ADOPTION OF ASSISTED REPRODUCTIVE TECHNOLOGIES AND SAHIWAL CATTLE BREED AND THEIR IMPACT ON HOUSEHOLD FARM INCOME IN NAROK AND KAJIADO COUNTIES OF KENYA

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A thesis submitted to the Graduate School in partial fulfilment for the requirements of the Collaborative Master of Science Degree in Agricultural and Applied Economics of Egerton University.

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DECLARATION AND RECOMMENDATION

This research thesis is my original work and has not been presented in this or any other University for the award of a degree.

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DEDICATION

I dedicate this thesis to my mother Florence Amiru, my wife Millicent Okumu, my Son Steve and brother Peter Khainga for their continued support and prayers.

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ABSTRACT

Livestock production in Semi-Arid Lands (SALs) of Kenya has continued to decline over the past decade, thereby threating the livelihood of pastoralists. In the recent past, there have been concerted efforts by the Government to supply more hardy cattle breeds with ability to produce enough meat and milk for pastoral communities. Despite introduction of high perfoming breeds such as Sahiwal, the dissemination of this genetic material among the pastoralists remain low. Whereas pastoralists' demand for the Sahiwalbull has outstripped its supply, the economic assessment for viability and implications of the alternativeAssited Reproductive Technologies (ARTs) among pastoralist communities remain a mystery. Using a random sample of 384 livestock farmers from Narok and Kajiado Counties, this study evaluated the actual and potential adoption of Artificial Insemination (AI) as an alternative breeding technology to the use of bull. Data were analyzed using ordered probit model, double bounded dichotomous choice model and Average Treatment Effect (ATE) estimation framework. The results from ordered probit model show that the decision to adopt AI as well as farmer perception is influenced by different factors. These factors differed across the AI perception and adoption decision, and they include: age and education level of household head, household size, herd size, access to extension services, group membership, experience in livestock keeping, technology awareness and the production system. The Double bounded dichotomous choice model results indicate that most of the pastoralists' willingness to pay (WTP) was 1,853.19 Kenya shillings (KES), which reflects a premium of 23.55%for AI compared to the existing market price of KES 1,500. The bidding decision by the farmer was determined by his/her access to extension services, herd size, off-farm incomeand awareness of AI services.The ATE for the treated revealed that there is potential for adoption of Sahiwalbreed since adopters earn an average of KES 661,179.87 compared to their counterparts who earn KES 564,779.67 from sales of live animals and milk. This reflects an annual increment of 17%in farm income over and above what Sahiwal non-adopters earn which was quite substantive given the difficulties involved in livestock production in SALs where access to water and seasonal changes affect the overall production yield of the farm.

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LIST OF ACRONYMS

AI	Artificial Insemination
ARTs	Assisted Reproductive Technologies
ATE	Average Treatment Effect
CAIS	Central Artificial Insemination Station
CV	Contingency Valuation
DLPO	District Livestock Production Officer
EAZ	East African Zebu
ET	Embryo Transfer
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
HPI	Heifer Project International
IFAD	International Fund for Agricultural Development
ILRI	International Livestock Research Institute
KALRO	Kenya Agricultural and Livestock Research Organization
KARI	Kenya Agricultural Research Institute
KLBO	Kenya Livestock Breeders Organization
KMC	Kenya Meat Commission
KNAIS	Kenya National Artificial Insemination Services
MOLDF	Ministry of Livestock and Fisheries
NSS	National Sahiwal Stud
PSM	Propensity Score Matching
SAL	Semi-Arid Land
SCBS	Sahiwal Cattle Breeders Society
SDP	Smallholder Dairy Project
SSA	Sub Saharan Africa
UNDP	United Nations Development programme
USA	United States of America
WTP	Willingness To Pay

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CHAPTER ONE

INTRODUCTION

1.1Backgroundinformation

Agriculture remains the most important economic sector in many African Countries in terms of food supply, employment creation, income generation and foreign exchange earnings for over 60% of rural population (UNDP, 2012). The importance of the livestock sub-sector to their farming systems in the sub-region is reflected by its contribution to crop production, providing employment throughout the year and spreading risks. It also providesfunds for buying crop inputs and financing farm investments through sales, forming a major capital reserve and enhancing the economic viability and sustainability of the farming systems (Steinfeld and Mack, 1995).

In Sub-Saharan Africa (SSA), pastoralism is predominantly practised in arid and semi-arid lands (SALs). These areas are hot and dry, with low and erratic rainfall. Pastoral livelihoods in Africa evolved in response to climate variability over thousands of years ago when the Sahara entered a period of prolonged drought (Kirkbride and Grahn, 2008).It is estimated that 70% of the rural poor in SSA own livestock (Otte and Knips, 2005). Moreover, the demand for livestock products in Africa is projected to double between the year 2000 and 2030 due to rapid increasing human population growth, urbanization, changing lifestyles and increasing incomes (Delgado *et al.*, 2001). Currently, most livestock related food products are obtained from smallholder and pastoral systems in SALs despite the production systems being characterised by low production as a result of climatic effects, lack of genetic merit on available livestock, inadequate feed supply and quality, poor animal health, livestock performing multiple functions in the livelihood systems, poor management and lack of credit facilities, especially among poor farming households (Mack, 1993).

In Kenya, over eighty percent of theland mass is SAL, with livestock contributing 10% of total and 30% of agricultural gross domestic product (GDP), withdairy products accounting for 30% of livestock GDP (Muriuki, 2011). Furthermore, livestock population is concentrated in the ASALs, whichaccounts for 90% of employment and more than 95% of family incomes (Muriuki, ibid). Yet, pastoralistsin these areas are among the poorest sub-populations by standard income or expenditure measures; they suffer from high rates of malnutrition and illiteracy, and they are vulnerable to regular drought, civil unrest and other economic shocks (Ng’eno *et al.*, 2010).

Narok and Kajiado Counties form part of the SALs in Kenya that are characterised by low crop production potential. Livestock production systems predominate since animals can be moved in response to spatio-temporal variability in economic, environmental, epidemiological and security conditions. Livestock provide herders not only with meat, milk andblood for sustenance, but also, through livestock sales asa means for financing basic needs including shelter, school fees andmedical expenses. During drought, there is increased livestock death, acute food shortage and increased migration by pastoralist communities in search of pasture and water resources which in some cases result in inter-communal resource conflicts.In the face of harsh climatic conditions, coupled with low access to basic social services, such as infrastructure and educational facilities, most pastoralists have established settlements and abandoned nomadic pastoralism (Desta and Coppock, 2004). Therefore an increasing number of cattle keepers have adopted a sedentary lifestyle and are practicing mixed crop livestock farming and deriving livelihoods from other non-pastoral activities (Fratkin and Mearns, 2003). Such a transformation necessitates appropriate strategies to increase livestock production in pastoral areas through continued improvement of existing indigenous breeds, feeding and grazing strategies that are sustainable across different production systems.

Indigenous cattle breeds are diverse with unique genetic attributes such as adaptation to heat and drought, tolerance to diseases and utilizaton of low-quality feeds that are readily available in SALs of Kenya.This means that improvement of the local breeds through crossbreeding with exotic breeds in order to achieve the desired traits is important for livestock farmers. Thus the need for importation of Sahiwalcattle (*Bos indicus*) in Kenya in early 1930s from India and Pakistan mainly for upgrading with the local Zebu for higher milkproduction and enhanced growth performance under low-input production conditions (Meynand Wilkins, 1974).Since then Sahiwalhas remained one of the most attractive breeds for pastoral farmers because of its relatively high milk production and growth potential as well as good reproductive ability (Ilatsia *et al.*, 2011).

Over the years, pastoralists have continued to upgrade their indigenous cattle with Sahiwalbreed through exchange of bulls among themselves. The use of the bull as the main means of disseminating genetic materials is prone to spreading reproductive diseases and inbreeding. Despite these shortcomings, adoption of Assisted Reproductive Technologies in pastoral areas is almost non-existent. These technologies involve introduction of semen or embryo into the dam using equipment by an expert instead of the natural mating. The technologies include AI andEmbryo Transplants (ET). Since the utilization of AI is still generally low even for the Kenyan highlands usually known for its lead in dairy production, preference for natural service is likely to prevail in the short term (Omiti, 2002).

1.2 Statement of research problem

Kenya has made tremendous improvements in the dairy sub-sector despite the numerous challenges facing pastoralist farmers in SALs. These challenges include inadequate supply of bulls for breeding which necessitate need to explore farmers perceptions towardsalternativeassisted reproductive technologies; specifically artificial insemination.Even though high perfoming breeds such as Sahiwalhave been introduced, dissemination and adoption of this genetic material among the pastoralists remains low. Whereas pastoralists' demand for the Sahiwalbull (superior breed) has outstripped its supply, the economic assessment for its viability and implications of the alternative ARTs among pastoralist communities is yet to be established. Therefore this study seeks to establish the viability of AI and the impact of Sahiwal adoption.

1.3 Objectives

1.3.1 General objective

The general objective of this study was to improve the dissemination of Artificial Insemination for Sahiwal breed adoption and its impact on household farm income of pastoralists in semi-arid areas of Narok and Kajiado Counties.

1.3.2 Specific objectives

1. To determine pastoral farmers' preferences for and choices of breeding services in semi-arid areas.
2. To estimate pastoral farmers' willingness to pay for artificial insemination services in semi-arid areas across Counties.
3. To determine the impact of Sahiwalbreed adoption on household farm income between Sahiwal adopters and non-adopters.

1.4 Hypotheses

To achieve the specific objectives, the following hypotheses were postulated for testing:

1. Farmer's preference for and choice offor bulls are not significanctly different from assisted reproductive technologies.

2. There is no significant difference in farmers' willingness to pay for artificial insemination services in semi-arid areas across Counties.
3. The impact of Sahiwal breed adoption on household farm income is not significantly different between sahiwal adopters and non-adopters.

1.5 Justification of the study

Low milk production in SALs pose both economic and nutritional threats to the rising population of the pastoralists. This therefore calls for urgent interventions to increase livestock production in these areas to curb malnutrition among pastoralists. Adoption of Sahiwal breed known for producing more milk compared to the small East African Zebus (EAZs) would cushion the disadvataged gender (women and children) against malnutrition. Moreover, sales from surplus milk would provide the much needed income to pastoralist families to cater for other expenses including production costs, schooling of children and diversification of animal feeds. This study therefore provide insights on factors that influence effective Sahiwal breeding in pastoral areas and inform policy and dairy sector players on the existing potential that can be harnessed through dissemination of Sahiwal breed. The study also highlights the significant role AI can play in dissemination of Sahiwal genetic resources andeasing the demand for the bull from the National Sahiwal Stud (NSS). Comparative study of production systems in SALs provide farmers with alternatives that optimise their production goals given the existing constraints in the face of climatic changes. The study findings are applicable in other SALs areas given that Sahiwal breed has high reproductive performance and is more adaptive to such conditions. Therefore the need for accelerated dissemination of high yielding breeds to increase livestock production and generate more income in pastoralist communities can not be over emphasized.

1.6 Scope and limitation of the study

The study focussed mainly on the livestock farmers in selected districts of Kajiado and Narok Counties. The study usedcross-sectional data collected during short rain season for purposes ofsocio-economic evaluation of the Sahiwalcattle.

1.7 Definition of terms

Nucleus breeding system: Is a breeding programme where the NSS coordinated nucleus herds were the main source of breeding animals for other medium and small holder livestock farms (KARI, 2004).

Perception: Refers to a mental set, thought or a conceptual direction of an individual or group of individuals about an issue in perspective (Van den Ban, 1996).

Technology adoption: This is the mental process an individual passes from first hearing about an innovation to final uptake (Rogers, 1962).

Pastoralism: Isan economic and social system well adapted to dry land conditions and characterized by a complex set of practices and knowledge that has permitted the maintenance of a sustainable equilibrium among pastures, livestock and people (Koocheki and Gliessman, 2005).

Pastoralists: These are people who live mostly in dry, remote areas. Their livelihoods depend on their intimate knowledge of the surrounding ecosystem and on the well-being of their livestock (IFAD, 2009).

Artificial Insemination: Is the process of collecting semen from very top genetic potential bulls, assessing, diluting, packing in straws and preserving in liquid nitrogen at low temperatures for depositing in the uterus of a cow that is on heat by use of equipment instead of allowing natural mating (Oluoch-Kosura *et al.*, 1999).

Household: A group of people bound together by ties, kinship or joint financial decision living together under a single roof or compound, are answerable to one person as the head and share same eating arrangements.

1.8 Outline of the thesis

The remaining part of this thesis is organized in seven chapters. Chapter two describes the general literature reviewed; dairy production systems in pastoral areas, reproduction technologies available to boost production and discusses the underpinning conceptual and theoretical framework of the study. Chapter three describes the study area, sampling procedure adopted, data collection approach and the data analytical tools used in the study. Chapter four presents pastoralists’ choice and preference for a particular breeding service in SALs. The second objective that seeks to establish pastoralists’ WTP for artificial insemination across different production systems is addressed in the fifth chapter. The last objective of this study on the impact of Sahiwal breed adoption on the income of adopters and non-adopters is established in the sixth chapter. Chapter seven provides the summary of the whole thesis covering each chapter conclusions, and implications for stakeholders.

CHAPTER TWO

LITERATURE REVIEW

2.1 Dairy sub-sector in pastoral areas

In SSA, dairy industry accounts for 3% of the worlds' cow milk production with Kenya producing 18% of this output (IFAD, 2006). Although the regional output of milk is low compared to the global production, the Country's output is significant. According to Smallholder Dairy Project report (SDP, 2003),Kenya has a well-developed dairy industry, which spans over 90 years and contributes 10% of total gross domestic product (GDP), 30% of agricultural GDP and the dairy products accounting for 30% of livestock GDP (Muriuki, 2011). The sector remains the primary source of livelihood for many smallholder livestock farmers who produce about 70% of the total milk marketed in the Country with an estimated annual per capita milk consumption ranging from 19 kg in rural areas to 125 kg in urban areas (Muriuki, ibid). Large proportion of dairy sector contribution to agricultural GDP is evidence enough to warrant both government and private sectorefforts to expand research and investment for poverty alleviation and job creation (UNDP, 2012). Poverty in rural areas has made it difficult for farmers to acquire quality breeds that have the ability to produce enough milk for consumption to fight malnutrition and surplus for sale. It's with this background that both International Development partners and Non-Governmental Organizations (NGOs) have partnered with farmers in training community animal health workers to administer routine animal vaccination, improve pastoralistfood security through provision of better breeds and raising their incomes (SDP, 2003). Over the last decade, research in livestock production across the Country aimed at reversing the declining milk production from local herds of zebu and exotic cattle through improved animal husbandry practices and breeding (Omore *et al*., 1999).

Improved agricultural production is the most important means in the fight against poverty through advancing rural livelihood and increasing economic growth. Growth in agricultural sector contributes more to poverty reduction more than any other economic sector (World Bank, 2007). However, thoughtful efforts have been made to ensure an ordinary African is self-reliant in food production. Transforming agriculture is hooked on the adoption of improved technologies. The transfer of technology and the subsequent adoption of same by the predominantly traditional farming communities is one of the challenges facing agricultural scientists and extension providers. Transfer of improved expertise to service providersand farmers is one of the responsibilities of any agricultural project. According to Olayide (1980), agricultural technology is the application of new waysfor the promotion and the development of agriculture. They further argue that adoption is a mental process whereby an individual decides to use a new approach. Better technologies are employed in agriculture generally to increase productivity and income of the farmers (Bennett, 1990). The rate of adoption of technology among farmers is the most crucial measure of success of the project and its effectiveness. The faster the rate of adoption of a given technology, the faster it diffuses to farmers who are not participating in the project and thereby raising their farm productivity and ensuring food security in the long run (De Janvry and Sadoulet, 2002).

Livestock production has a fundamental contribution to food and rural development in pastoral areas. It has a significant influence on pastoralists' ability to manage risks and support main social networks within their vast vulnerable communities. Furthermore, a study done by Ogle (1996) reveals that SSA has the largest area of pasture on any continent with the largest number of pastoralists. The importance of animal keeping is rising as human population increases in developing countries thus fuelling a substantial upsurge in demand for foods of animal origin (Hoffmann, 2011). Approximately, 70% or 150 million of the rural poor in SALs at least partially dependent on livestock to sustain their livelihoods (Ashley*et al.,* 1999).In Kenya, pastoralism remains amajor economic activity forpeople living in SALs. They derive their livelihood from livestock production which has contributed to poverty reduction in various ways. Animal keeping has increased food supply (through meat and milk for consumption), serves as a source of income (through meat and milk sales) and a means for capital accumulation for future generation. It also generates employment for youths within the meat and dairy value chains.

Over the decades, cross-breeding has remained a major alternative means of generating genetic change in livestock population among small and poor farmers worldwide. Cross-breeding may be implemented in various forms including sustained development of a new synthetic breed or breed substitution through recurrent crossing of desired breed with local breed that is more adaptive to local environment (Hoffmann, 2011). Where prolonged crossing is envisioned, specific emphasis is set to ensure that the propagation of superior germplasm is feasible using available technologies.

2.2 Assisted reproductive technologies in livestock production

To achieve desired production in both dairy and beef production, there has been concerted effort to disseminate existing technologies among livestock farmers by both government agencies and non governmental organizations in the Country such as Kenya Agricultural and Livestock Research Organization (KALRO) formally known as KARI, International Livestock Research Institute (ILRI), Heifer Project International (HPI) and Kenya Livestock Breeders Organization (KLBO). Some of these breeding technologies (AI and ET) are new to farmers while other approach is to upgrade existing cattle breeds with more superior ones to deliver required results effeciently. Johnson and Ruttan (1995) in a study in the United States of America (USA) found breeding technologies as the most significant factor contributing to farm productivity in the livestock sector since the 1940s. In their study, dairy production was the first livestock sub-sector to adopt the concept of commercial breeding for increased productivity. Likewise, the dairy industry in Kenya has experienced a substantial increase in milk production per cow, mostly attributed to innovations in breeding and feeding systems (Ilatsia *et al.*, 2010).

Breeding technologies such as AI and ET as alternatives to using the bull for reproduction are among key components of structural change in the Kenyan livestock sector. Modern dairy cows with high production potential have been developed through genetic selection and gene upgrading. This is consistent with the findings of Short (2004), who indicated a relatively large proportion of farms used genetic selection and breeding programs to improve herd quality. In order to optimize production among high yielding animals on the farm, it is imperative to invest in greater management and animal health care so as to avoid financial losses within the dairy enterprise (Britt, 1985). In his investigation on enhanced reproduction and its economic implication, Britt (1985) found a direct relationship between herd management and reproductive performance with ultimate influence on farm profit. Further comparative studies on genetic formation of animals and their reproduction performance by Shook (2006), indicates that genetics has accounted for about 55% of gains in the yield and about one-third of the change in the time interval required to conception. The same can be accomplished in Kenya through ARTs such as AI andET in livestock breeding.

The afore mentioned reproductive methods have been widely used in the country especially in disseminating the exotic breeds in the highlands and western parts of Kenya. However, there has been little emphasis to disseminate these technologies to the SALs despite there potential adoption. ARTs have numerous benefits including identification of quality sires for both fertility and milk yield for desired offsprings. The ability of the semen to be frozen, kept and be used after long period of time even after the bull is dead makes both economic and biological rationale to preserve most treasured genetic resources for future generations. The use of ARTs also allows usage of few sires on a large female population.In their studies, Abdulai *et al*. (2008) examined the decision of dairy farmers to acquire information and adopt technology in the presence of uncertainty in Tanzania. They found that human capital and the scale of operation were positive and significant in the adoption decision. This decision must therefore be supported by the production system the farmer is keeping his/her livestock.

Moreover, Weigel (2004) found that early adopters of this technology capture economic benefits because adopters will get an increased supply of (extra) replacement heifers and the chance to expand rapidly from within a closed herd. In Kenyan highlands, AI is widely used by dairy farmers keeping exotic breeds.However, focussed group discussions with pastoralists in SALs prior to the survey established that AI was not common in the region. The increased demand for Sahiwal breed whichis more adaptive to the SALs has motivated researchers to explore ways and means of disseminating genetic material to pastoralists in the face of Sahiwal bull shortage. A study on Sahiwalcattle in Kenyan SALs, "Genetic evaluation of growth performance and survival rate and their relationship to milk production and fertility" by Ilatsia*et al.* (2011) found that Sahiwal was the best suited breed to rear in the SALs because of its genetic formation that is hardy and more adaptive to harsh climatic conditions in these areas. Moreover, they also established that Sahiwal has higher reproductive performance compared to local breeds.

2.3 Willingness to pay for Artificial Insemination in SALS

A study on impact using auction procedure in valuation of quality differentiated goods by Lusk *et al*. (2004) found respondents to be overstating their WTP in hypothetical settings as compared to more realistic conditions with real money and budget constraints. Moreover, there is a growing concern that hypothetical nature of Contingent Valuation (CV) might not produce good estimates for WTP, since they are not incentive compatible as illustrated by Umberger and Feuz (2004). A mechanism is said to be compatible if it provides an incentive for consumers to reveal their true preferences. In experimental auctions, real transactions take place and participants bid with real money on real products. Unfortunately, auctions are more difficult to organize in the field, and require more time and resources. In a typical incentive compatible experimental auction, subjects make a bid to obtain a novel good. The respondent with the highest bid wins the auction and pays the price that is determined exogenously from the individuals' bid (Lusk *et al.*, 2004). Experimental auctions have the advantage of creating an active market environment with feedback where subjects exchange real goods and real money. In such an environment, individuals have an incentive to truthfully reveal their preferences.

Following reviewed literature by Breidert *et al.* (2006) on methods for measuring WTP, researchers have tested different approaches of estimation for external validity. Breidert*et al.* (ibid) performed an empirical comparison of the methods using direct survey, conjoint analysis, first-price auction, and Vickrey auction. The authors elicited WTP for different prepaid telephone cards among students using the four approaches. Based upon the WTP estimates derived from the four instruments, they systematically tested for differences. Furthermore, they tested for external validity by requesting a sub-sample of respondents for each instrument to actually purchase the telephone card at their indicated WTP. All approaches except the two auction mechanisms showed significant differences in estimated WTP. WTP for telephones was found to be systematically higher in hypothetical settings where students did not have to purchase at the end. In real settings, with a purchase at the end, the estimated WTP are systematically lower. Same bias was discovered for the methods of conjoint analysis, ascending auction, and Vickrey auction. When required to purchase at the end, the estimated WTP exhibit significant pair-wise differences between the four methods. The authors draw the conclusion that one cannot decide which method mimics real market best.

2.4 Cattle production systems in pastoral areas

Livestock production systems in SALs include nomadic pastoralism, agro-pastoralism and ranching.

2.4.1: Nomadic pastoralism

Nomadic pastoralism is often considered to be relatively unproductive with large numbers of animals migrating from one region to another in search of pasture and water. Ouma *et al*, (2004) found that nomadic pastoralists rear poor breeds of animals, poorly fed and badly managed herd. The findings further revealed that the large numbers of animals cause serious environmental degradation thus endangering the livelihood of the pastoralists. In their argument, Ouma *et al*, (2004) observed that choice of a breed for adoption in those areas would have toconsider its adaptability and disease tolerance. Recent studies by Ilatsia *et* *al.* (2011) indicates that pastoral farmers from Kajiado and Narok counties preferred Sahiwal breed based on its qualities as enumerated earlier. It is from these expositions that we explore ways and means of disseminating Sahiwal genetic material through available technologies without interfering with their production systems.

2.4.2 Commercial ranching

Ranching is a commercial system mainly producing animals for milk and meat for sale mostly on unimproved natural pastures. This production system is primarily achieved by opening and fencing new grazing areas. Ranching is still practised in Kenya by the Maasai communities through group ranches. The ranches are owned and managed through group managers but all the members are allowed to graze the animals without any restrictions. The impact of future cattle production on biodiversity will largely depend on the extent to which rising demand for dairy products is met through expansion of grazing areas to land currently occupied by important native habitat. In establishing the technical efficiency and technology gaps in beef cattle production systems, Otieno *et al.* (2011) applying stochastic meta-frontier analysis established that there is a significant inefficiency in pure pastoralism/nomadic and agro-pastoral systems. Further, in contrast with ranches, the study by Ouma *et al.* (2011) found that these two systems to have lower technology gap ratios. The average pooled technical efficiency was estimated to be 0.69, which suggested that there was considerable scope to improve livestock production through adoption of appropriate breeding technologies such as AI and better animal husbandry practices. Further, the study observed that ranchers benefited from relatively better access to livestock extension and veterinary advisory services, coordinated by their skilled farm managers.

2.4.3 Agro-pastoralism

A larger number of agro-pastoralists use controlled cattle breeding. This is consistent with the observation by Gamba (2006). that more commercially oriented farmers such as ranchers and agro-pastoralists preferred cattle breeding strategies that targets market and profitability requirements, e.g., faster growth and higher gains in live weight and milk production, while the relatively less commercialized nomads mainly focus on cattle survival traits such as drought resistance, hardiness and disease tolerance. Agro-pastoralism integrates livestock and crop production, whereby each activity complements the other. Livestock consume crop residues while manure contributes to crop fertilization unlike in pastoral production system where mobility in search of water and grazing is the sole survival strategy for people and their stock (Muhereza and Ossiya, 2004). However, some pastoralists in Trans

Mara region have established settlements and abandoned nomadic pastoralism. Transhumance is also declining due to increasing population growth, land pressure and political perception of pastoralism as a backward lifestyle (Desta and Coppock, 2004). Therefore an increasing number of cattle keepers have adopted a sedentary lifestyle and are practicing agro-pastoralism and deriving livelihoods from other non-pastoral activities (Fratkin and Mearns, 2003).

2.5Sahiwalproduction in pastoral areas

The KenyanSahiwalis a dual-purpose breed which has been bred in Kenya since 1939. The breed originated in Pakistan and India and the breeding stock, mainly bulls, were imported, maintained and used for upgrading indigenous zebu cattle at various livestock improvement centres (Muhunyi *et al.,* 1999). Muhunyi *et al.* (ibid), in his study on conservation and utilization of the Sahiwal cattle in Kenya, reported that some improved indigenous zebu cows were selected and used as foundation stock in the upgrading and multiplication of the Sahiwalcattle by systematic crossing with imported purebred Sahiwal bulls in the early 1962. The main objective of establishing these improvement centres was to improve the breed for milk and meat production in marginal areas. Moreover, the NSS was meant to produce semen from proven bulls as a breeding stock for Kenyan farmers and to conserve and improve the Sahiwal genetic resource. However, the above objectives were weakened by the change in government's policy on extension which led to shifting from government led to demand oriented system making it difficult for pastoralist to access the semen from the NSS.

Muhunyi *et al.* (1999) reports that breeding schemes were implemented for genetic improvement of milk yield and growth rate in the nucleus closed herd. A recent study by Ilatsia *et al*. (2011) showed that pastoralists' demand for the Sahiwal bull from the NSS out stripped the available stock. The closed nucleus breeding scheme was found to be an appropriate system of organization for testing, selection and dissemination of genetic progress in view of the poorly developed infrastructure in the marginal areas for AI and field recording. But given the high number of Sahiwal cattle population in these areas, promotion of open nucleus breeding system that can hasten dissemination of Sahiwal genetic materials using AI in pastoral areas through trained community animal health workers remains a viable option to the government. However, there is need to ensure that these genetic resources are well matched to the existing production systems and the dissemination of such improved germplasm is feasible with the available technologies and infrastructure (Hoffmann, 2011).

2.6 Production and functional traits of Sahiwalcattle

The primary breeding goals of producers are high milk production, large body size, good fertility and adaptation to local production conditions (Roessler *et al*., 2010). In their study on optimized breeding strategies for the local Sahiwalcattle in Kenya considering useful values and important breeding traits, Roessler *et al*. (ibid) foundhigh milk production per cow to have provided requisite motivation for the households to rear Sahiwalbreed compared to EAZs. However, households keeping EAZs only or those who were still in early stages of adopting Sahiwalbreed had a large number of animals per herd. Cattle traits considered important by breeders include milk production per lactation, reproductive efficiency, growth potential, adaptability, udder conformation and temperament and these happens to be the traits that the Sahiwal breed was credited for. However, some studies report that Sahiwalcattle are comparatively less resistant to drought, travel shorter distances, require more forage and can be more susceptible to disease while being more expensive to purchase unlike the EAZs and that these trade-offs are well understood by the pastoral farmers (Boone *et. al.,* 2006).

2.7 Challenges facing pastoral livestock production

Livestock production in SALs faces numerous challenges including inadequate pastures and water. Unlike the exotic breeds, Sahiwal breed is more adaptive to agro-pastoral production systems though it’s a high feeder compared to the EAZs. Because of its high body frame and high feed requirements the Sahiwal canbreak down easily in case of feed shortage especially during the dry spell. The level of management including husbandry practices and disese control required for Sahiwal is slightly higher than that of the EAZs (Ilatsia *et al*., 2011). Prevalence of livestock diseases, prohibitive socio-cultural practices such as cattle rustling, lack of capital for modernization of production systems, low literacy levels, poor and unavailability of quality pastures, lack of value addition along marketing chains, presence of vector harbors’ in form of wild animals, diminishing land sizes due to human activities, increase in frequency of droughts in short span, high cost of inputs for livestock, land tenure reforms and policy and environmental degradation are some of the constraints which were identified by pastoralists and service providers as illustrated by Ilatsia *et al*.(2010).

Hesse (2006), in his study on pastoralism as an invisible asset in dry landsestablished thatin order to cope with these constraints, pastoralists have adopted some livestock management strategies including herd mobility, herd diversification, raising several species of animals in one herd and maintenance of a high proportion of female stock. However, due to increased pressure on land arising from the population growth, individualization of land and gazetting of land by government for national parks and game reserves, the pastoralists in TransMara have adopted a sedentary lifestyle by engaging in crop cultivation, agro-pastoralism and increasing involvement in the market economy to purchase grains for supplementing their diets especially during the dry periods.

2.8 Theoretical framework

This study is based on utility maximization theory which is concerned with people's choices and decisions. It is concerned also with people's preferences and judgments of a goods' worth and its value or any of a number of similar attractiveness**.** This theory is based on individual's preference-indifference relation for a given set *X* of bundles *x*, *y*and *z*usually interpreted as decision alternatives or courses of action. For instance by transitivity assumption; if *x* is preferred to *y* and *y* is preferred to *z*, then *x* is preferred to *z*hence farmer's preference for bull, AI and ET can be explored within utility context.

We consider an individual farmer F_1 who wishes to maximize utility subject to certain constraints in his/her farm enterprise. This livestock farmer in SALs will adopt and/or use a technology when the utility of a new technology (e.g. AI) exceeds the utility of the existing technology (bull). The utility derived from the use of AI is postulated to be a function of the vector of observed farm characteristics, farmer characteristics, institutional factors, perceived technology characteristics (*Xi*) and a random disturbance term having a zero mean. This arises from unobserved variation in preferences for AI, attributes of the bull, and errors in optimization.

If farmer F_i's utility of adopting AI is denoted by $U_{ai}(X)$ and the preference of continual use of the bull as $U_b(X)$ then, the preference for adopting the new and old technologies can written as:

$$U_{ai}(X) = X\beta_{ai} + e_{ai} \qquad (2.1)$$

$$U_b(X) = X\beta_b + e_b$$

(2.2)where $\beta_{ai,}\beta_b$ and $e_{ai,}e_b$ are response coefficients and random disturbances associated with the adoption of AI and the bull respectively.The probability of farmer F_i adopting a technology could be denoted by a dichotomous variable Y, which assumes a value of 1 if the farmer is willing to adopt AI or zero if otherwise. The probability that the farmer will adopt AI can be expressed as a function of X as:

$$\begin{aligned}\Pr(Y=1) &= \Pr(U_{ai} > U_b) \\ &= \Pr(X\beta_{ai} + e_{ai} > X\beta_b + e_b) \\ &= \Pr[X(\beta_{ai} - \beta_b) > e_{ai} - e_b] \\ &= \Pr(X\beta > e) \\ &= F(X\beta)\end{aligned} \quad (2.3)$$

where P is the probability function, $\beta = (\beta_{ai} - \beta_b)$ which is a vector of unknown covariates and could be interpreted as the net influence of the vector of independent variables on adoption of AI. The random disturbance term $e = (e_{ai} - e_b)$ and $F(X\beta)$ is cumulative distribution function F evaluated at $X\beta$ .Perceived technology characteristics themselves are usually a function of subjective characteristics of a technology, farm and farmer-specific characteristics. A study on technology characteristics, farmers' perspectives and adoption decisions by Adesina and Zinnah (1993), using a Tobit model shows that indeed a farmer weighs the utility derived from adopting different technologies, and chooses the technology that promises higher utility than the traditional technology.Moreover, the choice of AI by farmer F_1 is influenced by his/her WTP for it. The farmer would say yes (y = 1) if he/she agrees and no (y = 0) if he/she disagrees on paying a previously determined amount (t_i,) that varies randomly across individuals. His/her WTP for AI can be modelled as defined by AlejandroLopez-Feldman, (2012) as:

$$WTP_i(X_i, e_i) = X_i\beta_i + e_i \quad (2.4)$$

WhereWTP_i is the maximum amount farmer F_i is willing to sacrifice to procure AI, X_i represents a bundle of explanatory variables(where X_1 are social-economic factors and $X_2$are institutional factors),$\beta_i$vector of parameters and $e_i$is an error term.It's expected that the farmer will answer yes when his WTP is greater than the suggested amount, i.e.

$$WTP_i > t_i \quad (2.5)$$

In this case, the probability of observing a positive response given the values of the explanatory variables will be:

$$P(y_1 = 1 | X_i) = P(WTP_i > t_i) \quad (2.6)$$

Thisis very similar to what is traditionally known as the probit model. The difference with the traditional probit model is that in this case in additionto the explanatory variables we have the variable t_i.Upon adoption of a preferred breeding technology for dissemination of Sahiwal genetic material, disaggregation of the impact of Sahiwal output between adopters and non-adopters can be established. Considering the farm income from milk and live animal sales, we can compare this difference as:

$$\Delta_{impact} = Y_1 - Y_0 \quad (2.7)$$

Where$Y_1$is farm income derived from milk and live animal sales by Sahiwal keeping households and $Y_0$is farm income derived from milk and live animal sales by Sahiwal non-adopters.

2.9 Conceptual framework

The conceptual framework (figure 2.1) outlines the inter relationships that exist among key variables in this study. Feder *et al.* (1985) in his study on adoption of agricultural innovations in developing countries, presented factors that determine uptake of new technologies as access to credit, access to relevant extension services, technology awareness and membership to groups. In the current study, those factors including others like current breeding policy, access to government agencies and support from NGOs categorized as institutional factors, arehypothesized to have a direct positive influence on the adoption of AI technology. In establishing farmers' perceptions and adoption of new agricultural technology in Burkina Faso and Guinea,Adesina and Baidu-Forson (1995) indicated thatfarmers' decision to adopt a new technology and how much of the technology to adopt can be influenced by socio-economic factors.

The current study, postulates positive influence of socio-economic factors such as age, gender of household head, education levels of the household head, farmer's experience in livestock keeping, land size owned by a household, herd size, and household size to the decision of adopting AI technology as a breeding method. On the other hand, it is assumed that in deciding to adopt and use a new technology, the farmer must be willing to accept and pay for its provision.The choice of a particular cattle breed to be kept by the farmer is partly influenced by his/her perception of its underlying breed traits. Here we hypothesize breed traits such as high milk yield, high reproductive performance, low feed requirements, low watering frequency, high disease tolerance and live weight of the animal to positivelyinfluence choice of the cattle breed. Given above breed attributes, Sahiwal and EAZs are well adapted for the communities under study area (Ilatsia *et al.*, 2011).

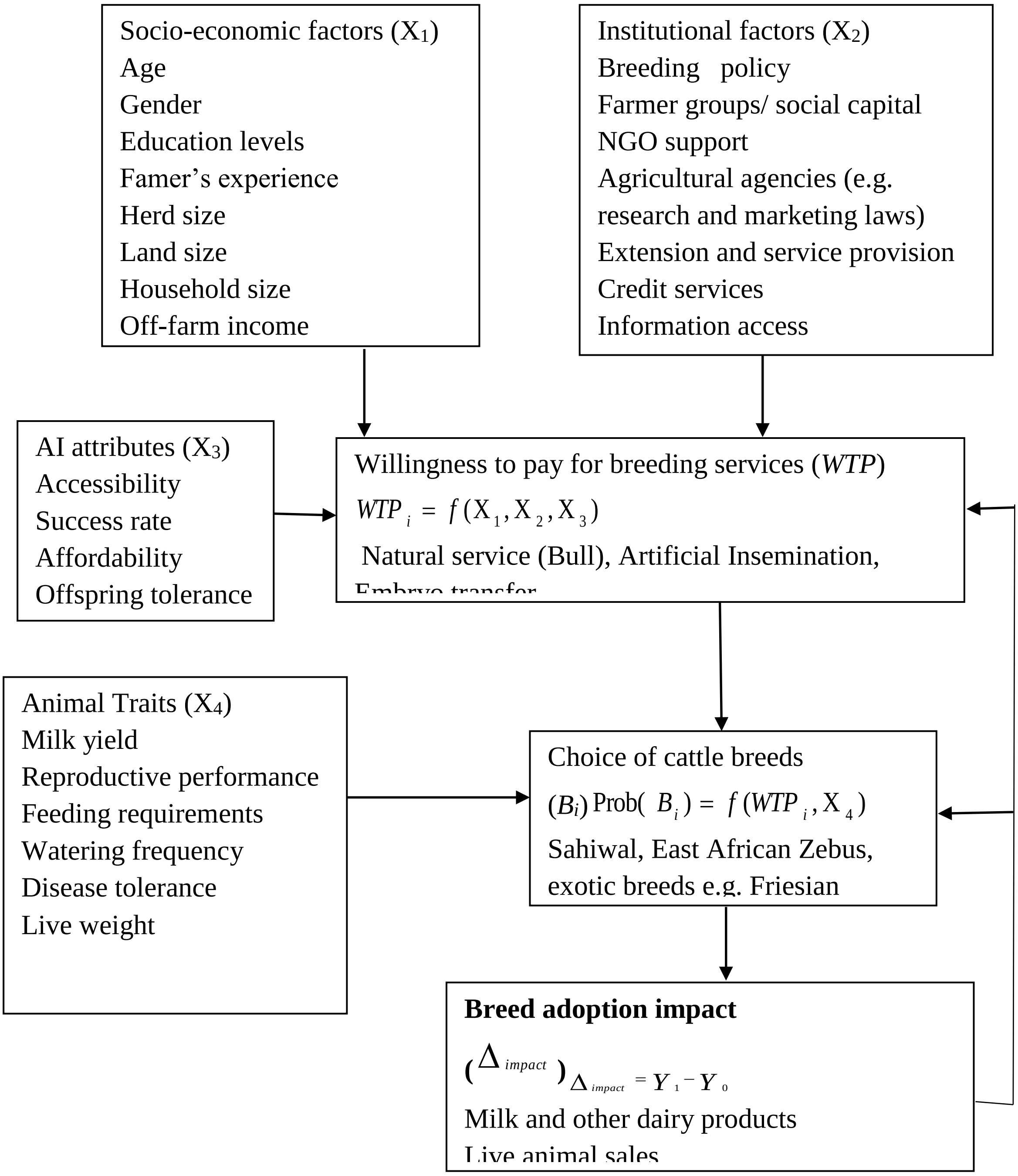

Figure 2.1 Conceptual framework.

Source: Own conceptualization.

Propensity score matching was used in the current study to establish the impact of adopting Sahiwal cattle in SALs compared to the EAZs and their exotic crosses. The farm income derived from milk sales and live animals was the key outcome variable for this study. The study postulates that farmers who adopted Sahiwal cattle breed received more farm income derived from milk and live animal sales than EAZs keepers.

CHAPTER THREE

METHODOLOGY

3.1 Study area

The study covered Kajiado and Narok Counties which are mainly inhabited by the Maasai community, whose main source of livelihood is pastoral livestock keeping. The Counties were purposively selected based on the high population of Sahiwal cattle and group ranches. The Maasai community formed the target population for the Sahiwal cattle breeding programme.

The Narok Countyhas relatively favourable weather conditions with an average annual rainfall of 1400mm p.a, temperature ranges from 18 ^{o}C to 28 ^{o}C in the North and West, while the southern part has a semi-arid climate. The climate is suitable for crop-livestock farming. Narok South is mainly semi-arid where pastoral livestock farming is the main activity. Sahiwal bulls were first introduced in Narok in the early 1980s for upgrading the local Zebu. Narok Countyhas an approximate cattle population of 770,000, out of which 5000 are pure Sahiwal cattle while 69,000 are crosses of Sahiwa land the local Zebu (MOLFD, 2006).

The Kajiado Countyhas a semi-arid to arid tropical environment, conditions that favour pastoral livestock production. The EAZ is the predominant cattle breed, followed by Sahiwa land their crosses with EAZ, and unimproved Boran (MOLFD, 2006). The Countyis estimated to be home for 440,000 heads of cattle, out of which approximately 39,000 are pure Sahiwal while approximately 130,000 are crosses of the Sahiwal breed and EAZ (MOLFD, 2006). Kajiado falls under the research mandate area of the NSS where Sahiwal breeding activities have actively been promoted, hence the relatively high concentration of Sahiwal genetic resources. Figure 3.2 shows the geographic location of the study area.

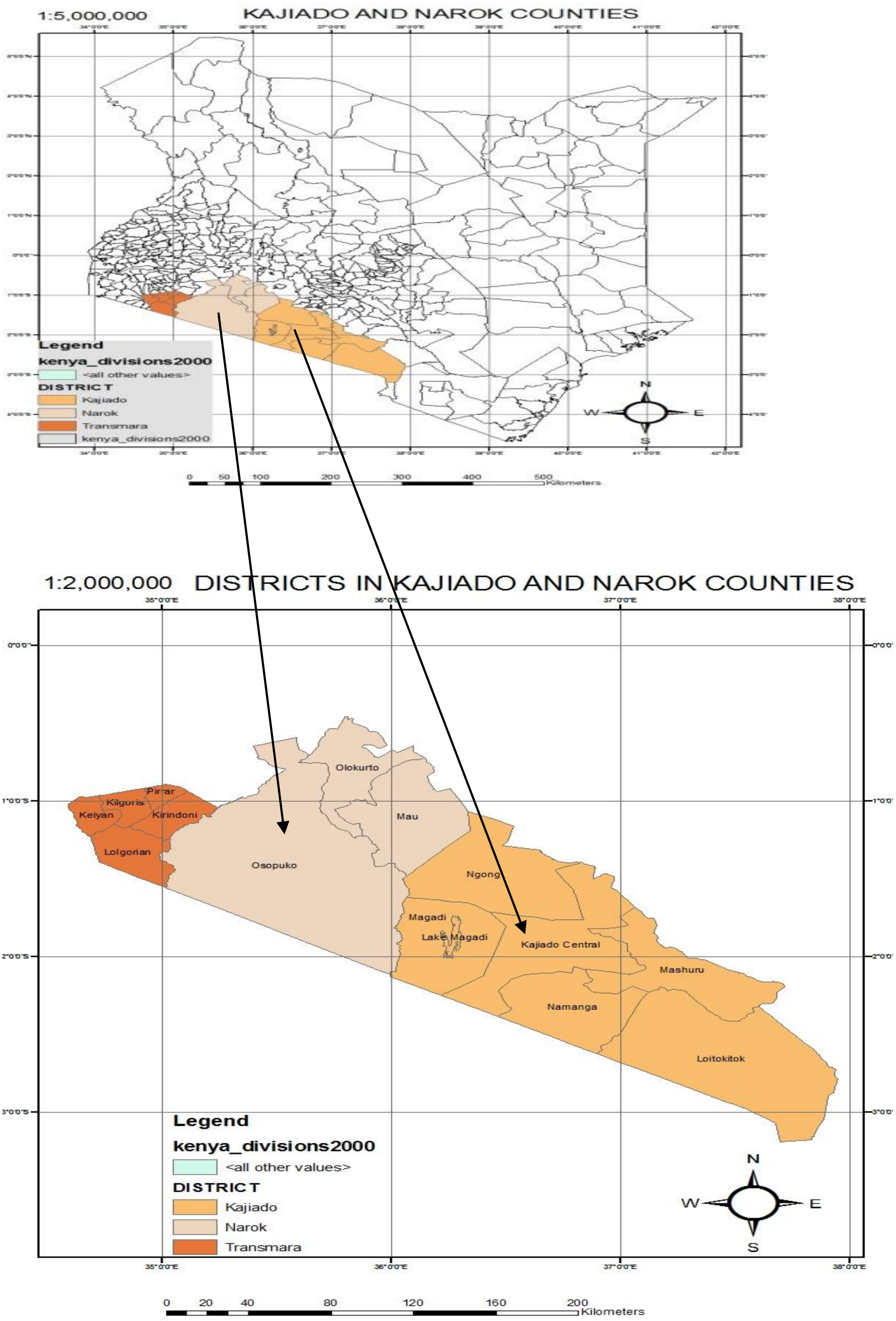

Figure 3.2: Map of Narok and Kajiado Counties.

Source: Kenya division 2000, World Resource Institute. 3.2 Research design.

3.2 Sampling Design

3.2.1 Sample size

Pastoralist households formed the sampling units. A total of 384 farmers were interviewed; 194 from Narok County, and 190 from Kajiado County. This sample size was calculated using the proportion sample size determination formula as given by Mugenda and Mugenda, (1999)

$$n = \frac{z^2 pq}{d^2} = \frac{(1.96)^2 (0.5)(0.5)}{(0.05)^2} = 384 \qquad (3.1)$$

Where *n* is the desired sample size of livestock farmers in Narok and Kajiado Counties,*z*is the standard normal deviate at the required confidence level,*p*is the proportion in the target population estimated to have characteristics of interest, *q* is 1- *p,* and *d* is the level of statistical significance set.

3.2.2 Sampling procedure

Multistage sampling technique was used. In the first stage, Keiyan, Kilgoris and Lolgorian divisions of Narok County and Namanga, Mashuru, Ngong and central divisions of Kajiado County were purposively selected because of their large concentrations of Sahiwal cattle populations. Moreover, these are high ranching zones suitable for Sahiwal production. In the second stage, pastoralist populations in these areas were divided into two strata based on their production systems i.e. Agro-pastoralists and Nomadic pastoralists using stratified random sampling technique. Third stage involved acquisition of lists of both nomadic and agro-pastoralists from District Livestock Development Officers (DLPO's) where systematic random sampling technique was applied to each list to obtain 205 agropastoralist and 179 nomadic pastoralists households for interview.

3.2.3 Data collection

Data was collected by way of structured interviews. The questionnaire was designed to obtain information from respondents on general household characteristics and relevant parameters of interest including farm characteristics, livestock production structure and production systems. Government field officers with some knowledge of animal production and familiarity with the study areas and ability to speak the local language were included as enumerators with the help of DLPO's.

3.3 Data analysis

The model variables were analysed using descriptive and inferential statistics. The Ordered probit model was used to analyse the determinants of farmer's preference for AI services as an alternative breeding methodto the bull. A Double bounded dichotomous choice model was adopted to establish farmer's WTP for AI services. The average treatment effect (ATE) framework was used to assess the impact of adoption of Sahiwal cattle breed among the pastoralists. SPSS and STATA software packages were used for data management and analysis. The results of the analysis are presented in subsequent chapters.

CHAPTER FOUR

EX-ANTE PASTORAL FARMERS'PREFERENCE FOR ARTIFICIAL INSEMINATION

4.1 Introduction

Over the years, the bull has been used as the only method of breeding in pastoral areas in the selected Counties of Kajiado and Narok. However, the introduction of new breeding techniques is vital to structural change in the dairy industry in Kenya. These techniques include AI and Embryo transplants in livestock production. In a bid to improve farm output, farmers have been crossbreeding various breeds within their reach which has led to development of cattle breeds with potential for high milk and beef production. A study by Short (2004) showed that relatively many farmers in US utilised genetic selection together with breeding technologies to better the quality of their herd. Thus, use of AI allows a farmer to select their preferred breed for production on the farm. Moreover, Shook (2006), found genetics to account for roughly 55% of gains in yield and a third in the time period required for conception. However, uncontrolled crossbreeding of cattle to improve production as used by pastoralists leads to depletion of genetic diversity often resulting in uncontrolled genetic mixing (Hoffmann, 2011).

Introduction of alternative breeding technologies are likely to cause shifts in the pastoralist production systems. According to Johnson and Ruttan (1995), breeding methods are the major significant componentleading to increased livestock farm production. AI is a breeding procedure in which sperm gathered from the bull is processed, stored and artificially introduced into the dam. Itremains as the most important technology for genetic improvement of domesticated animals. In the past decades, studies have showed the important role of AI dairy cattle through maximizing use of superior sires thus resulting in reasonable economic returns (Hillers *et al.,* 1982). The bull's genetic characteristics and the choices the farmers make given the available bulls are the driving factors for genetic improvement in cattle herds (Shock, 2006). In Kenya pastoral areas, Sahiwal breed has been promoted as the most profitable breed to keep because of its dual purpose nature (provide both milk and meat). However, dissemination of this breed has been limited to availability of Sahiwal bull.

In over 50 years ago, AI developed as a solution for the need for genetic improvement and elimination of costly venereal diseases (Foote, 1996) in the US, Hillers *et al*. (1982) in their study compared the cost and returns of breeding dairy cows both using AI and the bull. Their study results showed the economic advantage of using genetically superior AI bulls in breeding. Their study findings further revealed that calving intervals with the bull in excess of 365 days or an initial conception rate of AI greater than 0.5 would make AI economically more preferred compared to the bull. However, management factors such as accuracy of estrus detection and knowledge of proper insemination procedures are the limitations to even wider use of AI (Hillers *et al.*, 1982). According to Johnson and Ruttan (1995), breeding technologies are highly information intensive. Understanding of the principles of breeding and genetics, as well as performance data collection is often necessary in order to use the new technologies effectively. The farmers breeding decision is the key factor in increasing productivity through AI. The current study is a response to high demand for Sahiwal genetic material in the face of bull shortage from the NSS. Therefore an understanding of farmers *ex-ante* preference for AI as an alternative breeding method in SALs would be informative in formulating a comprehensive breeding programme for pastoralist in the study areas.

4.2 Model specifications and empirical analysis

The objective was to determine pastoraslists preference for breeding services and the factors that influence the choice of such decision. Various studies on adoption have employed different methodologies, for instance; Monero and Sunding (2005) found that technology choice differed for different crops, even though technology and crop decisions were taken jointly. Their study estimated technology adoption using a nested logit model of technology adoption and crop choice. The authors showed a farmer's crop technology choices as a two-level nested choice.

Gillespie *et al*. (2004) studied the adoption of four breeding technologies in the hog industry. They used a multivariate probit technique to estimate the impact of factors affecting adoption. The multinomial probit technique would have also been possible, but use of either multivariate or multinomial probit becomes less relevant when considering only one technology as is the case in the current study. Due to the non-interval nature of the dependent variable Ordinary Linear regression is inappropriate for this kind of analysis, while binomial and multinomial models fail to account for the ordinal nature of the dependent variable (Greene, 2003). Thus, ordered probit is considered appropriate for analyzing such categorical data in order to account for the ordinal nature of the dependent variable and was used in this study.

Literature review indicates extensive use of either probit or logit models in analyzing factors that influence farmers perceptions for a given technology or a programme. Unlike thestudy by Makohha *et al.* (2007) that employed binary choice model for dependent variable, the currentstudy adopted ordered probit because ordered dependent variable informs us the determinants of preference for artificial insemination among various pastoralists across the study area. The respondent revealed his/her perception by ranking AI services on a scale of 1 to 3, where 1 denotes least preferred, 2, preferred, and 3, most preferred, respectively. Despiteattractiveness of ordered probit in analyzing categorical data, it fails to account for protest attitudes of respondents and choice task complexities which may influence consistency of results (DeShazo and Fermo, 2002). The above challenges were addressed through participatory approach adopted in data collection in which choice tasks were simplified and farmers' concerns addressed through discussions by researchers from the Kenya Agricultural and Livestock Research Organization (KALRO) during the survey.

The ordered probit is related to the latent class of models. We adopt the approachby Long (1997), where we consider variable *Y* which denotes preference rank given to AI by farmer *i* and takes on *j* values which are ranked on a scale of 1 to 3, where 1 denotes lowest rank as least preferred, 2 as moderately ranked (preferred), and 3 as highly ranked (most preferred). However, these observed values are assumed to be derived from some unobservable latentvariable Y_i* such that:

$$Y_i^* = X_i\beta + e_i \qquad (4.1)$$

Where X_i refers to the observable individual specific factors, β is a vector of parameters to be estimated and e_i is the stochastic-disturbance term with normal distribution (Greene, 2003). Observed choice outcomes Y_i are assumed to be related to the latent variable Y_i^* as:

$Y = 0$ if $Y^* < \mu_0$

$Y = 1$ if $0 \le Y^* < \mu_1$ (4.2)

$Y = 2$ if $\mu_1 \le Y^* < \mu_2$

where μ_i is unknown threshold parameter for outcome *i* thatseparates the adjacent boundary values and is estimated together with the $\beta' s$. The estimated μ_i, (where *i*=0,1,2)follows the order $\mu_0 < \mu_1 < \mu_2$.

The probability that the case falls into each category *j*, using the estimated μ_i parameters as threshold limits is given as:

$$\Pr(Y=0) = \lambda(-\beta' X)$$
$$\Pr(Y=1)\lambda(\mu_1 - \beta' X) - \lambda(-\beta' X) \quad (4.3)$$
$$\Pr(Y=2) = 1 - \lambda(\mu_1 - \beta' X)$$

where λ represents the cumulative density function of μ_i.

The values of β parameters were estimated by computing the marginal effects using maximum likelihood functions defined by Greene (2003) as:

$$\frac{\partial \Pr(Y=0)}{\partial X} = -\lambda(-\beta' X)\beta$$
$$\frac{\partial \Pr(Y=1)}{\partial X} = [\lambda(-\beta' X) - \lambda(\mu_1 - \beta' X)]\beta \quad (4.4)$$
$$\frac{\partial \Pr(Y=2)}{\partial X} = [\lambda(\mu_1 - \beta' X)]\beta$$

The estimated marginal effects indicate the change in the likelihood that a farmer would "prefer" or "most prefer" (as opposed to least preference) AI as a result of a unit change in the specifc explanatory variable. An ordered probit regression was fitted for AI technology to obtain estimates of the coefficients and marginal effects. The equation below represents the empirical model specified and used to estimate the relationship between preference ranks for AI and other farmer attributes (socio-economic, institutional and animal traits).

$$\begin{aligned} AI\_pref &= \beta_0 + \beta_1 educ + \beta_2 Grp\_Mshp + \beta_3 extension + \beta_4 AI\_aware \\ &+ \beta_5 agro\_past + \beta_6 county + \beta_7 lifestyl + \beta_8 credit + \beta_9 Hh\_size + \\ &\beta_{10} herd\_size + \beta_{11} experience + \beta_{12} age\_youth + \beta_{13} age\_ygadul\ t + \\ &\beta_{14} distan + \beta_{15} comp\_index + \beta_{16} lnd\_size + \beta_{17} off\_farm + e_i \end{aligned} \quad (4.5)$$

There's extensive literature on past empirical studies on factors that influence farmers' adoption of new technologies and training programs (e.g. Makokha, *et al.,* 2008; Shiferaw and Holden, 1998; Mbaga-Semgalawe and Folmer, (2000); Odendo *et al.,* 2010; Howley *et al.*, 2012; Abebe *et al*., 2013). The independent variables included in the ordered probit model are age, education and gender of household head, household size, land size, herd size, years of experience in keeping livestock, off-farm income, location of farm and variables that condition spread of information; AI awareness, group membership, access to credit, extension services and production system. Table4.1 shows variable definitionsand justification for their inclusion in our model.

Table 4.1: Definition of variables and study postulations.

Variable	Variable description	H_0 sign	Justification
Dependent variable			
AI_pref	Preference ranking for AI (1=least preferred, 2=preferred, 3=most preferred)		Ranking of preference for AI will reveal whether it's worthy employing service providers in pastoralist communities.
Explanatory variables			
Age	Age of household head (years)	-/+	Older household heads are less likely to adopt artificial insemination since they lack information about artificial insemination. (Youth-18-35years, middle aged- 36-50 years, and elderly- above 50 years).
Education	Years of schooling	+	Education is likely to positively influence AI preference ranking because it exposes individual to knowledge hence high probability to try new technologies.
Household size	Total number of household members	+	Household with large numbers need more food and therefore will need a technology with capacity to increase livestock production for sustenance.
Land size	Number of acres owned by a household	+	Large land size provide enough pasture to accommodate large herd size due to increased production.
Herd size	Number of cattle	+	Large herd size will necessitate a faster breeding method that is cost effective.
Off-farm activity	1=off-farm as the major source of income (dummy)	-	Off farm employment decrease dependence on livestock and therefore reduce preference for AI.
Experience	Years of keeping livestock	+	Experience accumulated over the years will necessitate a farmer to improve production through new improved technologies.
AI awareness	1= the household head is aware of the AI(dummy)	+	Relevant information about a new technology reduces the risk averseness of the farmer.
Group membership	1=a household member belongs to local group (dummy)	+/-	Membership to a relevant group exposes a farmer to useful production (e.g. AI) and marketing information.

Credit access	1=household member accessed credit in the past 5 years (dummy)	+	Access to credit enables the farmer to borrow and invest in livestock production technologies.
Extension services	1=household member accessed extension services in the past 5 years (dummy)	+	Extension services inform the farmer on availability, costs and benefits of a technology and how to use it.
Distance to market	Distance to livestock markets	_	The shorter the distance to livestock market to sell livestock and animal products earns a farmer income to afford new technologies
Agro-pastoralism	1=household is agro-pastoralist (dummy)	+	The farmer's rears animals on his farm with limited movements which makes it easier for heat detection.
Nomadic pastoralism	1= household is nomadic pastoralist	-	Farmer's movement with animals for long distances over time has a bearing on heat detection.
County	1=Household is located in Narok County and 0= in Kajiado County(dummy)	+	Farmers in Narok are close to the source of AI thus expected to have easy access to AI.
Nomadism	1= household is living nomadic lifestyle and 0= permanently settled (dummy)	_	Long distant seasonal movement with animals across borders reduces the chance to engage with service providers hence minimum chance for adoption of AI.
AI Attribute index	The weighted composite index of breed specific variables that condition preference	+/_	Attributes of farmers behavioral attitudes influence their perceptions towards preference for AI.

Variables relating to AI attributes (affordability, offspring motility, accessibility and its success rate) were each ranked by farmer on a scale of 1 to 5 capturing famer-specific perceptions of AI (1=strongly disagree, 2 = disagree, 3= indifferent, 4 = agree and 5 = strongly agree). The score of an individual respondent for all the attributes was divided by the total possible score (20) that a farmer would have received had he/she scored a maximum of five for each of the attributes. This was used to generate attribute index which was used in the ordered probit model. The reason for computing this weight was to establish how AI attributes as a composite variable influence perception of the farmer towards its adoption.

The composite index generated is then used as an explanatory variable in our econometric analysis to find its effect on preference. The composite index variable indicates the direction of influence the ranked attributes have on the likelihood of a farmer revealing his preference for AI.

4.3 Data

General information of household and socioeconomic characteristics of the household head such as age, household size, herd size, years of schooling, land size, experience in keeping livestock in years, distance to closest market in kilometres, group membership, production systems, awareness of AI, access to credit and extension services was collected. Respondents were interviewed using a semi-structured questionnaire based on a recall period of 12 months.

4.4 Results and discussions

4.4.1 Descriptive statistics of farmer and farm characteristics

Pastoralist production is a livestock production system characterized with large herds reared on huge chucks of arid and semi-arid areas. It involves movement with animals looking for pasture over long distance and is prone to risks especially during dry seasons. Table 4.2 presents a descriptive summary of key variables on farmer and farm characteristics.

The number of years of schooling was recorded to inform the level of education attained by the household head. Farmer's level of education is expected to have a positive effect on decision making process. On average, sampled farmers had schooled for 6 years and 6.5 years in Kajiado and Narok Counties respectively (upper primary). This is consistent with the findings of Rotich *et al.* (2014) who reported that 60% of the Maasai children in rural areas do not attend formal schools.Rotich *et al.* (ibid) further established that majority of the parents in Narok and KajiadoCounties were illiterate with the mothers being in the lead 45.0% and the fathers 43.3%. It isexpected that farmers with more years of education would be able to understand the benefits of AI technology and the need for adopting these high yielding livestock breeds. Education influences one's perception towards a new technology thereby increasing its adoption chances when used as a proxy of a farmer's ability to acquire and effectively use information (Genius *et al.*, 2006). A more educated farmer is hypothesized to have positive perception towards AI technology.

Table 4.2: Descriptive statistics for farmers and farm characteristics by County.

Variable	Whole sample	Counties		Tests	
		Kajiado	Narok	*t*-test	*z*-test
Education	6.63(6.18)	6.29(0.49)	6.59(0.47)	-0.44	
Household size	11.3(6.39)	10.39(0.48)	11.9(0.52)	-2.20**	
Land size	233(55.31)	368(54.41)	117(30.20)	4.20***	
Herd size	110.6(12.7)	90.7(8.17)	133.4(11.34)	-2.97***	
Experience	23.8(12.1)	25.6(0.98)	23.7(0.91)	1.41	
Distance to market	9.64(8.9)	8.97(0.69)	10.1(0.75)	-1.10	
AI awareness	0.80(0.4)	0.87(0.03)	0.75(0.32)		2.64***
Group membership	0.56(0.5)	0.54(0.04)	0.57(0.04)		-0.61
Credit access	0.70(0.46)	0.67(0.04)	0.73(0.03)		-1.03
Extension services	0.32(0.5)	0.22(0.03)	0.41(0.04)		-3.64***
Off farm income	0.15(0.4)	0.13(0.03)	0.16(0.03)		-0.79
Nomadic pastoralism	0.41(0.5)	0.51(0.04)	0.34(0.04)		3.13***
Lifestyle	0.16(0.4)	0.22(0.03)	0.11(0.02)		2.79***
Youth (18-35 yrs)	0.18(0.3)	0.16(0.03)	0.19(0.03)		-0.65
Middle aged(36-50yrs)	0.68(0.5)	0.72(0.04)	0.66(0.04)		1.18
Elderly (above 50yrs)	0.14(0.3)	0.12(0.03)	0.15(0.03)		-0.87

Note: Standard deviations are inparenthesis.
*******$p< 0.01$ and ******$p< 0.05$ mean statistically significant at 1% and 5% probability levels.

The results show that the average family size was eleven members. Pastoralists' household size is known to be relatively large as revealed by Serunkuuma and Kent (2001) in Nyabushozi who reported an average household size of 10 members among the agro-pastoralists in Soroti Eastern Uganda. This could be an indicator for the need to derive labour from household members in livestock production. Unlike in most Counties in Kenya, the Maasai community still own huge tracks of land parcels with a mean holding of 369 acres in Kajiado and 117 acres Narok.Most pastoralists owned this land in groups commonly referred to as group ranches. The land sizes indicated by the respondent refer to his/her share within the group ranch. Those still owning land collectively in the ranches do not have titles while those with private land had title deeds.

Livestock keeping being the main economic activity of pastoralists, they keep large herds (mean of 90 heads of cattle in Kajiado Countyand 133 in Narok County) of cattle since it is their main source of livelihood and provide social security (Ashley *et al.*, 1999). The large herds are viewed by many as the result of the pastoralists' attachment to their animals, with prestige and status, rather than economic gain, allegedly being the pastoralists' main concerns (Ouma *et al.*, 2004).

Most of the respondent had many years of experience in keeping livestock with a mean of 24 years and a significant deviation of 12 years as shown in Table 4.2. This implies that it is possible that the farmers starts keeping livestock at very young age and probably assumes full ownership immediately they are married as stipulated by the Maasai culture (focused group discussions results). Farmers with advanced age are associated with more experiencethrough which they can use to discern economic benefits of the technology before making the adoption decision (Fernandez-carnejo *et al*., 2001).

Given the vastness of the SALs, pastoralists cover long distances (mean of 9.64 km) (Table 4.2) in both Counties to reach the nearest market centres. These markets provides the only avenue to exchange live animals for cash to cater for other household needs. It is expected that long distances to the market provide a disincentive to the farmers to participate in livestock markets leading to so many deaths of animals during drought.Long distances also increase transaction costs (Abdulai andHuffman, 2005), which essentially translates to inability to access essential services.

Most farmers were aware of AI services as an alternative breeding method to the bull with a mean of 0.87 and 0.75 in Kajiado and Narok counties respectively. This difference in awareness of AI was high and significant across the sampled farmers in Kajiado and Narok Counties respectively. Nonetheless, most of the farmers admitted to not having used this technology before. Availability of information on given technology reduces perceived risks and uncertainties about that technology and influences a farmer to make informed decision to either adopt or not. Moreover, access to extension services was low with a mean of 0.22in Kajiado County compared to 0.41 in Narok County (Table4.2). The high numberof farmers having contact with extension officers in Narok County could be attributed to its proximity to main towns of Kisii and Kilgoris where a number of private extension officers are available. Access to extension services is likely to positively influence adoption of new technologies as reported by Khan *et al*. (2008) in their study on on-farm evaluation of the push pull technology for the control of stem bores and striga weed on maize in western Kenya.

Most farmers in both Counties belonged to either a production or marketing group (mean of 0.54 and 0.57 in Kajiado and Narok Counties respectively). It is within these groups that they are able to constructively share production knowledge on livestock feeds and general animal health and marketing strategies of livestock and livestock products. Moreover, farmers used these organized groups to sponsor a few “lead” farmers to learning seminars and field days in research organizations so that in turn they could learn from them. Farmer groups have been found to be an avenue through which new technologies can be promoted for adoption and it's expected to positively influence adoption of AI.Pastoralists have low access to formal credit institutions like the banks but they do access credit within their groups and farmer cooperatives. Most of sampled farmers (mean of 0.67 and 0.73 from Kajiado and Narok Counties respectively) had access to credit from their informal groups in the last 12 months (Table 4.2). Farmers with easy access to credit have higher likelihood to adopt AI since it's easier to finance acquisition of Sahiwal genetic material and pay the service provider.

Very few farmers with a mean of 0.13 and 0.16 of sampled farmers in Kajiado and Narok Counties respectively had other off-farm income generating activities besides livestock production. Nomadism was practiced by a small percent of the sampled population. On average, 0.54 and 0.34 of sampled respondents were practicing nomadic livestock production system. This system involves moving with livestock for long distances in search of water and pasture. Nomads are less likely to adopt new innovations such as AI because of their movements and therefore they are not able to detect a cow on heat and/or to locate an extension officer within the required time period in the fields.

Most of the sampled farmers were middle aged adults in the age bracket of 36-50 years. Such farmers are considered enthusiastic about new technologies and therefore are likely to adopt. Despite the fact that most of the farmers interviewed had no formal education, the willingness to try new ways of breeding was observed. The influence of age on adoption of innovation has beenmixed and is described as a composite of the effect of farming experience and planning horizon (Fernandez-carnejo *et al*., 2001). Older farmers (above 50 years) were not enthusiastic about AI, since the benefits are not expected in the short run.

4.4.2Pastoralist Farmers' Preference for Artificial Insemination

Pastoralists have different perceptions of artificial insemination as indicated in Table 4.3. An average of 0.68 of the farmers ranked artificial insemination as'least preferred' while 0.23 and 0.08 ranked their preference as 'moderately preferred' and 'most preferred' respectively within the whole sample.

Comparison of farmers' ranking of AI services in the sampled Counties revealed significant difference in ranking patterns with most farmers ranking AI as least preferred alternative breeding method in Kajiado County with a mean of 0.81 compared to 0.57 in Narok County as shown in Table 4.3.

Table 4.3: Pastoralist farmers' preference for artificial insemination.

Ranking levels	Whole sample (N =326)		KajiadoCounty (N =161)		NarokCounty (N =193)		*z*
	N	Mean	Mean	Std err	Mean	Std err	
Least preferred	223	0.68	0.81	0.032	0.57	0.037	4.635***
Preferred	77	0.23	0.13	0.027	0.33	0.035	-4.298***
Most Preferred	26	0.08	0.06	0.019	0.10	0.022	-1.22

*****p*< 0.01 and ****p*< 0.05 mean statistically significant at 1% and 5% probability levels.

In contrast, a mean of 0.13 and 0.33 of sampled farmersin Kajiado and Narok Counties respectively ranked AI technology as moderately ranked preferred method of spreading Sahiwal genetic resources for its adoption. This difference is significant across the counties and could be explained by the differences in nature of lifestyles. Most of the pastoralists in Kajiado are nomads and therefore movement with animals for long distances across borders reduces their ability to detect when the cows are on heat and if they do by chance, they may not be close to service providers (breeders) unlike agro-pastoralists in Narok who live on the farm with their animals and might access the breeders.

4.4.3 Factors that influence pastoralists' perception of artificial insemination

Some of the factors that may influence pastoralist preference for AI are shown in Table 4.4. Most pastoralists, 0.73 preferred AI based on its affordability across the two Counties. There was insignificant difference in perceptions of pastoralists about the cost of using this technology across the two Counties with 0.74and 0.75 of sampled farmers in Narok and Kajiado acknowledging it as the best cheap alternative breeding method. This high numbers could be attributed to the inadequate supply of Sahiwal bulls that influence farmers to be willing to pay for alternative breeding methods apart from the bull to enhance their Sahiwal production.

Based on the ability of a calf bred using AI to motility in semi- arid climate, 0.26 of the sampled population prefers to use artificial insemination. Disaggregated results by County mirrored the same low levels of AI preference with a significant difference in levels of preference across the two Counties. A high proportion of pastoralists in Narok County (0.47) approve of AI calves survival ability compared to their counter parts in Kajiado County (0.23).

Table 4.4: Factors that influence farmers' perception of AI.

Determinants	Whole sample		KajiadoCounty		NarokCounty		*z*
	n	Mean	Mean	Std err	Mean	Std err	
AI cost	334	0.67	0.75	0.036	0.74	0.034	0.1416
AI calf motility	334	0.26	0.23	0.037	0.47	0.034	-0.331**
AI accessibility	330	0.23	0.22	0.039	0.68	0.035	-0.89***
AI success rate	331	0.24	0.5	0.042	0.49	0.039	0.212

*****p< 0.01 and ****p< 0.05 mean statistically significant at 1% and 5% probability levels.

Among the pastoralists sampled, a few showedtheir interest in using AI based on its accessibility. Kajiado Countyregistered the lowest numbers of farmers (0.22) who rated accessibility to AI as compared to those in Narok County (0.57) as key to its adoption. These results are in line with findings of Omiti (2002), who found that about 20% of smallholder farmers in Kenyan highlands use AI. The sparse nature of settlements in Kajiado Countyexplains low perceptionrates of assisted reproductive technologies in livestock production compared to Narok County. These statistics confirmed the views of most farmers who participated in focused group discussions that it was not easier to access artificial insemination in the SALs.

An insignificantly low number of pastoralists would be interested in adopting based 'success rate' of AI (mean of 0.24). This can be attributed to lack of relevant information about AI among pastoralists, which explains why there are low rates of AI adoption in SALs compared to highland dairy farmers.

4.4.4Determinants offarmers' preference of Artificial insemination

Results of ordered probit regression are presented in Table 4.5. The likelihood ratio(LR) Chi-Square test for the goodness of fit shows that at least one of the covariates in the model is not equal to zero thus the model provides good fit for the data. The chi statistic (χ) is highly significant (p < 0.0000).To test our ordered probit model specification, a link test was performed and the results confirmed good model specification.

From the results the model coefficients indicate that group membership, access to extension, AI awareness, agro-pastoralism as a production system, County of residence, nomadic lifestyle, years of education, household size and herd size have a positive significant effect while farming experience and age had a negative significant effect on the perception of farmers towards AI adoption. Access to credit, distance to local market, land size and off-farm income were insignificant. The marginal effects presented in Table 4.6 refer to a smallchange in the dependent variable due to a marginal change in the explanatory variable, *ceteris paribus*.

Table 4.5: Ordered probit regression model results for revealed preference of AI.

Explanatory Variables	Coefficients	*t*-values
Group membership	0.358(0.185)*	1.93
Access extension	0.327(0.177)*	1.84
AI awareness	0.369(0.205)*	1.80
Agro-pastoralism	0.527(0.177)***	2.93
Narok County	0.538(0.192)***	2.81
Nomadism	0.406(0.237)*	1.71
Education	0.421(0.065)***	6.45
Access credit	0.188(0.200)	0.94
Household size	0.051(0.014)***	3.59
Herd size	0.001(0.001)**	2.06
Experience	- 0.025(0.008)***	-3.03
Youth (18-35years)	-0.742(0.300)**	-2.49
Young adult(36-55years)	- 0.508(0.233)**	-2.18
Distance	0.004(0.009)	0.49
Attribute index	1.935(0.571)***	3.39
Land size	0.00005(0.0001)	0.35
Off-farm income	-0.121(0.238)	-0.51
/cut1	3.290853	0.5689348
/cut2	4.675676	0.6063153
Number of observations		296
Prob > chi2		0.0000

Note: Standard errors are in parenthesis.
$^{***}p<0.01$, $^{**}p<0.05$ and $^{*}p<0.10$ mean statistically significant at 1%, 5% and 10% probability levels.

Membership to a group was found to have significant positive influence on farmers' perception towards AI. Group membership increases the probability of rating AI as 'preferred' by 9.4% and 'most preferred' by 1.6% (Table 4.6). This could be attributed to the fact that group members benefit from established social capital that enhances sharing of production information and knowledge. Most of the existing groups were mainly engaged in livestock production and marketing (for men) and milk selling (women). Members share knowledge within the groups and can invite livestock experts to teach them on better means of production, which was common in Narok County. The results suggest that groups provide a better avenue, through which interventions targeting farmers could be disseminated, thusconfirms findings by Mignouna *et al.* (2011) on adoption of a new maize and production efficiency in western Kenya.

The results further show that access to extension services increases the probability of a farmer moving from a lower preference level to a higher level by 8.9 % (p<0.1). These findings are consistent with those of Kaaya *et al.* (2005) in Uganda and Adegbola and Gardebroek (2007) in Benin who found adoption of technologies by maize farmers depended largely on receiving production information from extension agents or from other farmers.

Table 4.6: Ordered Probit marginal effects results.

AI preference	Marginal effects (least preferred)	Marginal effects (preferred)	Marginal effects (most preferred)
Group membership	- 0.109(0.055)**	0.094(0.047)**	0.016(0.009)*
Access extension	- 0.105(0.059)*	0.089(0.049)*	0.017(0.011)*
AI awareness	- 0.123(0.072)*	0.102(0.058)*	0.021(0.015)
Agro-pastoralism	- 0.165(0.059)***	0.139(0.049)***	0.027(0.012)**
Narok County	- 0.165(0.057)***	0.140(0.049)***	0.024(0.011)**
Nomadism	- 0.138(0.085)	0.113(0.068)*	0.025(0.020)
Education	- 0.131(0.020)***	0.112(0.020)***	0.019(0.006)***
Access credit	-0.059(0.059)	0.049(0.051)	0.008(0.008)
Household size	- 0.016(0.004)***	0.014(0.004)***	0.002(0.009)***
Herd size	- 0.0004(0.0002)**	0.0003(0.000)***	0.0001(0.00003)*
Experience	0.008(0.003)***	- 0.007(0.002)***	- 0.001(0.0005)**
Age -youth	0.190(0.060)***	- 0.168(0.055)***	- 0.022(0.009)***
Young adult	0.167(0.080)**	- 0.138(0.065)**	- 0.029(0.018)*
Distance	- 0.001(0.003)	0.001(0.002)	0.0002(0.0004)
Attribute index	- 0.602(0.177)***	0.515(0.158)***	0.087(0.034)**
Land size	- 0.00001(0.000)	0.000001(0.000)	0.000002(0.00001)
Off-farm income	0.037(0.070)	- 0.032(0.061)	- 0.005(0.009)

Note: Standard errors are in parenthesis. ***p< 0.01, **p< 0.05 and *p< 0.10 mean statistically significant at 1%, 5% and 10% probability levels.

In our studyat least22% of farmers in Kajiado and 41% in Narok had access to extension services (Table 4.6) which shows that extension services were still limited. In response to government's policy of demand driven extension services provision to farmers, NGOs in pastoral areas organize open field days for farmers to interact and share production experiences. Field days are taken as a form of extension, and explain the reason as to why farmers participating are more likely to adopt AI than non-participants. These results complement the findings of Amudavi *et al.* (2009) on evaluation of farmers' field days as a dissemination tool for Push-Pull technology in western Kenya, who observed that the farmers' propensity to seek new agricultural knowledge motivated farmers to attend the field days and seek extension services. The current results further corroborate with findingsof

Murage *et al.* (2011) who found high preference of field days by farmers as key to new technology dissemination. In some cases, hands-on training and physical demonstration to farmers at KALRO multiplication centres are encouraged.

AI awareness was found to have a significant positive relationship with the preference. The coefficient indicates that being aware increased the probability of a farmer to move from lower rank (least preference) to preferred rank by 0.102 times. Preference of a new technology depends on the availability of information to the farmers about that technology. The current low preference of AI in SALs could be attributed to lack of relevant knowledge to the farmers about its potential to increase production and the technical know-how. These results are consistent with findings of Johnson and Ruttan (1995), who found breeding technologies to be highly information intensive. The farmer or service provider is required to understand principles of breeding and genetics, as well as performance data collection, management and analysis, in order to use the new technologies effectively.

Experience in keeping livestock had a positive significant effect on the probability of a farmer rating AI as 'least prefer' while it had a negative significant effect on a farmer rating AI as 'preferred' or 'most preferred'. This means that a unit increase in years of farming experience in keeping livestock reduces the likelihood of moving from a lower level of preference to higher preference levels for AI ($p < 0.01$). This result contradicts most studies that found relative farming experience to accumulate knowledge that influence a farmer to use new technologies that would boost production (Odendo *et al.*,2010; Motuma *et al.* 2010). Most pastoralists who have kept livestock for many years hold a pessimistic view about the ability of breeding using assisted reproductive technologies besides the bull. The coefficients for age groups indicate negative significant relationship with AI adoption. That is, the older a pastoralist becomes the less likely that he/she would shift his/her low perception towards AI to higher preference. This is consistent with the experience effect in the current study. However, young farmers are more willing to take the risk of adopting new technologies unlike their old counter parts that are more risk averse, thus, corroborating study findings by Howley *et al.* (2012) on AI adoption in Ireland.

Education of a household head had a significant positive influence on the perception of a pastoralist towards AI. Given that it is a new technology among most pastoralists, those who are educated were willing to take the risk and try, while the less and non-educated are more risk averse. These findings are consistent with most adoption studies (e.g. Genius *et al.,* 2006; Abebe *et al*., 2013; Howley *et al.,* 2012; Velandia *et al.,* 2011) since a new technology is developed to better production. Education has been found to increase farmers' ability to obtain and evaluate information about an innovation before making informed decision on its adoption. However, most of the older farmers were not educated and therefore their probability of moving from a lower level of preference was low unlike their young counter parts.

There was a significant difference in the perception effect of AI across Counties. Most farmers in Narok County areagro-pastoralists hence movement of their animals is limited to short distances from their homesteads except during prolonged dry spells. Limited movement of livestock makes it easier to spot animals on heat and call service providers to their homes to administer AI unlike those pastoralists in Kajiado who move with animals from one locality to another in search of water and pasture (nomadism). Household size was significant at one percent and positively related to preference for AI. This means that an additional member to the household would increase the likelihood of preferring artificial insemination as a breeding technology. This could be alluded to the fact that huge herd sizes symbolizes wealth in Maasai community and livestock being the major source of their livelihood, any attempts to improve and grow the herd size is most welcome. These results were in line with findings of Mignouna *et al.*(2011) whose study reported household size as a proxy to labour availability and a positive relationship with adoption of insect resistant maize. Further, pastoralist households depend on livestock for food, manual labour and other cultural obligations like payment of dowry. There is desire to increase production of Sahiwalbreed that fetches high returns on the market as well as produce more milk to cater for household requirements.

Herd size was found to be significant at 1% indicating that an increase in the number of animals in the herd by one increase the probability of a pastoralist to prefer AI by 0.0003 times. This is sensible given that AI can be done simultaneous on many animals unlike a single bull in a large herd size. The small influence herd size had on adoption of AI contradicts findings of a study by Janssen *et al.* (2006) who found availability of AI to be practically zero and needs an organization structure that targets livestock under current management with intensive herd movement and far distances between herds in Kenyan SALs. They also established that use of AI required comparatively more input into the infrastructure and education since pastoralist's experiences with this technique is very little and they consequently have less confidence in it. However, in the current study the small probability of farmers who wish to use AI could be attributed to the ability of service provider to synchronize insemination on many dams in order to increase milk production in given seasons which cannot be achieved by a single bull. It's also imperative to note that a huge herd size is a symbol of wealth and efforts to increase the number of animals are highly appreciated by the pastoralists.

Land size, distance to the market and off-farm employment were not significant in determining the probability of a farmer moving form a lower to a higher preference level or *vice versa*. Farm size had a positive but insignificant effect on AI adoption unlike the findings of Howley*et al.* (2012) who found a significant negative relationship. This was inconsistent with our prior expectation that more land holding capacity a household has, the more he/sheis interested in a technology that would be able to increase its herd size and maximize use of the land. Again this insignificance can be attributed to the fact that pastoralists graze beyond their land boundaries, in communal lands, group lands and nationals reserves.

4.5Conclusion

This chapter focused on the analysis of farmers' preference of artificial insemination and the determinants influencing their perceptions. Current study results have revealed low ranking for AI services as an alternative breeding technology to the bull. Success rate of AI technology in breeding, its accessibility, and the ability of the AI calf surviving in pastoral areas were key factors that influenced low preference for AI compared to the bull. However, given the difficulties in accessing quality bull from the NSS, most farmers would adopt AI because of its affordability compared to the cost of buying the bull or hiring one from other farmers. Pastoralists' level of preference for AI was significant and positively influenced by education levels which means that targeting educated farmers and community leadership through groups will positively influence farmers' perception of AI thereby increasing its adoption. Comparing the cost of hiring or acquiring a bull and the cost of procuring AI, its cost effectively to use AI on large herd size besides other animal health benefits associated with not using the bull such as avoiding the spread of diseases andinbreeding. The results also showed that production system and location of resident were significant in influencing the breeding method chosen by the pastoralist. This means that concerted efforts by both government should target high ranching zones where Sahiwal are well adapted for optimal productivity. Targeting Trans Mara district and lower central parts of Kajiado County in dissemination of AI will yield the desired of goal of increased production. Large family size requires food to feed on and physical investment to secure its future needs as well as cushion it against seasonal shocks like drought and hunger. Investing in AI technology for better and quality breeding to increase herd size which is wealth to the Maasai community is a better entry point to its adoption. Current study findings indicate that pastoralists who were aware of AI would prefer AI. This means that creating awareness through existing local media and local leadership would promote its acceptance. However, livestock keeping experience and the age of the pastoralist had negative significant effect on his preference of AI. Significant institutional variables such as; access to extension services and group membership provide important policy intervention avenues when designing strategies to enhance adoption of AI in pastoral areas. This therefore implies that both County and national leadership to train and deploy livestock extension officers in these areas to facilitate AI uptake through provision of relevant information.

CHAPTER FIVE

PASTORALISTS' WILLINGNESS TO PAY FOR ARTIFICIAL INSEMINATION

5.1 Introduction

Most farmers in the Country have at least encountered a new agricultural technology in their course of production. These technologies are either new to the farmers or an improvement of the traditional ones with enhanced efficiency in delivery. In order to ensure sustainability of a technology after the exit of its promoters, the beneficiaries (farmers) upon adoption in the short run, must be willing to pay for it. In their study on consumers' awareness and Willingness to Pay (WTP) for insect resistant maize development through genetic modification in Kenya using double bounded contingent valuation methodology, Bett *et al.* (2010) found that most rural consumers expressed willingness to purchase genetically modified maize even at a premium provided it reduces crop losses and increase productivity. Moreover, a study by De Groote and Kimenju (2008) in Kenya on comparison of consumer preferences for colour and nutritional quality in maize using a semi-double bounded logistic model on urban consumers established that most consumers showed strong preference for white maize compared to yellow maize. However consumers require a price discount to accept yellow maize since most of them were not aware of its nutritional value. Similarly, it requires sensitization of the targeted beneficiaries to accept to pay for a new technology in the long term.

The use of Contingent Valuation (CV) methods for estimating farmers' valuation of non-market goods or new technologies has gained popularity in SSA. Originally, social economists developed these methods in environmental studies, wildlife conservation and natural resource economics (Hanemann *et al.*,1991**;** Carson and Mitchell, 1989). The technique is appropriate in imploring producers' WTP for a product that is not yet on the market, such as AI in pastoral areas of Kenya. Applicability of this approach demands that the researcher crafts a hypothetical market for a non-market good or unique product, requests a set of subjects to operate in that market, and records the outcomes. The values generated through the usage of the hypothetical market are treated as estimates of the value of the non-market good or service, depending on that hypothetical market as illustrated by Carson and Mitchell (1989).

Establishing the opinion of stakeholders is crucial before introduction of a new technology because it shapes the direction of their adoption and diffusion (Kimenju and De Groote, 2008). The importance of establishing pastoralist farmers' WTP for AI is to attach a monetary value to the technology before its introduction. Inclusion of all the stakeholders at initial stages of situational analysis and feasibility of AI as an alternative breeding method in pastoral systems signalled the relevance and enthusiasm with which pastoralists would wish to explore new production technologies. This was done in view of the fact that despite inception of AI services in the Country, its utilisation among pastoralist farmers is very low. This objective therefore seeks to establish the feasibility and viability of introducing AI technology and its sustainability through market structures. The value that was established during the survey forms the baseline upon which the price of AI can be set for uptake in pastoral areas.

5.2 Model specifications and empirical analysis

Following the analytical framework of Hanemann *et al.* (1991), WTP can be estimated using questions that are open-ended, asking the respondents to declare the maximum amount they would be willing to pay, or close-ended, asking the respondents if they would be willing to pay a specific amount or not (dichotomous choice). The open-ended format is appropriate when the consumer is well informed about the new product and its characteristics. However, literature indicates that such an approach would be misleading if the respondent lacks appropriate information and incentives to comprehensively determine the values to attach to a good or technology if a market were to exist (Arrow *et al*., 1993).Closed-ended questions, are easier and more realistic since they correspond more to a real market situation.

In many transactions, farmers are offered a technology at a given price such that after considering his ability to buy, the decision is then reached on whether to buy or not. Estimating WTP using single-bounded method, the individual only responds to one bid which is incentive-compatible; it is in the respondent's strategic interest to say ‘‘yes" if his WTP is greater or equal to the price asked, and ‘‘no" otherwise (Carsonand Mitchell, 1989). Utility maximization implies that a farmer will then only answer ‘‘yes" to the offered bid if his maximum WTP is greater than the bid. However, the single-bounded method requires a large sample size and is statistically inefficient (Hanemann *et al.,* 1991). In order to ensure efficiency of the estimates, we adopted double bounded method by offering the respondent a second bid, higher or lower depending on the first response. This approach includes more information about the respondents WTP and, therefore, provides more efficient estimates and tighter confidence intervals (Hanemann, ibid). Table 5.1 presents the definition of variables included in the model used.

Table 5.1: Variable definition for contingent valuation.

Variable name	Definition
B_i	Initial bid in KES
B_i^u	Second higher bid in KES if answer to initial bid was yes
B_i^d	Second lower bid in KES if answer to initial bid was no
Nn	Dummy (1= if the answer to the WTP questions was no, no)
Ny	Dummy (1= if the answer to the WTPquestions was no, yes)
Yn	Dummy (1= if the answer to the WTP questions was yes, no)
Yy	Dummy (1= if the answer to the WTPquestions was yes, yes)
Awareness	Dummy (1= if the farmer has ever heard of AI in the last 5 years)
Credit	Dummy (1= if the farmer had access to credit facilities in the last 12 months)
Herd size	Current total number of cattle owned by farmer
Extension	Dummy (1= if farmer had access to extension services)
Education	Number of years of schooling
Age	Number of years the farmer has been living
Household size	Number of household membership
Off-farm income	Dummy (1= if farmer earns some extra income from off-farm) activities

The respondent is asked if he/she is willing to pay an amount B_i, for the provision of AI services on his farm per animal. If the farmer answers 'no' then we can assume that $0 \leq$ WTP<B_i, if he answers 'yes' then $B_i \leq WTP < \infty$. More explicitly, the respondents will fall within one of the following categories:

The farmer answers 'yes' to the first question and' no'to the second question, then $B_i^u > B_i$ thus we can infer that $B_i \leq WTP < B_i^u$

The individual answers 'yes' to the first question and 'yes' to the second question, then $B_i^u \leq WTP < \infty$.

The individual answers 'no' to the first question and 'yes' to the second question, then $B_i^d < B_i$, thus conclude that $B_i^d \leq WTP < B_i$,

The individual answers 'no'to the first and second questions, then we have 0 $< WTP < B_i^d$

Adopting the modelling framework of Hanemann *et al.* (1991), the likelihoods of these outcomes are π^{yy}, π^{nn}, π^{yn}, π^{ny},respectively. Under the assumption of utility-maximizing farmer, the formulas for these likelihoods are as shown below. In the first case where the respondent accepts the initial and second higher bid, we have $B_i^u > B_i$;

$$\pi^{yy}(B_{i,}B_i^u = \Pr\{B \leq \max WTPand \quad B_i^u \leq \max WTP\}$$

$$= \Pr\{B_i \leq \max WTP \mid B_i^u \leq \max WTP\}\Pr\{B_i^u \leq \max WTP\} \quad (5.1)$$

$$= \Pr\{B_i^u \leq \max WTP\}$$

In the second case where the respondent rejects the initial bid and second lower bid, we have $B_i^d < B_i$;

$$\pi^{nn}(B_i, B_i^d) = \Pr\{B_i > \max WTP \ \ and \ \ B_i^d > \max WTP\} \quad (5.2)$$

Third case where the respondent accepts the initial bid and rejects the second bid, we have $B_i^u > B_i$;

$$\pi^{yn}(B_i, B_i^u) = \Pr\{B_i \leq \max WTP \leq B_i^u\} \quad (5.3)$$

The last case where the respondents rejects the initial bid and accepts the second bid, we have $B_i^d < B_i$;

$$\pi^{ny}(B_i, B_i^d) = \Pr\{B_i \geq \max WTP \geq B_i^d\} \quad (5.4)$$

Computing the mean WTP a logistic curve was specified, fitted on the data and estimated. The log-likelihood function was then defined and estimated as:

$$\ln^D(\theta) = \sum_{i=1}^{N}\{d_i^{yy}\ln \pi^{yy}(B_i, B_i^u) + d_i^{nn}\ln \pi^{nn}(B_i, B_i^d) + d_i^{yn}\ln \pi^{yn}(B_i, B_i^u) + d_i^{ny}\ln \pi^{ny}(B_i, B_i^d) \quad (5.5)$$

where $d_i^{yy}, d_i^{nn}, d_i^{yn}$ and d_i^{ny} are binary-valued indicator variables.

The final step was to specify and estimate a WTP regression model to determine factors influencing WTP. The regression method allows inclusion of other factors in the analysis, in particular socioeconomic characteristics of the respondents to explain the bidding behaviour.

5.3 Data

In order to establish WTP for AI services, information regarding households age, household size, years of schooling as a proxy for education, off-farm income, awareness of AI, access to credit and extension services was collected. Information on different bids was also elicited from farmers to aid in computation of their WTP for AI.

5.4 Results and discussions

5.4.1 Farmers' awareness of AI services

Prior to establishing the extent to which farmers would be willing to pay for AI, it's imperative that we determine if they are aware of this technology. To illustrate this, descriptive analysis was carried out and the results presented in Figure 5.1. It was evident that 64.37% and 70.15% of farmers in Kajiado and Narok Counties respectively knew about the existence of AI services. This provides much needed background upon which sensitization needs to be built in order to achieve maximum diffusion of the technology. However, awareness of AI does not guarantee its uptake as noted by Chinese consumers towards biotech rice. Lin *et al.* (2005) found that consumers who were aware of biotech foods were less inclined to purchase biotech rice than those who had no or little awareness. Moreover, the impact of the awareness variable was not statistically significant in the case of biotech soybean oil (Lin *et al.*ibid).

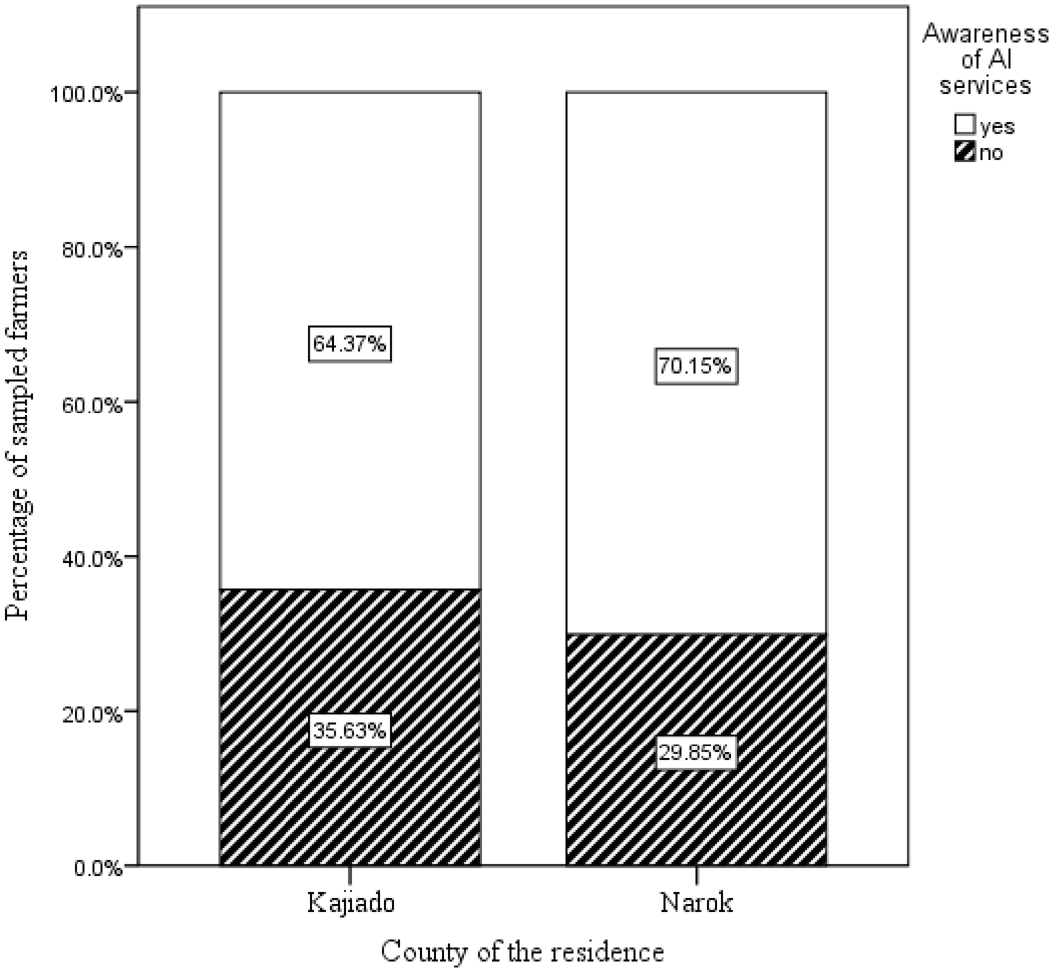

Figure 5.1: Percentage of farmers' who were aware of AI services in the last 5 years.

However, most farmers still use the natural service method as the major breeding method (Figure 5.2). Results showed that 86.39% and 73.76% of sampled farmers in Kajiado and Narok counties use natural service as their major breeding method despite their awareness of AI. This could be attributed to the fact that accessibility of the services is still a major challenge due to infrastructural constraints, faith in the technique and the communities' preference for bull service as reported by Janssen-Tapken *et al.* (2006). There are few service providers in the area which makes it even harder for farmers who would have wished to adopt AI technology. Figure 5.2 shows the distribution of major breeding methods by County against the herd size held by the pastoralists.

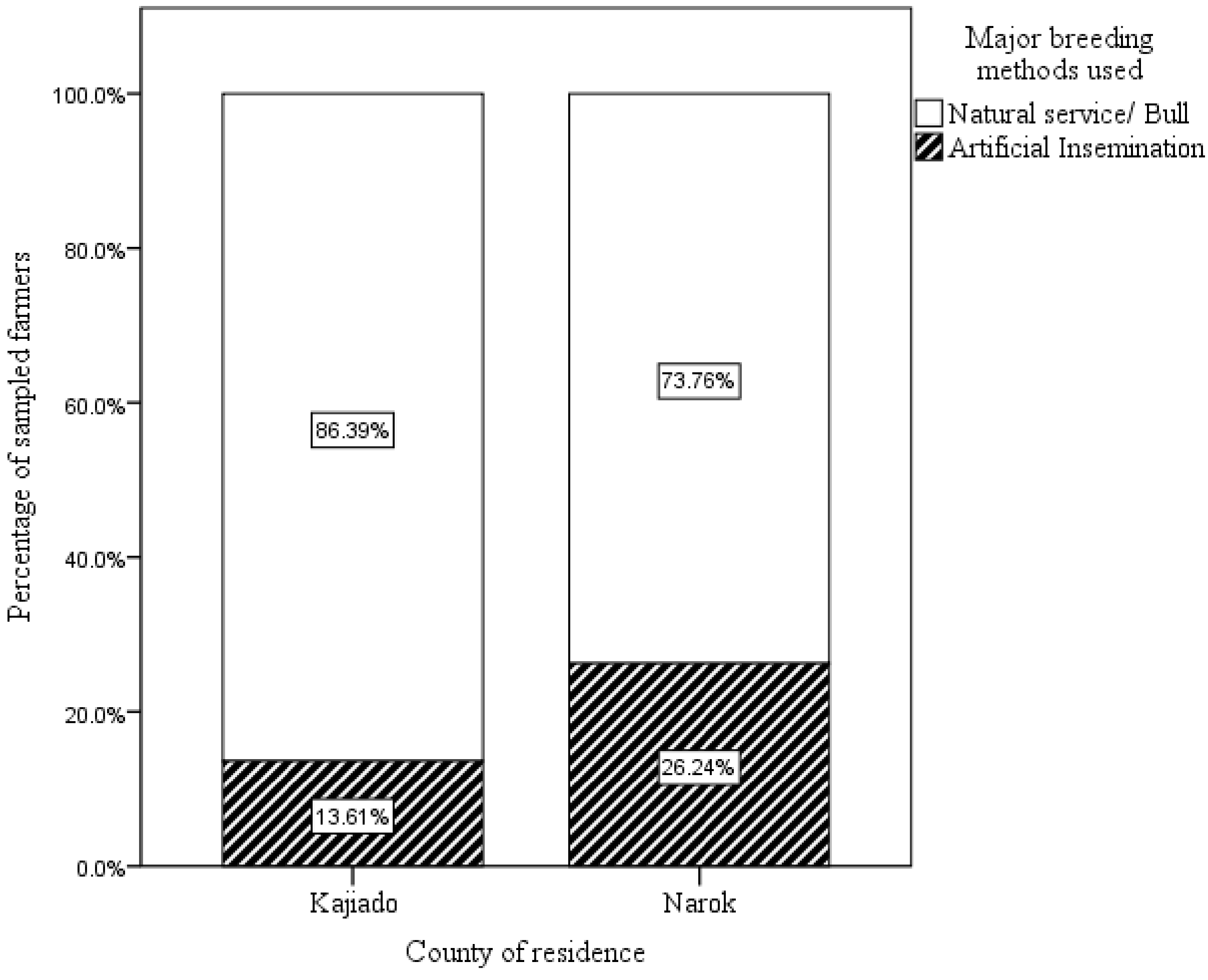

Figure 5.2: Distribution of major breeding methods in sampled SALs.

Despite AI as a technology being technically beneficial, lack of appropriate delivery system, its adoption and effectiveness in pastoral areas is declining. The consequence of this fall is undesirable because the genetic potential and productivity of the dairy herd in SALs is bound to decline very rapidly.The inadequate incentives for both public and private breeders to practice in SALs have been a major hindrance to the spread of AI services across from the highlands to the SALs (Oluoch-Kosura *et al.,* 1999). The long distances that must be covered by a service provider between one household to another in SALs and to the nearest markets as illustrated in chapter four of this thesis (average of 9.6km) and the cost incurred outweigh the revenues that are likely to be generated from such business. This therefore necessitates deliberate government intervention in deploying public AI service providers and facilitate their movements within these areas (Oluoch-Kosura *et al.,* 1999). It's only through such initiatives that the goal of disseminating Sahiwal genetic material would be achieved without creating unnecessary pressure on NSS to supply the bulls to the farmers.

5.4.2 Sources of breeding materials in the study area

Previous AI service was provided by the government through Kenya National Artificial Insemination Service (KNAIS), which was highly subsidized to the dairy farmers. Israelsson and Oscarsson (1991) reported that the most low cost method of providing AI service to the farmer was daily run model, as long as such inseminations are made per day by one inseminator, covering between 100 and 120 km along a prescribed route. However, another alternative model would be where the inseminator waits for a call from farmers on when to provide the service. Given the high cost and distant constraints most farmers face in their efforts to procure AI in SALs, most of them end up buying the bull among themselves without considering the possible challenges of in-breeding. Figure 5.3 shows various sources of getting the bull either by buying or hiring. In most instances, production goal of the farmer is often overlooked when searching for the bull from fellow farmers or when animals mate in the pasture fields without the knowledge of the farmer. Discussions with pastoralist farmers revealed that it is expensive to hire a bull (about KES 2000 for one day) which may not be economical compared to the options of owning the bull or procuring AI service.

It's evident from figure 5.3 that most farmers share the bull or buy/ hire amongst themselves rather than getting it from the known ranches within their reach (21.35% and 25% from Kajiado and Narok respectively). This provides insights for livestock breeders in terms of dealing with in-breeding and fighting livestock diseases that are related to genetic formation of the animal. It also highlights the important role played by extension service providers in terms of educating the farmers on recording keeping.

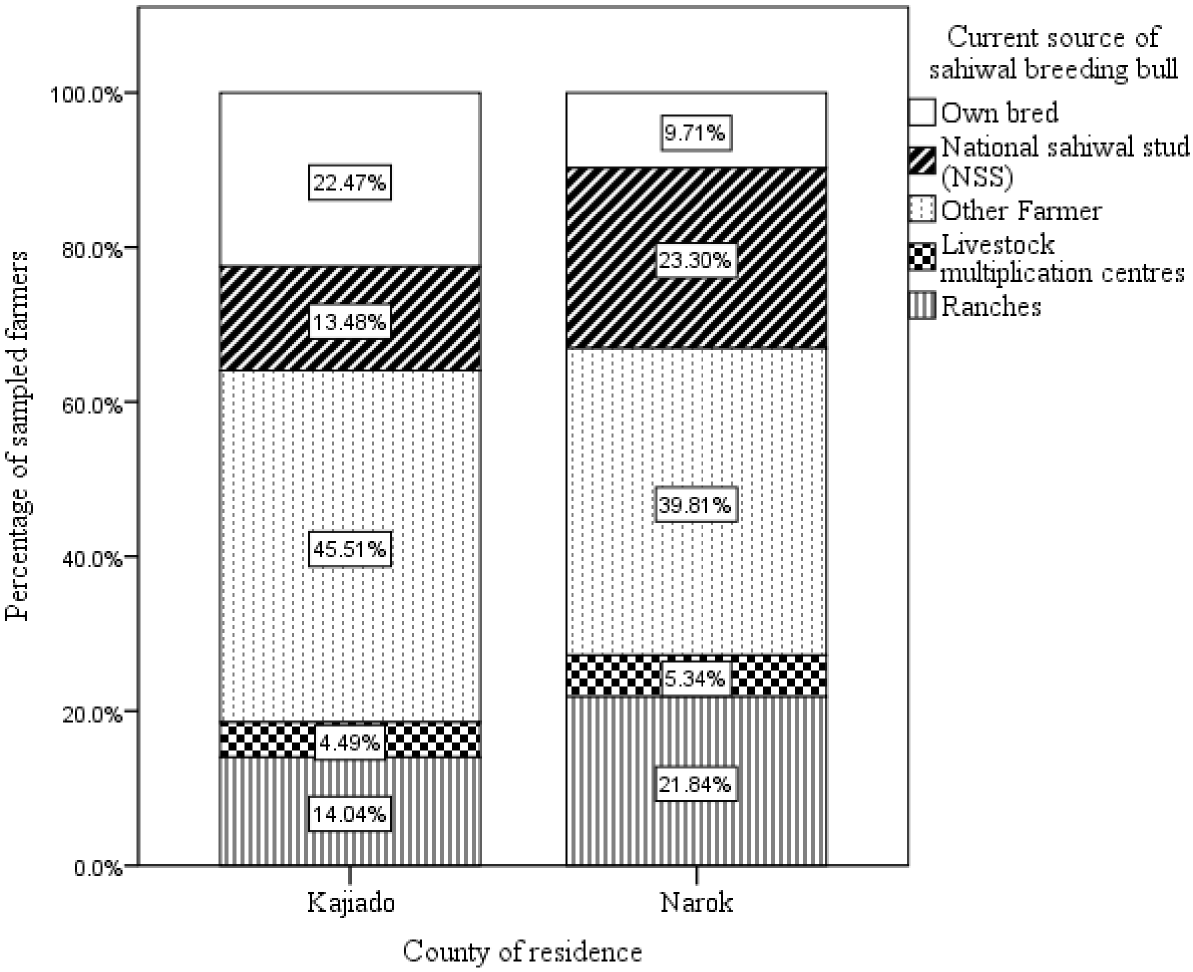

Figure5.3: Distribution of major sources of Sahiwal breeding material in pastoral areas.

The survey also revealed that most ranches (Ilkerin, Loita and Keiyan) are private and do not keep pure Sahiwal breed. This was because private farmers have different production objectives and therefore would mix the breeds as long as their production goal is maximized. For instance the Ilkerin and Loita ranches had mostly crossbred the Sahiwaland Boran to produce cattle with high live weight while the Keiyan ranch had pure breed concentrating on milk production. This could be the reason as to why very few farmers chose the ranches as their source of breeding materials. Despite government efforts to denuclearize breeding services from the NSS, very few farmers have access to the only two existing livestock multiplication centres in pastoral areas. These multiplication centres include KALRO-Trans-Mara and Kajiado which were meant to provide bulls for pastoralists in Narok and Kajiado Counties respectively. However, these centres are underdeveloped and understocked to meet the demand which is explained by low populations they serve as illustrated in Figure 5.3 above. In this study, we also found that most of the pastoralists' preferred dual purpose based breeding strategy whereby the major goal is milk and meat. This could be informative for breeders so that they actually understand what exactly highland *viz-a-vis* pastoralist production goals are so that appropriate breeding strategies are adopted for pastoralists.

5.4.3 Farmers' willingness to accept AI services

The decision to pay for a particular technology depends solely on the prior response on the willingness to accept it. This underscores the importance of qualitative studies on perceptions of both producers and consumers of services and goods before introducing them in the market. The question of amount is only relevant if the farmer is willing to accept AI otherwise a hypothetical scenario has to be created to entice him to reveal his willingness to accept (Arrow *et al*., 1993). This is based on the assumption that there are underlying constraints to access AI (accessibility, cost and success rate) such that if they are addressed then he/she may be willing to value the technology.Figure 5.4 indicates the percentage of the farmers who were willing to accept AI services on their farms.

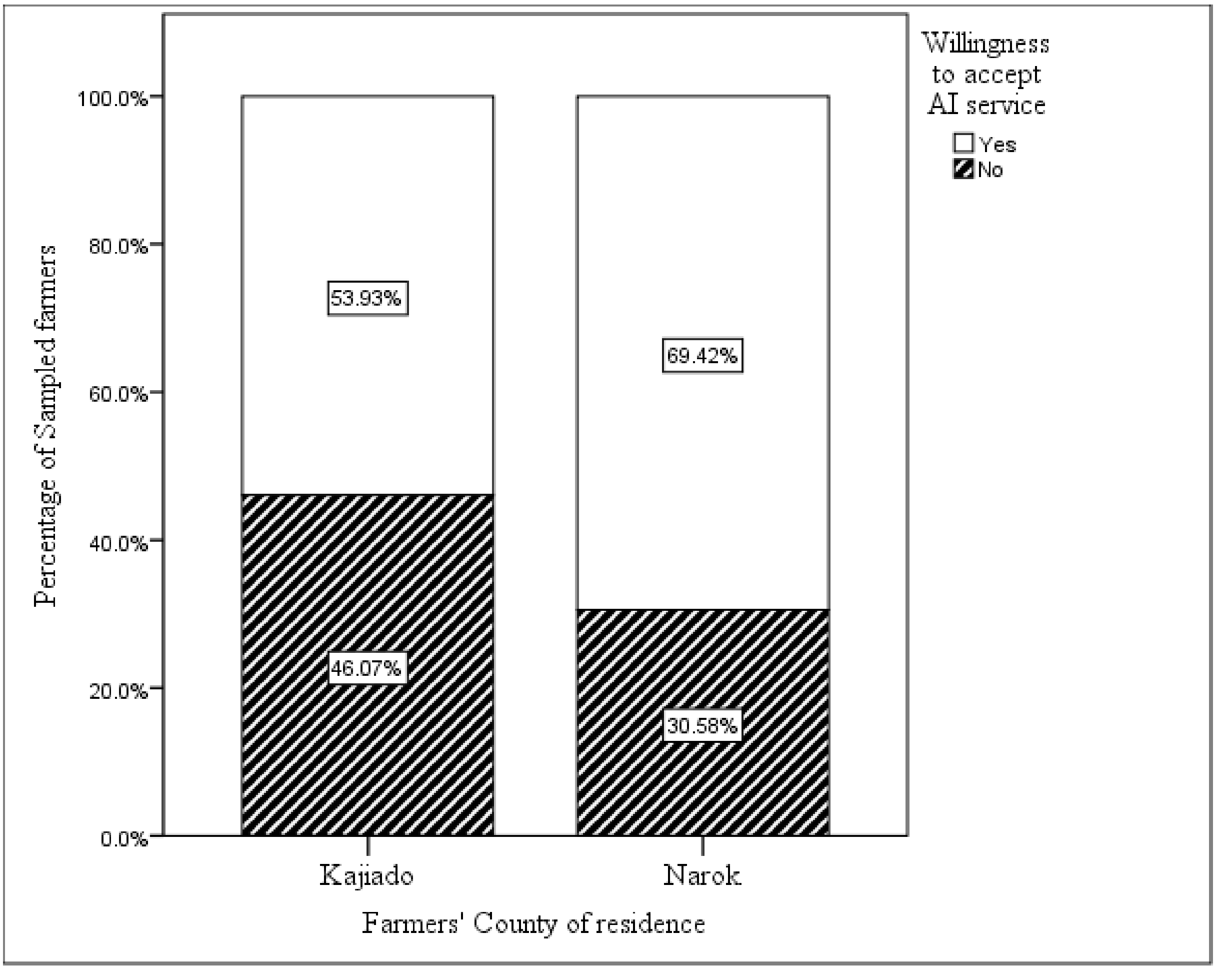

Figure 5.4: Distribution of farmers' willingness to accept artificial insemination.

The results indicate that 43.93% of the farmers in Kajiado were willing to accept AI compared to their counterparts (69.42%) in Narok County. This implies that indeed farmers are much more willing to adopt new production technologies (specifically AI) capable of increasing output more rapidly at minimum cost possible. Current study findings are consistent with the findings of a study by Kimenju and De Groote (2008) on consumers' WTP for genetically modified food in Kenya. Their study established that most consumers were willing to accept genetically modified maize despite low awareness.

5.4.4 Monetary valuation for artificial insemination in pastoral areas

To ensure sustainability of the technology in pastoral areas, farmers we presented with different bids in order to establish their true amount they are willing to pay for AI. On average, 51.30% of the sampled farmers were willing to pay the initial bid proposed to them. Table 5.2 illustrates farmers bidding behavior with respect to different bids that were given. Note that only one bid was given to an individual farmer as his initial bid.

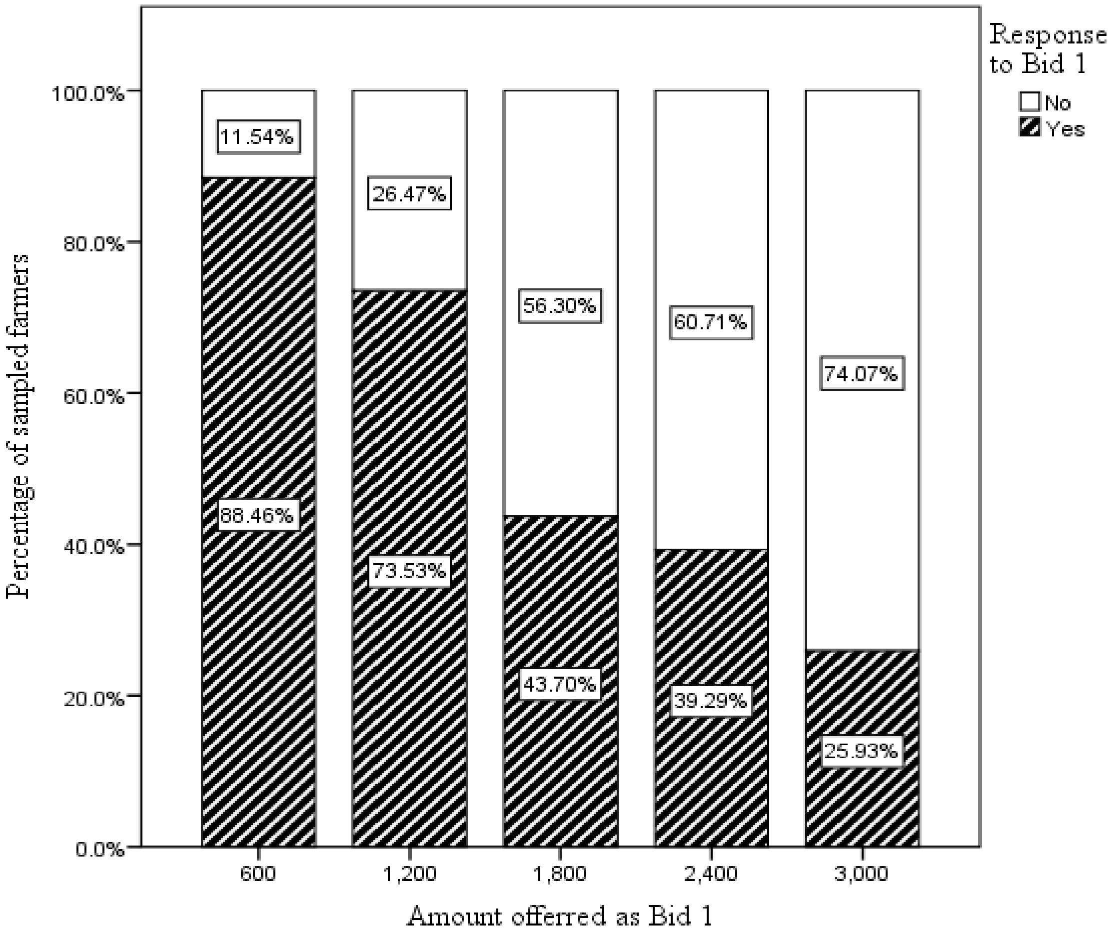

Figure 5.5: Farmers bidding pattern for the initial bid.

The results also indicates that as the bid increases from KES 600 to KES 3000, the number of farmers affirming their ability to incur that cost declines. This is rational of farmers because as the cost of a new technology increases, given their cost outlay, they pursue a minimization objective and keep their production goals intact.

The second bid is contingent on the response and amount indicated by the farmer in the initial bidding (Hanemann *et al*., 1991; De Groote andKimenju, 2008; Arrow *et al*., 1993). It's evident from Table 5.3 that 49.22% of farmers were willing to pay a second bid compared to 50.78%. The second bid offered was either a discount to the first bid offered for those farmers who declined to pay initial bid or a premium on the initial bid for farmer who were willing to pay initial bid as the true price for getting AI. The bidding behaviour of farmers towards the second bid was similar such that as the amount increases, then few are willing to incur such cost as can be seen when bid rises from KES 400 to KES 3600.

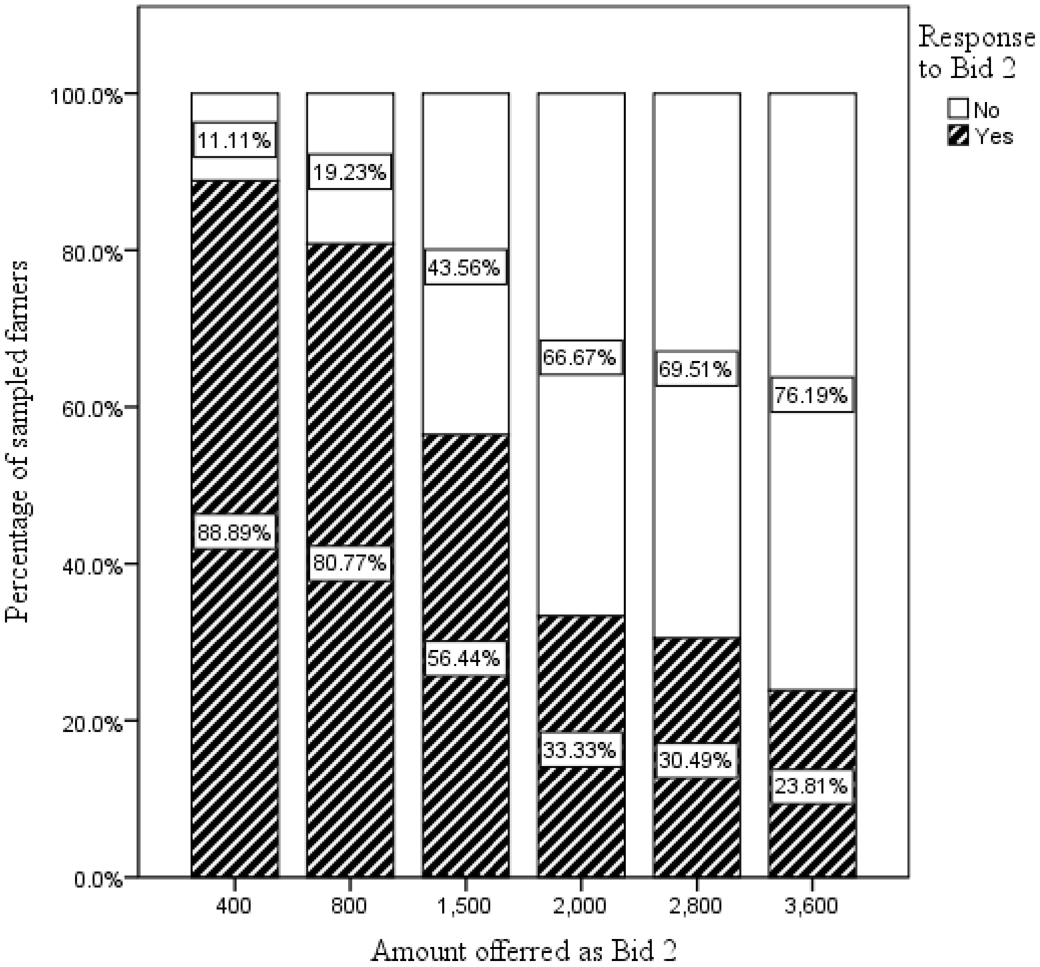

Figure 5.6: Farmers bidding pattern for the second bid.

Computation of farmers WTP can be done with or without inclusion of covariates in the modelling strategy (Lopez-Feldman, 2012). Table 5.4 shows results of a double bounded contingent valuation approach without including covariates. The results revealed an average of KES 1881.25 as the mean WTP for AI by pastoralists in SALs of Kajiado and Narok Counties. This reflects a premium of 25.42% placed on AI by pastoralists with reference to the base price of KES 1500 offered for exotic breeds in Kenyan highland.

Table 5.2: Results for double bounded contingent valuation without covariates.

Variable	Coefficient	*z*	*p*-value
Beta constant	1881.25(50.79)	37.04	0.000
Sigma constant	844.13(43.28)	19.50	0.000
Number of observations	384		

Note: Standard errors are in parenthesis.

However, the bidding decision by the farmer is informed by various factors including his awareness of AI, access to credit facilities to finance new technologies, herd size, household size, age education levels, access to extension services, and his farm income. It's worth noting that in expressing the amount they are willing to pay for the provision of the service, there is implied price comparison between the cost of the bid and the cost of acquiring the bull. Sahiwal bull at market price at that time was KES 120,000 if bought from KALRO – Naivasha and KES 80,000 if bought from the local markets. However, the survey revealed that most Sahiwal farmers interested in replacing the bull or acquiring an extra one would prefer getting it from KALRO.

Inclusion of factors influencing the bidding behaviour of the farmer, the Mean WTP for AI services reduces to KES 1853.19. This reflects a deviation of KES of 28.06 (23.55% of base price of KES 1500). As indicated in Table 5.5; awareness, herd size and access to extension had significant positive influence while farm income had significant negative effect on farmer's bidding process.

Knowledge about the existence of a good or technology by the consumer or farmer influences his decision to approve its uptake. In the current study, we found farmers awareness to positively influence his WTP for AI. Exposure to information on AI technology increases the probability of accepting a higher bid by 68.3%. These findings corroborate findings of Bett *et al.* (2010), who found that awareness of the gene had significant increment on consumers' WTP for GM maize in Kenya. However, the current study results are contradicts the study findings byLin *et al.*(2006) who found consumers with exposure or awareness of biotech rice to be less inclined to purchase biotech rice than those who have no or little awareness. This implies that targeting the dissemination of information to farmers with the least exposure orno awareness would be a more effective strategy to achieve sustainability of AI technology in pastoral areas.

Table 5.3: Parameter estimates for WTPmodel for AI with covariates.

Variable	Coefficient
Awareness	0. 683(0.242)***
Credit	0.192(0.164)
Herd size	0.001(0.001)*
Extension	0.643(0.147)***
Education	0.022(0.050)
Age	-0.135(0.098)
Household size	-0.010(0.013)
Off-farm income	0.533(193)***
Number of observations	384
LR χ^2	119.11
Prob $>\chi^2$	0.0000
Mean WTP	1853.19

Note: Standard errors are in parenthesis.

*** $p< 0.01$ and * $p< 0.10$mean statistically significant at 1% and 10% probability levels.

Farmers herd size had a positive significant effect on farmers'WTP for AI. This could be attributed to the fact that farmers with large herd sizes found it economical to use AI than to procure the bull which is more expensive compared to the cost of AI. Moreover, repeated use of same bull leads to in-breeding. Inbreeding in pastoral areas is a reality given the fact that most farmers do not keep record as established from our survey and this explains low livestock productivity levels experienced by most pastoralists.

Access to extension had positively significant effect in establishing farmers'WTP for AI. Availability of relevant information from credible sources has the effect of influencing farmers' perceptions towards a new technology. Thus, efforts by promoters of a technology through extension officers has the probability to yield its sustainability upon their exit in agricultural subsector. Access to extension services has been found to increase adoption of new technologies (Kaaya *et al.*, 2005; Adegbola and Gardebroek, 2007; Amudavi *et al.*, 2008).In the current study, we establish that access to extension service influences WTP for that particular technology.

Farmer's ability to purchase new technologies depends on his disposable income given his existing production cost outlay. From Table 5.3, off farm income had a positive significant effect in establishing farmer's WTP for AI services in pastoral areas. This could be attributed to the fact that pastoralists with extra income have the ability to buy more productive technologies to increase their output. These results confirm findings of Kimenju and De Groote (2008) who found that consumers with higher income have high WTP for fortified maize. Increased livestock production for pastoralist would ensure adoption of better breeds and reproduction technologies (e.g. AI) to support their livelihood. However, these findings contradict study findings of Lin *et al.* (2006) who found that consumers with higher incomes were not willing to purchase biotech foods (soy oil). Pastoralist farmers' income is limited given that they have large family sizes to maintain and still meet other production costs on the farm. This implies that farmers with off-farm income have higher propensity for new technologies

5.5 Conclusion

Promotion of new agricultural technologies in rural areas to boost agricultural production has always faced challenges especially when the project lapses. To ensure sustainability of the adopted technology, it's imperative that the beneficiaries be willing to financially and materially support its existence. In the current study, most farmers showed their willingness to accept AI technology despite challenges in accessing the service providers. This implies that provision of appropriate support structure in high ranching zones such as subsidized AI and extension services by county governments will increase the likelihood of adopting AI technology since its acceptance is evident. It was also evident that the high proportions of farmers still got breeding materials from others farmers despite availability of known and established ranches within their reach. Further findings indicated very lower usage of Multiplication centres from acquisition of Sahiwal genetic resources. This therefore requires joined efforts by NSS and the county leadership in restocking and managing of these multiplication centres in Trans Mara and Kajiado Central for better services to pastoralists with their proximity. Creation of awareness of AI through informal education and influences pastoralists willingness to pay for AI. This means that promotional campaigns by local leaders on both production and marketing of livestock and related technologies would spur community development and improve household livelihood through livestock production. The current study findings provide an incentive for venturing into private AI service provision by reporting WTP for this services. It was established that most farmers were willing to pay an average of KES 1853.19 for AI services per cow. This reflected a premium of 23.55% placed on AI by pastoralists with reference to the base price of KES 1500 offered for exotic breeds in Kenyan highland.This was considered by most farmers to be cheap compared to the price of buying a bull from either KALRO or the local animal markets and the accompanying cost of maintaining the bull on the farm. This would provide incentive for private AI service providers to venture, which in turn makes dissemination of this genetic resources in pastoral areas sustainable in the long run.

CHAPTER SIX

IMPACT OF SAHIWALADOPTION ON HOUSEHOLD WELFARE

6.1 Introduction

Past studies on the role of Sahiwal genetic resources in pastoral production systems in Kenya, Roessler *et al.* (2010) and Ilatsia *et al*. (2010) reported that pastoralists ranked Sahiwalbreed highly in regard to production and fertility traits but remained more apprehensive of their disease, parasite and drought tolerance relative to the EAZs. However, some of the EAZs are relatively more adapted to pastoralproduction systems, a fact that provides a trade-off between the Sahiwal breed and EAZs with regard to productivity and adaptability in SALs. Sahiwal cattle breeds are generally raised under low-input production systems characterized by limited animal husbandry intervention by both pastoralists and ranchers as was recommended for stud herds in raising breeding animals (Meyn and Wilkins, 1974).

The production goals of pastoralists keeping Sahiwal cattle breed paints a clear picture of the multiple roles that livestock play in the livelihoods of pastoral communities. This multipurpose goal is consistent with findings of similar studies (e.g. Ouma *et al.*, 2004). Milk is a staple food in pastoral communities and adoption of a high milk yielding breed is a desirable option for the Maasai pastoralists. A study by Ilatsia *et al*. (2007) reported that Sahiwal cattle produces an average of 4.8 litres per day compared to the EAZs that hardly produce more than 2 litres a day (Muhuyi *et al.*, 2000). A survey at various cattle markets during the study revealed that the Sahiwal breed anditsby-products attracted relatively higher prices compared to EAZs, probably because of their large body size and milk production potential. In an empirical comparison of stated and revealed preferences value estimates of cattle keepers in Kenya, Scarpa *et al.* (2003) showed that market prices were strongly determined by the slaughter weight, which is correlated to body size.

Given the advantages of keeping Sahiwal cattle breed in pastoral areas, there is need to evaluate and promote dissemination of its genetic materials to most farmers. Government through KALRO have been promoting adoption of this breed by pastoralist to enhance their productivity in the recent years. However, the impact of this program has not been established. The most conventional technique for evaluating social and non-experimental programs is to use the outcomes of non-adopters to estimate what adopters would have experienced had they not adopted the technology. The variance between adoption and non-adoption outcomes is the estimated gross impact of a project. The outcomes of non-participants may differ steadily from what the outcomes of participants would have been without the program, producing selection bias in estimated impacts. In this study, we seek to illustrate that there is a distinction in outcomes of Sahiwaladopters compared to the non-adopters. The use of farm-income (revenue from livestock production) is a key indicator for investigating the feasibility and indeed impact of the deliberate government efforts to disseminate Sahiwal cattle in the pastoralist areas given previous programs spearheaded by KALRO.

6.2 Analytical framework

6.2.1 Evaluation problem and model specification

Assessing the impact of any intervention requires making an inference about the outcomes that would have been observed for program participants had they not participated. DenoteY_1asthe outcome conditional on participation and by Y_0 as the outcome conditional on non-participation, so that the impact of participating in the program is

$$\Delta = Y_1 - Y_0 \qquad (6.1)$$

For each person, only Y_1 or Y_0 is observed, so Δ is not observed for anyone. This missing data problem lies at the heart of the evaluation problem.

Let D =1 for the group of individuals who applied and got accepted into the program for whom Y_1 is observed. Let $D = 0$ for persons who do not enter the program for whom Y_0 is observed. Let X denote a vector of observed individual characteristics used as conditioning variables. The most common evaluation parameter of interest is the mean impact of treatment on the treated,

$$TT = E(\Delta \mid X, D = 1) = E(Y_1 - Y_0 \mid X, D = 1)$$
$$= E(Y_1 \mid X, D = 1) - E(Y_0 \mid X, D = 1)$$

(6.2)which estimate the average impact of the program among those participating in it. When Y represents earnings, a comparison of the mean impact of treatment on the treated with the average per participant cost of the program indicates whether or not the programmes' benefits outweigh its costs, which is a key question of interest in many evaluations.

Most experiments are designed to provide evidence on the treatment-on-the-treated parameter. Data on program participants identifies the mean outcome in the treated state $E(Y_1 \mid X, D = 1)$ and the randomized-out control group provides a direct estimate of.

$E(Y_0 \mid X, D=1)$. In non-experimental (or observational) studies, no direct estimate of this counterfactual mean is available. Instead, econometrically adjusted outcomes of the nonparticipant' proxy for the missing counterfactual. Selection bias, or evaluation bias, consists of the difference between the adjusted outcomes of the non-participants and the desired counterfactual mean. In the next section, we discuss common approaches for estimating the missing counterfactual mean.

6.2.2 Reduction of dimensionality

Matching may be difficult to implement when the set of conditioning variables *Z* is large. Rosenbaum and Rubin (1983) proved a result that is useful in reducing the dimension of the conditioning problem in implementing matching methods. They show that for random variables *Y* and *Z* and a discrete random variable *D;*

$E(D \mid Y, \Pr(D=1 \mid Z)) = E(E(D \mid Y, Z) \mid Y, \Pr(D=1 \mid Z))$,

So that

$E(D \mid Y, Z) = E(D \mid Z) = \Pr(D=1 \mid Z)$,

Implies

$E(D \mid Y, \Pr(D=1 \mid Z)) = E(D \mid \Pr(D=1 \mid Z))$. This implies that when Y_0 outcomes are independent of program participation conditional on *Z*, they are also independent of participation conditional on the propensity score $\Pr(D=1 \mid Z)$. Provided that the conditional participation probability can be estimated using a parametric method, such as a logit or probit model, or semi-parametrically using a method that converges faster, the dimensionality of the matching problem is reduced by matching on the univariate propensity score. If the propensity score must be estimated non-parametrically, then the curse of dimensionality reappears in the estimation of the propensity score. This potential for reducing the dimensionality of the problem has led much of the recent evaluation literature on matching to focus on propensity score matching methods.

6.2.3 Propensity score matching

The recent literature focuses on matching on the probability of participating in the program. This technique, introduced in Rosenbaum and Rubin (1983), is called propensity score matching. Traditional propensity score matching methods pair each program participant with a single nonparticipant, where pairs are chosen based on the degree of similarity in the estimated probabilities of participating in the program (the propensity scores). The mean impact of the program is estimated by the mean difference in the outcomes of the matched pairs. Matching estimators are justified by the assumption that outcomes are independent of program participation conditional on a set of observable characteristics. That is, matching assumes that there exists a set of observable conditioning variables *Z* (which may be a subset or a superset of *X*) for which the nonparticipation outcome Y_0 is independent of participation status *D* conditional on *Z*.

$$Y_0 \perp D \mid Z \qquad (6.3)$$

It is also assumed that for all *Z* there is a positive probability of participating, (*D=1)* or not participating (*D=0)*, i.e.

$$0 < \Pr(D = 1 \mid Z) < 1 \qquad (6.4)$$

This assumption implies that a match can be found for all D =1 persons. If assumptions (6.3) and (6.4) are satisfied, then, after conditioning on *Z*; the Y_0 distribution observed for the matched nonparticipant group can be substituted for the missing Y_0 distribution for participants.

Assumption (6.3) is overly strong if the parameter of interest is the mean impact of treatment on the treated (*TT*), in which case conditional mean independence suffices:

$$E(Y_0 \mid Z, D = 1) = E(Y_0 \mid Z, D = 0) = E(Y_0 \mid Z) \qquad (6.5)$$

Furthermore, when TT is the parameter of interest, the condition $0 < \Pr(D = 1 \mid Z)$ is also not required, because that condition only guarantees the possibility of a participant analogue for each nonparticipant. The *TT* parameter requires only the possibility of a nonparticipant analogue for each participant. For completeness, the required condition is

$$\Pr(D = 1 \mid Z) < 1 \qquad (6.6)$$

Under these assumptions, either (6.3) and (6.4) or (6.5) and (6.6), the mean impact of treatment on the treated can be written as;

$$TT = E(Y_1 - Y_0 \mid D = 1)$$

$$= E(Y_1 \mid D = 1) - E_{Z|D=1}\{E_Y(Y_0 \mid D = 1, Z)\} \quad (6.7)$$ where the first term can be estimated from

$$= E(Y_1 \mid D = 1) - E_{Z|D=1}\{E_Y(Y_0 \mid D = 1, Z)\}$$

the treatment group and the second term from the mean outcomes of the matched (on *Z*) comparison group.

In a social experiment, (6.3) and (6.4) are satisfied by virtue of random assignment of treatment. For non-experimental data, there may or may not exist a set of observed conditioning variables for which the conditions hold. If there are regions where the support of

Z does not overlap for the D=1 and $D = 0$ groups, then matching is only justified when performed over the common support region. The estimated treatment effect must then be redefined as the treatment impact for program participants whose propensity scores lie within the common support region.

6.2.3.1 Nearest-neighbour matching

Its pair wise matching, also called single nearest-neighbour matching without replacement, sets

$$C(P_i) = \min \ j \, \| P_j \|, \ \ j \in I_0$$

That is, the nonparticipant with the value of P_j that is closest to P_i is selected as the match and j is a singlet on set. This estimator is often used in practice due to its ease of implementation. Traditional applications of this estimator typically did not impose any common support condition and matched without replacement, so that each $D = 0$ observation could serve as the match for at most one $D = 1$ observation. In our empirical work we implement this method with both a single nearest neighbour and with the ten nearest neighbours. Each nearest neighbour receives equal weight in constructing the counterfactual mean when using multiple nearest neighbours. The latter form of the estimator trades reduced variance (resulting from using more information to construct the counterfactual for each participant) for increased bias (resulting from using, on average, poorer matches).

We also match with replacement, which allows a given nonparticipant to get matched to more than one participant. Matching with replacement also involves a trade-off between bias and variance. Allowing replacement increases the average quality of the matches (assuming some re-use occurs), but reduces the number of distinct nonparticipant observations used to construct the counterfactual mean, thereby increasing the variance of the estimator. More generally, nearest neighbour matching without replacement has the additional defect that the estimate depends on the order in which the observations get matched.

6.2.3.2 Kernel and local linear matching

Recently developed nonparametric matching estimators construct a match for each program participant using a kernel-weighted average over multiple persons in the comparison group. The neighbourhood $C(P_i)$ depends on the specific kernel function chosen for the analysis. In this thesis, we implement a generalized version of kernel matching, called local linear matching. Research by Fan (1993) demonstrates several advantages of local linear estimation over more standard kernel estimation methods. These advantages include a faster rate of convergence near boundary points and greater robustness to different data design densities.

Kernel matching can be thought of as a weighted regression of Y_{0j} on an intercept with weights given by the kernel weights that vary with the point of evaluation. The weights depend on the distance between each comparison group observation and the participant observation for which the counterfactual is being constructed. The estimated intercept provides the estimate of the counterfactual mean. Local linear matching differs from kernel matching in that it includes in addition to the intercept a linear term in P_i: Inclusion of the linear term is helpful whenever comparison group observations are distributed asymmetrically around the participant observations, as would be the case at a boundary point of P or at any point where there are gaps in the distribution of P.

6.3 Data

To achieve this objective, information was collected on various household characteristics including age, years of schooling, household size, land size, labour cost, distance to nearest market and water source, animals watering frequency and reproductive performance. Respondents were categorised into two groups; those who have adopted Sahiwal breed and those without Sahiwal cattle breed. Farm income collected from farmer's milk and live animal sales were used in determining the impact of Sahiwal Breed adoption.

6.4 Results and discussions

6.4.1 Factors influencing adoption of Sahiwalcattle breed

Since the inception of Sahiwalbreed in Kenya, many livestock farmers have shown much interest in its adoption given its aforesaid benefits compared to the indigenous breeds. This has over the years increased demand from the limited breeding centres across the Country. It is on this basis that this study explores the impact of Sahiwalbreed among the pastoralists in SALs. We first establish various factors that influence the pastoralist household to adopt Sahiwal breed besides existence of other livestock breeds. Table 6.1 indicates factors that influence adoption of Sahiwal cattle.

Age of the household head was found to have a positive significant effect on their decision in adopting Sahiwal breed. This was consistent with our study prior expectation given that the number of years a farmer is actively engaged in farming accumulates experience thus enhancing the appropriateness of the decision taken towards improving productivity. The above results indicate that the older an individual becomes the higher the likelihood of adopting Sahiwal cattle. Farmer's perception of high reproductive performance of Sahiwalcattle compared to the local indigenous breeds increases their likelihood of adopting Sahiwal cattle. This confirms findings by Ilatsia *et al.* (2007) from an experimental study on the reproductive performance of Sahiwal with reference to milk production.

Table 6.1: Coefficients estimates for propensity score matching using kernel matching.

Variable	Coefficient
Distance to market	-0.00593(0.0135)
Middle aged farmers	1.01867(0.3805)***
Elderly farmers	1.38416(0.3462)***
County	0.11315(0.2682)
Household size	-0.01931(0.0201)
Herd size	-0.00212(0.0011)*
Land size	-0.00013(0.0002)
Labour cost	0.00001(0.0001)*
Education	-0.13626(0.0802)*
Distance to water source	-0.02243(0.0263)
Watering frequency	-0.02577(0.3298)
Reproductive performance	1.98787(1.1397)*
Number of observations	311
LR χ^2	38.52
Prob> χ^2	0.0001

Note: Standard errors are in parenthesis.

***$p< 0.01$and *$p< 0.10$mean statistically significant at 1% and 10% probability levels.

Production cost is a key component in livestock production especially among the pastoralist given the vastness of dry areas they have to cover in search for feeds. Their various costs including feed costs (leasing land during dry seasons to feed the animals), feed supplements like concentrates and salt, labour costs and security costs incurred in bid to guard against theft from cattle rustling communities. Labour cost had a small but positive significant effect on the likelihood of Sahiwal adoption. This result complements the findings of Jamala *et al.* (2011) who found labour and the decision to adopt irrigated rice in Nigeria to have a positive significant relationship. This could be attributed to the fact that keeping a few Sahiwal cattle generates more revenue in terms of milk and live animal sales compared to keeping a lot of local indigenous breeds to achieve the same output levels. Therefore few herd boys are required compared to many for local breeds.

Study findings indicate thatherd size reduces the likelihood of Sahiwaladoption among the pastoralists. This could be as a result of ever decreasing land size as population rises. Farmers own land either in their individual capacity or in group ranches and therefore those with a big herd size tends to reduce it instead of investing in other breeds given the long period of time it takes to see the effect of such initiative. As mentioned earlier in this thesis, the prohibitive nature of the cost of acquiring Sahiwal bull from the local or breeding centres could be another reason as to why most farmers (with their strong attachment to livestock) would not sell many local cattle breeds just to acquire one Sahiwal.

Most of the pastoralists are not educated. Most household heads sampled did not have education beyond upper primary and this explains the reason why education was negatively related to adoption of new cattle breeds with high production levels compared to the existing breeds. This finding contradicts most adoption studies (e.g. Mwabu *et al*. 2006, Abebe *et al.* 2013 and Howley *et al.*2012) who found education to have a positive relationship with adoption.

6.4.2 Common support region

The overlap condition rules out the phenomenon of perfect predictability of *D* given *X*. It ensures that persons with the same *X* values have a positive probability of being both participants and non-participants (Heckman, *et al.*, 1999). PSM estimator is the mean difference in outcomes over the common support, appropriately weighted by the propensity score distribution of participants. Implementing the common support condition ensures that any combination of characteristics observed in the treatment group can also be observed among the control group (Bryson, *et al.*, 2002). For ATT, it is sufficient to ensure the existence of potential matches in the control group, whereas for ATE it is additionally required that the combinations of characteristics in the comparison group may also be observed in the treatment group (ibid). During the matching process, there were only two respondents who were off support in computing the propensity score. This consists of two respondents from the treated group while the rest of sampled respondents were used in estimating the assignment probabilities.

Table 6.2: Common support region.

Treatment assignment	Common support		Total
	Off support	On support	
Untreated	0	144	144
Treated	2	165	167
Total	2	309	311

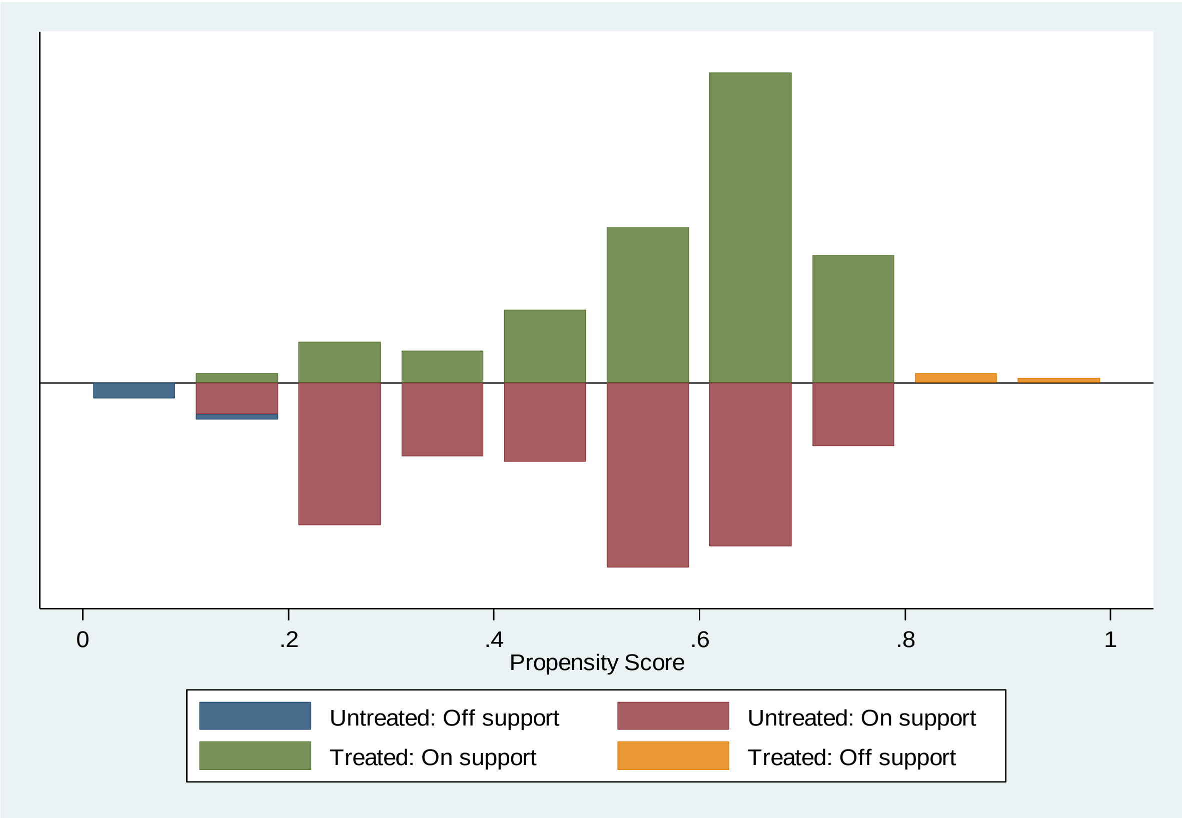

Figure 6.1: Graph for common support region.

6.4.3Covariate imbalance testing

Propensity score test calculates several measures of balancing the variables before and after matching. It considers balancing for the treated group only. Using *t*-tests for equality of means in the treated and non-treated groups for all the covariates, both before and after matching should be insignificant after matching for good balancing. From Table 6.4, it is evident that kernel matching procedure achieved a good balance except for elderly farmers (*t*-value of -2.87) and herd size (*t*-value of 1.82) variables.

Considering another measure; the standardized bias before and after matching (Rosenbaum and Rubin, 1983): this should be less than 5% after matching. The results above shows that all covariates provided a good balance except for watering frequency which had a standardized balance of 6% after matching.

Table 6.3: Propensity score test for kernel matching procedure.

Variable	Unmatched/ Matched	Mean		% bias	% reduction |bias|	*t*-test	
		Treated	Control			*t*-value	*p>t*
Distance to market	Unmatched	8.479	9.267	-8.7		-0.77	0.442
	Matched	8.588	8.913	-3.6	58.8	0.90	0.368
Middle aged	Unmatched	0.287	0.271	3.7		0.32	0.746
	Matched	0.302	0.294	1.8	50.7	-0.32	0.748
Elderly farmers	Unmatched	0.617	0.438	36.4		3.20	0.002
	Matched	0.597	0.613	-3.1	91.4	-2.87	0.004
County	Unmatched	0.557	0.534	4.4		0.39	0.697
	Matched	0.547	0.547	-0.0	99.5	-0.11	0.913
Household size	Unmatched	10.84	11.65	-12.3		-1.08	0.281
	Matched	10.97	11.10	-2.0	84.0	0.33	0.739
Herd size	Unmatched	95.65	130.56	-27.4		-2.44	0.015
	Matched	97.98	100.77	-2.2	92.0	1.82	0.070
Land size	Unmatched	192.74	263.45	-12.6		-1.12	0.262
	Matched	195.27	193.41	0.9	93.1	1.40	0.162
Labour cost	Unmatched	28774	20110	17.7		1.52	0.131
	Matched	21694	21538	0.3	98.2	-1.16	0.249
Education	Unmatched	1.509	1.74	-14.9		-1.32	0.189
	Matched	1.547	1.53	1.0	93.6	1.40	0.162
Distance to	Unmatched	2.896	3.68	-15.5		-1.36	0.174
water	Matched	2.922	3.12	-3.9	74.9	0.10	0.918
Watering	Unmatched	0.826	0.792	8.8		0.78	0.438
frequency	Matched	0.824	0.800	6.0	31.8	-0.11	0.911
Reproductive	Unmatched	0.994	0.958	23.5		2.12	0.034
performance	Matched	0.994	0.991	2.0	91.4	-0.24	0.809

Sample	Pseudo R^2	LR χ^2	$p>\chi^2$	Mean Bias	Median Bias
Raw	0.090	38.45	0.000	15.5	13.8
Matched	0.068	28.22	0.005	2.2	2.0

The percentage reduction bias indicates the ability of the matching procedure to minimize the bias in covariate balancing. The results above show that the balancing is good for all the covariates given they all yielded more than 20% reduction in bias. The overall matching performance is good: after matching the average abs (bias) is 2.2 unlike for the raw which is 15.5. This therefore justifies the choice of kernel matching.

6.4.4 Average treatment effects

The last objective for this study was to establish whether there was substantive effect in monetary terms for continued dissemination of Sahiwal breed among the pastoralist. Table 6.2 presents analysis of the effect of keeping Sahiwal breed compared to the returns of those who didn't in the last ten years.

Table 6.4: Model results for Average Treatment Effects.

Variable	Sample	Treated	Controls	Difference	S.E.	*t*-stat
Income	Unmatched	666808.44	484748.30	182060.15	161691.90	1.13
	ATT	661179.87	564779.67	96400.21	186274.30	0.02
	ATU	496013.86	842904.06	346890.20		
	ATE			213686.49		

The study used farm income generated from sales of live animals and milk by farmers in a period of 12 months prior to the survey. We matched farmers with and without Sahiwal cattle based on selected covariates.

Assessing the average treatment effect on the treated i.e. the effect of keeping Sahiwal on those who have adopted, there is a substantive returns from sales. The treated group (Sahiwal adopters) received annual income worth KES 661,179.87 compared to KES 564,779.67 for the control group. This yields a difference of KES 96,400.21 in excess over the control group which translates to KES 8,033.35 per month. Considering livestock production has recurrent costs that need to be offset besides family needs and farm profit requirements, Sahiwal keeping has proved to be more beneficial compared to the local breeds.

ATE is useful to evaluate the expected effect on the outcome if individuals in the population were randomly assigned to treatment.The overall effect of keeping Sahiwal breed among the pastoralists is KES 213,686.49 per annum. This was quite substantive given the difficulties involved in livestock production in SALs where access to water is a challenge and seasonal changes affect the overall production yield of the farm. A monthly increment of

KES 17,807.21 in income over and above what Sahiwal non-adopter receive is evidence enough to illustrate that indeed adopting Sahiwal breed can improve household farm income Besides high reproductive performance and low labour cost involved in Sahiwal production, it fetches high market prices compared to the local breeds in local markets as well. This indeed is among the reasons as to why the supply of Sahiwal bulls has been outstripped by the demand thus necessitating other means of breed dissemination as illustrated in the first objective of this thesis.

The results above can be presented in a kernel density function (Figure 6.1). It is evident from the graphical presentation that Sahiwal adopters at all probability levels would earn higher farm income than non-adopters. For instance, Sahiwal adopters would earn log of 12 while non-adopters would earn log of 11 at the same probability level of 0.2. This means that probability of earning KES 162,754.8 by adopters is 20% while non-adopters have similar 20% probability of earning KES 59,874.14. The difference is triple what one would get in return without adopting Sahiwal breed. The graphical results are therefore more convincing to any rational farmer since any producer would always wish to be on the lower graph with high returns. The distance between the two functions tend to reduce at very high probabilities, these are regions where differences in production tend to be minimum.

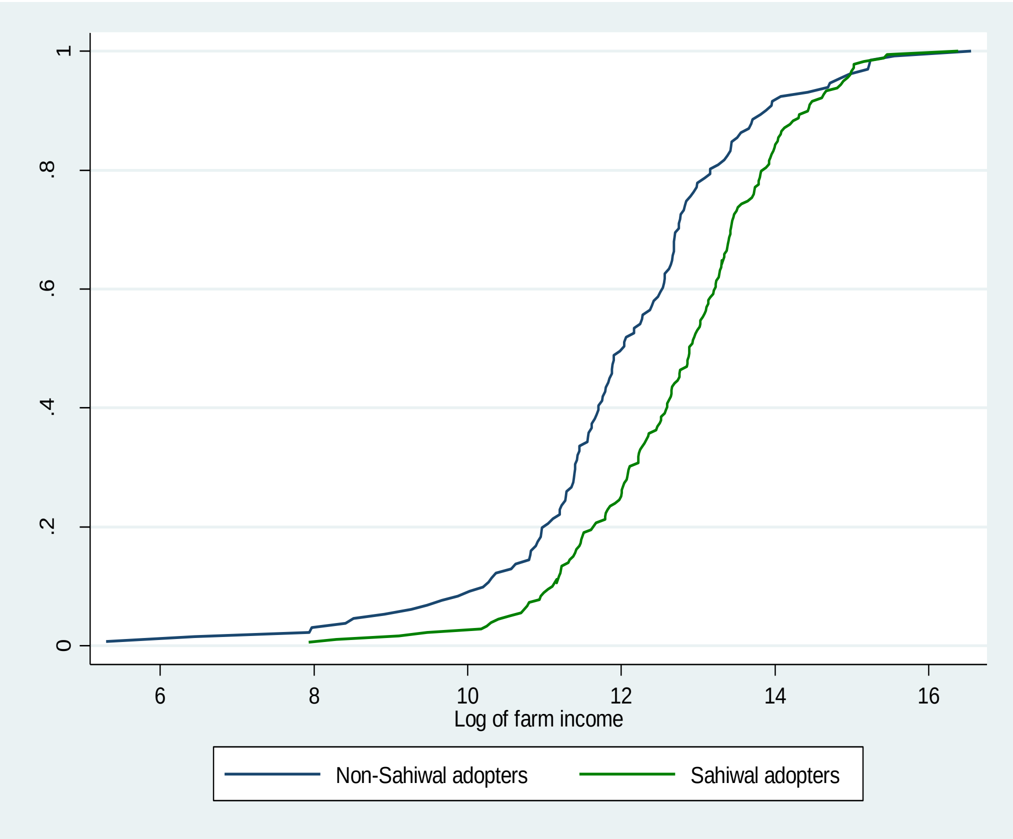

Figure 6.1: Kernel density function for treatment effect.

6.5Conclusion

Since the inception of Sahiwal breed in pastoral areas, it was necessary to perform an evaluation of its economic benefits to small holder livestock farmers. The current study using propensity score matching procedure, compared farm incomes accrued to Sahiwaladopters and non-Sahiwal adopters from both milk sales and sales of live animals. Study results showed a significant difference in farm earnings with Sahiwal adopters drawing more revenues than non-adopters. This provides a motivation for non-adopters to start upgrading their EAZs with more superior breed (Sahiwal) that is more adapted to the high ranching zones in Narok, Lower Kajiado, and Machakos and has high reproductive performance. Reproductiveperformance of the Sahiwal breed had positive significant influence on adoption of Sahiwal effect. This means that Sahiwal production has the potential to improve the livelihoods of pastoralists in terms of farm income than the indigenous breeds which were reported to have low reproductive performance. The age of the household head was significant in determining adoption of Sahiwal. As the main decision maker in the household and the responsibilities involved, he/she makes informed decision when choosing the breed to keep that has more benefits than the other. The older the head, more he/she assumed to have accumulated knowledge and experience to make better and informed decision that has higher yields for the sake of family. Sahiwal breed move for less distances compared to the EAZs and therefore requires less attention by herd’s boy. This is reflected in low labour cost to keep Sahiwal which positively influences its adoption.

CHAPTER SEVEN

SUMMARY AND IMPLICATIONS

7.1 Summary and conclusions

The overall objective of this study was to promote the contribution of Sahiwal breed on household farm income in pastoral areas of Kajiado and Narok Counties. Since the inception of Sahiwal breed in Kenya, its adoption has been rising as evidenced by high demand for its bulls from the NSS. It's because of this high demand that the Government of Kenya through KALRO, are exploring means of disseminating Sahiwal genetic materials to livestock farmers in SALs. Sahiwal cattle is well adapted in high ranching zones of Narok, lower parts of Kajiado County (semi-arid) and has high reproductive performance that suits pastoralists whose main livelihood is depended upon livestock keeping. Moreover, it has been found to be a dual purpose breed (suitable for both milk and meat) which justifies government efforts to enhance its spread in vulnerable pastoral communities since its guarantees household food on a daily basis (milk and milk products, and meat) while generating income through milk and live animal sales.

From the general objective three specific objectives are defined and analyzed in separate chapters. They include determining pastoral farmers' preferences and choices for breeding services, their WTPfor artificial insemination and the impact of Sahiwal breed adoption on household farm income between adopters and non-Sahiwal adopters. These objectives were addressed using data collected from a random cross-section sample of pastoralists in Kajiado and Narok Counties of Kenya. These Counties had relatively large concentrations of the Sahiwal cattle. The study area was stratified into nomadic pastoralists and agro-pastoralists in Keiyan, Kilgoris and Lolgorian divisions of Narok County and Namanga, Mashuru, Ngong and Kajiado central divisions of Kajiado County. Using the DLPOs'respondents were identified and categorised into Sahiwal and other breed keepers from each location. The chosen farmers were interviewed using a structured questionnaire on various livestock production aspects including reproduction methods, animal husbandry practices and livestock returns to the household. The survey covered the period between November 2012 and February 2013.

Chapter four uses an ordered probit model to explore farmers' preferences and choices for breeding services. Artificial insemination services and the bull were the only breeding options under this objective. The model allows for ranking of a breeding service on a likert scale. Results show that most of the pastoralists ranked AI as their least preferred alternative breeding service compared to the bull. Success rate of AI technology in breeding, its accessibility, and the ability of the AI calf surviving in pastoral areas influenced the dislike for adopting AI. However, given the difficulties in accessing quality bull from the NSS, most farmers revealed their willingness to accept AI because of its affordability compared to the cost of buying the bull or hiring one from other farmers. Education levels, herd size, household size, group membership, access to extension services, production system, his/her location and awareness of AI were key factors that influenced pastoralists' ranking of AI significantly while experience in rearing livestock and farmers age had negative effect.

Chapter five provides an estimation of farmers' WTP for artificial insemination. This was key given that sustainability of AI in pastoral areas depends on pastoralists' willingness to accept and pay. This objective was analysed using double bounded dichotomous choice model, a contingent valuation approach that utilises both lower and upper bids as revealed by the responded. Computation based on his/her initial bid followed by a second question (either discount or premium based on initial response) is deemed to be the respondents true WTP. Results showed that most of farmers were willingness to accept AI technology despite challenges in accessing the service providers. It was also evident that the high proportions of farmers still get breeding materials from others farmers despite availability of known and established ranches within their reach. It was further established that most farmers were willing to pay an average of KES 1,853.19 for AI services per cow which was 23.55% more than the base price of KES 1,500 offered in the market for exotic livestock farmers. Farmer's awareness of AI, access to extension services, his/her herd size and off-farm income were factors that significantly influenced his/her WTP.

Impact of Sahiwal breed adoption on household farm income among pastoralists was evaluated in chapter six using treatment effect model and propensity score matching technique. This comparative analysis was done to establish whether investing in Sahiwal breed had substantive benefits compared to keeping the EAZs over the last 5 years. Study results reported a significant difference in farm earnings with Sahiwal adopters drawing more revenues than non-adopters. There is potential for adoption of Sahiwal breed since adopters earn an average of KES 661,179.87 compared to their counterparts who earn KES 564,779.67 from sales of live animals and milk. This provides an incentive for non-adopters to start upgrading their EAZs with more superior Sahiwal breed that is more adapted to the SAL environment. Reproductive performance of the Sahiwal breed, age of the household head andlabour cost had positive significant effect in determining its adoption while herd size and education levels of household head reduces the likelihood for its adoption.

7.2 Implications

This research provides some insights into the determinants of Sahiwal breed adoption and factors that influence uptake of artificial insemination in SALs. Estimates on pastoralists WTPfor AI also provides policy implications on possible support initiatives by both the government and NGOs.

Investments by stakeholders in required structures have the capacity to improve livestock production in SALs and guarantee pastoralists livelihoods. Results of this study generally support the fact that pastoralists in high ranching zones can enjoy both material and financial benefits from adopting Sahiwal breed and AI as an alternative breeding method. Adoption of AI has the potential of increasing production by allowing the Maasai pastoralists to acquire quality semen of well documented bulls at a cheaper rate than buying the bull from the market without record. However, the cost of AI could be inhibiting to most pastoralists and this calls for partnerships among the stakeholders (Government, NGOs, farmers, livestock breeders and private AI service providers, NSS). Subsidizing AI services for pastoralists could serve as a catalyst for Sahiwal adoption thus reducing the demand for the bull while lowering the production cost for the farm. This subsidy could be administered at two levels; at the NSS level where semen is acquired whether locally or imported and at farm level by subsidizing the cost of service provider. It also warrants efforts by local County governments to strongly invest in subsidizing this service in pastoral communities.

There is motivation for private AI service providers to venture in pastoral areas given that current study findings indicate farmers' WTPin monetary values to sustain its provision. The high number of farmers expressed their desire to use AI to avoid shortage of bulls, this implies a ready market for AI service providers. However, we strongly recommend registration of service providers at County level so that quality of semen and service delivered to unsuspecting farmers isguaranteed. It is also worth noting that efforts done by community animal health assistants have the potential in making pastoralist adopt AI on a large scale because the assistants belong to their communities and are pastoralists as well. Building capacity of these assistants so that they can couple up as AI service providers in SALs would be economical and sensible in addressing cultural concerns towards AI calves.

Revision of government policy on extension services in the Country would boost acceptance of AI services thereby increasing the spread of Sahiwal genetic materials in pastorals areas. Under the current policy, extension services are provided on demand basis and to some extent these services only reach farmers who can afford. Employing enough and well trained extension officers with relevant AI knowledge by either the national government or respective County governments on permanent basis is highly recommended. Study findings strongly indicate that farmers' access to extension services has a significant influence in adopting both AI and Sahiwal breed. Currently farmers in pastoral areas use information from lead farmers and community animal health assistants which may not be as factual and informative as required in production.

Supporting of institutions within the SALs is critical in achieving long term improved livestock production. Development and linkage of local livestock markets to national output and export markets can help create wealth for pastoralists. The price at which pastoralist exchange the animals is low compared to the price offered by Kenya Meat Commission (KMC). Livestock markets were found to be very far from the farmers and efforts to facilitate farmers' access to KMC is recommended. Encouraging and strengthening of both formal and informal groups is recommended. Study results reported that most of the pastoralists belonged to either production or *chama* group. It's within these groups that farmers get credit from their contributions, call livestock extension specialists for training and land management. Extending support to such groups through County governments will go a long way in enhancing cohesiveness among pastoralists for easy decision making towards new production technologies.

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Appendices

Research Questionnaire

Introduction

I am a postgraduate student at Egerton University pursuing Collaborative Masters in Agricultural and Applied Economics. This study intends to establish the farmers' willingness to accept and pay for AI services in the face of increasing demand for Sahiwalcattle. The information you provide will be treated as private, highly confidential and will be used only for the purposes of this research. The report of this study will not use names of the respondents or any information that may identify them.

Instruction (tick where appropriate)

SECTION A: HOUSEHOLD AND VILLAGE CHARACTERISTICS

1. Name of the respondent (optional)...
2. Respondent's County (1) Kajiado [__] (2) Narok [__]
3. District of the respondent..................................
4. Division of the respondent.................................
5. Location of the respondent....................................
6. Sex of respondent (1) Male [__] (2) female [__]
7. Gender of Household head................. (1) male [__] (2) female [__]
8. Age of the household head

(1) Below 25 years [__] (2) 25yrs to 35yrs [__] (3) 36yrs to 45yrs [__] (4) 46yrs to 65yrs [__] (5) Over 66 years [__]

9. Marital status of the farmer

(1) Single [__] (2) married [__] (3) Separated/ divorced [__] (4) widowed [__]

10. Marriage type of the respondent (1) monogamous [__] (2) polygamous [__]

11. Do you own a mobile Phone? (1) Yes [__] (2) No [__]

12. If yes, give the number..................................

13. Number of household members............................

14. Religion of the respondent

(1) Christian [__] (2) Muslim [__] (3) [__] Traditional

15. Educational levels of the household head?

(1) No education [__] (2) Lower primary [__] (3) Upper primary [__]

(4) Secondary [__] (5) College/ university [__]

16. Occupation of the household head..............................

(1) Off-farm self-employment [__] (2) Formal employment [__]

(3) Farming [__]

17. Main source of drinking water.................

(1) Piped [__] (2) Bore hole protected and covered [__]

(3) Bore hole unprotected and uncovered [__] (4) Stream [__]

(5) River [__] (6) Lake [__] (7) Water pans [__]

18. What is the distance to main source of water for domestic use during dry seasons ....kms

19. What is your major source of information?

(1) Chief/local leaders [__] (2) Radio [__] (3) TV [__]

(4) Newspapers [__] (5) Others.............................

20. What is the land tenure system of the respondent?

(1) Owned with title deed [__] (2) Owned without title deed [__]

(3) Leased/ rent [__] (4) Owned by parent/ relative [__]

(5) Government [__] (6) Communal/ customary [__]

(7)Group ranch [__]

21. Farmers land size .... acres

22. What is the area under crops...........................acres

23. Which enterprises do you have on your farm?

(1) Livestock only [__] (2) Crop-livestock/agro-pastoralism [__]

(3) Crops only [__]

24. The number of houses in the homestead....................

25. Type of house structure the respondent is living in

(1) Manyatta [__] (2) Grass thatched [__] (3) Iron roofed [__]

26. What is the roofing material of the main house?

(1) Grass/ Makuti [__] (2) Iron sheet [__] (3) Tiles [__]

(4) Other specify...

27. What is the wall material of the main house?

(1) Mud [__] (2) Bricks/ stones [__] (3) Iron sheet [__]

(4) Wood [__] (5) Plastered [__]

(6) Other specify...

What is the floor material of the main house

(1)Earth [__] (2) Cement [__] (3) Wood tiles [__]

(4) Othe specify...

28. What type of toilet do you use?

(1) Pit latrine [__] (2)Bush [__] (3)Flush toilet [__] (4) Other specify...

29. What is your main cooking fuel?

(1) Electricity [__] (2)Paraffin [__] (3) Firewood [__] (4) Gas [__] (5)Charcoal [__] (6) Solar power [__] (7) Other

30. What is your main type of lighting?

(1) Electricity [__] (2) Pressure pump [__] (3) Pin [__] (4) Fuel wood [__] (5) Lantern [__] (6) Solar power [__] (7) Other specify ....

SECTION B: BREEDING

1. How long have you been keeping livestock ....years
2. Which type of cattle breed do you keep by the number.(*please tick appropriately*)

Breed	Tick	Number
Sahiwalgenetic resource		
Small East African zebus		
Exotic (specify)		

3. How long have you been keeping Sahiwal(experience) ....years.
4. What is the main reason for keeping the Sahiwalcattle?

(1) Milk [__] (2) Meat [__] (3) Both milk and meat [__]

(4) Other (e.g. wealth stock, paying dowry etc.) [__]

5. Do you prefer Sahiwalto the local breed?

(1) Yes [__] (2) No [__]

If yes continue to question 7 below

6. If No above why

(1) The breed is not available [__] (2) Its expensive [__]

(3) Susceptible to diseases [__] (4) requires more care than others [__]

(5) No market for it [__]

7. What is the current source of the Sahiwalbreeding material?

(1) Own bred [__]

(2)NSS [__]

(3) Neighbour [__]

(4) Livestock multiplication centres [__]

(5) Ranch(specify) ....

8. What is the major source of breeding material?

(1) Natural service/ Bull [__]

(2) Artificial Insemination service (AI) [__]

9. Following the choice made in question 7 above, Rank the breeding service in order of their preference to you? *(Please choose one service)*

Breeding service	(1 = most preferred 2 = preferred 3 = least preferred)
Bull	
Artificial insemination	

10. Is it easy for you to access breeding bulls from the above sources? (*Please use the code given to rank the listed sources)*

Source	Now 1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree	10 years 1.Strongly disagree 2.Disagree 3. Don't know 4. Agree 5. Strongly agree
NSS		
Ilkerin ranch		
Elkarama ranch		
loita ranch		

11. Why do you prefer the above source *(please tick as appropriate)*

(1) Milk [__] (2) Meat [__] (3) Donation [__] (4) Proximity [__] (5) Cost [__]

12. Have you ever heard of AI services in cattle breeding

(1) Yes [__] (2) No [__]

13. Would farmer be willing to accept AI services?

(1) Yes [__] (2) No [__]

14. Farmers will be willing to use AI services based on the following attributes. *(please rank these attributes on a scale of 1 to 5 using code provided*)

Parameter	Rank 1 to 5 (1= strongly disagree, 2= Disagree, 3 =don't know, 4 =Agree, 5=

	strongly agree)
Affordability/ cost	
Better breed quality	
More accessibility	
High success rate	

14. The current market price of hiring a bull is KES.................... are you willing to pay more for an equivalent amount for AI.

(1) Yes [__] (2) No [__]

15. Suppose the most limiting factors accesing AI services are addressed to suit your expectations and thereafter the price of AI was provided at a higher price than the current market price, would you be willing to pay more?

(1)Yes [__] (2) No [__]

16.If Yes or No in 15, then provide the following bid levels at random to the farmer

Bid levels (premium price) i.e. if answered yes in question 15	Yes	No	Bid levels (discount price) i.e. if answered no in question 15	Yes	No
600			400		
1200			800		
1800			1500		
2400			2000		
3000			2800		
More than 3000			3600		

17. Indicate the state of Sahiwalnumbers in your herd.

(1) Increasing [__] (2) Constant [__] (3) Decrease [__]

18. What is your future plan in Sahiwalproduction?

(1) Increase [__] (2) Steady [__] (3) Reduce [__]

19. Farmers prefer Sahiwalto local breed because of the following breed characteristics. *(Please rank the first four important characteristics using the scale provided)*

Factor	Rank (1=Least important; 2=important; 3= most important)
High milk yield	
High mature live weight	

Watering frequency	
Feeding requirements	
Reproductive performance	
Drought tolerance	
Disease tolerance	
Coat colour	

SECTION C: LIVESTOCK MANAGEMENT

1. What is keeping livestock activity to you?

(1) Full time job [__] (2) Part time job [__]

2. What is your lifestyle with respect to your livestock?

(1)Sedentary [__] (2) Nomadic [__]

3. Do you keep records of the animal performance?

(1) Yes [__] (2) No [__]

4. If No above, why?

(1) Lack of knowledge [__] (2) Not aware of their importance [__]

(3) Illiteracy [__]

5. Who is in charge of grazing the animals?

(1) Household head [__] (2) Family children [__] (3) Women [__]

(4) Herds boy [__]

6. Do you grow pasture for your livestock?

(1) Yes [__] (2) No [__]

7. If yes above, what type do you grow?

Napier grass [__] (2) Lucerne [__] (3) Rhodes grass [__]

8. What are your sources of income?

Off-farm income [__] (2) On-farm income [__]

9. What is the proportional contribution of household income

Source	Proportion
On-farm	
Off-farm	

10. Livestock production systems and management practices

For each of the dairy animal category, please provide the following information

	Cattle	Goats	Sheep	Camels

Production system (1=Pastoralism 2= Agropastoralism				
Farming system (1=Pastoralism 2= Agropastoralism 3 = ranching)				
Feeding systems (1 = Zero grazing/cut and carry, 2 = Semi-intensive, 3 = Extensive, 4 = Roadside grazing, 5 = Tethering)				
Livestock housing and structures used (1 = Cattle shed, 2 = Goat shed, 3 = Bomas, 4 = Calf pens, 5 = Kid enclosures, 6 = Others (specify)_____________				
Type of livestock structures: 1= Traditional, 2 = Improved				
Other handling structures on the farm: 1 =Crushes, 2 =Milking shed, 3 = Milking machines, 4 = Parlour,				
Indicate if these husbandry practices are done:				
1. Disease control: 1 = Yes, 2 = No				
Spraying				
Dipping				
Routine vaccination				
2. Castration: 1 = Yes, 2 = No				
Method of castration				
Age at castration				
3. Animal identification: 1 = Yes, 2 = No				
Mode of identification: 1 = Ear tagging , 2 = Notching				
4. Debudding 1 = Yes, 2 = No				
5. Milking methods used: 1 = Hand milking, 2 = Machine milking				
Other management practices (specify)____________				

10. Livestock production cost (please record for the last 12 months)

Description	Total quantity per year	Price per unit	Total cost
Crop residue			
Green fodder			
Dry fodder			
Concentrates			
Veterinary services			
Herds boy /Labour			
Mineral lick			
Total			

11. Please provide information on the milk production for each household in the following table.

Breed	Number of cows milked	Average milk produced per day (*litres*)	Quantity consumed	Quantity sold	Marketing cost
Sahiwal					
Zebus					
Exotics (specify)					
Others (specify)					
Total					

12. Since the introduction of Sahiwalbreed, the following production aspects have improved. (*Using the likert scale provided below, please rank them*)

Attribute	Rank (1= strongly disagree, 2= Disagree, 3 =don't know, 4 =Agree, 5= strongly agree)
Growth rate	
Off take	
Milk yield	
Sale weight	
Calf survival	
Veterinary cost	

Feed costs	
Age at first calving	
Lactation length	
Calving interval	
Drought tolerance	
Tolerance to feed severity	

13. Where do you sell milk? (1)Neighbour [__] (2) Hawker [__] (3) KCC [__] (4) Cooperatives [__]
14. Based on the above information, rank the marketing points in order of importance to the farmer using codes below the table.

Point of sale	Rank (1=Most important 2=Important 3=Least important)	Distance to the farm gate (*km*)	Remarks (why) 1=Good neighbourliness 2=Cheap to deliver 3=Better price 4=Payment schedule 5=Support services 6=Guaranteed market
Neighbour			
Hawker			
KCC			
Cooperatives			

15. The following factors have been hindering milk marketing among the farmers. *(please rank them using the scale provided)*

Constraint	Rank(1=strongly disagree 2 = disagree 3 = somehow 4 = agree 5 = strongly agree)
Lack of market	
Need to travel long distances	
Inadequate handling facilities	
Poor road network	
Low prices	

16. The following factors have been hindering purchase of Sahiwalbreed among the farmers. *(please rank them using the provided scale)*

Constraint	Rank(1=strongly disagree 2 = disagree 3 = somehow 4 = agree 5 = strongly agree)
High price of Sahiwal	
Low supply	
Need to travel long distances	
Lack of information about Sahiwal	
Non- availability of Sahiwal	

17. During drought, do you sell your cattle (1)Yes [__] (2) No [__]

    If No proceed to question

18. If yes above how much per animal on average...

19. If NO in (15) Above, Why?

(1) Lack of markets [__] (2) Low prices [__] 3) Cultural attachment [__]

(4) Sign of wealth /prestige [__] (5) Distance to markets [__]

(6) Others list)..........................

20. Have you heard of livestock insurance?

    (1) Yes [__] (2) No [__]

21. Have you insured your herd?

    (1) Yes [__] (2) No [__] If no continue and if yes go to question 22

22. If the current market price of insuring one cattle is KES............. are you willing to pay more for an equivalent quantity?

    (1) Yes [__] (2) No [__]

23. Suppose the most limiting factors accessing insurance services are addressed to suit your expectations and thereafter the insurance policy was provided at a higher price than the current market price, would you be willing to pay more? (1)Yes [__] (2) No [__]

24. If Yes or No in 18, then provide the following bid levels at random to the farmer

Bid levels (premium price) i.e. if answered yes in question 18	Yes	No	Bid levels (discount price) i.e. if answered no in question 18	Yes	No
5%					
10%					
20%					

25. Farmers face various constraints in accessing livestock insurance services.

(Using the scale provided rank each costraint)

Constraints	Rank (Scale: 1=strongly disagree 2 = disagree 3 = somehow 4 = agree 5 = strongly agree
Lack of insurance knowledge	
No presence of insurance firms in the area	
High insurance premiums	
Insurance procedure too long	
Other (specify)...........	

SECTION E: PROCESSING

1. In which form do you sell your milk?

(1) Raw [__] (2) Mala [__] (3) Ghee [__] (4) Cheese[__] (5) Yorghut [__] (6) Others (specify)...............................

2. What methods of milk processing do you know of?

(1) Traditional methods [__] (2) Modernised methods [__]

3. Is there a difference in price between processed and unprocessed dairy products?

Yes [__] (2) No[__]

4. In which form is milk consumed at home

(1) Fresh [__] (2) Fermenmted [__] (3) Others (specify)..............................

SECTION F: DECISION MAKING IN THE HOUSEHOLD

1. Who among the household members owns, access and controls the following

Resources	Who owns 1=Husband 2=Wife3=Children	Who has access 1=Husband 2=Wife 3=Children	Who has control 1=Husband 2=Wife3=Children
ASSETS			
Land			
Livestock - cows			
Livestock - bulls			
Credit			

Farm equipment			
On farm Income			
INPUTS			
Concentrates			
Veterinary services			
Drugs			
Own labour			
Hired labour			
Milking churns			
OUTPUTS			
Milk			
Meat			
Live animal			
Fodder			

SOCIAL CAPITAL

1. Do you or any member of your household belong to any form of organized farming groups? 1 Yes [ ], 2 = No [ ]
2. If Yes, Please provide the following information on household involvement in organized group activities

Attribute	Group 1	Group2
Type of group 1 = Women group, 2 = Welfare groups, 3 = Merry-go-round, 4 = Self-help groups, 5 = Cooperatives, 6 = Farmer associations, 7 = Limited companies, 8 = Others (Specify)………………….		
Main objectives/activity of group 1=Crop Production, 2 =Processing, 3=Marketing, 4= livestock production, 5 =Training 6=input access 7=welfare support 8 =Other (specify) ……………..		

3.0 ACCESS TO MARKETS AND INFORMATION

Please fill in the table below on information access

Sources	Sources of production information		Sources of market information	
	Tick if you	Effectiveness	Tick if you	Effectiveness

	have access	1= Not effective 2 = Somewhat effective 3 = Effective 4 = Very effective	have access	1= Not effective 2 = Somewhat effective 3 = Effective 4 = Very effective
Other Farmers				
Extension officer				
Research organizations				
Field days				
Farmer field schools				
Agricultural shows				
Family and friends				
Mass media (Radio/TV)				
Farmer organization				
Internet				
Traders				
Market place				
Print materials (Posters, bulletins)				
Other non-farmer associations				

1. Do you have access to <u>markets</u> for agricultural inputs? 1 = Yes [ ], 2 = No [ ]
2. If Yes, what is the distance to the nearest market for inputs? _______________
3. Do you have access to <u>markets</u> for agricultural output? 1 = Yes [ ], 2 = No [ ]
4. If Yes, what is the distance to the nearest market for outputs? _______________
5. How are the road conditions to the market?

1 = Poor condition [ ], 2 = Accessible [ ]

4.0 ACCESS TO CREDIT

1. Have you or any member of your household borrowed credit in the last 5 years?

1 = Yes [ ], 2 = No [ ].

2. If **yes**, please provide the following details

Source of credit	Tick if borrowed from this source	Who among the household members accessed the credit Household head =1 Spouse =2 Child =3	Purpose of borrowing (see codes)
Relative and friends			
Informal savings and credit group			
Money lender			
Government credit schemes			
NGO/Church/Mosque			
Bank or micro-finance institution			

Purpose for borrowing: 1=Purchase of food, 2=Purpose of household assets, 3=Payment of fees, 4=Cover medical costs, 5=Buying crop inputs, 6 = Buying livestock inputs, 7=Cover educational costs

3. If No credit was borrowed, give reasons why?

1 = didn't need it [ ]

2 = Credit facilities not available [ ]

3 = Credit was too costly [ ]

4 = Lack of collateral [ ]

5 = Fear of being unable to pay [ ]

6 = others (specify)…...…

Appendix2

1. Local linear matching

Average treatment effect

Variable	Sample	Treated	Controls	Difference	S.E.	*t*-stat
Income	Unmatched	666808.443	484748.299	182060.145	161691.908	1.13
	ATT	661179.874	765657.618	-104477.744	173293.858	-0.60
	ATU	496013.857	804992.679	308978.822		
	ATE			89113.9589		

Covariate imbalance test

Variable	Unmatched/ Matched	Mean		% bias	% reduction |bias|	*t*-test	
		Treated	Control			*t*-value	*p>t*
Distance to market	Unmatched	8.479	9.2674	-8.7		-0.77	0.442
	Matched	8.5881	9.8774	-14.2	-63.6	-1.15	0.251
Middle aged	Unmatched	0.28743	0.2708	3.7		0.32	0.746
	Matched	0.30189	0.2641	8.4	-127.4	0.75	0.457
Elderly farmers	Unmatched	0.61677	0.4375	36.4		3.20	0.002
	Matched	0.59748	0.6540	-11.5	68.4	-1.04	0.298
County	Unmatched	0.55689	0.5347	4.4		0.39	0.697
	Matched	0.54717	0.5471	0.0	100.0	-0.00	1.000
Household size	Unmatched	10.844	11.646	-12.3		-1.08	0.281
	Matched	10.969	11.302	-5.1	58.4	-0.49	0.622
Herd size	Unmatched	95.653	130.56	-27.4		-2.44	0.015
	Matched	97.981	98.013	-0.0	99.9	-0.00	0.998
Land size	Unmatched	192.74	263.45	-12.6		-1.12	0.262
	Matched	195.27	186.32	2.1	83.1	0.24	0.807
Labour cost	Unmatched	28774	20110	17.7		1.52	0.131
	Matched	21694	23854	-4.4	75.1	-0.65	0.513
Education	Unmatched	1.509	1.7431	-14.9		-1.32	0.189
	Matched	1.5472	1.7421	-12.4	16.7	-1.12	0.265
Distance to water	Unmatched	2.8958	3.684	-15.5		-1.36	0.174
	Matched	2.922	2.4101	10.0	35.0	1.13	0.260
Watering frequency	Unmatched	0.82635	0.7916	8.8		0.78	0.438
	Matched	0.8239	0.8239	0.0	100.0	0.00	1.000
Reproductive performance	Unmatched	0.99401	0.9583	23.5		2.12	0.034
	Matched	0.99371	0.9811	8.3	64.7	1.00	0.316

2. Nearest neighbour matching

Average treatment effect

Variable	Sample	Treated	Controls	Difference	S.E.	*t*-stat
Income	Unmatched	666808.443	484748.299	182060.145	161691.908	1.13
	ATT	661179.874	575850.049	85329.8252	198183.897	0.43
	ATU	496013.857	863322.214	367308.357		
	ATE			217359.907		

Covariate imbalance test

Variable	Unmatched/ Matched	Mean		% bias	% reduction |bias|	*t*-test	
		Treated	Control			*t*-value	*p>t*
Distance to market	Unmatched	8.479	9.2674	-8.7		-0.77	0.442
	Matched	8.5881	9.5811	-11.0	-26.0	-0.93	0.352
Middle aged	Unmatched	0.28743	0.2708	3.7		0.32	0.746
	Matched	0.30189	0.2905	2.5	31.8	0.22	0.826
Elderly farmers	Unmatched	0.61677	0.4375	36.4		3.20	0.002
	Matched	0.59748	0.6125	-3.1	91.6	-0.27	0.004
County	Unmatched	0.55689	0.5347	4.4		0.39	0.697
	Matched	0.54717	0.5295	3.5	20.5	0.31	0.913
Household size	Unmatched	10.844	11.646	-12.3		-1.08	0.281
	Matched	10.969	11.175	-3.2	74.3	-0.30	0.739
Herd size	Unmatched	95.653	130.56	-27.4		-2.44	0.015
	Matched	97.981	98.353	-0.3	98.9	-0.03	0.070
Land size	Unmatched	192.74	263.45	-12.6		-1.12	0.262
	Matched	195.27	186.43	2.1	83.3	0.25	0.162
Labour cost	Unmatched	28774	20110	17.7		1.52	0.131
	Matched	21694	22306	-1.2	92.9	-0.19	0.249
Education	Unmatched	1.509	1.7431	-14.9		-1.32	0.189
	Matched	1.5472	1.4881	3.8	74.7	0.34	0.162
Distance to water	Unmatched	2.8958	3.684	-15.5		-1.36	0.174
	Matched	2.922	3.256	-6.6	57.6	-0.61	0.918
Watering frequency	Unmatched	0.82635	0.7916	8.8		0.78	0.438
	Matched	0.8239	0.7974	6.7	23.8	0.60	0.911
Reproductive performance	Unmatched	0.99401	0.9583	23.5		2.12	0.034
	Matched	0.99371	0.9924	0.8	96.5	0.13	0.809

3. Kernel matching

Average treatment effect

Variable	Sample	Treated	Controls	Difference	S.E.	*t*-stat
Income	Unmatched	666808.44	484748.30	182060.15	161691.90	1.13
	ATT	661179.87	564779.67	96400.21	186274.30	0.02
	ATU	496013.86	842904.06	346890.20		
	ATE			213686.49		

Covariate imbalance test

Variable	Unmatched/ Matched	Mean		% bias	% reduction |bias|	t-test	
		Treated	Control			*t*-value	*p>t*
Distance to market	Unmatched	8.479	9.267	-8.7		-0.77	0.442
	Matched	8.588	8.913	-3.6	58.8	0.90	0.368
Middle aged	Unmatched	0.287	0.271	3.7		0.32	0.746
	Matched	0.302	0.294	1.8	50.7	-0.32	0.748
Elderly farmers	Unmatched	0.617	0.438	36.4		3.20	0.002
	Matched	0.597	0.613	-3.1	91.4	-2.87	0.004
County	Unmatched	0.557	0.534	4.4		0.39	0.697
	Matched	0.547	0.547	-0.0	99.5	-0.11	0.913
Household size	Unmatched	10.84	11.65	-12.3		-1.08	0.281
	Matched	10.97	11.10	-2.0	84.0	0.33	0.739
Herd size	Unmatched	95.65	130.56	-27.4		-2.44	0.015
	Matched	97.98	100.77	-2.2	92.0	1.82	0.070
Land size	Unmatched	192.74	263.45	-12.6		-1.12	0.262
	Matched	195.27	193.41	0.9	93.1	1.40	0.162
Labour cost	Unmatched	28774	20110	17.7		1.52	0.131
	Matched	21694	21538	0.3	98.2	-1.16	0.249
Education	Unmatched	1.509	1.74	-14.9		-1.32	0.189
	Matched	1.547	1.53	1.0	93.6	1.40	0.162
Distance to water	Unmatched	2.896	3.68	-15.5		-1.36	0.174
	Matched	2.922	3.12	-3.9	74.9	0.10	0.918
Watering frequency	Unmatched	0.826	0.792	8.8		0.78	0.438
	Matched	0.824	0.800	6.0	31.8	-0.11	0.911
Reproductive performance	Unmatched	0.994	0.958	23.5		2.12	0.034
	Matched	0.994	0.991	2.0	91.4	-0.24	0.809

Sample	Pseudo R2	LR chi2	p>chi2	Mean Bias	Median Bias
Raw	0.090	38.45	0.000	15.5	13.8
Matched	0.068	28.22	0.005	2.2	2.0

Appendix 3

Publication

Ex-ante perceptions and knowledge of artificial insemination among pastoralists in Arid and Semi-Arid areas of Kenya. Journal: *Livestock Research for Rural Development*