversion factors, the livestock population number was converted into Tropical Livestock Unit (see appendix I). The livestock owned by farm household is considered as a proxy indicator of wealth. Households that own larger number of livestock are relatively rich as compared to those who own less number of livestock. Farmers with larger herd size are assumed to have more cash and thus the variable was expected to positively influence adoption and extent of adoption of AI technology.

Off-farm income (OFRM): Additional income earned from outside agricultural activities increases the farmers' financial capacity and expected to increase the probability of investing on new technologies. The variable is a dummy variable taking the value of 1 if the farmer has income source outside of agricultural activities, 0 otherwise. Hence, this variable was hypothesized to affect adoption and intensity of use AI positively.

Experience in keeping crossbred/exotic cattle (EXPCRS): This is the number of years a household has been keeping crossbred/exotic cattle. Farmers, who have more experience in keeping crossbred cattle, develop a skill on how to manage these cattle and have seen the advantages of keeping these over local breeds compared to less experienced or inexperienced ones. Therefore, experience in keeping crossbred cattle was expected to have positive relation with decision to adopt AI technology and extent of adoption.

Contact with development agents (EXTN): This is a continuous variable measured by the number of days per year an extension agent had visited the farmer during the past one year. The higher the linkage between farmers and development agents, the more the information flow and the technological (knowledge) transfer from the latter to the former. Here, the frequency of contact between the extension agent and the farmers was hypothesised to be the potential force which accelerates the effective dissemination of adequate agricultural information to the farmers, thereby enhancing farmers' decision to adopt new technologies. Thus, those farmers who had frequent contacts with development agents were expected to use AI technology, as opposed to those who had no or few contacts.

Distance from AI station (DISTAS): This is measured in terms of the walking hours required to travel from the respondent's residence to the nearest AI station. Farmers residing near the AI station have a location advantage and can take their cows to get the service more easily and frequently than those who live in more distant locations. Therefore, location advantage was expected to increase the adoption and extent of adoption of AI.

Income from milk sales (INCMLK): This refers to monthly income in Birr obtained from sales of milk and milk products. Since farmers are rational producers, the income they earn from previous milk sale initiates them to produce more milk by adopting the suitable technology and hence earn more. Moreover, the amount of income left from consumption could be used to utilize the available technology. Therefore, a household with better income from milk sales was expected to have higher chances of adopting AI technology.

Feeding concentrates to cattle (CONCFD): This is a dummy variable which takes a value of 1 if a farmer uses concentrate feeds for cattle or 0, otherwise. In order to make use of technologies, farmers should be able to get what the output of the technology requires. That is, since crossbred animals need more feeds to provide high yield, farmers who feed their cows with concentrate feeds are more likely to adopt AI technology than those without. Thus, this variable was hypothesized to affect adoption and intensity of adoption of AI positively.

Access to credit (ACRDT): This is a dummy variable, which indicates whether the farmer has access to credit or not. Adoption and utilization of AI technology requires certain amount of capital as the crossbred cattle born with this technology need more feeds and management. The availability of farm credit especially from formal sources becomes a vital component of the modernization of agriculture and to improve the wealth status of farmers. Hence, credit was hypothesized to influence adoption of AI technology positively.

Membership in dairy cooperatives (MDCOP): Belonging to an association or cooperative as member can influence farmer's decision to adopt an improved technology. In most farming communities farmers form or join associations or cooperatives of various kinds for all sorts of reasons. Service cooperatives are more likely to be aware of new practices as they are easily exposed to information. Moreover, farmers may use the membership opportunity to sell their milk and milk products, and this causes them to adopt the AI technology which helps them produce more milk. This is a dummy variable which takes a value of 1 if the farmer is member in a dairy cooperative or 0, otherwise.

Access to crossbred/exotic Bull (ACBUL): Bull service is one way of getting crossbred cattle in rural areas especially where access to AI service is limited either because of distance or because of absence of infrastructures. Farmers who have access to both AI and crossbred bull services have two alternatives and hence, can choose between the two as compared to those who have only one choice. Therefore, the availability of crossbred/exotic bull service was hypothesized to negatively affect the use and intensity of use of AI technology. The variable takes the value of 1 if farmers have access to crossbred/exotic bull, 0 otherwise.

Years of using AI (YRADPT): This variable only considers those farmers who have already adopted AI and hence affects only the extent of adoption. It is a continuous variable measured by the number of years since the farmer has started using AI technology. Farmers who have more experience of using AI service are more likely to use it intensively as compared to those with less experience of using it. Therefore, the variable was hypothesized to affect extent of adoption positively.

Effectiveness of the AI service (AIQLTY): This measures the quality of the AI technology when compared to the bull services. This variable is included only on the second dependent variable as it considers farmers who have already used the technology. It is a dummy variable which takes the value of 1 if the technology is considered as effective, and 0 otherwise. In this study AI technology is considered as effective if the cows served with AI in the past two years conceived in one or two services. And it is considered as ineffective if the cows served with AI conceived in more than two services or failed to conceive. This variable indirectly takes in to account the efficiency of the AI inseminators and the quality of the semen used for insemination; although the heat detection ability and timing of the farmer also affects the quality of the service. Therefore, the relationship between effectiveness of AI and the extent of AI adoption was hypothesized to be positive.

3.6 Preparation of Variables in the Empirical Model

3.6.1 Multicollinearity Test

Before running the econometric analysis, hypothesized explanatory variables were checked for problems of multicollinearity. Multicollinearity problem arises when some or all of the explanatory variables have perfect or exact linear relationship (Gujarati, 2004). The existence of multicollinearity might cause the estimated regression coefficients to have the wrong signs and smaller *t*-ratios that might lead to drawing the wrong conclusions. Therefore, it is important to check whether serious problems of multicollinearity existed among and between the potential continuous and dummy explanatory variables, of the model estimation.

Following Gujarati (2004), the problem of multicollinearity for continuous explanatory variables was assessed using a technique of variance inflation factor (VIF) and Tolerance Level (TOL), where each continuous explanatory variable is regressed on all the other continuous explanatory variables and coefficient of determination is computed. The measure of multicollinearity associated with variance inflation factor is defined as:

$$VIF(X_i) = (1 - R_i^2)^{-1} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (11)$$

Where R_i^2 is the coefficient of determination when the variable X_i is regressed on the other explanatory variables

$$TOL(X_i) = (1 - R_i^2) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (12)$$

As R_i^2 increases toward unity, that is, as the collinearity of one regressor with the other regressors increases, VIF also increases. The larger the value of VIF, the more collinear is the variable X_i. As a rule of thumb, if the VIF of a variable exceeds 10, which will happen if R_i^2 exceeds 0.90, that variable is said be highly collinear. Similarly, TOL approaches to 1 when the variable is not correlated with others. In this study, the values of VIF were less than 10, and hence no signals of multicollinearity problems (Table 4).

Table 4: Variance inflation factor of continuous explanatory variables

Variable	VIF	TOL
Total land size	2.20	0.455
Tropical Livestock Unit	1.92	0.522
Age of household head	1.84	0.544
Family size	1.39	0.719
Education level	1.39	0.722
Experience with crossbred	1.28	0.781
Income from milk product sales	1.27	0.788
Distance from AI station	1.22	0.820
Extension visits per year	1.16	0.864

In order to see the degree of association between dummy explanatory variables, contingency coefficients were computed. Contingency coefficient is a *chi*-square based measure of association which assumes a value between 0 and 1 (Healy, 1999). The contingency coefficient is computed as follows:

$$C = \sqrt{\frac{\chi^2}{N + \chi^2}} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \quad (13)$$

Where C = Coefficient of contingency, χ^2 = *Chi*-square random test and N = total sample size.

The decision rule for contingency coefficients states that a value of 0.75 or above indicates a stronger relationship between explanatory variables (Healy, 1999). This was also checked and was found to be less than 0.75 (Table 5).

Table 5: Contingency coefficients of dummy explanatory variables

	GEND	OFRM	CONCFD	ACRDT	MDCOP	ACBUL	AIQLTY
GEND		0.018	0.012	0.008	0.054	0.021	0.168
OFRM			0.247	0.188	0.283	0.021	0.220
CONCFD				0.077	0.142	0.035	0.141
ACRDT					0.040	0.054	0.169
MDCOP						0.054	0.109
ACBUL							0.000

Based on the VIF and contingency coefficient results, the data were found to have no serious problem of multicollinearity, therefore, the continuous and dummy explanatory variables were retained in the model.

3.6.2 Heteroscedasticity

One of the assumptions in regression analysis is that the errors terms have a constant variance. However, if the error terms do not have a constant variance, then they are heteroscedastic (Maddala, 1992). In cases of existence of heteroscedasticity, though the estimated parameters of a regression are consistent, they are inefficient. Therefore, in this study to avoid heteroscedasticity problem, robust standard error was estimated.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results from the descriptive and econometric analyses. The descriptive analysis made use of such tools as percentage, mean and standard deviation. In addition, the *t* and *chi*-square statistics were employed to compare adopters and non-adopters with respect to some explanatory variables. Econometric analysis was carried out to identify the most important factors that affect the probability and extent of adoption of artificial insemination technology.

4.1 Descriptive Results

4.1.1 Socio-economic and Institutional Characteristics of Adopters and non-Adopters

The socio-economic and institutional characteristics of adopter and non-adopter farmers are presented in two tables: Table 6 and Table 7. Table 6 describes continuous variables while Table 7 describes discrete variables.

A comparison of means was done for continuous variables affecting the two groups. Out of the nine continuous institutional and socio-economic characteristics considered, five were found to be significant at 5 percent significance level. These were education level, experience in keeping crossbred cattle, extension visits per year, distance of farmers' residence from AI station and income earned from milk and milk product sales. The hypothesis that socio-economic and institutional characteristics between adopters and non-adopters are not different was rejected in these cases since *t* calculated was greater than *t* critical, as presented in Table 6.

Table 6: Socio-economic and institutional characteristics of AI adopters and non-adopters for continuous variables

Characteristics	Adopters (N=98)		Non-adopters (N=98)		t-value	P-value	Total sample (N=196)	
	Mean	Std. D	Mean	Std. D			Mean	Std. D
Age of household head	45.04	12.35	45.54	14.51	0.260	0.795	45.29	13.44
Family size	6.51	2.42	6.89	3.02	0.965	0.336	6.70	2.74
Education level	5.21	3.91	3.54	3.29	-3.245	0.001***	4.38	3.70
Total land size	3.34	2.58	3.43	2.48	0.241	0.810	3.38	2.53
Tropical livestock unit	11.75	5.76	11.42	8.10	-0.323	0.747	11.59	7.01
Experience in crossbred cattle	7.95	5.63	4.98	5.12	-3.864	0.000***	6.46	5.57
Extension contacts	2.98	1.96	1.79	1.30	-5.016	0.000***	2.38	1.77
Distance from AI station	0.87	0.54	1.61	1.03	6.296	0.000***	1.24	0.90
Income from milk	972.02	756.88	480.61	593.86	-5.057	0.000***	726.31	721.85

*, ** and *** show significance at 10, 5 and 1 percent respectively.

The level of education attained by the household head showed that on average, AI users had spent a longer period of time in school (5.21 years) than non-users who spent 3.54 years. There was a significant difference between the average years of schooling of the two groups at 1 percent significance level. Successful breeding of animals using AI involves knowledge of record keeping, observation for signs of heat which requires a minimum level of education. Education increases the farmers' capacity to comprehend technical recommendations that require a certain level of literacy or numeracy. Tambi *et al*. (1999) reported similar results.

Farmers who keep crossbred cattle are in better position to evaluate the advantage of keeping these over local breeds. The most common crossbred cattle were those bred with Holstein Friesian. On average, the experience of the household heads in keeping crossbred cattle for all the respondents was 6.46 years, while independently the average years of experience; were 7.95 and 4.98 for adopters and non-adopters respectively. This difference between adopters and non-adopters was significant at 1 percent level.

The mean number of extension visits per year for the whole sample was 2.38 times for the year 2012/13, the minimum number of visits being 0 and the maximum 10. The adopter farmers were on average visited 2.98 times, whereas the non-adopter farmers were contacted 1.79 times during the same period. This difference was significant at 1 percent probability level. Similar results were found by Mignouna *et al*. (2011), where the adopters of Imazapyr-resistant maize technology had significantly higher contact with extension visits than non-adopters. Nkonya (1997) and Enki *et al*. (2001) also reported similar results.

The distance in hours that the farmers travelled on foot to get to the nearest AI station was assessed. Farmers living near the AI station have a location advantage and can contact the service providers more easily and frequently than those who live in more distant locations. In line with this, the average time required to reach the nearest AI station was 0.87 hours for adopters and 1.61 hours for non-adopters. The nearest and the farthest farmers needed to walk for 0.15 and 4 hours respectively to get to the AI station while the average distance for the whole sample was 1.24 walking hours. This means that non-users have to spend more time and money to get to a technician thus making the service less accessible and more expensive. The mean difference between the distances covered by adopters and non-adopters was statistically significant at 1 percent level of probability. The study result is in agreement with the results of Murage and Ilatsia (2011).

Livestock production, crop production and off-farm activities were important income sources for the sampled dairy farmers. The average pooled monthly income earned from milk and milk products sales was 726.31 Birr. On average, adopters of AI reaped more cash from milk product sales (972.02 Birr) than non-adopters (480.71 Birr). The mean difference between the two groups was significant at 1 percent probability level. This study conforms to the findings of Foti *et al*. (2008) in which the proportion of income earned from livestock was higher for adopters of the selected soil fertility and water management technology than for non-adopters.

A summary of socio-economic and institutional characteristics for dummy variables of the AI users and non-users is presented in Table 7. The *chi*-square test results revealed that off-farm income, access to credit facility, membership in dairy cooperatives and feeding cattle with concentrate feeds were significant at 1 percent level of probability. Hence, the null hypothesis that socio-economic and institutional characteristics between adopters and non-adopters are not different was rejected at 5 percent significance level.

Table 7: Socio-economic and institutional characteristics of adopters and non-adopters for dummy variables

Characteristics	Adopters (N=98)		Non-adopters (N=98)		χ^2 value	P-value	Total sample (N=196)	
	No.	Percent	No.	Percent			No.	Percent
Gender								
Female	5	5.10	7	7.14			12	6.1
Male	93	94.90	91	92.86	0.355	0.551	184	93.9
Off-farm income								
No	50	51.02	87	88.78			137	69.9
Yes	48	48.98	11	11.22	33.196	0.000***	59	30.1
Feeding concentrates								
No	21	21.43	56	57.14			77	39.3
Yes	77	78.57	42	42.86	26.203	0.000***	119	60.7
Credit access								
No	30	30.61	65	66.33			95	48.5
Yes	68	69.39	33	33.67	25.023	0.000***	101	51.5
Dairy Cooperative member								
No	57	58.16	88	89.80			145	74.0
Yes	41	41.84	10	10.20	25.471	0.000***	51	26.0
Access to crossbred bull								
No	21	21.43	18	18.37			39	19.9
Yes	77	78.57	80	81.63	0.288	0.591	157	80.1

*, ** and *** show significance at 10, 5 and 1 percent respectively.

During slack periods, farmers earn additional income by engaging in various off-farm activities. This raises their financial position to acquire new inputs. Therefore, in this study, it was hypothesized that there is a positive correlation between the amount of off-farm income and the level of adoption of AI technology. About 30.1 percent of the household heads reported that at least one of their family members was engaged in off-farm activities, which helped them to earn additional income. Nearly half of the adopter households (48.98 percent) had additional income from non-farm activities as compared to about 11.22 percent of non-adopters. The *Chi*-square test indicated a systematic association between adoption of AI technology and off-farm income at 1 percent level of significance. The result is in agreement with the finding of Mal *et al*. (2012).

Access to credit is one way of improving farmers' access to new production technology as it increases the farmers' economy to purchase improved breeds of cattle, improved forages and concentrate feeds, fertilizer and other inputs. The result presented in Table 7 indicates that, among adopters 69.39 percent had access to credit services and 30.61 percent had no access. On the other hand, about 33.67 percent of non-adopters had access to credit and 66.33 percent had not. Hence, there is a significant difference between adopters and non-adopters with regard to access to credit services at 1 percent level of significance. Farmers without cash and no access to credit will be disadvantaged in adopting new technologies, hence supporting the findings of Kaaya *et al*. (2005) and Simtowe and Zeller (2007).

Feed is an important factor farmers consider before accepting technologies related to livestock production (Mekonnen, H. *et al*., 2010). While most farmers use crop residues in addition to the common free grazing, some dairy farmers give additional concentrate feeds to boost the production and maintain the condition of their cows. The common concentrate feeds in the area were residue from lentil oil factory (*fagulo*), brewery residue (*atela*), wheat-bran, molasses and mineral salt (*amole-chewu*). In this study, about 78.57 percent of households who adopted AI technology had used concentrates to feed their cows while only 42.86 percent of the non-adopters had fed their cows with concentrates. The Pearson *chi*-square test indicated that there is a systematic association between adoption of AI and feeding concentrates to cows. Kaaya *et al*. (2005) found similar results where providing supplementary concentrate feeds to cows significantly discriminated between users and non-users of AI technology in Uganda.

Participation in an organization is expected to have an indirect influence on the adoption behaviour of farmers as it exposes them towards innovative ideas and practices. Dairy cooperative group is one of farmers' association groups that were expected to have significant relationship with adoption of AI as farmers may use the union to find market for their produces. The only dairy cooperative unions in the area are Bekoji dairy cooperative and Lemu-Ariya dairy cooperative. The result in Table 7 indicates that 26 percent of the total sampled households were members of the dairy cooperatives while 74 percent were not members. Nearly 42 percent of AI adopters were members of dairy cooperative union where as only about 10 percent of the non-adopters were members in dairy cooperative. The result revealed that there is significant relationship between membership in dairy cooperative and the adoption of artificial insemination technology at 1 percent level. Similar results were reported by Mignouna *et al*. (2011) and Kaaya *et al*. (2005).

4.2 Empirical Results

The two stages of the double-hurdle model were run separately as Probit and truncated regression. The parameter estimates of the Probit and truncated regression models employed to identify factors influencing a farmer's decision about adopting artificial insemination technology and its extent of adoption are presented in Table 8 and 9, respectively. Results of the analyses revealed that the probability of adoption and extent of adoption of AI were influenced by different factors and at different levels of significance for different factors. The discussion of the results about the significant variables is presented as follows.

4.2.1 Factors Determining the Probability of Adoption of Artificial Insemination

The determinants of probability of adoption were identified through a Probit model, which is the first stage or Tier 1 of Cragg's double-hurdle model. The Probit results presented in Table 8 revealed that out of the 15 explanatory variables considered in the model, 9 were found to significantly influence the probability of adopting artificial insemination. The log likelihood estimates of the Probit regression model indicated that off-farm income (OFRM), family size (FMSZ), feeding concentrates to cows (CONCFD), contacts with extension agents (EXTN), credit access (ACRDT), distance from AI station (DISTAS), income from milk sales (INCMLK), membership in dairy cooperative (MDCOP) and access to crossbred bull (ACBUL) were important factors influencing the decision of smallholder dairy farmers to adopt AI technology. The marginal effects of the Probit model show changes in the probability of adoption of AI for additional unit increase in the continuous independent variables and for the change from 0 to 1 for dummy variables.

Table 8: Probit model estimates of the determinants of probability of AI adoption

ADAI	Marginal Effects	Robust Std. Error	Z	P>z
Gender of household head	-0.0237	0.5151	-0.12	0.908
Age of household head	-0.0031	0.0118	-0.65	0.513
Family size	-0.0499	0.0506	-2.48	0.013**
Education level	-0.0010	0.0403	-0.06	0.949
Total landholding	0.0261	0.0712	0.92	0.357
Total livestock owned	-0.0056	0.0253	-0.56	0.577
Off-farm income	0.3160	0.2960	2.83	0.005***
Experience with crossbred cattle	0.0145	0.0262	1.39	0.164
Feeding concentrates to cattle	0.3998	0.2605	4.03	0.000***
Extension visits per year	0.0674	0.0792	2.14	0.032**
Distance from AI station	-0.2745	0.1582	-4.36	0.000***
Credit access	0.3410	0.2517	3.51	0.000***
Income from milk product sales	0.0002	0.0003	2.18	0.029**
Membership in dairy cooperative	0.2561	0.3284	2.04	0.041**
Access to exotic/crossbred bull	-0.2545	0.3031	-2.22	0.026**
Constant		0.7756	0.13	0.899
Number of observations		196		
Log likelihood		-68.859		
Wald chi2(15)		78.21		
Prob >chi2		0.000		

*, ** and *** show significance at 10, 5 and 1 percent respectively.

Earning off-farm income influenced the decision behaviour of farm households to adopt artificial insemination positively at 1 percent level of significance. Farmers who were earning income from off-farm activities had 31.6 percent more probability of adopting AI than farmers without off-farm income, *ceteris paribus*. Theoretically, off-farm income can help to overcome a working capital constraint or may even finance the purchase of a fixed investment type of innovation. The result implies that households with off-farm income have a higher potential of becoming adopters, thus they are more likely to pass through the first hurdle than those with no off farm-income. Empirical evidence of similar findings has been reported by Feder *et al*. (1985), and Mal *et al*. (2012).

Contrary to the expectations, family size had a negative and significant influence on adoption of AI at 5 percent level. The marginal effect of family size implies that an increase in number of family size by one member is associated with a decrease in the probability of household head's decision to adopt AI by about 5 percent, having other variables held constant. The negative sign implies that the more the number of family members, the less will be the probability of using AI. The possible explanation is that, due to the subsistence nature of the farmers they would rather spend the little they get on dependants than on new technology. Though the result disagrees with some (Asfaw *et al*., 2011; Idrisa *et al*., 2012), it is consistent with the results of Aksoy *et al*. (2011) and Simtowe and Zeller (2007).

The positive coefficient of concentrate feed in the adoption equation supports the hypothesis that farmers who have already practiced provision of additional concentrate feed are more likely to adopt AI technology. The positive effect of concentrate feeds suggested that farmers who feed their cows with supplementary feeds have 40 percent higher probability of AI adoption than those who do not. The introduction of complementary practices enhances the adoption and diffusion of the introduced technological innovation (Teklewold *et al*., 2006). Adopting AI technology to get improved dairy breeds and the practice of feeding concentrates together provides synergistic benefits as crossbred cows have larger responses to supplementary feeding. The results are similar with the findings of Kaaya *et al*. (2005) and Tambi *et al*. (1999).

Access to extension services had the expected positive and significant effect at less than 5 percent significance level on probability of adoption of AI. It can be derived that *ceteris paribus*, for each additional extension visit a farmer received, the probability of using AI was higher by 6.74 percent. Extension as a source of agricultural information has been reported to increase adoption and use of new agricultural technologies (Feder *et al*., 1985). Extension contact determines the information that farmers obtain on production activities and the procedures of cattle breeding using AI. The effect of exposure to extension programmes is enormous. For instance, Teklewold *et al*. (2006) found that farmers who had access to extension contact adopted poultry technologies 31 percent greater thhan farmers who did not get contact with extension agents. This could be due to increased farmers' interaction with development agents in the form of multiple visits, and technical support to farmers increases farmers' knowledge of the available technologies and their potential benefits. The result agrees with the findings of adoption studies in Nigeria (Idrisa *et al*., 2012), Uganda (Kaaya *et al*., 2005) and Tanzania (Nkonya *et al*., 1997).

Access to credit services influenced the probability of AI adoption positively and significantly at 1 percent significance level due to access to finance for this technology. Agricultural credit services are the major sources for improved agricultural technologies to solve financial constraints. If farmers can get access to credit, they can purchase improved technologies. According to the results, relative to farmers who face credit constraint, farmers who have access to credit were about 34.1 percent more likely to adopt AI technology. Since using AI results in more demanding breeds; farmers would need to plant forages, buy concentrate supplements and get more feeds either from crop residues or hay. These activities require funds which force the farmers to take credit. The finding that credit significantly increases the likelihood of adoption is in line with *a priori* expectations and concurs with findings from a number of studies; for instance, Feder *et al*. (1985); Teklewold *et al*. (2006); Simtowe and Zeller (2007); Idrisa *et al*. (2012); Mal *et al*. (2012) which have shown that the lack of access to credit significantly inhibits the adoption of high yielding varieties even when fixed pecuniary costs are not large.

The coefficient of distance to AI station had the expected negative sign and significant effect on the probability of AI use. Result in Table 8 revealed that, holding other factors constant, the probability of adopting artificial insemination reduced by 27.45 percent for a further walking distance of one hour to the AI station. This clearly indicates the importance of proximity to the source of technology. Proximity to source of technology such as AI station can be an important factor in determining the likelihood of adoption, especially in developing countries where linkage to extension services is weak (Idrisa *et al*., 2012). Farmers that are close to sources of improved technologies take the advantage of their proximity and tend to adopt the innovations compared to farmers that are far away. With particular reference to the study area, poor road network coupled with difficult terrain make movement difficult thus inhibiting communication and accessibility of farmers to the technology. The result is in agreement with the findings of Murage and Ilatsia (2011) in which distance from AI inseminator significantly affected breeding services in Central Kenya.

The monthly income earned from milk and milk product sales had a significant and positive influence on the decision of smallholder dairy farmers to adopt AI. When all other factors are held constant; an increase in monthly income from sale of milk products by 100 Birr is associated with an increase in the probability that a dairy farmer would adopt AI by 2 percent. This is plausible as earning income from milk product sales strengthens the financial capacity of the farmers so that they have more disposable income to buy the necessities for the crossbred animals such as supplementary feeds and grass land, and are willing to adopt AI services. Thus, the higher the amount of milk produced and sold from the farm, the higher the probability of using AI. Previous studies have also indicated the positive influence of farm income on adoption and use of new agricultural innovations (Feder *et al*., 1985; Kaaya *et al*., 2005).

Membership in dairy cooperative significantly and positively influenced the likelihood of AI adoption by smallholder dairy farmers. For a discrete change in this dummy variable from 0 to 1, the probability of AI adoption was higher by 25.61 percent. The dairy cooperatives buy milk from the member farmers and as such they have the guarantee of the market. Milk being perishable product; unless there is assured market, farmers do not invest in producing more milk by adopting AI. However, cooperatives make them eager to get the breeds which can produce more milk by adopting AI. The study result is consistent with the finding of Beshir *et al*. (2012) in which household's membership in farmers' organization significantly increased the likelihood that the farmer would adopt inorganic fertilizer.

Access to crossbred bull was significant at 5 percent level and had negatively influenced the probability of adopting AI. The marginal effect of the result indicated that; *ceteris paribus*, dairy farmers who had access to crossbred bull service were 25.45 percent less likely to adopt AI technology than those without access. This result is logical because farmers who have access to bull services would prefer bull service over AI. Coupled with limited understanding (awareness) of farmers about the difference between the off-springs born with AI and bull; the lower cost of bull service and low success rates associated with AI made farmers to prefer bull services. Murage and Ilatsia (2011) reported similar results in their study in Kenya.

4.2.2 Factors Determining the Extent of use of Artificial Insemination

The extent of adoption was determined as proportion of calves born with artificial insemination given the total calves born within the past two years per household. The overall average extent of AI adoption in the study area was 0.28 (see appendix II). This means out of the total calves born for AI adopter households within the past two years, 28 percent were those conceived with AI.

The determinants of the extent of AI adoption were identified through a truncated regression model, which is the second stage or Tier 2 of Cragg's double-hurdle model. The results are presented in Table 9. The result of the truncated regression shows that a total of 17 explanatory variables were considered in the econometric model out of which, 8 were found to significantly affect the intensity of adopting artificial insemination. The log likelihood estimates of the truncated regression model indicated that education level (EDUC), years of experience in keeping crossbred cattle (EXPCRS), off-farm income (OFRM), access to crossbred bull (ACBUL), distance from AI station (DISTAS), membership in dairy cooperative (MDCOP), the quality/effectiveness of AI services (AIQLTY) and the years of using AI (YRADPT) were important factors influencing the extent of AI utilization by the smallholder dairy farmers in Lemu-Bilbilo district.

The level of education of the respondents as measured by the number of years spent in school was a very important factor that significantly influenced the extent of adoption of artificial insemination technology in the study area. The marginal effect shows that, conditional on adoption of AI, the extent of use increases by 1.93 percent for an additional year of schooling of a farmer. This positive relationship between level of education and extent of adoption of AI is plausible as education increases the capacity of farm households to acquire information and knowledge of improved technologies and promote the decision to use it on own farm. Educated farmers are more likely to be conversant with the associated negative effects of using bull service such as inbreeding and related diseases and therefore are more likely to use AI service. Similar results were reported by Aksoy *et al*. (2011) and Murage and Ilatsia (2011).

Table 9: Truncated regression model estimates of the determinants of extent of AI use

PCAI	Marginal Effects	Robust Std. Error	Z	P>z
Gender of household head	-0.1509	0.1069	-1.42	0.156
Age of household head	0.0015	0.0025	0.61	0.545
Family size	0.0151	0.0086	1.77	0.077*
Education level	0.0193	0.0060	3.25	0.001***
Total land holding	0.0050	0.0118	0.43	0.665
Total livestock owned	0.0007	0.0049	0.14	0.887
Off-farm income	0.0917	0.0460	2.02	0.043**
Experience with crossbred cattle	-0.0112	0.0038	-2.96	0.003***
Feeding concentrates to cattle	-0.0318	0.0531	-0.61	0.545
Extension visits per year	0.0212	0.0115	1.87	0.062*
Distance from AI station	-0.1443	0.0313	-4.66	0.000***
Credit access	0.0662	0.0433	1.55	0.121
Income from milk product sales	-0.0000	0.0000	-0.78	0.436
Membership in dairy cooperative	0.0947	0.0435	2.21	0.027**
Access to exotic/crossbred bull	-0.1476	0.0537	-2.77	0.006***
Years of using AI	-0.0102	0.0044	-2.37	0.018**
Effectiveness of AI technology	0.1170	0.0528	2.27	0.023**
_cons		0.1759	3.27	0.001***
/sigma		0.0125	15.05	0.000***
Number of observations		98		
Log likelihood		29.99		
Wald $\chi^2(17)$		174.64		
prob> χ^2		0.000		

*, ** and *** show significance at 10, 5 and 1 percent respectively.

Experience of keeping crossbred cattle in the past years had negative effect on the extent of adoption of AI. This variable was significant at 1 percent probability level. The result revealed that, keeping crossbred cattle for one more year is associated with a reduction in the proportion of calves born with AI by 1.12 percent. The implication of the inverse relationship is possibly due to the fact that farmers start to own their own crossbred bulls and hence prefer to use them rather than going for AI. Since the education level and knowledge of most farmers about breeding is limited, they consider the off-springs produced by the crossbred bulls and AI as the same. The result contradicts with the hypothesis and the findings of other researchers (Idrisa *et al*., 2012; Kaliba *et al*., 2000) as farming experience is mostly associated with the positive use of the technology in question. However, there are also findings which support this result (Mal *et al*., 2012; Kaaya *et al*., 2005).

The coefficient of earning income from off-farm activities is another factor that positively and significantly affected the extent of AI use by smallholder dairy farmers. On average, the proportion of calves born with AI for farmers who had off-farm income was higher by 9.17 percent as compared to those who did not have off-farm income. The possible explanation of this result is that off-farm income earned might solve the financial constraints to hire labour and to purchase inputs like livestock feeds. Having additional sources of income for smallholders could help them keep more crossbred cows as managing these breeds need more income than keeping local cows. This result supports the hypothesis and complies with the results obtained in the descriptive analysis. Similar results were obtained by Mwangi *et al*. (2004) where farmers with more income sources utilized AI technology in Bomet district of Kenya.

The negative influence of access to crossbred bull on the extent of AI adoption was significant at 1 percent level. The result, similar to in the case of first hurdle, implies that farmers who could easily access crossbred bulls were reluctant to use AI intensively as compared to those who did not have access to crossbred bull. The variable was significant at 1 percent, and on average the extent of AI utilization for farmers who had access to crossbred bull was lower by 14.76 percent than farmers who did not have access. In this case, since the respondents have already adopted the AI, it means they have owned crossbred cattle/bulls. Hence, they prefer using their own bulls instead of going for the poorly accessible AI technology and incurring costs besides the risks of the low conception rate associated with the technology. This translates to increased production costs to the farmer, a fact that makes most farmers resort to natural mating which is believed to have high success rates and more accessible. The result conforms to the findings of Mwangi *et al*. (2004) and Murage *et al*. (2006).

Distance from AI station had the expected negative sign and significant influence on the extent of utilization of AI technology by farmers. The negative sign of the coefficient implies that farmers who live closer to the source of technology are more likely to adopt the technology and are also more likely to use intensely compared to farmers who live farther away from the AI station. The marginal effect of distance from AI station on the extent of AI use was -0.144. The possible explanation for such trend is the level of risk which tends to increase with increase in distance to source of technology. That is, as the estrus time in cows lasts only for limited hours, for successful AI service farmers have to follow the heat signs and take the cows to the inseminators on time. Hence, since there are risk factors associated with using AI for farmers located at distant places; they prefer to use bull services. When studying the determinants of service use among rural households in Zambia, Wanmali and Jane (1995) found that services that were farthest from the household were least used.

Being member of dairy cooperative has been found to positively affect the extent of use of artificial insemination. The result indicated that; member of dairy cooperatives had 9.47 percent more proportion of calves born with AI than non-members. The dairy cooperatives, besides buying the produce of member farmers, serve to educate farmers about how they can keep and manage their cows and about the marketing of their produces. Interaction with different information sources and clubs helps farmers gather information and knowledge about breeding services and performance of the different breeds. Membership in dairy cooperatives in the study area mostly assured the market for their produce. Therefore, as compared to non-members, farmers who were members of dairy cooperatives used AI intensively to produce more milk by owning better breeds. A similar observation has been made by Mwangi *et al*. (2004) and Njoroge *et al*. (2004) who linked low usage of AI to farmers' difficulty in milk marketing.

The results revealed that; the quality of the AI service provided influenced the extent of AI use positively and significantly at less than 5 percent. On average, farmers who rated AI as effective service were associated with possessing 11.7 percent higher proportion of calves born with AI than those who rated it as ineffective. While the quality/effectiveness of AI service was measured by the number of services per conception; it depends on the ability of inseminators, quality of the semen, and heat detection ability and timing of the farmers. Repeats in insemination lead to delayed conception and calving, longer calving intervals, and loss of money in terms of unrealized sales from milk and in-calf heifers. This explains why the number of cows conceiving at the first service is a crucial variable for extent of use of AI. The result is in line with the findings of Kaaya *et al*. (2005) and Mwangi *et al*. (2004).

Contrary to the hypothesis made, the experience of using AI technology was negatively related to the extent of using the technology. As the number of years increase since a farmer started using AI, the extent of AI utilization declines. The result in Table 9 shows that, for every added year of experience in using AI, the extent of AI reduces by 1.02 percent. The probable reason given by Kaaya *et al*. (2005) for this negative relationship is that AI is more likely to be adopted on farms with unimproved cattle. Initially, farmers adopt and use AI for the purpose of improving their dairy cattle productivity and when such herds are improved to the farmers' satisfaction AI is only used for routine breeding. Such a farmer is likely to use natural service as it is less costly and readily available. In this case farmers with graded cattle herds were found to be more likely to use the bull instead of AI.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Different socio-economic characteristics of both categories of farmers (AI adopters and non-adopters) were determined. There was significant difference between the two categories of the farmers in terms of education level, off-farm income, membership in dairy cooperatives, contacts with extension agents, experience in keeping crossbreeds, feeding concentrates to cows, access to credit services, income from milk products sales and distance from AI station ($p<0.05$).

The interesting aspect of the econometric results is the distinct differences in explanatory variable effects between the two hurdles. Specifically, contacts with extension agents, access to credit, income from milk sales, feeding concentrates to cows and family size influenced the probability of adoption positively (except family size) without affecting the extent of adoption in the second hurdle. Education level of household head whereas had positive impact on the extent of AI use without affecting the probability of adoption.

Membership in dairy cooperatives and income from off-farm activities can be instrumental in AI adoption due to milk market guarantee and the strengthening of financial capacity from off-farm income. Farmers located at farther distances from AI station and those with access to crossbred bulls preferred to use bulls than AI.

5.2 Recommendation

Access to AI can be improved by expanding service giving stations in the district along with training more technicians. Private sector and NGOs have to be encouraged to involve in providing AI service as this can help improve technology dissemination. To enhance extension contact, integrated and participatory rural development strategies can be used. This can work because development agents create strong social and cultural links with the people they assist. Therefore, organizing regular in-service and on-job training, providing adequate incentives and remuneration as well as employing adequate number of development agents will be necessary conditions to change the farmers' attitude toward agricultural transformation.

Establishing more microfinance or any other credit providing institutions all over the district can help to expand credit access to dairy farmers. To ensure widely adoption of AI, it is also vital to establish more dairy cooperatives and strengthen the existing ones as they are sources of information besides serving as way of milk marketing for the farmers.

Farmers can be made to acquire more knowledge about AI technology and its difference with using bull services by establishing farmers training centres and through adult education. Rural development strategies should not only emphasize on increasing agricultural production but simultaneous attention should be given to promoting off-farm activities in the rural areas.

5.3 Further Research

This study determined the factors responsible for adoption and use of AI technology but did not determine the profitability of the technology. Therefore, further research to determine profitability of this technology is recommended. Considering the costs of every input used and benefits obtained from the products will be important in formulation of effective and efficient policies necessary for improvement of the dairy sector.

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APPENDICES

Appendix I: Conversion Factors used to Estimate Tropical Livestock Units (TLU)

Livestock type	Tropical Livestock Unit (TLU)
Camel	1.0
Cattle	0.7
Horse	0.8
Mule	0.7
Donkey	0.5
Sheep	0.1
Goat	0.1

Source: Makeham and Malcolm (1986)

Appendix II: Extent of Adoption

Variable	N	Minimum	Maximum	Mean
Extent of adoption	98	0.2	1.00	0.28

Appendix III: Test Statistics of Double-Hurdle model

Type of statistics	Probit,D	Truncated, Y(Y>0)
Wald χ^2	78.21	174.64
Prob> χ^2	0.00***	0.00***
LOG-L	-68.86	29.99
AIC(-LOG-L+k/N)	0.43	-0.13
χ^2-Test Double Hurdle versus Tobit	Γ=193.44> χ^2(17) = 33.41	

Appendix IV: Questionnaire

Title: Determinants of Use of Artificial Insemination by Smallholder Farmers in Lemu-Bilbillo District, Ethiopia

Department of Agricultural Economics and Agribusiness management, Egerton University,

Introduction

This survey is being conducted by postgraduate student at Egerton University- Kenya in Partial fulfillment of a master degree in Applied Agricultural Economics. Therefore the purpose of this research is purely academic. You are kindly requested to provide information through interview in the questionnaire.

N.B Information given will be treated as confidential and shall only be used for this study.

Section A: General Information

A.1 Questionnaire code number […….………………….……..]

A.2 Enumerator's Name [……………………………………]

A.3 Date of Interview [………………………………………]

A.4 Name of household head [………………………………]

A.5 PA […………………..] District [...……………………]

Section B: Household composition and characteristics

B.1 **Gender** of the hh head 1. Male 2. Female

B.2 **Age**……….years.

B.3 Religion 1. Muslim 2. Orthodox Christian

3. Protestant 4. Others (Specify) ………………………..

B.4 Marital status   1. Married   2. Single   3. Divorced

4. Widowed   5. Others (Specify) ……………………..

B.5 How many persons have you been living in the household for at least six months? (**Family size**)?

Household Members	Number
Men	
Women	
Children	
Total	

B.6 Have you been to school?

1. Yes   2. No

B.7 If yes, indicate the **years of schooling**…………years.

B.8 **Farming experience**:   Number of years since started cultivating land………years

Number of years since started rearing cattle……...years

B.9 List your major source of income by order of importance.

1. Crop production […………...]
2. Livestock production […..…..]
3. Both equally [……….……....]   4. Others (Specify) [………...…]

B.10 Do you have other means of earning income other than farming? **Off-farm income**

1. Yes   2. No

B.11 If yes, indicate the amount of income earned during last one year from off-farm activities.

Source of Income	Amount (Birr)
Casual village labor	
Handcraft	
Local beverage	
Remittance	
Selling fire wood	
Business net income (shops, trade, tailor, etc)	
Others	

Section C: Institutional Factors

C1. Extension services

C1.1 Is there any development agent assigned to your PA? 1. Yes 2. No

C1.2 Have you ever consulted a development agent? 1. Yes 2. No

C1.3 If yes, about which did you consult?

1. Crop production 2. Animal production

3. Both 4. Other (specify) […………..……………..…….]

C1.4 Have you received extension advice on breeding services and crossbred cattle practices during the last 3 to 5 years? 1. Yes 2. No

C1.5 If yes, which of the following have you heard so far?

1. Crossbred 2. Improved feeding 3. Bull services 4. AI service

5. Others (Specify)[…………………………………………………]

C1.6 On average how many times has the development agent visited you with in past one year? ..…..days.

C1.7 Have you found the advice given to you very important in improving your livestock production? 1. Yes 2. No

C2. Credit Provision

C2.1 Did you get credit during the last 3 production years? 1. Yes 2. No

C2.2 If yes, who did provide you with the service?

1. Development Bank 2. Commercial Bank

3. Agricultural Bureau 4. NGO 5. Local moneylender
6. Service cooperatives 7. Others (specify)………………………………..

C2.3 For what development activities did you get credit during the year?

1. To purchase fertilizer …………….. birr

2. To purchase crossbred cows……….birr

3. To purchase seed ………………… birr

4. To use AI service…………………...birr

5. Others (specify)……………………. birr

C2.4 On what basis did you get credit? 1. Individual basis 2. Group basis

C2.5 What was the duration for loan repayment?...........years

C2.6 What was the interest rate for the credit you received?............... %

C2.7 If you have not used credit so far for livestock, what were the main reasons?

1. Due to high interest rate 2. Shortage of down payment

3. Inaccessibility to credit 4. Unavailability 5. Others (specify)

C3. Membership in Cooperatives

C3.1 Are you a member of any cooperative union? 1. Yes 2. No

C3.2 If yes, which cooperative?

1. Input supply coop. 2. Saving and Credit coop.
3. Producer marketing coop. 4. Welfare/funeral coop
5. Local administration 6. Water users coop
7. Others (Specify)…………………………………………………………………..

C3.3 Is there any dairy cooperative in your area? 1. Yes 2. No

C3.4 If yes, are you a member of the dairy cooperative? 1.Yes 2. No

C3.5 If yes, what have you benefited being member in the dairy cooperative?

1. Sell my Products (On time market)
2. Access to improved breeds
3. Credit services
4. Others (Specify)……………………………………………………………

C3.6 Are you satisfied with the services from dairy cooperative? 1. Yes 2. No

C4. Road Availability

C4.1 How long do you walk to get transport services?.................hours

C4.2 What type of road is there in your area?

1. All season road 2. Dry season road 3. Only on market days

C5.Veterinary Services

C5.1 Is there a veterinary/animal health station in your area? 1. Yes 2. No

C5.2 If yes, how far is it located from your stay?.........walking hours.

C5.3 Have you ever gotten animal health services? 1. Yes 2. No

C5.4 If yes, who has provided animal health services for livestock in your area?

1. Agricultural Bureau 2. NGO

3. Private 4.Others (Specify) ……………………….……

C5.5 How frequently do you get vaccination service in your area?

1. Very frequent 2. Yearly 3. Only during outbreak

4. Less frequent 5. Never

Section D. Crop Cultivation and Land Ownership

D.1 How many hectares in total land holdings do you own?.....................

D.2 How many hectares of cultivated land do you own?.......................

D.3 Do you have rented land? 1. Yes………hectares 2. No

D.4 Indicate the utilization of the land:

1. Cultivated for crop……….ha 2. Grass land (can't be plowed)………ha

3. Covered with different forages…….ha

D.4 Crop grown, production and utilization during 2011/12

Type of crop	Area planted ha	Total production
Wheat		
Barley		
Lentils		
Pea		
Beans		
Linseed		
Others(specify)		

Section E. Livestock Production

E.1 Type of livestock kept (local, crossbred)

Type of lives stock		Local (number)	Crossbred (number)	Exotic (number)
Cattle	Cows			
	Bulls			
	Oxen			
	Heifers			
	Calves			
Small ruminant:	Sheep			
	Goats			
Equines:	Horses			
	Donkeys			
	Mules			
Poultry	Chicken			
Pigs				

E.2 Describe why you keep livestock? (Mark with **X**)

Purpose	Cattle		Sheep and Goats	Equines	Poultry	Pigs
	Local	Crossbred/ Exotic				
Milk						
Meat						
Eggs						
Plowing						
Transportation						
Cash						
Others						

E.3 Do you have crossbred/exotic cattle? 1. Yes 2. No

E.4 If yes, which one do you have? 1. Ox 2. Cow 3. Heifer 4. Calf

E.5 When did you get that? In year………or ……….years ago.

E.6 How did you obtain the crossbred/exotic cattle first?

1. Purchase from agricultural bureau……….birr
2. Purchase from local market………….. birr
3. Born by using AI
4. Born by using bull service
5. Obtained on credit from agricultural bureau
6. Purchased in the village/from relatives

E.7 Though now not, did you have crossbred cattle before? 1. Yes 2. No

E.8 If yes, in which year? From year ....to…………

E.9 Indicate the source of crossbred/exotic cattle by then:

1. Purchase from agricultural bureau……….birr
2. Purchase from local market………….. birr
3. Born by using AI
4. Born by using bull service
5. Obtained on credit from agricultural bureau
6. Purchased in the village/from relatives

E.10 Do you want to have crossbred/exotic cattle? 1. Yes 2. No

E.11 Do you prefer crossbred cattle over local breeds? 1. Yes 2. No

E.12 If yes, what made you prefer them?

1. Higher milk yield 2. Higher sales income 3. Better plowing power

4. Others (specify)…………………………………………………..

E.13 Through which way do you think you can get that?

1. Purchase from agricultural bureau……….birr

2. Purchase from local market………….. birr

3. Using AI service

4. Using bull service

5. Obtain on credit from agricultural bureau

6. Purchase in the village/from relatives

E.14 Are crossbred cows available in your area if you want to buy? 1. Yes 2. No

E.15 If yes, in your opinion how is the price of crossbred heifers?

1. Very expensive 2. Expensive 3. Fair price 4. Cheap

F. Livestock Feeding and Management

F.1 What are the major livestock feeding systems you use?

1. Free grazing 2. Zero grazing 3. Rotational grazing

F.2 Specify type of pasture land and its availability found in your area.

1. Communal grazing 2. Individual grazing

3. Both depending on seasons 3. Others (specify)………………………

F.3 Do you have feed shortage for your livestock? 1. Yes 2. No

F.4 If yes, what do you think are the main causes for the problem?

1. Lack of rain 2. Lack of grazing land 3. Increased livestock population

4. Poor pasture quality 5. Others (specify) …………………………………

F.5 Do you grow any fodder and forage crops? 1. Yes 2. No

F.6 If yes, how many hectares of your land is allocated to that? ………………

F.7 Do you have access to different forage crops if you want to grow? 1. Yes 2. No

F.8 If yes, where do you obtain it from?

1. Agriculture offices 2. Private sales 3.NGOs
4. Other (specify)………………………………………………..…………

F.9 Do you feed concentrates to your livestock? 1. Yes 2. No

F.10 If yes, which livestock category you often feed concentrates?

1. Local cows 2. Crossbred cows 3. Oxen

4. Only lactating ones 5. Other (specify)……………………………..

F.11 Are concentrates available in the market at required amount and time?

1. Yes 2. No

F.12 Do you use hay (from traditional pasture) for livestock feeding? 1. Yes 2. No

F.13 What are the main sources of livestock feed during dry season?

1. Crop residues 2. Hay

3. Tree legumes (leaves) 4. Others (specify)…………………..…

F.14 Do you use crop residues (straw) for livestock feeding? 1. Yes 2. No

F.15 If yes, where do you get it from?

1. From own farm 2. By purchasing 3. Others (specify)………………….

F.16 If purchased specify the total cost you incurred to buy crop residue during

2011/12……. birr.

G. Breeding Services (Technology Availability)

G.1 Which breeding services do you use for you cattle?

1. Any bull around 2. Selected local bulls in the area
3. Crossbred/exotic bull around 4. AI service
5.Others (specify)…………...

G.2 Is there any crossbred/exotic bull used for service in your area? 1. Yes 2. No

G.3 If yes, have you ever used the crossbred/bull service? 1. Yes 2. No

G.4 If yes, how much does it cost per service? ………birr

G.5 How far is the crossbred/exotic bull located from your place?............walking hours.

G.6 Have you ever heard of AI? 1. Yes 2. No

G.7 If yes, when did you first hear about AI? In year............or ……….years ago.

G.8 Do you have access to use AI in your area? 1. Yes 2. No 3. I don't know

G.9 If yes, how far is the AI station from your place?................... walking hours.

G.10 Have you ever used AI? 1. Yes 2. No

G.11 If yes, when did you first use AI? In year............or ……….years ago.

G.12 When is the AI service available?

1. Always 2. On market days 3. Mornings only
4. Other (specify)…………...

G.13 At present, how many of the cattle you own are bred using AI?................cattle heads.

G.14 How many calves were born at your home within the last two years using any breeding service? ………calves.

G.15 How many of those calves were bred with AI?...........calves

G.16 How many of these were bred using crossbred/exotic bull service?...........calves

G.17 What is the price of AI per service?............birr

G.18 In your opinion, how expensive is the price of AI service?

1. Expensive   2. Fair price   3. Cheap

G.19 If you have used AI before, in how many inseminations did your cow/s conceive?

1. One   2. Two   3. Three   4. Other (specify)……………….

G.20 If you have used AI service, how do you rate the efficiency of AI in conception compared to bull service?   1. Very good   2. Good   3. Poor

G. 21 What do you think of your heat detection ability?

1.Very good   2. Good   3. Poor

G.22 In your opinion is the AI service in your area effective or not?

1.Yes   2. No   3.No idea

G.23 What do you think is/are the major problem/s with using AI?

1. Distance to AI station   2. Inefficiency of the service

3. Inefficiency of the Inseminators   4. Availability of the service

5. Others (specify)……………………………………………………….

G.24 What do you think are the advantages of using AI over crossbred/exotic bull service?

1. Timely availability   2. Lower price

3. No fear of diseases   4. Others (specify)……………………

G.25 Which one do you prefer from AI service and crossbred/exotic bull service? ....Why?..

H. Milk Production and Market Service

H.1 How many litres of milk do your cows give per day?

1. Local………litres/cow/day 2. Crossbred…… litres/cow/day

3. Exotic…….litres/cow/day 4. Other (specify)…………………..

H.2 Do you sell livestock products like milk and milk products? 1. Yes 2. No

H.3 If yes, how many litres of milk do you sell per day?............ Per month?.................

H.4 How many kilograms of butter do you sell per month?..........kg and cheese?..........kgs

H.5 What is the price of milk in your area?..................birr/liter.

H.6 Where do you sell your milk?

1. At farm gate 2. Taking to nearest town 3. Only on market days
4. Through dairy cooperative 5. Other (specify)………………………………

H.7 If you do not sell milk and milk products, what are the reasons?

1. Price too low 2. No surplus to be marketed

3. No market 4. Others (Specify)…………………………………

H.8 Have you ever faced problem in finding market for your milk? 1. Yes 2. No

H.9 If yes, what did you do as a solution?
1. Convert to butter and cheese 2. Consume at home

3. Feed to calves 4. Other (specify)…………………….………

H.10 For how far do you have to walk from your home to sell your dairy products?
...............walking hours.

H.11 At which season do you mostly sell your dairy products?.................................

H.12 What are the major livestock and livestock products marketing constraints you have observed? ……………………………………………………………………………………

Thank the interviewee very much for his/her time and useful information.