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Economic Valuation of Phenotypic Cattle Trait Preferences in Trypanosomosis Prevalent Production Systems of Eastern Africa: Implications for Sustainable Cattle Breeding Programs

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M.Sc. Emily Awuor Ouma

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Dekan: Prof. Dr. Joachim Krieter
Erster Berichterstatter: Prof. Dr. Awudu Abdulai
Zweiter Berichterstatter: Prof. Dr. Uwe Latacz-Lohmann
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Dedicated to my parents,

Mr and Mrs Simon Ouma Onyinge

and

my husband,

Mr Apollo Odhiambo Anyango,

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Table of Contents

List of Tables

List of Figures

Summary

The livestock sector plays crucial multifunctional roles in the rural livelihoods and economies of many sub-Saharan African countries yet productivity remains relatively low in the region. Breed improvement programs that utilize advanced animal breeding technologies provide key entry points for improving livestock productivity. However, there are tendencies for genetic breed improvement programs to focus on single traits associated with production outputs such as meat or milk production with an assumption of a profit maximizing objective function when calculating economic values of traits to be included in a breeding objective. This potentially excludes adaptability traits and important non-income and socio-cultural roles of livestock from the breeding objective since such functions are often embedded in traits that lack market values or prices. This may result in breeds that are not well adapted to the environment and not capable of performing the multiple objectives of the livestock enterprise in developing countries. In order to design sustainable breed improvement programs aimed at improving productivity, livestock keepers' preferred traits need to be integrated into the breeding objective.

This study examines cattle keeping households' preferences for phenotypic cattle traits in trypanosomosis prevalent production systems of Kenya and Ethiopia, using cross-sectional choice experiment survey data of 506 cattle keeping households collected between September 2004 and May 2005. Further, it investigates potentially sustainable pathways by which the cattle keeping households can access improved genetic materials based on their cattle traits of preference. Mixed logit and latent class models are employed to model preference behavior for cattle traits from the choice experiment data with a focus on heterogeneity among cattle keeping households. Specifically, mixed logit model is employed to investigate existence of preference heterogeneity, while a latent class model is used to investigate the existence of endogenous preference segmentation for cattle traits among the cattle keeping households.

The results reveal significant preference heterogeneity among cattle keeping households. Good traction potential, fertility, trypanotolerance and reproduction performance are found to be the most preferred cattle traits. Traits related to beef and milk yield are ranked below these traits. The findings are particularly interesting because traditional economic analyses on livestock and cattle breeding programs often focus on raising milk and meat productivity, with little emphasis on the non-income traits such as traction potential and disease resistance. This reveals the need for the evaluation of a broader set of cattle traits for cattle breeding

programs besides beef and milk yield. The results of the latent class model indicate that the households' preferences are clustered around the production systems under which cattle production takes place. Three distinct classes of cattle keeping households in the sample population emerge, each displaying differing preferences for the same set of cattle traits. This indicates the importance of considering heterogeneity within population segments as it provides a useful framework for adapting breeding policy interventions to specific producer segments.

Additional results indicate that communal breeding initiatives provide important pathways through which resource-poor cattle keepers can access genetically improved livestock. Factors that influence a household's willingness to participate in such a collective action decision are analyzed using a binary logit model. The results indicate that the probability of participating in a collective action decision is influenced by several socio-economic and location characteristics. High human population density increases the probability of taking up collective action decision. Similarly, presence of adult females in the household as well as higher level of formal education and age of the head of the household increases the likelihood of participation in a collective action initiative. Conversely, households with higher wealth endowments in the form of access to off farm income and land tenure security, have a lower probability to participate in a collective action initiative. This has important implications for communal livestock breeding initiatives since resource constrained cattle keepers may not individually afford to purchase improved breeding bulls and may be willing to participate in communal breeding initiatives in order to access improved genetic material.

Zusamenfassung

Der Nutzviehsektor spielt für die Existenzgrundlage in ländlichen Gebieten und die Wirtschaft vieler Länder südlich der Sahara bedeutende multifunktionelle Rollen, wobei die Produktivität in der Region jedoch relativ gering ist. Programme zur Verbesserung der Züchtungen, die Technologien der modernen Tierzucht nutzen, liefern zentrale Ansatzpunkte zur Produktivitätssteigerung in der Viehhaltung. Es bestehen jedoch Tendenzen, dass sich die Zuchtprogramme auf einzelne Merkmale konzentrieren, die mit Produktionsoutputs wie Fleisch- und Milchproduktion verbunden sind. Dabei wird zur Berechnung der ökonomischen Werte der Merkmale, die in ein Zuchtziel aufgenommen werden sollen, eine gewinnmaximierende Zielfunktion unterstellt. Dabei werden möglicherweise Merkmale des Anpassungsvermögens sowie wichtige nicht-einkommensbezogene und soziokulturelle Rollen des Nutzviehs aus den Zuchtzielen ausgeschlossen, da diese Funktionen oft in Merkmalen enthalten sind, für die Marktwert oder Preise nicht vorhanden sind. Als mögliche Folge werden Rassen gezüchtet, die unzureichend an die Umweltbedingungen angepasst sind und nicht in der Lage sind, die vielfältigen Ansprüche der viehhaltenden Betriebe in Entwicklungsländern zu erfüllen. Um nachhaltige Zuchtprogramme zu entwickeln, die die Produktivität steigern, müssen die von den Viehhaltern gewünschten Merkmale in das Zuchtziel aufgenommen werden.

Diese Arbeit untersucht die Präferenzen von viehhaltenden Haushalten hinsichtlich phänotypischer Merkmale von Rindern in von Trypanosomosis betroffenen Produktionssystemen in Kenia und Äthiopien. Dabei wurden zwischen September 2004 und Mai 2005 mittels eines Choice Experiments Querschnittsdaten von 506 viehhaltenden Haushalten erhoben. Weiterhin werden mögliche nachhaltige Wege analysiert, mit denen die viehhaltenden Haushalte Zugang zu verbesserten genetischen Material erhalten können, das auf ihren bevorzugten Merkmalen basiert. Dabei werden Mixed Logit und Latent Class Modelle angewandt, um die Präferenz für Merkmale der Rinder aus den Daten des Choice Experiments abzubilden. Hierbei wird besonders auf die Unterschiede in den Präferenzen zwischen den Haushalten eingegangen. Insbesondere wird das Mixed Logit Modell eingesetzt um die Existenz von Heterogenität in den Präferenzen zu analysieren, während mit dem Latent Class Modell eine endogene Segmentierung der Präferenzen für Merkmale von Rindern unter den viehhaltenden Haushalten nachgewiesen werden soll.

Die Ergebnisse zeigen eine signifikante Heterogenität der Präferenzen zwischen den viehhaltenden Haushalten auf. Ein gutes Zugvermögen, Fruchtbarkeit, Trypanotoleranz und

Fortpflanzungsleistung werden als wichtigste Merkmale der Rinder identifiziert. Merkmale die mit der Fleisch- und Milchleistung in Verbindung stehen, werden in ihrer Bedeutung hinter diesen Merkmalen eingereiht. Diese Resultate sind von besonderem Interesse, da traditionelle ökonomische Analysen von Vieh- und Rinderzuchtprogrammen sich häufig auf die Steigerung der Milch- und Fleischproduktivität konzentrieren und den nichteinkommensbezogenen Merkmalen wie Zugvermögen und Krankheitsresistenz nur wenig Bedeutung beimessen. Daraus ergibt sich die Notwendigkeit zur Evaluierung einer breiteren Auswahl von Merkmalen für Rinderzuchtprogramme die über Fleisch- und Milchleistung hinausgehen. Die Ergebnisse des Latent Class Modells deuten an, dass die Präferenzen der Haushalte in Bezug zu dem Produktionssystem stehen mit dem sie Rinderhaltung betreiben. Aus der Stichprobe können drei verschiedene Gruppen von rinderhaltenden Haushalten identifiziert werden, die unterschiedliche Präferenzen für die gleiche Auswahl von Zuchtmerkmalen der Rinder zeigen. Dieses zeigt die Bedeutung der Berücksichtigung von Heterogenität in verschiedenen Bevölkerungsgruppen, da ein nützlicher Rahmen für die Anpassung von Eingriffen in die Zuchtmaßnahmen an die spezifische Produzentengruppen geschaffen wird.

Zusätzliche Ergebnisse deuten an, dass gemeinschaftliche Zuchtinitiativen wichtige Wege bieten können, welche ressourcenarmen Viehhaltern Zugang zu genetisch verbessertem Vieh zu ermöglichen. Einflussfaktoren auf die Bereitschaft eines Haushaltes an solchen gemeinschaftlichen Aktivitäten teilzunehmen werden mit einem binären Logitmodell analysiert. Die Ergebnisse zeigen, dass die Wahrscheinlichkeit der Teilnahme an gemeinschaftlichen Aktivitäten von verschiedenen sozioökonomischen und regionalen Charakteristika abhängig ist. Bei hoher Bevölkerungsdichte steigt die Wahrscheinlichkeit der Teilnahme. Ebenso beeinflusst die Anzahl weiblicher Erwachsener im Haushalt sowie der Bildungsstand und das Alter des Haushaltvorstandes die Wahrscheinlichkeit der Teilnahme an gemeinschaftlichen Aktivitäten positiv. Im Gegensatz dazu zeigen Haushalte mit größerem Wohlstand in Form von Zugang zu außerlandwirtschaftlichem Einkommen und höherer Sicherheit der Pachtverträge eine geringere Wahrscheinlichkeit der Teilnahme. Daraus leiten sich wichtige Implikationen für die gemeinschaftlichen Zuchtinitiativen ab, da Viehhalter mit limitieren Ressourcen es sich nicht leisten können, einen eigenen Zuchtbullen zu kaufen und möglicherweise dazu bereit sind an diesen gemeinschaftlichen Zuchtinitiativen teilzunehmen, um Zugang zu verbessertem genetischen Material zu erhalten.

List of Acronyms

AIC	Akaike Information Criterion.
BIC	Bayesian Information Criterion.
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit.
CBD	Convention on Biological Diversity.
CGIAR	Consultative Group on International Agricultural Research.
DNA	Deoxyribonucleic acid.
EU	European Union.
FAO	Food and Agriculture Organization of the United Nations.
GDP	Gross Domestic Product.
GEV	Generalized Extreme Value models.
GIS	Geographic Information System.
GPS	Global Positioning System.
ICIPE	International Centre for Insect Physiology and Ecology.
IIA	Independence of Irrelevant Alternatives.
IID	Identically and Independently Distributed.
ILRI	The International Livestock Research Institute.
IPR	Intellectual Property Rights.
ISAAA	International Service for the Acquisition of Agri-biotech Applications.
ITC	International Trypanotolerance Centre.
KARI	Kenya Agricultural Research Institute.
KETRI	Kenya Trypanosomiasis Research Institute.
NARS	National Agricultural Research Systems.
NOAA	National Oceanic and Atmospheric Administration.
PAAT	The Programme Against African Trypanosomiasis.
QTL	Quantitative Trait Loci.

SLL	Simulated log-likelihood function.
TIGR	The Institute for Genomic Research.
WTP	Willingness to Pay.
Ha	Hectares.

Chapter 1

General Introduction

1.1 Background

Livestock play a critical and integral role in the livelihood of rural populations and agricultural development of sub-Saharan Africa. Estimates show that livestock production account for 30% of the gross value of agricultural production in the region (FAO, 2004). At the household level, livestock performs multiple functions and are not only a source of income and nutrition, but also an integral component of agricultural systems that rely on traction and other inputs such as manure for fertilization of crop fields. In pastoral systems, livestock production are an integral part of the socio-cultural life and are highly fundamental to survival since alternative forms of land-use are uneconomic. In such systems, livestock are the most important fungible asset owned by the households and herd size is often directly associated with wealth and status in the society. Further, in rural Africa, livestock assume finance and insurance roles due to absence or ill functioning of financial and insurance markets (Moll, 2005; Bosman et al., 1997).

Research conducted by the International Food Policy Research Institute (IFPRI), the Food and Agriculture Organization of the United Nations (FAO) and the International Livestock Research Institute (ILRI) reveals an even increasing significance of livestock production in sub–Saharan Africa over the next two decades and possibly beyond. It projects a global increase in demand for food of animal origin with most of the increase in demand emanating from developing countries. This is projected to result from rapid urbanization, rising incomes and human population growth. This increase in demand is expected to be of such extent and scope that it has been described as a “Livestock Revolution” (Delgado et al., 1999). In sub-Saharan Africa, demand for meat and milk has almost doubled over the past two decades. In Eastern Africa the same pattern has been observed. For instance, milk consumption in the region increased from 1.5 million metric tons in 1975 to 3.2 million metric tons in 1995, while meat consumption rose from 0.5 million metric tons to 0.9 million metric tons in the same period (Ehui et al., 2002). Further projections indicate that total consumption of meat and milk in Eastern Africa will more than double between 1997 and 2020 to reach 1.9 and 7.3 million metric tons respectively, by 2020. Under favorable conditions, total production of the two animal products is also expected to almost double (ibid.).

Despite the increasing demand for livestock products in sub-Saharan Africa, productivity in the region remains very low compared to other parts of the world (Otte and Chilonda, 2002). Beef and milk productivity virtually stagnated in the last two decades. Meat productivity remained at 120kg/head between 1975 and 1995, while milk productivity increased from 210kg to 225kg within this period. Milk production per animal was estimated at about 60% of the world average while meat production per animal was only about 24% of the world average (Ehui et al., 2002). The livestock revolution presents attractive growth opportunities for the livestock sector in sub-Saharan Africa given the expected rise in demand for livestock products. In order for the livestock keepers to benefit, issues of productivity improvement need to be addressed since increased productivity has a direct impact on household income and incidence of poverty. Productivity improvement is predicated upon identifying and removal of constraints that impact negatively on the production systems and processes. A large body of literature (e.g. Teale, 1993) investigates the sources of low livestock productivity in the region and finds its linkage to an intricate web of constraints and factors. Identified constraints to improved livestock productivity range from technical, institutional and infrastructural constraints related to feeding, animal health and genotype. The severity of these constraints varies by the various production systems under which livestock production takes place.

Animal diseases, especially those caused by parasites, are severe constraints on animal production in sub-Saharan Africa. Trypanosomosis disease is one of the most important constraints to food security and agricultural development in Africa as it limits the development of livestock production through poor growth, weight loss, low milk yield, infertility and abortion (d'Ieteren et al., 1998)[1]. Kristjanson et al. (1999), estimate the annual cost of trypanosomosis in terms of foregone milk and meat production alone to be US$1.3 billion. Other losses emanate from farmers' responses to the perceived risk of the disease and may include reduction in herd size and reduced crop production due to insufficient animal draft power. Control of trypanosomosis disease is estimated to potentially result in increased milk and meat supply in sub – Saharan Africa by a substantial 17% (De Haan and Bekure, 1991). In Africa, the major pathogenic trypanosome species for livestock are transmitted by several species of the blood-sucking tsetse fly (*Glossina* sp.)[2]. The disease is endemic in 7mn Km^2 of Africa, comprising more than a third of the land area across Africa, with forty six

[1] Trypanosomosis is caused by trypanosomes, which are minute protozoan parasites specially adapted for life in the blood of a vertebrate. In sub-Saharan Africa, the disease is transmitted by tsetse flies.

[2] The major pathogenic trypanosome species for livestock in Africa include *Trypanosoma congolense, T. vivax, T. brucei brucei* and *T. simiane* (van der Waaij, 2001).

million cattle at constant risk of infection (Kristjanson et al, 1999). Trypanosomes infect not only cattle but also wild animals. The latter are the natural hosts of tsetse flies and do not suffer severe clinical disease but become carriers and constitute an important reservoir of infection for livestock.

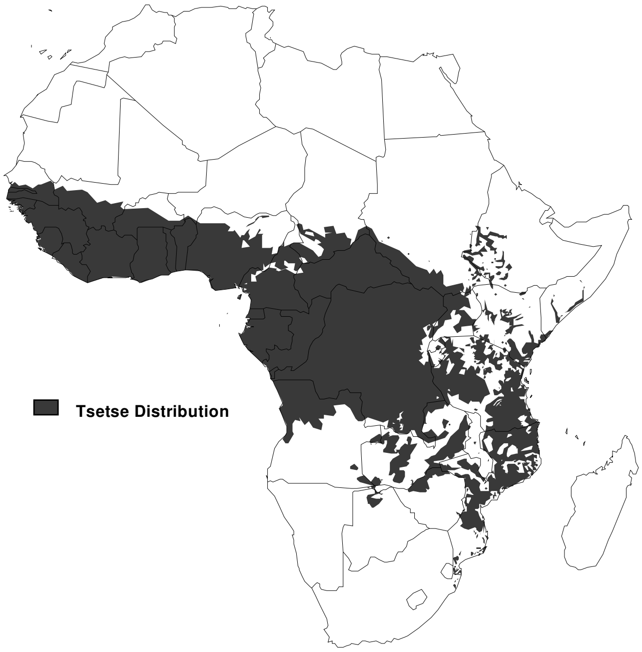


Figure 1: Tsetse fly distribution in Africa
Source: ILRI GIS database

Figure 1 presents tsetse fly distribution in Africa, showing areas at risk of trypanosomosis disease. Tsetse fly occurrence is mainly below the Sahara and above the Kalahari deserts, with a higher incidence in the central and western parts of the continent as well as parts of eastern Africa. Non tsetse fly transmitted trypanosomosis is also common in parts of Asia and the Middle East but this form of transmission is considerably less significant than the tsetse fly transmission form.

Figure 2 shows total cattle population in sub-Saharan Africa and the population in tsetse fly infested areas. Western and Central Africa have a high population of cattle in tsetse infested areas, though some cattle breeds in the two regions have been identified as trypanotolerant. Eastern Africa has the highest cattle population of about 68 million with 30% in tsetse fly infested areas. The livestock sector plays an important role in the livelihoods of about 70% of the rural households in eastern Africa and contributes 30-35% of agricultural GDP (Halderman, 2004). Livestock have considerable potential for contributing towards the achievement of the millennium development goal of eradication of extreme poverty and hunger as they serve as productive assets that allow households to be self provisioning. For instance, in 40% of Kenya's districts livestock represent more than a quarter of the total household income, while in Ethiopia, it accounts for 37-87% of rural households' cash income (Thornton et al. 2002; Halderman, 2004). Livestock also has potentials to act as a critical buffer for poor households against falling into greater poverty and also serve as springboards that may enable households to advance to relative wealth. In order for the livestock poverty reduction potentials to be realized, research and policy ought to be geared towards reducing risks and losses that livestock keepers face through constraints such as trypanosomosis disease.

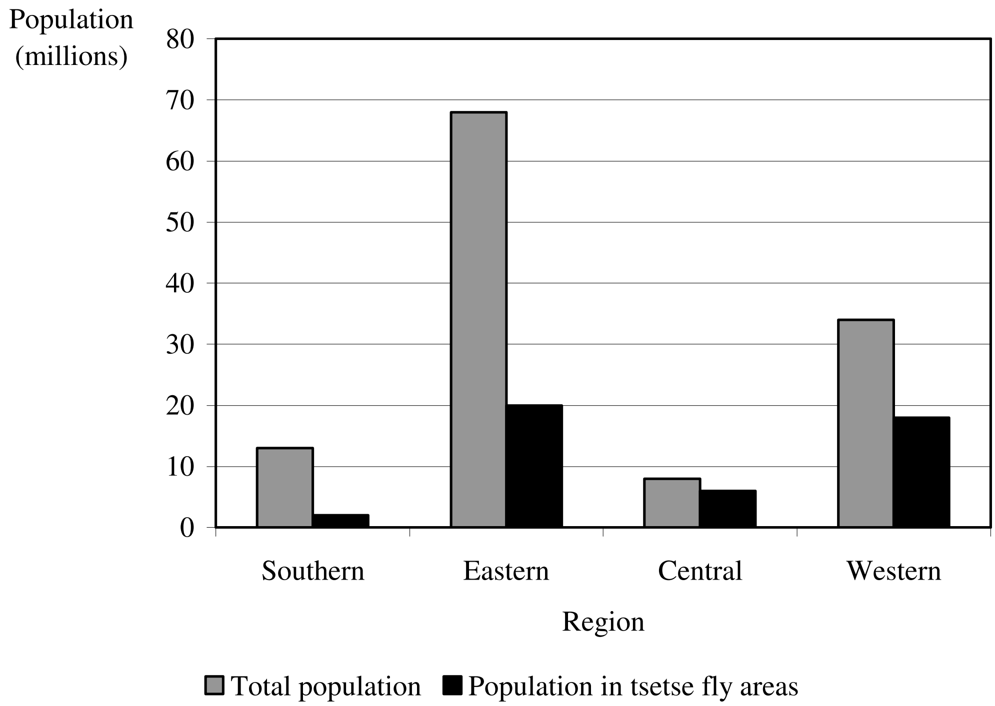


Figure 2: Total cattle population and populations in tsetse fly areas of southern, eastern and western African countries.
Source: Rushton et al., 2002

Control of trypanosomosis in sub-Saharan Africa currently relies largely on the use of chemotherapeutic drugs and tsetse vector control. In most cases, such control remains costly and only partially effective[3]. Total annual expenditures on curative and preventive treatments for trypanosomosis in sub-Saharan Africa by livestock keepers and governments, has been estimated at about US$ 35 million, administering 25–35 million curative and prophylactic treatments of trypanocidal drugs at a price of approximately US$ 1 per treatment (Kristjanson et al., 1999 and McCarthy, et al., 2003). These are colossal amounts that could be invested in alternative development initiatives such as improvement of the dilapidated physical infrastructures common in rural areas in Africa. Control using chemotherapeutic drugs is

[3] Tsetse fly control programs have been ineffective largely due to reinvasion, arising from the resilience of tsetse populations.

further limited by the development of drug-resistance in target parasites, especially arising from administration of sub-optimal doses of the trypanocidal drugs (FAO, 1998). Sinyangwe et al. (2004) and Codjia et al. (1993) find evidence of drug-resistance to bovine trypanosomosis in the Eastern provinces of Zambia and south-western Ethiopia. Other control options such as aerial spraying of insecticides are not common due to environmental concerns and potential human health hazards. In addition, the cost implications of aerial spraying may be too high for most African governments to afford. Attempts to develop an effective vaccine have so far been unsuccessful and immediate prospects are not promising.

Genetically controlled tolerance to trypanosomosis in livestock has been identified as a highly promising route for control of the disease and livestock productivity improvements (d'Ieteren et al., 1998). Genetic tolerance to trypanosomosis has been defined by Naessens et al (2002) and d'Ieteren et al (1998) as the relative capacity of an animal to control the development of the parasites and to limit their pathological effects, the most prominent of which is anaemia, the primary cause of death of infected cattle. Trypanotolerant animals are able to survive, reproduce and remain productive under trypanosomosis risk without the aid of curative or prophylactic drugs. The advantage of genetic control over other methods of control is that genetic changes are cumulate and permanent. In crop research, exploitation of plant genetic resistance to disease through breeding has been shown to result in substantial agricultural productivity improvements in the United States and other countries (Zohrabian et al., 2003). The prospects for producing cattle with genetic tolerance to trypanosomosis are high given recent advancements in genomics research and the fact that trypanotolerance is genetic and heritable and is known to exist in several cattle populations in Western and Central African countries in reasonably high numbers.

Table 1 presents the trypanotolerant cattle populations in West and Central Africa for three years, 1975, 1985 and 1998. The trypanotolerant cattle are mainly the *Bos taurus* breeds such as the N'dama and the West African Shorthorn breeds that have developed a genetic capacity to cope with trypanosomosis disease, resulting from their long survival in tsetse fly infested areas. There were an estimated 11.68 million trypanotolerant cattle in 1998. Agyemang (2005) indicates that 11 million of the trypanotolerant cattle were in West Africa and 0.68 million in Central Africa. Overall, the trypanotolerant cattle population grew by 1.4% between 1985 and 1998. The growth pattern has been partly attributed to increased cross-border trade in trypanotolerant livestock between West and Central Africa that has contributed to an increase in numbers and regional diversity of the stocks (ibid.)[4].

Table 1: West and Central African trypanotolerant cattle breeds

	Population in Million (Mn)			% annual increase	
	1975	1985	1998	1975-85	1985-98
N'Dama	3.40	4.86	5.35	4.3	0.73
Savannah Shorthorn	1.67	1.96	2.53	1.8	2.07
Dwarf Shorthorn	0.09	0.10	0.15	1.1	3.57
Cross-breeds	2.44	2.89	3.63	1.8	1.83
Zebu-N'dama crosses	1.01	1.24	1.30	2.3	0.34
Zebu-Shorthorn crosses	1.43	1.65	2.33	1.5	2.94
All breeds	7.60	9.82	11.68	3.1	1.40

Source: Agyemang, 2005

Development of cross-border trade in trypanotolerant livestock between Central and East Africa and between West and East Africa on the other hand has been hampered to date by regulatory and phyto-sanitary laws governing the cross-border transportation of biological materials into East African countries, particularly Kenya. In 1985, however, despite these laws, frozen embryos of N'Dama cows were introduced from the Gambia into Kenya for transfer into Boran surrogate mothers raised at the International Livestock Research Institute (ILRI) in Nairobi (Jordt et al., 1986). The objective was to establish laboratories in East Africa in order to undertake studies on the genetic and molecular bases of trypanotolerance traits (ibid.). This initiative enabled the first N'Dama cattle herd to be established in the region, allowing its use for producing first (F1) and backcross generations required for quantitative trait loci (QTL) studies. In East Africa, Orma Boran, an indigenous *Bos indicus* breed has also been identified to exhibit some natural resistance to trypanosomosis disease (Dolan, 1997). One major drawback of most trypanotolerant cattle breeds is their innate low productivity relative to the trypanosusceptible breeds.

Advanced genomics researches have selected and identified a number of heritable genes, controlling trypanotolerance using modern biotechnology[5] particularly

[4] The breeds and strains have adapted to trypanosome species in their respective countries.

[5] The 1992 Convention on Biological Diversity (CBD) defined biotechnology as "any technological applications that uses biological systems, living organisms or derivatives thereof, to make or modify products or for specific uses"(Kameri-Mbote, 2001). Biotechnology covers diverse applications such as genome mapping,

deoxyribonucleic acid (DNA) technology in some trypanotolerant African cattle breeds. These favorable genes can then be introduced into susceptible breeds using marker-assisted introgression (MAI), a breeding strategy aimed at introducing favorable genes such as those that explain disease resistance such as trypanotolerance into a more productive but susceptible breed (Van der Waaij, 2001). These are major research advancements in molecular genetics and genomics research on trypanotolerance and provide potentially viable and sustainable opportunities for improving cattle productivity in other areas at risk of trypanosomosis, by utilizing trypanotolerance trait and integrating other preferred traits through systematic breeding in a breed improvement program[6]. The initial step in any genetic breed improvement program is the definition of a breeding objective including the calculation of economic values for the genetic traits to be improved, based on an economic decision criterion.

1.2 Problem Setting and Motivation

Calculation of economic values by animal breeders for inclusion in a breeding objective has often utilized profit functions, focusing on single, market driven traits such as meat and milk production in isolation from broader livelihood system needs. This has often resulted in the substitution of exotic cattle for indigenous breeds. Although indigenous cattle are often less productive than exotic breeds, when traits such as milk and beef production are considered in isolation, they may be better suited to the local environmental conditions. The low productivity in sub-Saharan Africa's cattle has also been partly attributed to the multiple functions that cattle perform in the livelihood system. It is estimated that approximately 80% of the value of livestock in low-input developing country systems can be attributed to non-income socio-cultural functions, while only 20% is attributable to physical products such as meat, milk and wool. In contrast, over 90% of the value of livestock in high-input developed country production systems is attributable to the direct production outputs (Gibson and Pullin, 2005).

Some of the important non-income and socio-cultural functions of cattle in developing countries are embedded in traits that are not traded in the market, therefore lacking price or market values. Hence, the utilization of profit functions for derivation of economic values for cattle traits in such systems would result in exclusion of such traits from the breeding

tissue culture, immunological techniques, molecular genetics, genetic transformation and recombinant DNA techniques in all facets of production.

[6] A breeding program is an organized breeding of a group of animals in which information on performance of potential breeding animals is used to estimate breeding values, and superior animals are selected to breed the next generation.

objective, potentially yielding genotypes not capable of fulfilling the multiple objectives of the cattle enterprise. This calls for the employment of valuation methods that capture cattle keepers' preferred phenotypic traits with and without market values in the calculation of economic values for cattle traits to be included in the breeding objective. There is little evidence and information regarding cattle breed improvement programs that allow priority setting, driven by cattle keepers' preferred traits, while taking the environmental constraints into consideration. Yet, participation of cattle keepers may contribute to the development of sustainable and effective breed improvement programs that utilize preferred traits. This study aims to fill this gap in the literature by employing choice experiments to assess preferences for cattle traits in trypanosomosis prevalent sites in pastoral, agro-pastoral and crop-livestock production systems of Eastern Africa. It further aims to investigate factors that may influence cattle keepers' willingness to participate in communal cattle breeding groups that utilize disease-resistant genotypes.

1.3 Study Objectives

The overall objective of this study is to assess preferences for phenotypic cattle traits in trypanosomosis prevalent production systems of Eastern Africa. This would contribute towards design of appropriate and sustainable cattle breed improvement programs, aimed at improving cattle productivity. Specifically the study seeks (i) to determine the socio-economic reasons for keeping cattle in trypanosomosis prevalent production systems of eastern Africa and to identify preferred phenotypic cattle traits, (ii) to estimate economic values of preferred cattle traits and investigate existence of preference heterogeneity and factors driving the preference structures, (iii) to investigate potentially sustainable pathways for poor cattle keeping households to access genetically improved livestock, and (iv) to draw recommendations, policy implications and best practices on the basis of the study results. To achieve these objectives, the following hypotheses will be tested:

(i) Cattle keepers in pastoral, agro-pastoral and crop-livestock production systems of eastern Africa keep cattle for both social as well as economic reasons. Culture, environment and infrastructural conditions influence the cattle traits preferred, the breeds kept and the production objectives.

(ii) Cattle keepers demonstrate heterogeneous preferences for cattle traits. Production system, socio-economic and market access factors are the main sources of preference heterogeneity.

(iii) Productive traits are highly valued relative to trypanotolerance trait among cattle keeping households with high levels of market access.

(iv) Communal cattle breeding initiatives provide potentially sustainable pathways for poor cattle keeping households to access genetically improved livestock. Socio-economic factors of the household and infrastructural constraints influence the households' willingness to participate in communal initiatives.

The following research questions are addressed:

(i) Which cattle traits are preferred by cattle keepers based on their prevailing environmental conditions and what factors influence their preferences?

(ii) Is there existence of preference heterogeneity for cattle traits and what are its determinants?

(iii) What factors determine cattle keeper's willingness to participate in communal breeding structures and what kind of improved breed access arrangements are possible?

1.4 Significance of Study

Most opportunities for future livestock development in sub-Saharan Africa will increasingly necessitate technology adoption to bring about increases in productivity as a means of reducing poverty and improving food security. Whilst this is true, technology only forms a part, although a critical one, to the solutions of poverty and environmental conservation. Voicelessness and isolation of the target group in the research process may yield technologies that are not sustainable or acceptable to the target group, albeit critical to improving livestock productivity. A research approach that addresses livestock keepers' constraints, while empowering them by involving them in the decision-making processes of their research needs provides sustainable solutions and opportunities which can be readily taken up by them. Breed interventions, through breed improvement programs that utilize trypanotolerance trait while at the same time taking into consideration preferred traits by cattle keepers and their environment provide a sustainable and viable option to improving livestock productivity and enhancing competitiveness by reducing production costs incurred through control of trypanosomosis disease. Information from this study is hoped to contribute towards design of appropriate and demand-led cattle breeding programs benefiting animal breeders, policy makers, livestock keepers, researchers and non–governmental organizations while also building up on the existing body of knowledge.

1.5 Study Sites

The study focuses on sites in Eastern Africa, specifically Kenya and Ethiopia where livestock form a vital component of the livelihoods of the rural poor. Trypanosomosis is an important constraint to livestock production in several sites in these countries yet animal health delivery systems are weak. The focus is on three cattle production systems, which are representative of similar systems and environments in Eastern Africa. This provides opportunities for scaling out of outputs from this study to similar environments. In order to identify the research areas in Kenya and Ethiopia, spatial mappings have been prepared by overlaying data layers on cattle densities and tsetse fly distributions in the two countries using Geographic Information Systems (GIS) in order to target areas at risk of trypanosomosis disease. Figures 3 and 4 present tsetse fly distribution in the two countries. Two tsetse fly prevalent districts; Narok and Suba, representing different cattle production systems have been randomly selected in Kenya in order to capture possible variations in cattle trait preference structure across production systems.

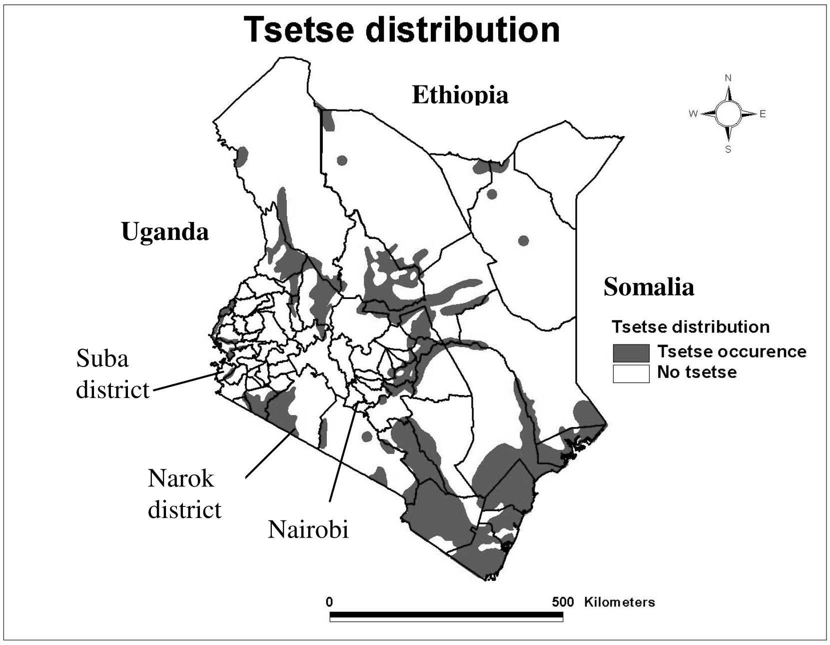


Figure 3: Tsetse fly distribution in Kenya
Source: ILRI GIS Database

In Ethiopia, the risk of contracting trypanosomosis disease is higher on the Western and South-western parts of the country as indicated in figure 4.

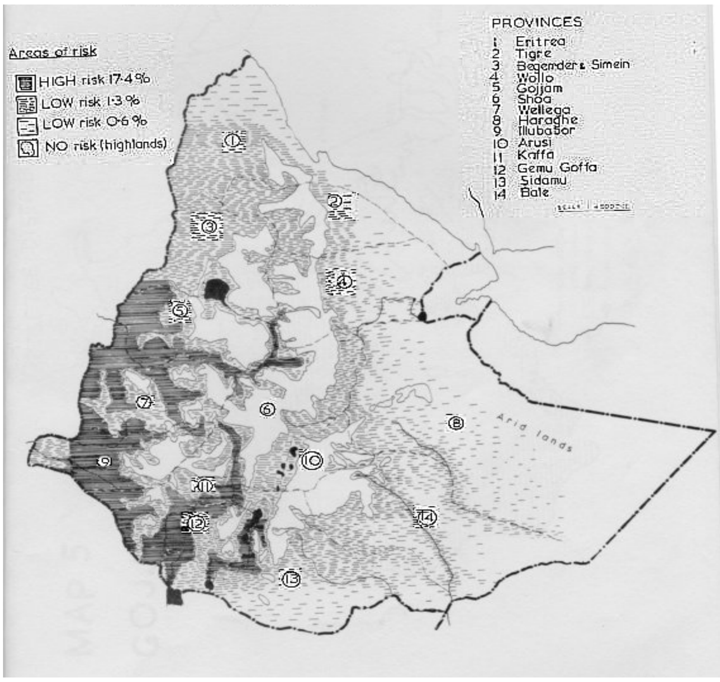


Figure 4: Tsetse fly distribution in Ethiopia
Source: PAAT (http://www.fao.org/paat/html/body_eth.htm)

The Ghibe valley, located in south western Ethiopia, has been selected since trypanosomosis has been a major cause of reduced agricultural development in the area over the past years. A brief background of each study site is presented in subsections 1.5.1 to 1.5.3.

1.5.1 Narok district, Kenya

Narok district is situated in the southwestern part of Kenya bordering the republic of Tanzania to the south, Trans-Mara district to the west, Bomet and Nakuru districts to the north and Kajiado district to the east. The district occupies a total land area of 15,088 km^2 and is divided into eight administrative divisions as presented in figure 5. The district has a varying topography with altitude ranging from 3,098 meters above sea level; in the highlands to 1,000 meters above sea level in the lowlands. The highlands, consisting of Mau, Olokurto and Mulot divisions, have a high potential for wheat, barley, maize, beans and potatoes. This is attributed to fertile soils, reliable rainfall ranging from 1200-1800 mm per annum and temperatures ranging from 10º to 15º centigrade (Government of Kenya, 2002a).

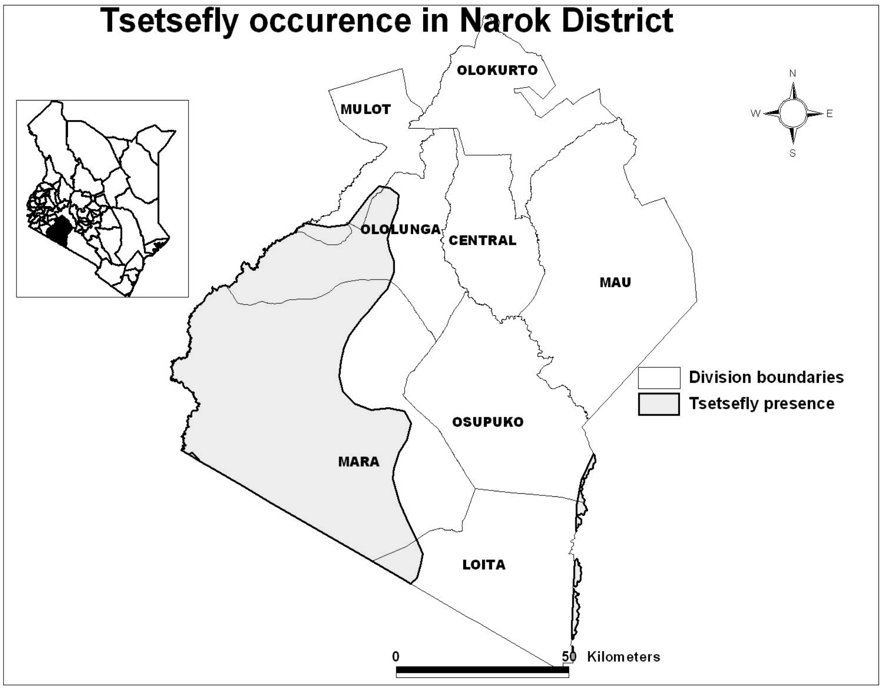


Figure 5: Tsetse fly distribution in Narok district
Source: ILRI GIS Database

The lowland areas, consisting of Ololunga, Mara, Loita and Osupuko divisions have high potential for livestock rearing. However, trypanosomosis pose a serious challenge to livestock production in Mara and parts of Ololunga divisions due to high tsetse fly occurrence as is evident in figure 5. The lowland areas lie in semi-arid zones with low potentials for cropping due to poor soil quality and unreliable rainfall. Temperature ranges from 5º in July to 28º in November and February. The Maasai people, who practice nomadic pastoralism and small scale subsistence agriculture, inhabit the area.

Human population in the district according to the population census was 403,812 in 1999 with a population density of 24 persons per km^2 up from 14 persons per km^2 in 1989, indicating a significant increase over the last 10 years (ibid.). The highland areas have the highest population densities in the district due to favorable agro-climatic conditions. There are relatively high poverty incidence levels in the district, with 52% of the rural population living below the national rural poverty line[7] (Government of Kenya, 2003). The main natural source of surface water in the district is Ewaso Nyiro River and its tributaries, Siapei and Narok. The Maasai Mara game reserve, which houses a variety of wildlife species falls partly within the district boundaries in the lowland areas, leading to livestock and wildlife co-existence in the

[7] Based on a monetary poverty line derived from the cost of a basic basket of goods that allows minimum nutritional requirements to be met (set at 2,250 calories per adult equivalent (AE) per day) in addition to the costs of meeting basic non-food needs (Government of Kenya, 2000). In Kenya, this poverty line was estimated to be about KSh 1,239 and 2,648 for rural and urban households respectively.

area. Some of the wildlife species are natural hosts to tsetse flies, constituting an important reservoir of trypanosomosis infection to livestock.

Mara and Ololunga divisions have been selected as the study sites in Narok district, owing to the presence of trypanosomosis disease in these divisions. The main cattle production system found in these divisions is nomadic pastoralism, characterized by movement of livestock herds in search of pasture and water as the seasons and circumstances require. In pastoral systems, livestock form an integral part of the socio-cultural life of the people and usually relatively large numbers of sheep, goats and cattle, mainly of local Zebu content are owned and raised under communal grazing and management. The livestock holdings represent the pastoral society's approximation of wealth, though the potential milk off - take is low. There is heavy reliance on livestock for sustenance, through blood, meat and especially milk. Livestock also serve as a form of insurance against risk, an important status symbol and an instrument for establishing social relations, including marriage (Barrett et al, 2003). Land ownership in Kenyan pastoral systems is mainly in the form of group ranches which range from 3,000 to 151,000 ha (Kristjanson et al., 2002). Group ranches are organizational structures in which a group of people have a freehold title to land, and aim to collectively maintain agreed stocking levels and to herd their livestock collectively, although livestock are owned and managed individually. Selection of members to a particular group ranch has been largely based on kinship and traditional land rights (Ng'ethe, 1993). Mau division where mixed crop-livestock production system is practiced has also been selected as a study site to assess possible existence of differences in the cattle preference structure among cattle keepers in the district.

1.5.2 Suba district, Kenya

Suba district is located in the South-western part of Kenya along Lake Victoria. It borders Bondo district to the north across the lake, Homa Bay district to the east, Migori district to the South and Lake Victoria to the west. The district occupies a total land area of 1,056 km^2 and is divided into 5 administrative divisions with several islands, as presented in figure 6. The district has an inland equatorial type of climate that is modified by its proximity to Lake Victoria and altitude which varies from 1,125metres to 2,275metres above sea level (Government of Kenya, 2002b).

The main relief feature is an upland plateau composed of undulating surfaces characterized by residual highlands to the south and north of the district. On the eastern part of the district lies Lambwe valley at 1,219 meters above sea level and forms a border between

Suba and Homa Bay districts. Annual rainfall in the district ranges from 700mm to 1,200mm with a 60% reliability while annual temperatures vary from 17º to 35º centigrade, with lower temperatures experienced in the highlands (ibid.). Gwassi and Lambwe divisions report high rainfall figures of 2,106mm and 1,962mm respectively. Total human population in the district according to the population census was 155,666 in 1999 with an average population density of 163 persons per km^2 and an estimated 67% of the rural population living below the national rural poverty line (Government of Kenya, 2003).

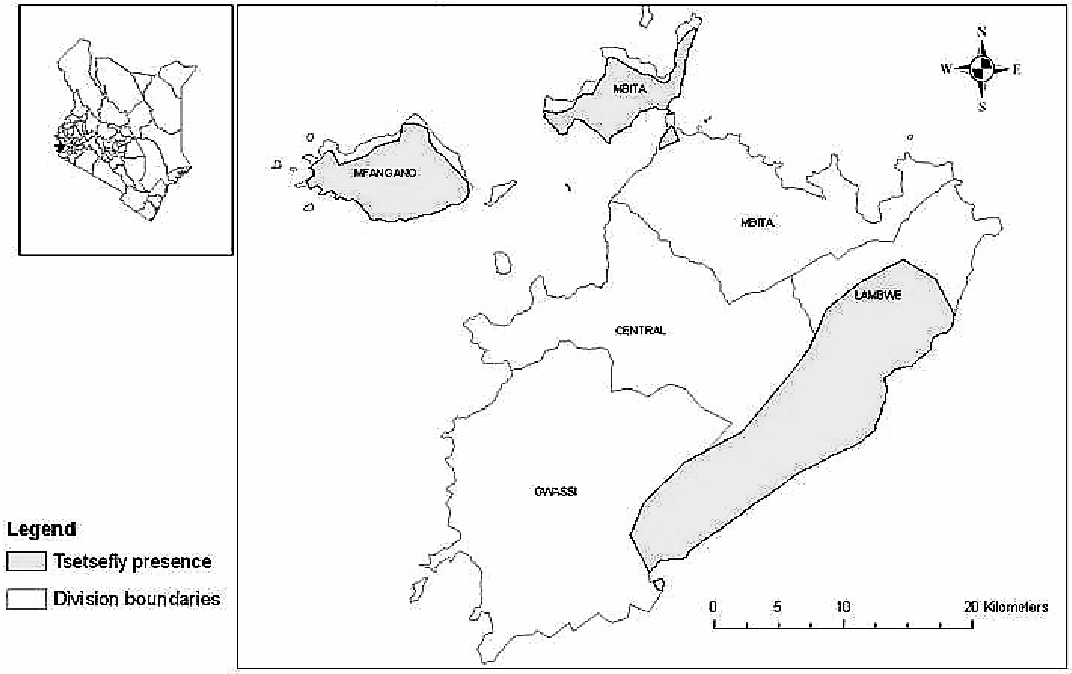


Figure 6: Tsetse fly distribution in Suba district
Source: ILRI GIS Database

The main economic activity in the district is subsistence and commercial agricultural production; for instance, in the highland divisions of Gwassi, cash crops such as cotton and sunflower are grown. Land tenure system in the district is predominantly freehold with an average farm size of 4 ha (Government of Kenya, 2002b). Fishing is an important economic activity in the islands. Majority of the population living in Lambwe division are migrants from neighboring districts attracted to the division by availability of highly productive tracts of land, consisting of black alluvial soils in Lambwe valley. The valley falls in the moist mid-altitude zone, an agro ecology that accounts for 44% of the maize growing area of Kenya. The valley also has a high potential for bananas, sweet potatoes, green grams, cow peas, finger millet and sorghum production (ibid.).

Lambwe and Central divisions have been selected as the study sites in Suba district due to their high agricultural potential and limitations arising from trypanosomosis disease which poses a significant threat to food security in the area. The main cattle production system in the area is mixed crop-livestock production[8], where farmers rely heavily on cattle for income generation and draft power to plough land as well as manure for fertilizing crop fields. The main avenue for trypanosomosis infection in the area is through wildlife, kept in the neighboring Ruma National Park, some of which are natural hosts to tsetse flies. Institutions such as International Centre for Insect Physiology and Ecology (ICIPE) and the Kenya Agricultural Research Institute (KARI) formerly, Kenya Trypanosomosis Research Institute (KETRI) have been working extensively in the area with the communities, primarily on tsetse fly control management using various techniques such as traps, targets and application of insecticide pour on. However, the challenge on the long-term sustainability of the control methods still remains.

1.5.3 The Ghibe Valley, Ethiopia

The Ghibe valley is situated 180 km South-west of the Ethiopian capital city of Addis Ababa, and lies between 37^{o}15' and 37^{o}40' east and 8^{o}00' and 8^{o}30' north. It has an altitude of 1,050 – 1,600 meters above sea level and experiences a unimodal annual rainfall range of 900 – 1000mm occurring between June and September. Annual temperature ranges from a minimum of 10 – 15° centigrade to a maximum of 30 – 37° centigrade (Ethiopian Economic Association, 2002). The Ghibe River cuts across the valley from north to south. The landscape is dominated by heavily forested Boter Becho Mountains (2300m) to the west, rising out of a 1600m plateau which is deeply incised by the river, forming rocky canyons, which are uninhabited and unsuitable for crop production. Wooded grasslands cover the rest of the landscape, with thick riverine forests along water courses (Reid et al, 2001). Compared with the nearby highlands, the Ghibe valley supports relatively little agricultural production, with arable soils consisting of heavy vertisols. Most cattle owners in the Ghibe Valley are sedentary agro-pastoralists who rely heavily on cattle for traction power (Swallow et al, 2000). Crop production mainly comprises teff, maize, pepper and oilseeds. The agro-pastoral system is characterized by the integration of livestock and agricultural activities as an essential strategy for survival since cropping is a high-risk enterprise due to scarce and unpredictable rainfall.

In Ethiopia, land ownership is vested in the government according to a land reform proclamation of 1975, still operational which nationalized all land and provided open-ended

[8] Mixed crop-livestock systems can be described as farming systems conducted by sedentary households where crop cultivation and livestock rearing together form integrated components of a single farming system.

usufruct right[9] to the farming population (Ethiopian Economic Association, 2002). Farmers access land through state mandated peasant associations where they reside, subject to proof of permanent physical residence, and ability to farm continuously and meet administrative dues and obligations. These use rights are inheritable. Peasant Associations or Kebeles are the lowest administrative unit of a regional state. Ethiopia has a federal government structure, comprising of regional states. The highest administrative unit within the regional state is known as Woreda, sometimes also spelt as Wereda. In 1975, the Ethiopian government introduced a policy to lessen population pressure in the highland areas by promoting resettlement in low-lying areas. In southwest Ethiopia, the originally sparsely inhabited Ghibe and Tolley areas in the Ghibe valley experienced an influx of people from the highlands promoting the conversion of the wooded grasslands of the Ghibe valley into cropland.

In the early 1980s trypanosomosis became prevalent in the area causing livestock deaths and rapid contraction in farmland. Farmers lost over 75% of their ploughing oxen within the first 12-24 months and were unable to plough 30% as much land as they had before the disease outbreak (Swallow and Mulatu, 1994). Studies of trypanosomosis and livestock productivity by the International Livestock Research Institute began in the Ghibe valley in 1986, followed by tsetse fly control trials in 1990 using cloth 'targets' sprayed with insecticides. This control method was abandoned in 1993 due to target thefts (ibid.). In another part of the valley, a trial began in 1991 using an insecticidal pour-on preparation, applied along the spine of cattle. The insecticide kills tsetse flies and other biting flies that land on treated animals. Figure 7 shows the location of the Ghibe valley and the location of crushes where cattle were treated with the insecticidal pour-ons by ILRI.

The control intervention has been very successful in reducing tsetse fly challenge and disease prevalence in parts of the valley with considerable positive impacts on farm productivity, farmer incomes, livestock population and human settlement in the Ghibe valley (Omamo and d'Ieteren, 2003). However, the challenge that remains is how to sustain the effects of the intervention beyond the involvement of ILRI given that the institute has been subsidizing the cost of the pour-ons to farmers. In addition, parts of the valley along the Ghibe River and a number of its tributaries are still prone to tsetse fly occurrence and trypanosomosis prevalence remains high despite regular treatment of cattle with the pour-ons (ibid.). Four Woreda in the upper and lower Ghibe valley have been selected as study sites, representing areas where trypanosomosis prevalence has remained high.

[9] The farming population is allowed to lease and use land and derive income from it but is not allowed to sell it.

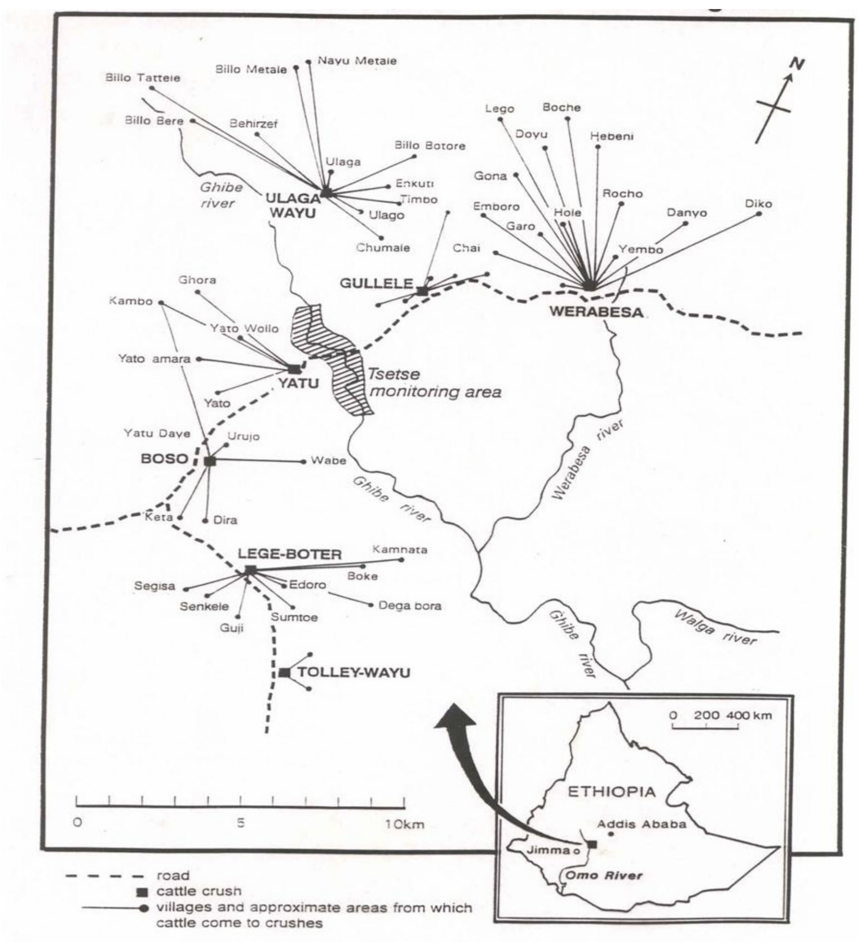


Figure 7: Location of Ghibe Valley and crushes where cattle are treated with pour-on as a control intervention
Source: ILRI

1.6 Definition of Terms

Breeding program: A breeding program is an organized breeding of a group of animals in which information on performance of potential breeding animals is used to estimate breeding values, and superior animals are selected to breed the next generation.

Traits/attributes: Traits or attributes refer to the characteristics of an alternative.

Breeding objective: A breeding objective is a list of traits that are to be improved by selection, and ordered according to their relative economic values.

Heterogeneity: Heterogeneity refers to variation in behavior that can be attributed to differences in the tastes and decision making processes of individuals in the population.

Crop-livestock system: This refers to farming systems conducted by sedentary households where crop cultivation and livestock rearing are

	managed by the same economic entity, such as a household, and the crop and livestock enterprises together form integrated components of a single farming system. That is, animal inputs are used in crop production and crop inputs are used in livestock production.
Pastoral system:	Refers to a system mainly characterized by livestock rearing and movement of livestock herds in search of pasture and water as the seasons and circumstances require.
Agro-pastoral system:	The agro-pastoral system is characterized by the integration of livestock and agricultural activities as an essential strategy for survival since cropping is a high-risk enterprise due to scarce and unpredictable rainfall. There is a higher reliance on livestock compared to the crop-livestock system.
Phenotype:	The phenotype of an organism represents its actual physical properties, such as height, weight, hair color, etc. Many phenotypes are determined by multiple genes and are influenced by environmental factors.
Genotype:	The genotype of an organism represents its exact genetic make-up and refers to the full hereditary information of an organism.
Quantitative trait locus:	A quantitative trait locus is a region of DNA that is associated with a particular phenotypic trait. The QTLs are often found on different chromosomes.
Bio-technology:	Biotechnology refers to any technological application that uses biological systems, living organisms or their derivatives to make or modify products or processes for specific use. It includes marker – assisted breeding, tissue culture, cloning and genetic engineering.

1.7 Outline of the Dissertation

The dissertation is organized as follows: Chapter two presents a review of extant literature on cattle breeding objectives and trait preferences in sub-Saharan Africa. The chapter presents a critique of the approaches used to calculate economic values of traits from an animal breeding perspective. The approaches used in socio-economic literature to assess trait preferences and calculate economic values of traits are also discussed and a critique of the econometric models employed is presented. Chapter three presents the theoretical underpinnings of choice experiments, the economic model of choice decisions as well as the econometric models that have been used in the study to model choice experiment data. The focus is on econometric models that allow for preference heterogeneity and endogenous preference segmentation in choice data. Chapter four provides a description of the methods that have been employed in the choice experiment study, including the survey instruments used. Chapter five presents some descriptive analyses as well as results of the econometric modeling estimations of choice behavior from the choice experiments. Chapter six discusses the alternative dissemination pathways by which cattle keepers can access genetically improved livestock. In the final chapter, a summary of the results is presented along with the implications of the results on policy. Directions for future research are also highlighted.

Chapter 2

Cattle Breeding Objectives and Trait Preferences in sub-Saharan Africa: A Literature Review

2.1 Introduction

This chapter presents a review of literature on cattle breeding objectives that have been used in breed improvement programs in sub-Saharan Africa by animal breeders. It reviews the methods used in calculation of the economic values of traits that are included in the breeding objective. It then discusses the alternative valuation methods that have been applied in social science studies, capable of estimating economic values of traits without market values. A review of literature that have applied such methods to estimate economic values of traits of animal genetic resources is then presented as well as the econometric models that have been used to model choice behavior.

2.2 Breeding Objectives and Economic Value Calculations of Traits from Animal Breeding Perspective

Definition of breeding objectives[10] for cattle by animal breeders is largely driven by market forces with an assumption of a profit maximizing objective. This is reflected in their definition of an economic value of a trait given as the amount by which net profit may be expected to increase for each unit of improvement in that trait (van Arendonk, 1991). It is therefore noteworthy that valuation of traits for genetic improvement by animal breeders in developing countries has often focused on traits associated with meat and milk production and utilized profit function approaches to estimate economic values. The initial step in estimation of economic values of traits using profit function approaches is to estimate net profits, by assessing the traits that influence revenues and costs, both variable and fixed, in a production system. This can be done over a fixed time period or the total herd life of the animal (Rewe et al., 2006). The profit function can be presented thus;

$$\pi_j(p, w) = py - wx \qquad (1)$$

Where, π_j is the profit associated with the j^{th} animal, *y* is a vector of output quantities, *p* is a vector of output prices, *x* is a vector of inputs used in the production of *y* and *w* is a vector of

[10] The breeding objective is a list of traits that are to be improved by selection, and ordered according to their relative economic values.

input prices. The economic value of a trait is then estimated by partially differentiating the profit function with respect to the trait of interest, for example for trait z, $EV_z = \partial\pi_j / \partial z$ or by partial budgeting, $\Delta \mathrm{Re}venue - \Delta Cost / \Delta trait, z$. The focus of the profit function approach tends to be on improvement of those traits that have a high positive impact on net profit.

Several animal breeding studies in developing countries have utilized the profit function approaches. For instance, Kahi et al. (2004), evaluate alternative breeding goals and schemes for pasture-based dairy production systems in Kenya using a two-tier open nucleus system that utilizes a young bull system by drawing upon the work of Kahi and Nitter (2004). The traits considered in the breeding objective are biological and those that influence revenue and costs which include milk yield, calving interval, daily weight gain, mature live weight, survival rate and productive lifetime. The economic values of the traits are then calculated using a partial budgeting approach, a purely accounting approach which uses field data to compare marginal returns and marginal costs arising from the improvement of a trait. Rewe et al. (2006) also use a partial budgeting approach to estimate economic values of production traits (meat and milk yield) and functional traits (feed intake and survival rate) to assess their influence on genetic improvement of Boran cattle in Kenya. The partial budgeting approach assumes a linear relationship between inputs, output and traits, and models the farm as artificially inflexible, not taking into consideration input and output substitution across farm activities. This approach is rather unrealistic in smallholder crop-livestock systems in Africa where there are strong interactions between crop and livestock enterprises. McIntire et al. (1992), provide a thorough description of the principal linkages between crops and livestock in mixed crop-livestock farming systems, common in sub-Saharan Africa; livestock provide manure to sustain crop-yields, while crop residues and forage on fallow lands provide feed for livestock, an important source of milk and other dairy products. As demographic pressure increases or new market opportunities arise, more intensive modes of agricultural production that involve increased use of labor per unit of land are sometimes adopted. The use of livestock draft power in these instances can alleviate labor shortages, improve the quality and timeliness of farming operations, and increase farm productivity.

To overcome the linearity assumption between inputs, outputs and traits in the partial budgeting approach, some studies such as Ladd and Gibson (1978) have used non-linear forms of the production function, whereby the cattle traits are considered as inputs in a production process. Marginal physical products and ultimately marginal value products of traits of interest are then derived. The limitation of this approach arises due to the fact that cattle traits have a probabilistic nature[11], implying that the underlying objective function is not deterministic and may include a risk preference which is difficult to specify in the production function (Sy et al., 1997). In addition, the complex interactions of factors in a livestock production system are difficult to capture empirically in a production relationship. Bio-economic simulation models have also been widely used in animal breeding studies to overcome the inflexibility of the partial budgeting approach. These models are used to derive economic values of traits through data simulation, though they are still based on a profit maximizing decision criteria. A large number of factors such as genetic, nutritional, management and economic as well as their complex interactions in a production system can be considered simultaneously. The economic values are then derived by examining the effects of genetic change for a specific trait on profit or production efficiency (Vargas et al, 2002). Several animal breeding studies have used these models to derive economic values of livestock traits. Kosgey et al (2003) use a bio-economic simulation model to derive economic values for traits in breeding objectives for meat sheep in medium to high potential areas of Kenya. Similarly, Dempfle and Jaitner (2000) also use a bio-economic simulation model to estimate economic values of traits to be included in the breeding objective for an open nucleus breeding scheme for N'dama cattle which was initiated in 1994 at the International Trypanotolerance Centre (ITC) for a low-input production system. The bio-economic simulation models have potentials to overcome the inflexibility of the partial budgeting approach by taking into consideration the substitution effects in inputs and outputs across farm activities. However, as Kahi and Nitter (2004) point out, it requires detailed data on technical coefficients as well as prices and knowledge to relate production functions to traits.

Reliance on profit functions to calculate economic values of cattle traits in developing countries is not pragmatic since cattle perform multiple functions, most of which are not profit oriented (Ouma et al., 2007). These functions are often embedded in traits without market values or prices such as *p* in equation (1). This makes it difficult for such traits to be captured through profit function approaches, yet they may be highly valued by cattle keepers. For instance, Romney et al. (1994), describe a study in Zimbabwe which recorded that farmers reduced grazing time by keeping cattle penned longer in order to collect more manure even though this meant a reduced feed intake thereby adversely affecting milk and meat production. Similarly, in Kenya as in other developing countries, the use of organic fertilizers particularly livestock manure has increased especially among the smallholder farmers due to its substitutability for inorganic fertilizer which is usually costly and unaffordable (Lekasi,

[11] Selecting an animal with a particular trait does not guarantee that the trait will be passed on to each offspring.

2000). Additionally, cattle are also an important source of draft power for ploughing agricultural fields in mixed crop-livestock systems. The importance of cattle traction in Africa has been shown to be significant in a number of studies (e.g. Savadogo, et al, 1994). Besides, cattle also assume financing and insurance roles, especially in the rural areas in Africa due to poorly functioning financial and insurance markets (Moll, 2005). They are also used for social and cultural functions through which ownership provides status and identity in some societies. This implies that focusing on single traits such as trypanotolerance or meat and milk production alone in isolation of other important traits and use of profit function approaches to estimate economic values in Africa may be inappropriate if traits of significant importance to cattle keepers are to be included in a breeding objective. An article by Dempfle and Jaitner (2000) reveal marked differences in preferences for cattle traits between policy makers and cattle keepers. Whereas policy makers indicate that trypanotolerance, milk and meat production are the most important traits to be included in the breeding objective, the cattle keepers identify priority traits to be milk and meat production, traction potential and traits associated with manure production. A bio-economic simulation model is then employed to calculate economic values for meat and milk production traits for improvement in that study. Traction potential and manure production traits are not included in the breeding objective and the authors do not provide a justification for the exclusion.

A holistic procedure for formulating breeding objectives that incorporates livestock sector objectives, cattle keepers' preferred traits and needs, environmental constraints and social concerns may encourage the adoption and use of improved breed technology such as disease-resistant genotypes. This necessitates a participatory process which largely lies in the social science domain, in identification of traits to be improved and application of methods that enable calculation of economic values of traits without market values or prices. Lack of involvement of cattle keepers in breed improvement efforts may partly explain the low adoption rates of improved cattle breeds in sub-Saharan Africa. De Haan (1995) notes that livestock technologies have been the source of puzzling outcomes more frequently than crop technologies, partly because new technologies that would improve productivity are simply not adopted. Abdulai and Huffman (2005) provide some insightful comments to this in the context of grade cattle technology and point out that the low adoption of high milk-yielding cattle breeds especially in sub-Saharan Africa may be the result of differing priorities for cattle attributes[12] between animal breeders and farmers. This is because animal breeding

[12] The terms attributes and traits are used synonymously in this dissertation.

programs place priorities on traits that improve milk and meat productivity while farmers interests may stretch beyond traits aimed at maximizing profits such as disease resistance, high fertility and adaptation to harsh environments. These traits might be more important to the farmers and may be present in indigenous and not high yielding crossbred cow technology.

2.3 Economic Valuation from a Social Science Perspective and Overview of Methods

Economic value is commonly expressed in monetary terms, but it is interpreted by economists as difference in preference or utility levels (Freeman, 2003). Measures of economic value are based on what people want, that is, their preferences. Economists generally assume that individuals are the best judges of what they want. Thus, economic valuation is based on individual preferences and choices. People express their preferences through the choices and tradeoffs that they make, given the constraints faced, such as personal income or available time. Hence, for economists, the economic value of a trait is measured by the maximum that someone is willing to give up in other traits in order to obtain a particular trait. In a market economy, dollars (or any other currency) are a universally accepted measure of economic value, because the number of dollars that a person is willing to pay for a good or service tells how much of all other goods or services they are willing to give up to get that good. This is often referred to as "willingness to pay" for a good. Preference theory provides a useful framework for valuing traits without market value or price since preferences are measured directly, and trade-offs between traits can be evaluated. Revealed and stated preference approaches, which are grounded in preference or utility theory, have been widely applied in economics literature in valuation of attributes of goods.

One limitation of utility theory is the fact that individual utilities are not observable. Revealed and stated preference approaches overcome this limitation by linking utilities to observed (revealed) or stated choices. The distinguishing feature between revealed and stated preference approaches lies in the types of data used. Revealed preference approaches draw statistical inferences on values from actual choices people make within markets (Boyle, 2003). As such, it represents events that have been observed to have actually occurred. Data is collected on real trait levels and alternatives chosen and not chosen. Examples of methods that use this approach include travel cost, hedonic pricing and defensive behavior[13]. Hedonic price models assume that a good is heterogeneous and its component traits yield utility

[13] Travel cost models are based on decisions to visit recreation sites that differ in travel cost and quality. Defensive behaviour models are based on expenditures that households make to avoid exposure to an environmental disamenity (Boyle, 2003).

(Rosen, 1974). These models assume a competitive market where the price of a good is a function of the traits of the goods. The marginal values of the traits then give the implicit prices of the traits.

For stated preference approaches, choices are made based on hypothetical scenarios using carefully worded survey questions. The answers are often in the form of monetary amounts, choices, ratings or other indications of preference which are scaled following an appropriate model of preference to yield a measure of value (Brown, 2003). This approach is useful especially when revealed preference data are absent, typical of non-market goods or when a good is not traded in the real market. In addition, it provides a useful framework for modeling the value of new innovations or estimating potential demand for new products with new attributes before their introduction into the market. With stated preference approach, the attributes and their levels are pre-specified by the analyst and given to the decision maker as determined by some statistical design in the form of hypothetical scenarios (Hensher et al., 2005). The onus is therefore on the analyst to identify the salient attributes and attribute levels which determine choice behavior within the population of interest. The attributes and levels to be considered can be identified through literature reviews or focus group discussions within the population of interest. Stated preference methods use a variety of approaches for asking valuation questions; from the straight forward request for maximum willingness to pay amounts of open-ended contingent valuation method, to indirect methods using choice in choice experiments or rankings and ratings in conjoint analysis (Louviere et al., 2000)[14]. Choice experiments apply the probabilistic theory of choice, where the choices made by decision makers from a discrete set of alternatives are modeled in order to reveal a measure of utility for the traits of the choices (Ben-Akiva and Lerman, 1985).

Both revealed and stated preference approaches have advantages and disadvantages. The main advantage of revealed preference approaches is that it represents real life choices, which takes into consideration personal constraints. However, there is limitation to collecting data only on the current existing alternatives within those markets. It neither takes into consideration new entrants in the form of new products/brands nor innovations which may suggest new attributes, which equate to new alternatives within a market which can have significant impact on choice behavior. Stated preference approaches, being hypothetical in nature, need to be properly designed to make the hypothetical scenarios as realistic as

[14] Choice experiment has an advantage over contingent valuation method in valuing separate attributes of goods since it allows systematic investigation of the single traits of a multi-attribute good (Scarpa et al., 2003b).

possible, taking into consideration personal constraints. It is also possible to collect data on alternatives and traits not yet existing in the markets which may be used with conventional modeling techniques for predictive purposes.

Debates have been on-going regarding the appropriateness of stated preference methodologies to yield data consistent with economic theory. The fundamental question has been whether the hypothetical nature of the survey instruments renders them relevant to yield valid and reliable inferences and predictions of real market behavior. Critics of stated preference methods point to numerous potential sources of bias. For instance it has been argued that survey respondents may ignore or down play their budget constraints in answering hypothetical questions. Additional criticisms include concerns that stated preference estimates fail to vary sufficiently with the scope of the resource being valued and that they are inordinately sensitive to the elicitation format used (Azevedo et al., 2003). Yet, there is also substantial evidence that answers to carefully designed surveys contain valuable information. Mitchell and Carson (1989) note that valuation estimates based upon stated preference methods are typically correlated in the expected direction with those independent variables that theory predicts should influence consumer preferences. This implies that useful information can be gleaned from properly designed stated preference surveys.

To further investigate the stated preference estimates validity, researchers have turned to comparisons of stated preference estimates based upon revealed preference data using convergent validity tests (e.g. Scarpa et al, 2003b and Adamowicz et al., 1994). Their results show preference consistency for both stated preference and revealed preference estimates. Further, other results also indicate that the results of both revealed preference as well as stated preference are highly correlated, with a rank correlation coefficient of between 0.78 and 0.92 (Carson et al, 1996a). Another view has also emerged arguing for a reliance on both revealed and stated preferences (Cameron, 1992; Adamowicz et al., 1994). This suggests a shift in focus away from viewing revealed preference and stated preference as competing sources of value and toward seeing them as complementary sources of information. In this view, both data sources illuminate consumer preferences for goods of interest. Discrepancies between individual parameter estimates obtained using revealed and stated preference estimates are not necessarily indicative of a failure of either method. Allowing for differences in the distribution of preferences in the revealed preference and stated preference models has been suggested by a number of authors, including Haab et al. (1999). This would be consistent with viewing stated preference and revealed preference data and models as providing unbiased parameter estimates but subject to different degrees of noise, due possibly to recall error.

Stated preference methods have received significant attention in economic literature and in the policy arena. For instance, in 1993 the methodology received endorsement by the National Oceanic and Atmospheric Administration (NOAA) expert panel in the US for use in litigation for environmental liability (Carson et al., 1996b). The expert panel developed a set of guidelines for stated preference surveys in order to ensure reliability and validity of the estimates. For instance, their report emphasizes the importance of the scenario surrounding the valuation questions and recommends the use of debriefing questions (Arrow et al., 1993). Respondents need to understand and believe the context in which the valuation question is given. The panel also recommends that the payment vehicle must be meaningful to respondents and that respondents be reminded of budget constraints and of available substitute resources. The panel also noted among other things the importance of pre-testing, and a preference for conservative design[15] as well as the use of follow-up questions and checks on respondents' understanding and acceptance of the scenario. Many stated preference surveys are still reviewed upon the basis of these recommendations.

2.4 Trait Preference Studies on Animal Genetic Resources

Few economic studies have attempted to investigate phenotypic trait preferences for animal genetic resources. Most of these studies have utilized stated preference approaches. Revealed preference approaches such as hedonic pricing have been largely used to investigate consumer preferences for crop traits (e.g. Dalton, 2004; Langyintuo, et al. 2004). Jabbar and Diedhiou (2003) and Barett et al. (2003) are among the few studies that have used hedonic pricing to estimate the economic value of cattle traits in Africa. Hedonic pricing is based on the assumption that the value of an animal is a function of its phenotypic and genetic traits. The approach is based on the Lancasterian consumer framework which is discussed in detail in chapter 3. Each of these traits contributes to the total economic value of the animal which under competitive market conditions is the market value of the animal. The market value of the animal can therefore be decomposed as a function of the individual traits, thus;

$$P_j = f(z_{1j}, z_{2j}, \ldots\ldots z_{nj}) \qquad (2)$$

Where P_j is the market price of the j^{th} animal, and $z_{1j}, z_{2j}, \cdots, z_{nj}$ are the traits $1, \ldots\ldots, n$ for the j^{th} animal. This presentation allows calculation of the marginal value or market price of each trait, $(\partial(P_j)/\partial z_{nj})$. The marginal values of the traits describe how price varies when a given

[15] When there are ambiguities in estimates one should opt for the one that underestimates willingness to pay (WTP). This enhances reliability by getting rid of extreme responses.

animal trait varies, ceteris paribus (Scarpa et al., 2003a). The use of hedonics is nevertheless limited to valuation of existing traits and not prospective traits that may be of interest to breeders. Besides, hedonic pricing is inadequate when market transactions data is poor as is the case in rural Africa where most cattle transactions do not take place in formal markets where transactions are transparent and easily recorded (ILCA, 1990). Rather, transactions usually take the form of private agreements between buyers and sellers using cash or barter. In addition, many cattle are never traded or sold, but stay within the farm household or are passed on to other households through traditional practices such as dowry payments. Market prices are also likely to be highly distorted due to the presence of intermediaries, implying that price data is likely to be incomplete and can suffer from substantial measurement errors.

A number of studies have employed stated preference approaches in valuation of traits of animal genetic resources. Sy et al. (1997) estimate cattle trait preferences of cattle producers in Manitoba, Canada using conjoint analysis and further employ an ordered probit model to empirically estimate trait preferences. Tano et al. (2003), use a similar framework to estimate preferences for cattle traits in southern Burkina Faso, a West African country where cattle perform multiple functions, where low-input management is the norm and where cattle are exposed to environmental stresses and a number of tropical diseases, mainly tick-borne as well as trypanosomosis. This is a pioneering work being the first to estimate the value of cattle traits in Africa using conjoint analysis, a survey-based stated preference method for measuring preferences for multiple-trait goods initially used in the field of market research. Their results indicate that fecundity, disease resistance and feeding ease are the highly preferred traits for cows while fitness for traction, disease resistance and fertility are the preferred traits for bulls. Meat and milk yields, parameters often used as the basis for development of a selection index for breed improvement by animal breeders are found to be relatively unimportant in their study, despite their being the focus of traditional economic analyses. This finding adds credence to arguments by Moll (2005) that meat and milk production may not be the most important determinants of livestock keeping in Africa and indeed reinforces the argument for a closer alignment of breeding objectives to the needs and objectives of the cattle keepers in developing countries.

Other studies have employed explicit ratings and rankings in livestock trait preference studies (e.g. Dempfle and Jaitner, 2000; Mwacharo and Rege, 2002; Jabbar and Diedhiou, 2003). Though ratings and rankings can shed some light on preferences for cattle traits, it may be problematic if it allows for ties and may also cause difficulties in standardization across people ratings since there is a lot of variability in ratings or rankings perceptions across individuals. In addition, as Tano et al. (2003) note, ratings and rankings cannot provide insight into the trade-offs that respondents make in choice of a breed with multiple traits. Cattle breeds tend to differ in a number of ways, so it is unlikely that cattle keepers would face choice decisions that focus on each animal trait individually. Instead, they usually face choices involving trade-offs between desirable multiple traits. Use of multi-trait preference methods such as conjoint and choice experiments may therefore be a promising method to value cattle traits since it mimics real world choice scenarios.

Recent literature has increasingly focused on the monetary value of traits by employing choice experiments, and including a monetary cost or benefit as one of the traits. For instance, Scarpa et al. (2003a) employ choice experiments to investigate trait preferences for locally adapted "creole" pigs in Yucatan, Mexico. Their results reveal high preferences for traits associated with weight gain, low feed costs, disease resistance and low bathing frequency[16]. The studies utilizing conjoint analysis (e.g. Tano et al., 2003; Sy et al., 1997) and choice experiments (e.g. Scarpa et al., 2003a) employ ordered probit or multinomial logit models to model preference behavior. A limitation of these models is that they do not explicitly account for heterogeneity of preferences among decision makers, rendering them less useful for analysis aimed at providing policy recommendations for different environments and production systems. Preferences for traits are characterized by heterogeneity, which should be accounted for in order to estimate unbiased models. Kline and Wichelns (1998) note the significance of accounting for preference heterogeneity, since preferences often vary among individual decision makers according to their environment, socio-economic characteristics and tastes.

Preferences are influenced by the structure of incentives and constraints that characterize livestock production systems. The production systems are determined by agro-ecology and differ in exhibiting various stress factors, such as water shortages, disease and parasites as well as temperature extremes. A number of studies such as Tano et al. (2003), have used production system dummy variables as the main explanatory variables driving farmer preferences, to proxy agro-climatology and location characteristics. Such dummy variable measures have shortcomings since they not only proxy agro-climate and location but also several other factors of policy concern such as market and institutional access which individually also influence farmer production objectives and preferences. Interpretation of the

[16] Bathing frequency is used as a proxy for heat tolerance in that study. Heat tolerance is an important factor in pig rearing and heat exhaustion is often avoided by securing periodical bathing of the animals.

results become rather difficult since it is impossible to isolate the factors associated with farmer choice outcomes.

In developing countries, rural households have limited market access to veterinary services, inputs and farm products, and face high farm-to-market transaction costs largely due to inadequate road infrastructure (Obare et al., 2003). Levels of market access for inputs and outputs influence households' utility for traits associated with high milk or meat yields for cattle even in high potential agro-climates. Baidu-Forson et al. (1997) in their study on farmer preferences for socio-economic and technical interventions in groundnut production systems in Niger report farmers preference for high yielding varieties only if there are reliable markets for the produce. Distance measures are the simplest measures of market access and are mainly based on respondents approximations in survey data. Major achievements have been made in obtaining reliable market access measures using GIS derived variables as opposed to farmer judgment and recall in survey questionnaires (Staal et al., 2000).

The constraints associated with different production environments may give rise to different preference structures, with cattle keepers trading off traits associated with adaptability and productivity. These preferences are not constant and change as the stresses associated with the production environments change. Jabbar and Diedhiou (2003) find evidence of preference changes from trypanotolerant cattle breeds towards trypanosusceptible White Fulani cattle breeds in South-west Nigeria as trypanosomosis disease challenge decreases. The White Fulani cattle breeds are large in size and have high milk yield. In areas with high trypanosomosis challenge, preference for trypanotolerant Muturu and Keteku cattle breeds which are smaller in size and low-milk yielding is still high. This shows that traits that guarantee multi-functionality and resilience in order to deal with variable environmental conditions may be more important in livestock systems of developing countries. Likewise, in environments where feed resources are constrained, feed efficiency traits become important. For example, Tano et al. (2003) show that the subsistence system and milk/beef system farmers have high preference for cattle which are not selective in the type of grass they eat. This is in contrast to mixed crop-livestock farmers who do not lay emphasis on this trait since feed resources are not constraining and cattle are fed on crop-residues.

Preferences for cattle traits differ not only across production environments but also across communities. Socio-cultural factors based on an ethnic community's belief system influences choice decisions for cattle traits since breeds that possess certain traits are used for cultural functions. For instance, Mwacharo and Rege (2002) find preference for horn size and shape in cattle for socio-cultural reasons in Kitui and Kajiado districts of Kenya. Ouma et al. (2004) also report preferences for bulls of specific color for slaughtering during socio-cultural ceremonies among the Maasai community in Kenya. Household characteristics such as gender, education level, income and past cattle keeping experience have not been included in most of the preference studies for cattle traits. These factors influence a decision maker's perceptions, attitudes and preferences. Economists investigating consumer demand have accumulated considerable evidence showing that consumers have subjective preferences for traits of products and that their demand for products is significantly affected by their attitudes and perceptions of the product's traits. For instance, Adesina and Zinnah (1993) show that farmer perceptions of technology-specific attributes of rice varieties are the major factors determining adoption and use intensities in Sierra Leone.

Lately, choice experiment studies aimed at investigating trait preferences of animal genetic resources have utilized mixed logit model to empirically model preference behavior. Scarpa et al. (2003b) use choice experiments and employ mixed logit model, in their empirical estimation of choice data to value the phenotypic traits expressed in indigenous breeds of livestock in a pastoral system in Kenya. They then compare value estimates from the choice experiment data with those from hedonic analysis of actual market transactions by the same sample population. Using an external test of preference consistency, they show that choice experiments may be a promising tool for valuing traits expressed by indigenous animal genetic resources in developing countries. Zander et al. (2005) use a similar framework and employ choice experiments and mixed logit model to estimate the value of Borana cattle breed in Ethiopia. Their findings indicate that highly preferred traits in the Borana cattle include short calving interval, good quality offspring, tolerance to ticks and drought. Mixed logit model is a recent advancement in discrete choice analysis that overcomes the constraints of the conventional logit and ordered probit models by accounting for preference heterogeneity by allowing taste parameters to vary randomly over individuals. It is however, not well suited to explaining the sources of heterogeneity. This caveat can be somehow overcome by forming interactions between the socio-economic characteristics and the choice traits in the utility function. By so doing, the mixed logit model can account for two types of variation in preferences. One is the variation due to varying socio-economic characteristics while another is unobserved variation, captured through the random tastes. However, a limitation in this is the problem of multicollinearity which often arises when there are too many interactions.

Many studies on animal genetic resources trait valuations have given little attention to analyses on preference heterogeneity that may result from endogenous preference segmentation which may be captured by employing latent class models. This information may provide rich policy information making it possible to adapt breeding policy interventions to specific population segments. Latent class models have been applied in the fields of consumer food choice (e.g. Kontoleon, 2003; Fader and Hardie, 1996) and environmental valuation (e.g. Boxall and Adamowicz, 2002; Morey et al., 2006). The present study builds on several insights developed in the paper by Scarpa et al. (2003b) and uses choice experiments to assess preferences for cattle traits in selected livestock production systems of eastern Africa. Mixed logit and latent class models are then applied to assess existence of preference heterogeneity and endogenous preference segmentation. Based on available literature, no previous attempt has been made to investigate the existence of endogenous preference segmentation for cattle traits among cattle keepers in sub-Saharan Africa.

2.5 Chapter Conclusions

The literature reviewed show substantial gaps in animal breeding approaches to estimate economic values of livestock traits in production systems of sub-Saharan Africa, where livestock perform multiple functions. This is mainly due to their focus on profit function approaches which fail to capture traits without market values. In addition, apart from the animal breeding study by Dempfle and Jaitner (2000), they fail to allow cattle keeper participation in identification of preferred priority traits, yet this would impact on the sustainability of a breed improvement program. Stated and revealed preference approaches used in most economics studies on trait valuations, provide a useful framework for valuing traits without market value since they are based on the utility theory. The economic literature reviewed, especially for low-input systems reveal high preferences for traits associated with adaptability such as disease-resistance, drought tolerance, feeding ease, traction ability and fecundity than those associated with milk or meat production, the primary focus of traditional economic analyses. Limitations of some econometric models that do not account for preference heterogeneity yet widely applied in economics literature are highlighted. Several factors have been shown to influence the preference structure of traits, including stresses and needs associated with the production environments, and socio-cultural factors. Important factors such as market access and those that influence perceptions and preferences are not included in most studies, albeit their importance in influencing preferences and potentially explaining preference heterogeneity. Besides, the economic studies on valuations of livestock traits have not taken into consideration preference heterogeneity that may result from endogenous preference segmentation, yet this may provide rich policy information. Participatory methods such as ratings and rankings that have been used in some extant literature to identify preferred traits are unrealistic in valuation of bundled traits such as those associated with livestock and have weaknesses associated with variability in ratings perceptions across individuals. These are the gaps that this research study intends to fill. High prospects exist for multi-attribute stated preference methods such as choice experiments, which utilize utility functions to value bundled traits including traits without market values. In addition, recent advancements in discrete choice models that account for preference heterogeneity such as mixed logit and latent class models provide opportunities to better understand preference behavior.

Chapter 3

Theoretical Framework for Choice Experiments and the Economic Model

3.1 Theoretical Framework

Choice decisions, the underlying framework for choice experiments are common place activities in all societies either at an individual, group or organizational level. Choosing manifests itself in several ways such as supporting one outcome and rejecting others, expressed through active responses such as choosing to use certain products or services through purchases, or through passive responses such as supporting particular views over an issue of interest (Louviere et al., 2000). This chapter presents the theoretical underpinnings and conceptual framework of choice experiments. The economic model as well as the econometric models that have been used to model choice experiment data is also presented.

3.1.1 Lancasterian Consumer Theory

The theoretical framework of choice experiments derives from Lancasterian consumer theory and discrete choice random utility theory. The basis for most microeconomic models of consumer behavior is the maximization of a utility function subject to a budget constraint. The essential point of departure of Lancasterian consumer theory from classical consumer theory germane to choice experiments is the postulate that utility is derived from traits or attributes of goods rather than the good *per se* (Lancaster, 1966). This implies that goods are either used singly or in combination to produce the attributes that are the source of a decision maker's utility. This is the basic point of departure from the traditional economic theory of demand which assumes that goods are the direct objects of utility. Lancaster's model may be defined more precisely as follows: A consumer maximizes an ordinal preference function for traits, $U(z)$ where z is a vector of traits $1,........,r,$ possessed by a single good or combination of goods subject to the budget constraint $px \leq K,$ where p is a vector of prices for each of these goods and K is income. Goods, x, are transformed into traits, z, through the relation $z = Bx,$ where B is a $r \times n$ matrix which transforms the n goods, into r traits of the alternatives and is invariant for all consumers. A range of mappings can exist such that several attributes can be produced by one good or several goods can produce one attribute. The model may therefore be written succinctly as:

$$\begin{aligned} &\textit{Maximise} \quad U(z) \\ &\textit{Subject to} \quad px \le K \\ &\textit{with} \quad z = Bx \\ &\qquad z, x \ge 0 \end{aligned} \tag{3}$$

In this case, the utility function is defined on a trait or attributes space, the budget constraint is defined on a goods space while the equation system $z = Bx$ represents a transformation between the goods space and the traits space. In this model, utility can only be related to the budget constraint after both have been defined on the same space. The caveat of the Lancasterian approach is its silence regarding existence of consumer heterogeneity in terms of consumer perception of the traits of the goods. Lancaster (1966) points out that if such heterogeneity exists, then it relates to the formation of the preference function for z which is outside the domain of his theory. He argues that economists are primarily interested in how consumers will react to changes in prices or traits of the goods that produce z and not how the preference function, $U(z)$ is formed. In addition, Lancaster's formulation assumes that goods are infinitely divisible, frequently purchased and of low unit value. Yet many goods are not perfectly divisible, especially goods relevant to discrete choice applications.

Rosen (1974) develops a goods-attributes model for indivisible (or discrete) goods[17] in which he assumes that a consumer buys only one brand of the good per year. Employing this assumption and an additional simplifying assumption that brands are available for a continuous range of attributes, enables Rosen to eliminate Lancaster's transformation from goods to attributes and to state his model directly in terms of prices and quantities of attributes. If Hicks' composite good theorem holds, then the prices of all other goods except those under study can be held constant and one intrinsic group of goods assumed, yielding attributes, $z_1, z_2, \ldots\ldots, z_n$. Hicks' composite good theorem permits aggregation of sets of goods that have identical price movements into composite groups of goods, each of which can be treated like a single good in demand analysis (Lewbel, 1996). Defining y as all other composite goods consumed, Rosen's model may be stated as:

$$\begin{aligned} &\textit{Maximise } U(z_1, z_2, \ldots\ldots\ldots, z_n, y) \\ &\textit{Subject to } P(z_1, z_2, \ldots\ldots, z_n) + y = K \end{aligned} \tag{4}$$

[17] It amounts to an assumption that packages cannot be untied. Rosen (1974) gives an interesting example of an indivisible good in terms of one characteristic (car length); two 6-foot cars are not equivalent to one 12 feet in length, since they cannot be driven simultaneously. Similarly, a 12-foot car for half a year and a 6-foot car for the other half is not the same as 9 feet all year round.

Where the price of y is arbitrarily set equal to one dollar, K is consumer's income, and $P(z_1, z_2, ..., z_n)$ represents the price of the one good yielding attributes z_1, z_2, ...z_n which is actually purchased. In this case, the budget constraint in terms of attributes is not necessarily linear; if goods are not divisible then, $P(z_1, z_2, ..., z_n)$ need not be linear. Unlike the traditional model where marginal utilities of goods are proportional to prices, maximization of the above function subject to the budget constraint would show marginal utilities of attributes, $\partial U / \partial z_i$ proportional to their marginal prices, $\partial P / \partial z_i$. These marginal prices are related implicitly to the prices of the underlying goods as the additional cost of a good which will yield a small increment of a particular attribute z_i. A change in price of a good can cause a discrete switch from one bundle of goods to another that will provide the most cost-efficient combination of traits. Rosen's model provides an appropriate framework to a discrete choice problem. Though Lancaster and Rosen's models provide important frameworks for choice experiments, they have some shortcomings considering that they are extensions of the traditional economic theory of consumer behavior. For instance, these models would break down when individual choice behavior is stochastic because the models are basically static and deterministic, and do not address the question of how preferences for attributes are formed. They link utility directly to attributes of goods, yet utility may plausibly be linked to attributes via complex functions due to the complex nature of choice decision making process which is also linked to behavioral theory. Louviere et al. (2000) and Ben-Akiva et al. (2002) present a complex choice paradigm where choice behavior is not only linked to attributes of a good but also to latent concepts such as attitudes and beliefs.

3.1.2 Discrete Choice Theory

A simple and direct approach to choice decisions has been provided by discrete choice theory, particularly as earlier formulated for economic analysis by McFadden (1986). In discrete choice framework, the set of alternatives (goods), called the choice set are naturally discontinuous and must exhibit three characteristics, as described by Train (2003). First, the alternatives must be mutually exclusive from the decision maker's perspective. Secondly, the choice set must be exhaustive, in that all possible alternatives are included and thirdly, the number of alternatives must be finite. A universal set of alternatives denoted C is assumed to exist. The constraints, for example the budget constraint faced by an individual decision maker n determines his or her choice set $C_n \subseteq C$. The third characteristic is restrictive and is the defining characteristic of discrete choice models which distinguishes their realm of application from that of regression models. With regression models, the dependent variable is continuous, implying an infinite number of possible outcomes. The mutual exclusivity characteristic implies a set of discrete choices, which deems the use of maximization techniques of calculus to derive demand functions following the classic consumer theory impossible since the Kuhn-Tucker necessary conditions for an optimum for derivation of demand functions would not hold. Instead, utility functions are applied directly in discrete choice theory (Ben-Akiva and Lerman, 1985; Varian, 1992). The assumption of rational decision makers in consumer theory is maintained. Rationality implies that when decision makers are faced with a set of possible consumption bundles of goods, they assign preferences to each of the various bundles and then choose the most preferred bundle from the set of affordable alternatives. Consistency and transitivity of preferences is assumed.

Describing the underlying framework of choice experiments necessitates linking the Lancasterian-Rosen consumer theory with discrete choice theory. Using Lancaster-Rosen's framework, the utility function is defined in terms of attributes;

$$U_{in} = U(z_{in}) \tag{5}$$

Where z_{in} is a vector of attribute values for alternative i as viewed by decision maker n. Income and other constraints determines the choice set C_n. In empirical applications, a vector of socio-economic characteristics of the decision maker S_n, is included to capture observed heterogeneity across the population to which the model of choice behavior applies, thus;

$$U_{in} = U(z_{in}, S_n) \tag{6}$$

The function $U(.)$, which maps the attributes values and socioeconomic characteristics to a utility scale is an ordinal utility function. The utility function $U(.)$ can usually take several forms but is often assumed additive to simplify it.

3.1.3 Random Utility and Probabilistic Choice Theories

The concept of random utility theory originated by Thurstone (1927) and further developed by Marschak (1960) and Luce (1959) forms an important framework for discrete choice modeling. Whereas classic consumer theory assumes deterministic behavior, random utility theory introduces the concept that individual choice behavior is intrinsically probabilistic. The notion behind random utility theory is that while the decision maker may have perfect information regarding his/her utility function, the analyst lacks precise knowledge about the decision maker's decision processes and therefore uncertainty must be taken into account in equation (6). In addition, the deterministic discrete choice framework does not take into consideration existence of unobserved heterogeneity in preferences among decision makers with identical choice sets, attributes of alternatives and socioeconomic characteristics. Consequently, utility is modeled as a random variable, consisting of an observable, deterministic component and an unobservable (random) component. Manski (1977) identified some sources of uncertainty to include unobserved attributes, unobserved taste variation, measurement errors and proxy variables. As in consumer theory, the random utility theory assumes that an individual derives utility by buying or choosing an alternative from a set of alternatives. A utility maximizing behavior is assumed, that is, a decision maker is assumed to buy or choose the utility maximizing alternative. The utilities are latent to the analyst and the actual choice which is what can be observed is a manifestation of the underlying utilities. The behavioral model for the analyst is that a decision maker *n* chooses alternative *i* from a finite set of alternatives in choice set $C_{n,}$ with probability *P(i)* if the utility associated with U_i is greater than the probabilities associated with all other alternatives in the choice set. This can be written succinctly as follows:

$$P(i \mid C_n) = P(U_{ni} > U_{nj}) \;\; \forall j \in C_n = 1, \ldots, J;\; i \neq j \tag{7}$$

The utility function U, can also be decomposed into deterministic (V_n) and stochastic (ε_n) components:

$$P(i \mid C_n) = P(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}) \;\; \forall j \in C_n = 1, \ldots, J;\; i \neq j \tag{8}$$

The deterministic component consists of the attributes of the alternatives and the socioeconomic characteristics of the decision maker as presented in equation (6).

Rearranging equation 8 yields the relation:

$$P(i \mid C_n) = P(\varepsilon_{nj} - \varepsilon_{ni}) < V_{ni} - V_{nj}) \tag{9}$$

For the analyst, ε is a random variable with some joint density function, denoted $f_\varepsilon(\varepsilon_1, ...\varepsilon_m)$ which induces a density on utility function, *U*. The distributional assumptions on ε and parameterization of the utility function lead to various choice models and the model outputs represent the probabilities of individuals selecting each alternative.

Simplifying assumptions are often made in discrete choice models in order to maintain a parsimonious and tractable structure. Such assumptions include utility maximizing behavior, deterministic choice sets, easily measurable characteristics of decision makers and simple error structures (ε) such as Gumbel (or extreme value type 1) distributions leading to multinomial logit (MNL), nested logit among others. Due to the strong assumptions and simplifications in discrete choice models, there has been much debate among behavioral researchers and economists regarding the validity of such models. A major limitation often raised regarding the multinomial logit models is the property of independence of irrelevant alternatives (IIA) which results from the assumption of identically and independently distributed (IID) random terms, ε. The IIA property states that, for a given individual, the ratio of his choice probabilities of any two alternatives is independent of the presence or absence of any other alternative in a choice set. An important behavioral implication of the IIA property is that all pairs of alternatives are equally similar or dissimilar. Hensher et al. (2005) point out that for the unobserved sets of attributes, this property assumes that all the information in the random components is identical in quantity and relationship between pairs of alternatives due to the identical and independent distribution assumption. The IIA property was first stated by Luce (1959) as the foundation for his probabilistic choice model, and was a catalyst for McFadden's development of the tractable multinomial logit model. The multinomial logit model has often formed the framework for discrete choice modeling because it is fairly robust and has a tractable closed form solution, leading to its wide application in discrete choice literature (e.g. Scarpa et al., 2003a). The main disadvantage of the IIA property is that the multinomial logit model would perform poorly when there are some alternatives that are similar and highly correlated. This is especially pronounced when there are cases of repeated choices by a single decision maker, common in discrete choice studies such as choice experiments. The multinomial logit model does not account for the stability of coefficients in such cases. In addition, the model cannot represent random taste variation and exhibits restrictive substitution patterns.

There are a number of ways to relax the IIA assumption and many variations of discrete choice models have been developed to accommodate more general random utility model-consistent behavior. The nested logit model, initially derived by Ben-Akiva (1973), is an extension of the multinomial logit model and a special case of the generalized extreme value (GEV) model designed to partially accommodate violations of IIA. The nested logit model allows the possibility of different variances across the alternatives and correlations in unobserved factors across sub-sets of mutually exclusive alternatives (Train, 2003). The model also has closed forms for the choice probabilities and is relatively robust. However its limitation is mainly centered on the fact that it does not accommodate complete relaxation of the IID assumption and the fact that it does not allow for overlaps between nests or sub-sets. Other models of the GEV group include the heteroscedastic extreme value logit model, developed by Bhat (1995) which allows the variance of the error or random term to vary across alternatives and cross-nested logit model which overcomes the nested logit limitation by allowing for nest overlaps. The limitation of the GEV group of models is that it cannot represent random taste variation and it cannot be used with panel data when unobserved factors are correlated over time for each decision maker.

The other major group of discrete choice models that relax the IID assumptions is the probit family, derived under the assumption of jointly normal unobserved utility components, ε. The multinomial probit model is highly flexible, because it allows for an unrestricted covariance matrix. Any pattern of correlation and heteroscedasticity can be accommodated. However, it is less popular than the GEV group of models since it is difficult to estimate and does not easily converge as it lacks a closed form solution. In addition, the requirement of normal distributions for all unobserved components of the utility function is rather limiting. In some cases, normal distributions provide an inadequate representation of the random components and can lead to perverse forecasts. Train (2003) provides an example of cost coefficients, which cannot be plausibly represented with a normal distribution as it would imply that some people have a positive cost coefficient due to the normal density distribution on both sides of zero. The mixed logit model is a powerful and highly flexible model that relaxes the IIA property and combines the advantages of probit and the GEV models by allowing for an unrestricted substitution pattern while still maintaining global concavity. It has been recently making its way into econometric text books, for example Louviere et al. (2000), Train (2003) and Hensher et al. (2005). Early applications of mixed logit have been in the fields of transportation research (e.g. Bhat, 1998) and consumer behavior (e.g. Revelt and Train, 1998). The mixed logit model has been known for many years but has only become fully applicable since the advent of simulations. This model is discussed in depth in section 3.3.

3.1.4 Discrete Choice Theory and Heterogeneity

Preference heterogeneity has increasingly become an important topic in discrete choice modeling literature. Heterogeneity has been described by DeSarbo et al. (1997) as individual differences that decision makers manifest with respect to the judgments and choices they make and the processes involved in making those judgments and choices. The rationale for it is that decision makers have varying characteristics that determine preferences over resource allocations. Greene (2003) and Kline and Wichelns (1998) note the importance of accounting for preference heterogeneity. Failure to account for preference heterogeneity, when it is warranted, leads to biased utility parameter estimates. Such biased estimates have been shown to produce misleading predictions of attribute valuations and welfare measures. Heterogeneity can be classified into two; observed and unobserved. Observed heterogeneity is observable by the analyst and captured by introducing socio-economic and demographic characteristics of the decision maker into the deterministic portion of the utility function as in equation (8). On the other hand, unobserved heterogeneity is unobservable to the analyst and numerous techniques have been employed to capture it. The mixed logit model, also referred to as the random parameters logit model and described by McFadden and Train (2000), Train (2003) and Hensher et al. (2005), captures unobserved individual heterogeneity by allowing taste parameters to vary randomly over individual decision makers. Another modeling technique used to capture unobserved heterogeneity is through latent class models which have been used to capture unobservable segmentation regarding tastes, choice sets and choice decisions (e.g. Kamakura and Russell, 1989).

Sources of unobserved heterogeneity that have long been acknowledged by behavioral researchers (e.g. Tversky and Kahneman, 1974; Kahneman and Tversky, 1979) and lately by discrete choice modelers in the analysis of choice decision making are psychographic variables such as attitudinal and perceptual variables. McFadden (2001) describes decision makers as heterogeneous in unobserved characteristics such as their taste templates and the mechanisms they use to form perceptions. Perceptions refer to the individual decision maker's beliefs of the perceived levels of the attributes. Attitudinal variables reflect the decision maker's needs, values, tastes and capabilities. McFadden (1999) notes from a discrete choice modeler's point of view, that both theoretical and empirical study of economic behavior would benefit from closer attention to how perceptions are formed and how they influence decision-making. The use of psychographic constructs in discrete choice modeling is an area that warrants further investigation since the variables are unobservable and difficult to capture using statistical models. Few studies on discrete choice modeling have attempted to address these issues by incorporating indicators of the psychological factors in econometric choice models to assess their influence on choice decision making (e.g. Ben-Akiva et al., 2002; Walker, 2001). Since preferences, attitudes and perceptions are unobservable to the analyst, they are represented as latent constructs as shown in figure 8, where the latent variables are indicated in ovals in the dashed box. These latent attitudinal and perceptual variables as well as the observable explanatory variables, affect individuals' preferences toward different choice alternatives.

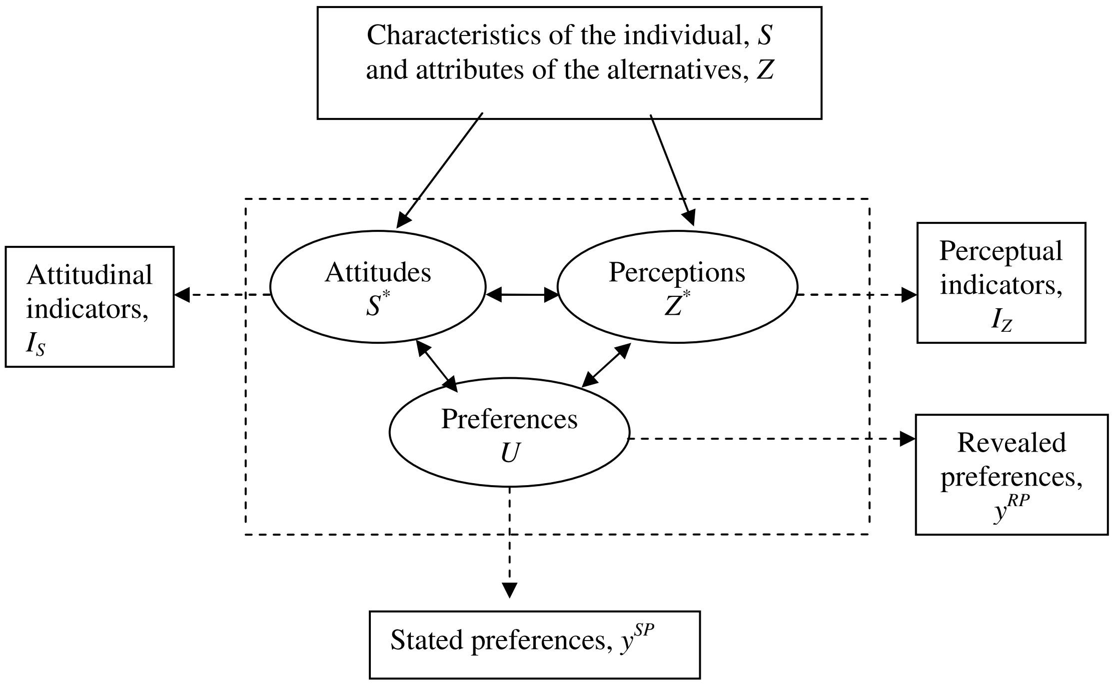


Figure 8: Behavioral framework for choice models
Adapted from Ben-Akiva et al. (2002)

Preferences are translated into decisions via a choice decision making process. In discrete choice models a utility maximization decision process is assumed. The revealed preferences and stated preferences are manifestations of the underlying preferences.

3.2 Conceptual Framework of a Choice Model for Cattle Traits

The conceptual framework derives from discrete choice models following Lancaster-Rosen approaches and the random utility framework. The framework aims at identifying the underlying influences on an individual or group choice behavior for cattle traits. A choice decision can be viewed as a decision-making process linked to an intricate web of factors both external and internal to the decision maker, as presented in figure 9. Terms in ovals represent latent variables while those in boxes are observable by the analyst. Cattle can be viewed as discrete-choice goods with multiple varying phenotypic traits with potentials to meet several objectives. The decision maker's problem is choice of a cattle profile that maximizes his utility from preferred traits and trait levels from a choice set of alternative profiles with different levels of traits. These profiles can be perceived to represent different cattle breeds with varying trait levels. The universal set of alternative cattle breeds is determined by the decision maker's environment as it influences the options available to him/her. This may include factors such as properly functioning markets and level of development of national breeding services. The personal constraints faced by the decision maker *n*, such as household income and information access then determine the feasible choice set, which is a sub-set of the universal set of alternatives, represented as $C_n \in C$.

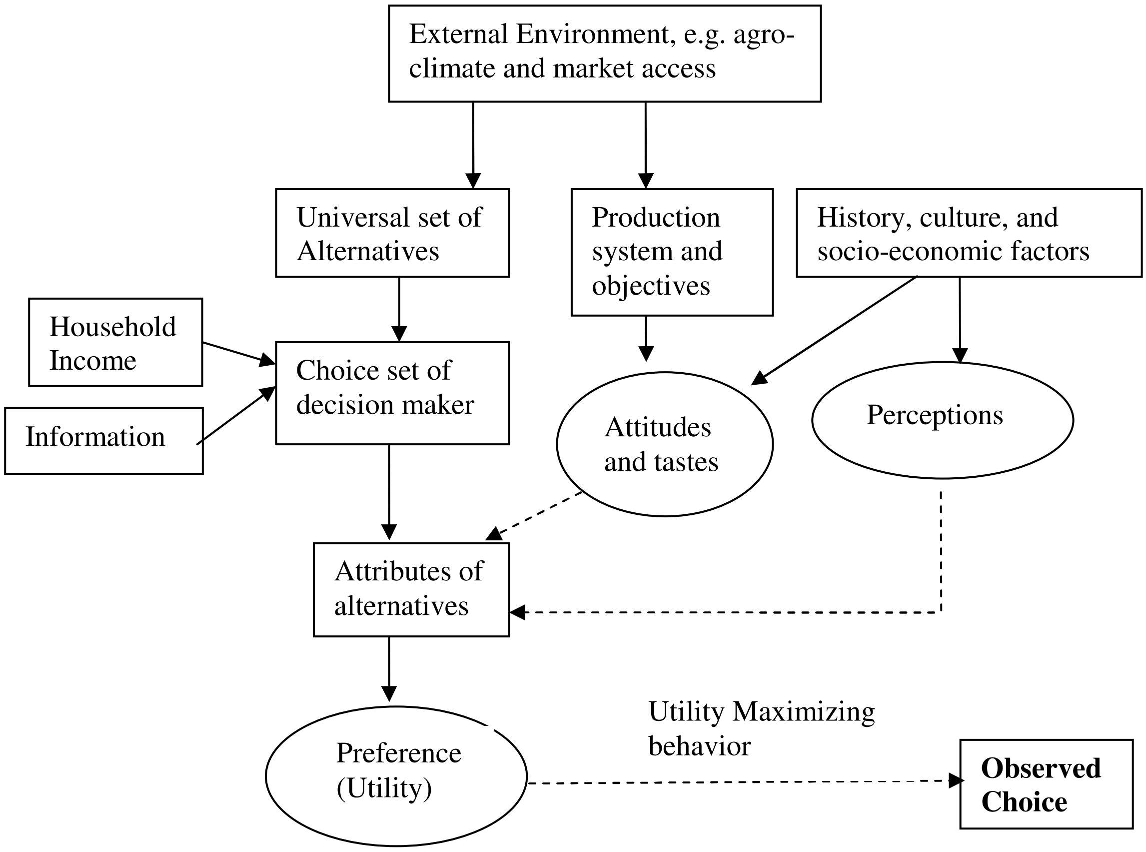


Figure 9: Choice model framework for cattle traits

Following Lancaster-Rosen theories, the utility derived from alternative cattle profiles within the choice set of the decision maker is perceived to be determined by the attributes of the alternatives. These are the sources of utility based on the neo-classical consumer theory. The decision maker is assumed to form a utility function for the alternatives and assign a utility value for each alternative by valuing and trading off the attributes that are important in his/her choice decision. A utility maximizing behavior is assumed to be exhibited, resulting in preference and choice of an alternative with the highest positive utility value.

Though the sources of utility are strictly linked to the attributes of the alternatives, the contextual characteristics and socio-economic characteristics of the decision-maker are included since they influence preference and choice behavior. These descriptors are not sources of utility of an alternative *per se*, but can condition the role of unobserved attributes and can be considered as influences on the parameter estimates of observed attributes. The inclusion of socio-economic characteristics of decision makers is one way of explicitly accounting for observed preference heterogeneity as explained by specific observable characteristics. For instance, preference for a cattle profile alternative can be influenced by environmental factors. Agro-climatic[18] conditions of an environment partly determine the type of production system, the production objectives and priorities of the livestock enterprise since they differ in exhibiting various stress factors and condition the household resources. Common livestock production systems in the study areas include crop-livestock systems, pastoral and agro-pastoral systems (Peeler and Omore, 1997). Crop-livestock systems vary in terms of amounts and types of productive factors applied as well as levels of crop-livestock interactions and are found in diverse production environments ranging from medium to high agricultural potential areas. Human population is high in areas with high agricultural potential, resulting in pressure on land, diminishing land holdings and cattle herd size. This is particularly true where population densities are high, such as the highland areas of East Africa (Staal et al., 2002). In such environments, cattle traits that guarantee crop-livestock interactions and higher returns per livestock unit may be preferred. In pastoral and agro-pastoral production systems, livestock keeping is the mainstay of the populations. These systems are mainly found in low agricultural potential areas, particularly in arid and semi-arid areas (Peeler and Omore, 1997). Minimal agricultural production is practiced in these systems due to harsh agro-climatic conditions; drought and vector-borne livestock diseases are common constraints to production. In this kind of environment, traits that guarantee adaptability to the environmental stresses may be preferred. External environment factors such as market access influence the incentives presented by the external environment, through access to inputs, outputs, veterinary services and other services. Market access factors also influence the objective of production; whether market or subsistence oriented and may result in interesting trade-offs by the decision maker between production traits such as milk or meat production and adaptability traits such as disease resistance in the context of availability of treatment drugs due to access to veterinary services.

A decision maker's attitudes and perception of the attributes and attribute levels are unobservable to the analyst and influences choice behavior. Attitudes reflect the decision maker's needs, values, and tastes and are influenced by external factors as well as socio-economic characteristics. Perception of the attribute levels is influenced by the decision maker's past experience, culture and other socio-economic factors such as age, level of

[18] Agro-climate refers to the complex of factors such as rainfall, temperature, rainfall distribution and soils that constitute the agricultural resource base and determines the potential productivity of farming and livestock keeping.

education, income and gender. High levels of education enhance a decision maker's capacity and influence his/her ability to conceptualize and comprehend the effects of different trait levels. Similarly, socio-economic factors such as household off-farm income and asset ownership proxy wealth and influence the decision maker's perception of traits that condition the household's financial resources. An example of perception of attributes in a cattle trait preference choice context is environmental adaptability while an example of attitude may be the importance of environmental adaptability. Perceptions and attitudes tend to vary overtime and across individuals and explain part of the random component of the utility function through individual-specific unobserved attributes and are therefore sources of unobservable preference heterogeneity.

The economic model for the discrete choice framework for cattle traits in figure 9 that considers unobserved heterogeneity is presented in this section. Each individual's choice set C_n, is assumed to have a finite set of J mutually exclusive and exhaustive alternative cattle profiles to choose from in each choice situation. The profiles are characterized by their observed attributes and attribute levels, where one of the attributes is the price of the cattle profile. For instance, one such profile could have traits such as a trypanotolerant bull whose market price is KSh 20,000 but has poor traction ability and has a live-weight of 250Kg. The J alternatives are determined depending on the type of design used to construct the choice profiles and the number of attributes and attribute levels in the choice experiment. For each choice situation, a sampled decision maker is assumed to have full knowledge of the factors that influence his/her choice decision when asked to choose the most preferred cattle profile from the competing J alternatives subject to the budget constraint. Following discrete choice and random utility theories, the decision maker's resource allocation, q describing the quantities and attributes of the goods consumed can be presented as;

$$q = (y_j(z_j), x, \varepsilon) \tag{10}$$

Where y_j denotes the alternative cattle profiles (discrete alternatives), z_j is a vector of observed attributes for the cattle profile alternatives that are experienced only if the cattle profile is chosen, x is a vector of quantities of other goods with its price normalized to 1 and ε is a vector of unobserved attributes of the discrete choice. The decision maker also has socio-economic characteristics, S which determines preferences over resource allocations. This can be presented as;

$$S = (s, \zeta) \tag{11}$$

Where s and ζ represent a vector of observed and unobserved characteristics, respectively. Following McFadden (2001) and McFadden and Train (2000), an assumption is made that the unobserved characteristics, ζ vary continuously with the observed characteristics of the decision maker and has a regular canonical representation[19]. Technically, this is an assumption that the unobserved characteristics of a decision maker are a continuous random field indexed by the observed characteristics $(\zeta = \zeta(s))$. An implication of this assumption is that the conditional distribution of the unobserved characteristics will depend continuously on the observed characteristics. An important postulate in consumer theory is that tastes are established prior to assignment of resource allocations. Therefore, $S = (s, \zeta)$ determines the preferences of individuals over possible resource allocation. This implies that the conditional distribution of unobserved decision makers' characteristics ζ, cannot depend on q. The unobserved characteristics of the decision maker can be written as;

$$\zeta(s) = h_1(v(s), s) \tag{12}$$

Where $v(s)$ is a uniformly distributed continuous random field[20]. Then, decision makers with similar observed characteristics will have similar distributions of unobserved characteristics.

Another postulate of the consumer theory is that the description of the resource allocation, q does not depend on the characteristics of the consumer. Although the measurement of the quantities defining q does not depend on S, S influences the decision maker's evaluation of the resource allocation q. Therefore, the distribution of ε cannot depend on S, though it may depend on z_j. In this framework, ε is also specified as a continuous random field with regular canonical representation. It can be presented as;

$$\varepsilon(z) = h_2(\varepsilon(z_j), z_j) \tag{13}$$

Where $\varepsilon(z_j)$ is a uniformly distributed continuous random field. Then, discrete alternatives that are similar in their observed attributes will have similar distributions of unobserved attributes. Substituting the transformations for h_1 and h_2 into the definition of utility for discrete cattle profile choice alternatives, a random utility function that is continuous in its arguments can be presented thus;

$$U = U(y_j(z_j), x, s, \varepsilon(z_j), v(s)) \tag{14}$$

[19] The cumulative density functions admit an inverse representation, such that realizations of the distributions can be generated using standardized uniform continuous distributions.

[20] A random field ζ is uniformly distributed if $\zeta(s)$ has a uniform distribution (0,1) for each $s \subseteq S$.

Where $\varepsilon(z_j)$ and $v(s)$ are independently uniformly distributed continuous random fields. The decision maker's utility maximization problem then takes the form;

$$\underset{y,z,x,s}{Max}\, U(y_1(z_1),\ldots,y_J(z_J);x,s,\varepsilon(z_j),v(s)) \quad \textit{subject to}$$

$$\begin{aligned}&(i) \quad \sum_{j=1}^{J} p_j y_j(z_j) + x \le M \\ &(ii) \quad y_i . y_j = 0, \qquad j = 1,\ldots J; \forall i \ne j \\ &(iii) \quad x \ge 0,\; y_j(z_j) \ge 0 \textit{ for at least one } j\end{aligned} \tag{15}$$

Where U is the true but unobservable indirect utility function, assumed to be strictly increasing and strictly quasi-concave $\forall y_j(z_j)$ *and* x. The budget constraint is reflected in (i) where p_j is the price of the jth cattle profile and M is income. Constraint (ii) induces an element of discreteness in the choice process. It restricts the choice alternatives in each choice scenario to be mutually exclusive. Constraint (iii) specifies that the decision maker chooses a non-negative quantity of x and $y_j(z_j)$. The solution to this problem yields the traditional Marshallian demand function which describes the decision maker's optimal cattle profile choice decisions given the prices, income and the decision maker's socio-economic characteristics. In each choice situation, the decision maker is assumed to evaluate the attributes and attribute levels of the cattle profile alternatives in his choice set, form a utility function for the alternatives and assign a utility value for each alternative by valuing and trading off the attributes that are important in his/her choice decision. The decision maker is assumed to be rational, in the sense that he chooses the alternative with the highest utility value. Following Hanemann (1984), an additional convenient assumption of "weak complementarity" is made, implying that the attributes of a profile does not matter unless that cattle profile is actually chosen. This is presented in (16);

$$\textit{if } y_i = 0 \rightarrow \partial U / \partial z_i = 0, \quad \forall i \ne j \tag{16}$$

From (15), the conditional indirect utility function, given the discrete cattle profile alternatives can be written as;

$$U'(p,z,M,s,\varepsilon,\zeta) = \max[U(y_j(z_j), M - p_j y_j(z_j), s, \varepsilon(z_j), v(s))] \quad j = 1,\ldots,J \tag{17}$$

U' is assumed to be a well-behaved utility function and is characterized by the standard economic properties, that it is quasi-convex and decreasing in p_j and increasing in M. The demand for discrete cattle profile alternative j can be derived from Roy's identity as:

$$-\frac{\dfrac{\partial U'}{\partial p_j}}{\dfrac{\partial U'}{\partial M}} = y_j(M, p_j, s, \varepsilon, \zeta), \quad j = 1, \ldots, J \tag{18}$$

Since there is randomness in the description of the utility function, a probability distribution can be assigned over the discrete choice set resulting from trade-offs between the levels of utility each alternative option is providing. The decision rule for an individual decision maker's utility maximizing choice decision can be presented thus;

$$\begin{aligned} &P(j) = P[U_j(y_j(z_j), M - p_j y_j(z_j), s, \varepsilon_j(z_j), v_j(s)) \geq U_i(y_i(z_i), M - p_i y_i(z_i), s, \varepsilon_i(z_i), v_i(s))]; \\ &j = 1, \ldots, J \ \ \forall i \neq j \end{aligned} \tag{19}$$

That is, the probability of an individual choosing cattle profile *j* is equal to the probability that the utility of alternative *j* is greater than (or equal to) the utility associated with alternative *i*, after evaluating each and every alternative in the choice set of $j = 1, \ldots i \ldots, J$. Equation 19 forms the basis for the econometric choice model for estimating utility parameters and estimation of economic values of cattle attributes that is discussed in the next section. The exact specification of the econometric model depends on how the random elements, $v(s)$ and $\varepsilon(z)$ enter the conditional indirect utility function and the distributional assumptions.

In a well-specified random utility model, there is zero probability of ties between utility levels, so that a realization of $v(s)$ and $\varepsilon(z)$ for $j = 1, \ldots, J$ of the random elements in the model almost surely determines a unique choice. McFadden and Train (2000) indicate that a sufficient condition for this when there is a continuously differentiable utility function is that the Jacobian has rank at least $J-1$ and that the support of $(v, \varepsilon_1, \ldots \varepsilon_J)$ contains the space spanned by the Jacobian:

$$\begin{bmatrix} \partial U(y_1(z_1), x, s, \varepsilon_1, v/\partial v & \partial U(y_1(z_1), x, s, \varepsilon_1, v/\partial \varepsilon_1 & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots \\ \partial U(y_J(z_J), x, s, \varepsilon_J, v/\partial v & 0 & \ldots & \partial U(y_J(z_J), x, s, \varepsilon_J, v/\partial \varepsilon_J \end{bmatrix} \tag{20}$$

Ways to guarantee no ties include taste factors (determined by v(s)) of the required dimension that interact with a full-rank array of alternative attributes, or a full set of alternative-specific effects (determined by $\varepsilon(z)$) or some combination. McFadden and Train (2000) have recently established a mixed logit model by adding independent extreme value type 1 disturbances to the conditional indirect utility function. The disturbances are scaled such that the probability that the original and perturbed indirect utility functions order alternatives differently is very small. They further approximate the indirect utility uniformly by a Bernstein-Weierstrauss polynomial in the observed arguments of the conditional indirect utility function and the uniformly distributed vector of unobserved characteristics. This is also done so that the probability of the approximation changing the preference order is very small. The mixed logit model is then obtained by conditioning on the uniform random vector that enters the utility function and then integrating this vector out as presented;

$$P(i) = \int_0^1 \cdots \int_0^1 \frac{e^{w_i \alpha}}{\sum_{j \in C_n} e^{w_j \alpha}} . G(d\alpha; \theta) \qquad (21)$$

Where w_j are vectors of polynomial functions of observed characteristics of the decision maker and observed attributes of alternative j. α are continuous polynomial transformations of the uniformly distributed continuous random fields $v(s)$ and $\varepsilon(z)$, drawn from a cumulative distribution function, $G(d\alpha;\theta)$. The random parameters α may be interpreted as arising from taste heterogeneity in a population of multinomial logit decision makers, θ is a vector of parameters of the mixing distribution, G. The mixing distribution G may come from a continuous parametric distribution such as multivariate normal or log-normal, or it may have finite support. When G has finite support, then the model is referred to as a latent class model. Mixed logit and latent class models are flexible models that account for unobserved preference heterogeneity in discrete choice models. McFadden and Train (2000) and Train (2003) describe mixed logit as a highly flexible model that can approximate any random utility model. It relaxes the limitations of conventional logit by allowing the taste parameters to vary randomly according to a parametric distribution. In addition, it allows for unrestricted substitution patterns and correlation in unobserved factors overtime (Train, 2003; Hensher and Greene, 2002). These properties are important since choice experiments often involve repeated choice cases per individual respondent, consequently increasing the likelihood of correlations in unobserved utility.

3.3 Econometric Choice Modeling

This section presents a description of the mixed logit and latent class discrete choice models that have been applied to empirically model the choices made by the decision makers from the choice experiment study and to estimate economic values of the cattle traits. Both mixed logit and latent class model account for heterogeneity in choice experiment data through taste heterogeneity. Another way of accounting for heterogeneity is through heterogeneity in scale, also known as error variance. Addressing variance heterogeneity involves estimating and parameterizing variance as a function of the sources of heterogeneity (Haener et al., 2001). Greene et al. (2006), have shown the possibilities of accounting for heterogeneity in the variance of unobserved effects using mixed logit. In this study, the interest is in understanding the sources of heterogeneity in tastes. Consequently, latent class and mixed logit models have been applied.

3.3.1 Mixed Logit

The mixed logit model applies the usual framework of random utility models developed by Marschak (1960), which postulates that individual decision makers choose alternatives that yield the greatest utility as presented in equation (19). Therefore, the probability of selecting an alternative increases as the utility associated with it increases. A sampled individual *n* faces a choice among alternatives in choice set *j (j=1,…..J)* on each of the *t (t = 1,….T)* choice situations. The individual decision maker considers the full set of alternatives in choice situation *t*, assigns each alternative with its associated utility and chooses the alternative with the highest utility. The utilities are unknown to the analyst, what is observed are the attributes of the cattle choice profile alternatives, the socio-economic characteristics of the decision maker and the choices made. The utility associated with each set of *j* alternatives as evaluated by each individual *n* in choice situation *t* is represented in a discrete choice model by a utility expression of the general form;

$$U_{njt} = \beta_n X_{njt} + \varepsilon_{njt} \tag{22}$$

Where X_{njt} is a vector of explanatory variables that are observed by the analyst and includes the attributes and the levels of the choice alternative, such as cattle profiles in this study, as well as the socio-economic characteristics of the respondent. β_n is the taste coefficient vector for the traits for person *n*, and is assumed to be random and varies in the population with density $f(\beta_n \mid \theta)$, where θ are the true parameters of a continuous joint population distribution. ε_{njt} is an unobserved random term that is independent and identically distributed (iid) extreme value type 1, across individuals, alternatives and choice situations. The focus in mixed logit shifts from finding estimates of β_n to finding the estimates of *θ*, the population parameters (for example the mean and covariance) that describe the distribution of individual parameters. This specification is the same as for the conventional logit except that the β's vary over decision makers rather than being fixed. The vector of random coefficients β_n can be expressed as the population mean (*b*) and the individual specific parameter deviation from that mean (s_n). Therefore the utility that individual *n* obtains from each set of *j* alternatives in choice situation *t* can be re-written as;

$$U_{njt} = bX_{njt} + s_n X_{njt} + \varepsilon_{njt} \tag{23}$$

The presence of a standard deviation *s* of a taste parameter accommodates the presence of preference heterogeneity in the sampled population. This is often referred to as unobserved heterogeneity. Conditional on β_n, the probability that person *n* chooses alternative *i*, in choice situation *t* is conventional conditional logit since the remaining random term ε_{njt} is iid extreme value. The probability takes a closed form between 0 and 1:

$$L_{nit}(\beta_n) = \frac{e^{\beta_n X_{nit}}}{\sum_j e^{\beta_n X_{njt}}} \tag{24}$$

Given that β_n is unknown to the analyst, the unconditional probability is employed. The unconditional probability is the integral of the conditional probability in (24) over all possible values of β, which depends on the distribution of β, that is unknown to the analyst. This integral takes the form:

$$P_{nit}(\theta) = \int L_{nit}(\beta_n) f(\beta_n \mid \theta) d\beta_n \tag{25}$$

This integration requires assumptions about the distributional structure of the tastes, β but once determined, the probabilities can be estimated. A number of alternatives are feasible for the distribution of $\beta's$, including normal, log-normal, triangular and uniform distributions. For instance, the log-normal distribution is useful when the coefficients is known to have the same sign for every decision maker, such as price coefficient that is known to be negative for everyone for normal goods (Train, 2003).

In this study, each person makes repeated choices for different choice experiment cattle profiles for bulls or cows, yielding panel data. Following Revelt and Train (1998), it is assumed that tastes vary across decision makers in the choice experiment survey, but not across repeated choice situations by an individual. The joint probability of the set of *t* repeated choices by respondent *n* and conditional on the drawn value for β is a product of logits:

$$S_n(\beta_n) = \prod_t \frac{e^{\beta_n X_{nit}}}{\sum_j e^{\beta_n X_{njt}}} \tag{26}$$

The unconditional probability of the set of *t* repeated choices is:

$$P_n(\theta) = \int S_n(\beta_n) f(\beta_n \mid \theta) d\beta_n \tag{27}$$

Models of this form are called mixed logits because the choice probability P_n is a mixture of logits with f as the mixing distribution. The probabilities do not exhibit the independence of irrelevant alternatives (IIA) property[21] and different correlation and substitution patterns may be obtained by appropriate specifications of the mixing distribution f. This is possible through the random parameters, which are specified as having both a mean and standard deviation. Maximum likelihood estimates for the parameter vector can be obtained by maximizing the logarithm of the likelihood in equation (27). However, this cannot be calculated exactly since the integral does not have a closed form. Instead, the probability is approximated through simulation and maximization of the simulated log-likelihood function (Train 2003). Specifically, $P_n(\theta)$ is approximated by a summation over randomly drawn values of β_n. For a given value of the parameters θ, a value of β_n is drawn from its distribution, $f(\beta_n \mid \theta)$. Using the draw of β_n, equation (26), the product of standard logits is calculated. This process is repeated for many draws and the average of the resulting $S_n(\beta_n)$'s is taken as the approximate choice probability:

$$SP_n(\theta) = (1/R) \sum_{r=1,\ldots\ldots,R} S_n(\beta_n^{r|\theta}) \tag{28}$$

Where R is the number of draws of β_n, $\beta_n^{r|\theta}$ is the *r*-th draw from $f(\beta_n \mid \theta)$, and $SP_n(\theta)$ is the simulated probability of person *n*'s set of choices. Revelt and Train (1998) notes that $SP_n(\theta)$ is an unbiased estimator of $P_n(\theta)$ whose variance decreases as *R* increases, and sums to one over alternatives. It is smooth, thus helping the numerical search for the maximum of the simulated log-likelihood function (SLL) and calculation of elasticities. The simulated log-likelihood function is constructed as:

$$SLL(\theta) = \sum_n \ln(SP_n(\theta)) \tag{29}$$

[21] The ratio of mixed logit probabilities, P_{ni}/P_{nj}, depends on all the data, including attributes of alternatives other than *i* or *j*.

The estimated parameters are those that maximize *SLL*. Computation of the maximum likelihood choice probabilities by simulation can be quite time consuming, depending on the number of draws made from the distribution. In this study, Halton draws, which yield much more accurate approximations in Monte Carlo integration relative to standard pseudo-random draws, are used (Hensher et al., 2005). The Halton draws have improved equi-dispersion properties which achieve good approximations with a lower number of simulations (Train, 2003). For instance, 100 Halton draws produce the same approximation as 1000 pseudo-random draws (ibid.).

The repeated choices for each sampled decision maker imply the presence of multiple observations on choice responses for each sampled individual. This creates the potential for correlated parameters across observations which are a violation of the independence of observations assumption in classical choice-model estimation. The random parameter specification of mixed logit in equation (22) explicitly incorporates the possibility of correlations of random parameters for attributes that are common across alternatives and also permits correlations in unobserved utility over repeated choices per individual. This correlation may arise due to the common influence of the unobserved $\beta's$ overtime which creates correlations in utilities overtime, due to the commonality of socio-economic descriptors that are invariant across choice situations for each sampled individual. Assuming that the $\beta's$ for individual *n* in each choice situation *t*, is drawn from a standard normal distribution, then each simulated β can be presented as a function of the underlying population parameters, such that $\beta_n = b + s\eta_n$, where *b* is the mean of the underlying population distribution, *s* is the standard deviation and η is a random element drawn from a standard normal distribution. The utility function in equation (22) can be rewritten thus;

$$\begin{aligned} U_{njt} &= (b + s\eta_n)X_{njt} + \varepsilon_{njt} \\ &= bX_{njt} + [s\eta_n X_{njt} + \varepsilon_{njt}] \end{aligned} \quad (30)$$

The elements of the square bracketed terms, η and ε represent unobserved variation, which is correlated overtime. Substituting these unobserved variation terms with *e*, such that $e_{njt} = s\eta_n X_{njt} + \varepsilon_{njt}$, its covariance yields;

$$Cov(e_{njt}, e_{njt-1}) = s^2 X_{njt} X_{njt-1} \quad (31)$$

Where s^2 is the variance of β_n and X_{njt-1} is a vector of observed explanatory variables in choice situation $t-1$. The mixed logit model allows for correlations across random parameters of attributes and generates a covariance matrix with diagonal and off-diagonal estimates that identifies the dependency of one attribute on another within and between alternatives.

The mixed logit model has commonly been applied within the discrete choice literature. For instance, Rigby and Burton (2005) and Tonsor et al. (2005) use it to assess consumer preferences for GM foods in Europe, Revelt and Train (1998) use it to assess households' choices of appliance efficiency levels in Southern California while Garrod et al. (2002) utilize it to estimate the benefits of traffic calming measures on British roads. Few studies, such as Scarpa et al. (2003b) have employed mixed logit to examine preferences for cattle traits. Although mixed logit accounts for unobserved preference heterogeneity by allowing taste parameters to vary randomly over individuals, it is not well suited to explaining the sources of heterogeneity (Boxall and Adamowicz, 2002). These sources often relate to the socio-economic characteristics and perception and attitude of the decision makers. Though it is possible to account for the socio-economic characteristics of the decision maker by interacting key individual characteristics with the traits, this is limiting since it requires *a priori* selection of key limited individual-specific variables. Moreover, multicollinearity is often a problem with too many interactions. A promising option for overcoming this constraint is the use of latent class models. In latent class modeling, unobserved heterogeneity is captured through latent class segmentation, that is, individuals are intrinsically sorted into a number of latent classes, each characterized by homogenous preferences though heterogeneous across classes (Bhat 1997). Assignment of individuals into classes is probabilistic based on their tastes.

3.3.2 Latent Class Model

The latent class model is similar to the mixed logit, however the main difference is that taste heterogeneity across individuals is modeled with a discrete distribution. In latent class model, the mixing distribution $f(\beta_n \mid \theta)$, is discrete, with β_n taking a finite set of distinct values (Train, 2003). In this case, it is assumed that decision makers are intrinsically sorted into a number of classes based on their tastes. Members of each class have similar tastes. However, the classes are latent, not observable by the analyst. Within the class, the individual choices from one choice situation to the next are assumed to be independent and choice probabilities are generated by the conditional logit model (Greene, 2002). For instance, the probability that individual n chooses alternative i in a given choice situation t, given that he belongs to latent class c is:

$$P(nit \mid c) = \prod_{t=1}^{T} \frac{\exp(\beta'_c X_{nit})}{\sum_{j=1}^{J} \exp(\beta'_c X_{njt})} \tag{32}$$

Where X_{nit} is a vector of observable traits associated with alternative i and β'_c is a class specific parameter vector, t denotes the choice situation for person n. The β'_c enables one to capture taste heterogeneity in preferences across classes. Whereas the mixed logit model allows choice parameters to vary across each individual, the latent class model assumes that these parameters vary across segments of individuals. In many cases, this makes the latent class model more policy relevant than the mixed logit model.

In order to construct the class membership function, it is assumed that there exists a finite number of classes, C($C \leq N$) in which each individual can be classified with some probability, P_{nc}. Since class membership is unobservable to the analyst, a latent membership likelihood function, M^* that classifies individual n into one of the C classes can be formulated. Following Boxall and Adamowicz (2002) this can be described by the following set of equations:

$$M^*_{nc} = \lambda_{pc} P^*_n + \lambda_c S_n + \zeta_{nc}$$

$$P^*_n = \alpha_P P_n + \zeta_{nP} \tag{33}$$

Where M^*_{nc} is the membership likelihood function for n and class c; P^*_n is a vector of latent perceptual and attitudinal constructs held by n; S_n is a vector of observed socio-economic characteristics of individual n; P_n is a vector of observed indicators of the latent perceptual and attitudinal constructs held by n; λ and α_p are parameter vectors to be estimated; and the ζ vectors represent error terms. Relating this function to the classical latent variables approach where observed variables are related to the latent variable, M^* can be expressed at the individual level as:

$$M^*_{nc} = \Gamma_c z_n + \zeta_{nc}, \quad c = 1,\ldots\ldots,C \tag{34}$$

Where z_n is a vector of both perceptual and attitudinal constructs (P_n) and socio-economic characteristics (S_n), and Γ_c is a vector of parameters. Since the membership likelihood function is random, a distribution of the error terms needs to be specified. The error terms are assumed to be independently distributed across individuals and classes with an extreme value type 1 (Gumbel) distribution. This allows the probability of class membership to be specified by the multinomial logit form:

$$P(c) = \frac{\exp(\Gamma_c z_n)}{\sum_{c=1}^{C} \exp(\Gamma_c z_n)}, \quad \Gamma_C = 0 \tag{35}$$

The specification in (35) allows individual-specific characteristics z_n, which are invariant of the choice sets to produce class probabilities. Class sorting is probabilistic to the analyst with mixing probabilities $\pi_1, ...\pi_{j,}$ with $\sum_{c=1}^{C} \pi_j = 1$ and $0 \le \pi_j \le 1$. The C^{th} parameter vector is normalized to zero to ensure identification of the model (Hensher and Greene, 2002).

Since the classes are unknown, the conditional probability in equation (32) cannot be used, instead an unconditional probability is employed. The unconditional probability that individual *n* chooses alternative *i* in choice situation *t* is obtained by combining the conditional probability with class membership probability in equations (32) and (35) to yield (36):

$$P(i) = \sum_{c=1}^{C} P(c) \times P(nit \mid c) \tag{36}$$

This means that for a given individual, the model's estimate of the probability of a specific choice is the expected value (over classes) of the class specific probabilities. This model has been described in literature (e.g. Kontoleon, 2003) as a mixture model since it utilizes both choice trait data and individual characteristics to simultaneously explain choice behavior and class membership. The sample log-likelihood function can then be specified as:

$$\ln L = \sum_{n=1}^{N} \ln P(i) = \sum_{n=1}^{N} \ln \left[\sum_{c=1}^{C} P(c) \left(\prod_{t=1}^{T} P(nit \mid c) \right) \right] \tag{37}$$

The unknown parameters of class membership (Γ_c) and choice probabilities (β'_c) are obtained in a joint and simultaneous estimation procedure by maximizing the unconditional log-likelihood of the sample over the parameter space. In this study, the log-likelihood function has been maximized directly using NLOGIT's general optimization package. Boxall and Adamowicz (2002) describe the class membership function presented in equation (35) that determines the structure of the latent classes *C*, as a statistical classification process and not a behavioral function. Consequently, one can ignore the correlation between the error in the utility functions and the classification function. It is worth noting that the restrictive IIA assumption need not be assumed in the case of latent class models (Shonkwiler and Shaw, 1997). For a given individual *n*, the model's estimate for the probability of a specific choice is the expected value, over classes, of the class specific probabilities. This implies that the ratio of probabilities of selecting any two alternatives would contain arguments that include the systematic utilities of other alternatives in the choice set as revealed in equation (36). Some few studies have used latent class models in discrete choice modeling. For instance, Kontoleon (2003) uses latent class models to account for consumer heterogeneity in preferences over GM foods, Kamakura et al. (1996) use latent class models to model preference and structural heterogeneity in consumer choice and Shonkwiler and Shaw (1997) utilize latent class models to analyze income effects in random utility models.

One major challenge of latent class model estimations is determination of the correct number of latent classes. It is a subjective process that requires the use of a combination of multiple statistical criteria as well as personal subjective judgment dictated by the objectives of the study. The optimal number of classes is reached when additional classes provide little extra information or are simply superfluous. Hence the aim is to attain 'class parsimony', that is the avoidance of choosing a superfluous number of classes that would lead to spurious results that do not add to the understanding of the underlying behavioral process but merely bring in undesirable noise into the model (Swait, 1994). Various information criteria for deciding on the optimal number of latent classes, *C*, have been suggested. Thus, following Bhat (1997), Swait (1994) and Boxall and Adamowicz (2002) two criteria have been used in this study to determine the optimal size of *C*. These are: the minimum Akaike Information Criterion (AIC), and the minimum Bayesian Information Criterion (BIC). The rationale behind these criteria is to penalize the log-likelihood improvements resulting from a larger number of parameters associated with each additional class. The model with minimum AIC or BIC value is chosen as the best model to fit the data. The main limitation of the latent class model is its assumption of local independence, where the choice variables are assumed to be independent of each other conditional on latent class membership.

3.3.3 Calculation of Trait Implicit Prices (Willingness to pay Values)

The choice modeling results can be used to estimate implicit prices or willingness to pay (WTP) values of the different attributes. The simple random utility function in equation (22) can be re-written as:

$$U_{njt} = \beta_{0nj} + \gamma_n P_{njt} + \beta_n X_{njt} + \varepsilon_{njt} \quad (38)$$

Where most terms are as earlier defined in equation (22), P_{njt} denotes the cost parameter or price of alternative *j* which is often included as one of the attributes of the choice alternative. X_{njt} denotes the other observed attributes of choice alternative, *j*. The constant, β_{0nj}, denotes individual *n*'s choice-specific intercept for alternative *j*, γ_n is the coefficient for the cost parameter and β_n represents the coefficient vectors for the other traits, for individual *n*. γ_n and β_n are assumed to be random. The implicit prices for the traits X_{njt} can then be estimated as the rate of change in the trait divided by the rate of change of the cost parameter (marginal rate of substitution) represented as:

$$-\left(\frac{\partial U/\partial X_{nj}}{\partial U/\partial P_{nj}}\right) = -\frac{\beta_n}{\gamma_n} \quad (39)$$

Since these are non-linear functions of parameter estimates, their confidence intervals can be approximated using delta method. The extant literature (e.g. Hensher and Greene, 2002) suggest that behaviorally meaningful willingness to pay (WTP) values from mixed logit model are obtained using conditional constrained individual parameter estimates compared with values obtained from draws of population distributions which tend to produce behaviorally unrealistic extreme value estimates. Although little is reported in the literature about the best constraint to implement, Hensher et al (2005) indicate that constraining the standard deviation parameter estimate to that of the mean of the random parameter for a triangular distribution guarantees non-negative implicit price values. The conditional parameter estimates are conditioned based on an individual's observed choices and the distribution of tastes in the population. Mixed logit produces estimates from draws of population distribution $f(\beta_n \mid \theta)$, while also providing individual conditional parameter estimates. Figure 10 presents the two distributions of taste parameters in the entire population *g,* and the individual conditional distribution *h*. The individual conditional distribution lies within the population distribution and has minimal variance.

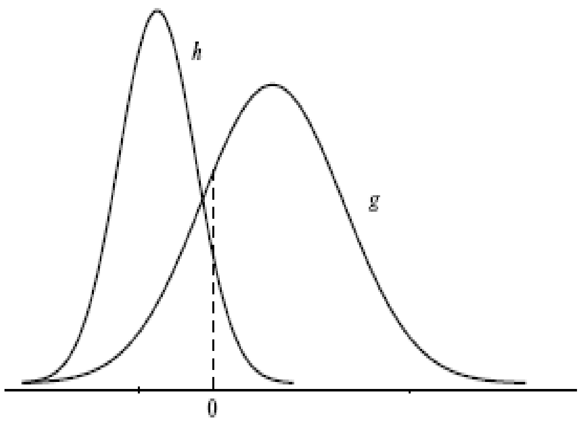


Figure 10: Unconditional population distribution, g and individual conditional distribution, h for a taste parameter.
Source: Adapted from Train (2003).

The conditional parameter estimates are strictly same-choice-specific parameters, or the mean of the parameters of the sub-population of individuals who, when faced with the same choice situation would make the same choices (Hensher et al., 2005). Train (2003) shows the conditional individual parameter estimate using Bayes theorem to be;

$$\overline{\beta}_n = \frac{\int \beta.P(y_n \mid x_n, \beta) f(\beta \mid \theta) d\beta}{\int P(y_n \mid x_n, \beta) f(\beta \mid \theta) d\beta} \tag{40}$$

Where $\int P(y_n \mid x_n, \beta) f(\beta \mid \theta) d\beta$ is the integral of the probability of a person's sequence of chosen alternatives y_n given choice situations x_n over the distribution of β. The mean $\overline{\beta}_n$ generally differs from the mean β in the entire population. Since the integrals in equation (40) do not have a closed form, it is simulated by taking draws of β from the population density $f(\beta_n \mid \theta)$. The weighted average of these draws are then calculated with the weight for draw β^r being proportional to $P(y_n \mid x_n, \beta^r)$. The simulated subpopulation mean is:

$$\breve{\beta}_n = \sum_r w^r \beta^r \text{ Where the weights are } w^r = \frac{P(y_n \mid x_n, \beta^r)}{\sum_r P(y_n \mid x_n, \beta^r)} \tag{41}$$

In this study, implicit trait prices from the mixed logit model are derived using conditional mean-constrained random parameter estimates while for the latent class model, the trait prices are calculated using class specific population parameter estimates and their confidence intervals approximated using the delta method.

Chapter 4

Choice Experiment Methodology

4.1 Introduction

This chapter presents a description of the methods employed in the choice experiment study. The choice experiment method is discussed, including the experimental design utilized in the study and a description of the cattle traits. The survey design and implementation is then presented, providing a description of the survey instruments and sampling methods used. Finally, the data and variables used are presented and discussed.

4.2 Choice Experiments

Choice experiment is a multi-trait stated preference method, which assesses the value of single traits of a bundled good by using individuals' stated preference in a hypothetical scenario (Louviere et al., 2000). The traits to be valued as well as their levels are identified and combined according to some experimental design to create sets of discrete choice alternatives. Respondents are then presented with a series of choice alternatives and asked to choose their most preferred option. Each alternative is characterized by a number of traits, one of which is a monetary trait, offered at different levels across alternatives. Analysts can then assess how respondents' choices change as the traits and monetary amounts are varied. Appropriate models are then applied to the choice data to reveal a measure of utility for the traits of the choices. Choice experiment method is particularly useful for valuing traits without market values since the trade offs that people make within traits demonstrate a willingness to pay (Loomis, 2005). Studies on livestock trait preferences have mainly utilized conjoint analysis (e.g. Sy et al., 1997; Tano et al., 2003; Makokha, 2006). The distinguishing characteristic of choice experiments from conjoint analysis is that the respondent expresses preferences by choosing from sets of alternatives, characterized by a number of traits rather than by rating or ranking them as in conjoint analysis. The choice-based task is similar to what buyers actually do in the marketplace. Choosing a preferred product from a group of products is a simple and natural task that can easily be understood by many people.

4.2.1 Identification of Cattle Traits

In this study, ten focus group discussions each comprising 8 to 15 cattle keepers was conducted between January and March 2004, in the study sites as part of a baseline survey.

The objective was to gain insight on the traits preferred by the cattle keepers to be included in the choice experiment design. The cattle keepers were asked to identify the traits that they prefer in cattle, based on the prevailing environmental conditions. Twelve traits were identified separately for bulls and cows. The separation was necessary since cows and bulls perform different functions in the household livelihood system. The traits were then listed and pair wise ranking techniques applied to identify priority traits for inclusion in the choice experiment design. This was necessary since inclusion of all the traits in the choice experiment would increase the cognitive burden on respondents. DeShazo and Fermo (2002) and Campbell et al. (2006) show that a high number of traits in a choice set can result in choice task complexity which may compromise choice consistency. In some cases, group discussions were conducted separately for men and women in order to assess if there were significant differences in trait preferences across gender. Comparison of the focus group discussion results between the gender groups showed no major differences in trait preferences identification, except for higher rankings for traits associated with high reproduction potential in cows by women relative to men. The traits included in the choice experiment design and their levels are presented in table 2. The trait levels were derived based on existing and achievable levels.

Seven highly ranked traits for cows and six for bulls were then included in the choice experiment design. An additional monetary trait, purchase price of the animal, was included in the trait set. The monetary trait levels were based on the prevailing market prices for the animals. Trypanosomosis and tick-borne diseases are serious disease constraints in production systems in the study sites, therefore trypanotolerance was highly ranked by the cattle keepers as an important trait. Traction ability in bulls was highly ranked as a priority trait in the cropping systems. Coat color also ranked as an important trait in the agro-pastoral system of the Ghibe valley and pastoral system in Kenya. In the Ghibe Valley, cattle keepers prefer light-coat colored cattle to dark-coat colored ones since the latter enhances the landing response of tsetse flies. In the Kenyan sites, coat color was only important in pastoral societies where black-coat colored bulls with white spotted dewlap are used for ceremonial functions. Carty (2002) reports results that tend to support the significance of cattle coat color in tsetse fly landing responses since color is an important stimulus in attracting tsetse flies to a target once they are in visual range. The results indicate the strongest landing responses to be on black surfaces and notes that cattle with light coat color such as light brown and fawn are less likely to be infected with trypanosomosis relative to dark-coat colored cattle.

Table 2: Traits and trait levels used for cows and bulls in choice experiments

Cows		***Bulls***	
Traits	Levels	Traits	Levels
Trypanosomosis	1. Tolerant 2. Susceptible	Trypanosomosis	1. Tolerant 2. Susceptible
Milk yield	1. up to 1 Lt. per day 2. 2 Lt. per day	Traction ability	1. Suitable 2. Unsuitable
Reproduction ability	1. 1 calf per year 2. 1 calf every 2 years	Fertility	1. High 2. Low
Coat color	1. Light-colored 2. Dark-colored	Coat color	1. Light-colored 2. Dark-colored
	Kenyan sites[a]		*Kenyan sites*[a]
Purchase price at 2 yrs	1. KSh 10,000 2. KSh 15,000 3. KSh 19,500	Purchase price at 4yrs	1. KSh 11,000 2. KSh 20,000 3. KSh 27,000
	Ethiopian sites[a]		*Ethiopian sites*[a]
Purchase price at 2 yrs	1. Birr 550 2. Birr 900 3. Birr 1200	Purchase price at 4yrs	1. Birr 850 2. Birr 1200 3. Birr 1500
Watering frequency	1. Once in 2 days 2. Once in a day 3. Twice in a day	Watering frequency	1. Once in 2 days 2. Once in a day 3. Twice in a day
Live weight at 2 yrs	1. 120Kg 2. 190Kg 3. 250 Kg	Live weight at 4 yrs	1. 200Kg 2. 320Kg 3. 450Kg
Feeding requirements	1. Need for purchased supplementary feeds 2. No need for purchased supplementary feeds		

[a] Exchange rate: 1 US$ = 8.7146 Ethiopian Birr and 1 US$=74.7 Kenya Shilling

Drought tolerance also ranked as an important trait for the cattle keepers, especially those located in semi-arid areas, where water and pasture are limiting resources during dry seasons. In this study, watering frequency has been used as a proxy for drought tolerance trait. High milk production and high reproduction potential traits in cows are highly preferred. The cattle keepers relate long tail, visible umbilical cord and narrow neck to high milk production while wedge shape is related to high reproduction potential in cows. Feeding ease also ranked as an important trait. The cattle keepers indicate preference for animals that are non-selective feeders, being able to feed on a variety of forages to avoid purchase of externally acquired feeds.

4.2.2 Choice Experiment Design

Experimental designs are fundamental components of choice experiments and are mainly used to construct the choice profiles. Several authors (e.g. Louviere et al., 2000; Kuhfeld et al., 2004) have emphasized the importance of experimental designs in developing reliable choice experiments. The point of concern in an experimental design is how to create choice sets in an efficient way. The process involves manipulations through a planned design process in which the traits and trait levels are combined and varied to create choice alternatives or choice sets to be presented to each subject or decision maker. The goal of choice experiment designs have largely been to maximize orthogonality and balance while also easing cognitive burden of respondents (Lusk and Norwood, 2005). Perfect orthogonality requires that across the design, all the traits are statistically independent, implying zero correlations between the traits. A balanced design necessitates that the levels of any given trait appear the same number of times as all other levels for that particular trait.

A full factorial design[22] achieves perfect orthogonality and balance. For a full factorial design, all main effects, all two-way interactions, and all higher-order interactions are estimable and uncorrelated. Hensher et al. (2005) define a main effect as the direct independent effect of each trait on a dependent variable. It is the difference in the means of each level of a trait and the overall mean. An interaction effect on the other hand, is the effect on a dependent variable by combining two or more traits which would not have been observed had each of the traits been estimated separately. The problem with a full-factorial design is that, for most practical situations, it is too costly and may place a significant level of cognitive burden on respondents, which is likely to result in response unreliability. Several strategies have been employed to reduce the number of choice sets given to respondents. These include reducing the number of levels used within the design, using fractional factorial designs, blocking the design or using a fractional factorial design combined with a blocking strategy.

[22] A full factorial design is a design in which all possible combinations of the trait alternatives are used.

Fractional factorial designs are generated by selecting subsets of choice sets from the full factorial design. In order to choose the subsets of choice sets from the full factorial design, an analyst may randomly select a number of treatment combinations without replacement. The limitation in doing this however is the likelihood in producing statistically inefficient or sub-optimal designs. An alternative strategy to select optimal combinations is to select the smallest orthogonal main effects design from the full factorial, which is determined by the total degrees of freedom required to estimate all implied main effects (Louviere et al., 2000). The total degrees of freedom are determined by summing the separate degrees of freedom in each main effect[23]. Several studies have utilized fractional factorial designs; for example, Adamowicz et al. (1998) and Revelt and Train (1998) generate choice sets using orthogonal main effects only designs. In a main effects only design, a sub-set of the full factorial design is selected such that all main effects are identifiable and completely orthogonal with each other (Lusk and Norwood, 2005). Main effects only designs significantly reduces the number of treatment combinations though its limitation arises due to the fact that only a fraction of the total number of possible combinations are used, resulting in possible information loss.

The blocking design strategy for reducing the number of choice sets shown to a respondent involves the use of an additional design column to assign sub-sets of treatment combinations to decision makers. It comprises the introduction of another orthogonal column to the design, the attribute levels of which are used to segment the design (Hensher et al., 2005). For instance, considering an experiment with three design attributes, each described by two levels, the full factorial design yields a total of eight treatment combinations. An additional two level orthogonal blocking variable may be introduced, thus producing two blocks of treatment combinations of size four. Each block is given to a different respondent, implying that two different decision makers are required to complete the full design. The main limitation in block design strategies is the rise in sample size required to complete a full experimental design, especially with a rising number of blocks. Block designs have been used in a number of conjoint analysis studies such as Makokha (2006).

Recently, researchers have suggested that from a statistical perspective, experimental designs underlying stated preference tasks should impart the maximum amount of information about the parameters of the traits relevant to each specific choice task, something that cannot

[23]7 Each main effect has exactly $L-1$ degrees of freedom, where L is the number of levels of the traits.

be guaranteed with orthogonal fractional factorial designs (Hensher et al., 2005). This has led to the introduction of optimal or statistically efficient designs. The difference between optimal designs and orthogonal fractional factorial designs is that the former are statistically efficient but will not be perfectly orthogonal and balanced, as they will likely have correlations, while the latter are generated so that the traits of the design are statistically independent. Therefore, orthogonal fractional factorial designs will have no correlations but may not be the most statistically efficient design available. One of the arguments for the use of orthogonal fractional factorial designs is the ability of such designs to produce unconfounded estimates of the population parameters due to the enforced statistical independence between the traits contained within the design. However, Rose and Bliemer (2004) point out that orthogonality is likely lost in the data sets and during estimation process since parameters are estimated from the data sets underlined by stated choice experiments and not from the design itself. The issue of generating statistically efficient designs has been addressed by several authors (e.g. Kuhfeld et al., 2004; Rose and Bliemer, 2004; Huber and Zwerina, 1996). The key consideration is that maximizing statistical efficiency minimizes the variability of the parameter estimates.

In determining the statistically efficient designs, choice models have tended to use linear design efficiency criteria as a surrogate for choice design goodness (Kuhfeld, 2004). This is because efficient experimental designs for the nonlinear models such as multinomial logit require knowledge of the true utility parameters, which are unknown prior to a study. The assumption commonly made when conducting a choice experiment is that good linear designs are also good for nonlinear models. Corroborating evidence of this is provided by Kuhfeld et al. (2004) and recently by Lusk and Norwood (2005). For linear models, the variance-covariance matrix of the vector of parameter estimates $\hat{\beta}$ is proportional to the inverse of the information matrix, $(X'X)^{-1}$ where X is the matrix of traits used in the design. Maximizing efficiency minimizes the variances, covariance and consequently, standard errors. Thus, an efficient design is one that has a small variance matrix, and the eigen-values of $(X'X)^{-1}$ provide measures of its size (ibid.). A good design for a linear model is created by picking the x's that minimize the functions of $(X'X)^{-1}$ then converting the linear design into a choice design. Two common efficiency measures are based on the idea of average variance or average eigen-value; A-efficiency is a function of the arithmetic mean of the variances, computed as $trace((X'X)^{-1})/p$ while D-efficiency is a function of the geometric mean of the eigen-values, given by $\left|(X'X)^{-1}\right|^{1/p}$ (Kuhfeld, 2004)[24]. The determinant, $\left|(X'X)^{-1}\right|$, is the product of the eigen-values of $(X'X)^{-1}$, and the p^{th} root of the determinant is the geometric mean. A third common efficiency measure, G-efficiency, is based on σ_M the maximum standard error for prediction over the candidate set. D-efficiency is commonly used in conjoint analysis and choice designs that utilize linear designs since it is faster to optimize than others (ibid.).

Recently, there has been a development of optimal experimental designs for choice experiments based on multinomial logit models. Researchers have developed design techniques based on the D-optimal criteria for non-linear models in a choice experiment context (Rose and Bliemer, 2004). D-optimal designs maximize the determinant of the variance-covariance matrix of the model to be estimated. In determining the D-optimal designs, analysts have tended to use the inversely related measure to calculate the level of D-efficiency that is, minimizing the determinant of the inverse of the variance-covariance matrix. The determinant of the inverse of the variance-covariance matrix, known as D-error yields the same results maximizing the determinant of the variance-covariance matrix (ibid.). The maximum likelihood estimator for discrete choice multinomial logit models is consistent and asymptotically normally distributed with a mean equal to β and a covariance matrix given by; $\Omega = (X'PX) = \left[\sum_{m=1}^{M}\sum_{j=1}^{J} x'_{njs} P_{njs} x_{njs}\right]$ and inverse, $\Omega^{-1} = (X'PX)^{-1} = \left[\sum_{m=1}^{M}\sum_{j=1}^{J} x'_{njs} P_{njs} x_{njs}\right]^{-1}$.

Where P is a JS x JS diagonal matrix with elements equal to the choice probabilities of alternatives j, over choice sets, s (Hensher et al., 2005). Minimization of the inverse of the covariance matrix will produce the design with the smallest possible errors around the estimated parameters. The covariance matrix is the main component of the D-optimal criteria and depends on the true parameters of the utility function, since the choice probabilities, P_{njs} depend on these parameters. This therefore, implies that prior information is required about the true parameters of the utility function prior to the choice experiment study. Several strategies have been used to obtain this information, including using results from other studies, expert judgments and sequential designs strategies. Apart from the need to have prior information regarding the utility parameters prior to a choice experiment study, several problems have been raised regarding this design strategy. Alpizar et al. (2001), highlight two notable issues; since the design is based on the conventional logit model, homogeneous

[24] The trace is the sum of the diagonal elements of $(X'X)^{-1}$, which is the sum of the variances and is also the sum of the eigen-values of $(X'X)^{-1}$.

preferences are assumed, violation of which may bias the estimates. In addition, there may be credibility issues regarding the different combinations of attributes. If the correlation between attributes is ignored, the choice sets may not be credible to the respondents. Due to these complexities, simplifying assumptions have often been made when conducting choice experiment studies that good linear designs are also good for nonlinear models (Kuhfeld et al., 2004).

Computer search algorithms have been largely used to generate efficient linear designs. The algorithms use the efficiency criteria to create efficient designs, by selecting trait combinations from the full factorial design that increase efficiency while deleting those that reduce efficiency. Different software applies different algorithms for selecting efficient combinations. Figure 11 shows a full factorial design for two attributes with three levels each. From a full factorial design of nine combinations, the algorithms pick those with the highest possible efficiency, represented by the circles. The example presented in the figure shows that efficiency tends to emphasize the corners of the design space. For larger full factorial designs, fractional factorial designs may be used from which efficient combinations are selected.

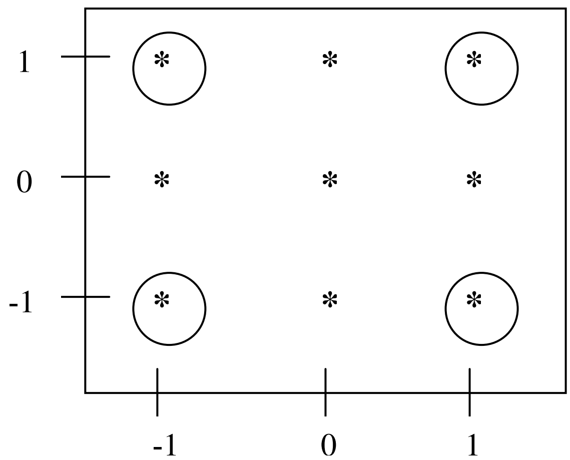


Figure 11: Candidate set and optimal design for two 3-level traits.
Source: Kuhfeld (2004).

In this study, a choice experiment design, following an efficient linear design model is created using Choice-Based Conjoint (CBC) Advanced Design Module software (Sawtooth Software Inc., 2006). A full factorial design which includes all possible combinations of the traits would yield 864 (2^5x3^3) possible generic choice sets[25] for cows, for 5 traits with two levels each and 3 traits with three levels each, and 432 (2^4x3^3) generic choice sets for bulls,

.[25] The generic choice sets do not refer to any particular breed or label, but rather are members of a class of alternatives. The alternatives are simply bundles of traits and the objective is to assess which traits are important drivers of choice.

with 4 traits with two levels each and 3 traits with three levels each. Since it is not practically feasible to work with such a large number of choice sets, a partially orthogonal main effects only design has been generated from the full factorial design to create feasible choice sets using the Choice-Based Conjoint (CBC) Advanced Design Module software. The main effects design is determined by the total degrees of freedom required to estimate all implied main effects. An assumption has been made that there are no significant interaction effects in the traits. This is justifiable given the findings of Dawes and Corrigan (1974) that the majority of variance within linear models can be explained by main effects only. Their findings suggest that 70-90% of variance in linear models may be explained by main effects and the remaining 10-30% by interaction effects. In this study, the design has resulted in twelve choice sets for cows and eleven choice sets for bulls. An effects coding structure for the nonlinear traits and trait levels has been used in order to avoid confoundment with the grand mean. Effects coding uses values for codes, which when summed over any given column (trait), equals zero. Use of dummy coding on the other hand, leads to perfect confoundment between the base level of a trait and the zero-utility associated with the “no-buy” choice alternative, which is the base level for the representative component of the utility function, making it difficult to estimate separate effects of each.

In order to understand the trade-offs that the decision makers are willing to make between traits, a fold-over design of the main effects design has also been created in order to construct choice alternatives for decision makers. A fold over is the reproduction of a design in which the trait levels of the design are reversed, for example replacing zeros with ones and ones with zeros. This has resulted in another twelve choice sets for cows and eleven for bulls. An opt-out “no-buy” alternative has also been created for each choice set to take care of respondents who prefer none of the offered alternatives and to act as a baseline alternative to help anchor the other alternatives in relation to the respondents’ actual choice. For each choice set, a decision maker would compare a choice alternative with its fold-over and a no-buy alternative and choose the preferred alternative. Tables 3 and 4 present the choice sets for bulls and cows.

Table 3: Bulls choice set

Choice task	Choice alternative	Tryps	Fertility	Traction ability	Coat color	Purchase price	Live-weight	Watering frequency
1	choice1	-1	1	1	1	1	0	-1
1	choice2	1	-1	-1	-1	-1	0	1
1	no buy	0	0	0	0	0	0	0
2	choice1	-1	-1	-1	1	-1	1	-1
2	choice2	1	1	1	-1	1	-1	1
2	no buy	0	0	0	0	0	0	0
3	choice1	-1	-1	-1	-1	0	0	0
3	choice2	1	1	1	1	0	0	0
3	no buy	0	0	0	0	0	0	0
4	choice1	1	1	-1	1	-1	0	1
4	choice2	-1	-1	1	-1	1	0	-1
4	no buy	0	0	0	0	0	0	0
5	choice1	1	1	1	-1	-1	1	-1
5	choice2	-1	-1	-1	1	1	-1	1
5	no buy	0	0	0	0	0	0	0
6	choice1	-1	1	-1	1	0	-1	0
6	choice2	1	-1	1	-1	0	1	0
6	no buy	0	0	0	0	0	0	0
7	choice1	1	-1	1	1	0	1	1
7	choice2	-1	1	-1	-1	0	-1	-1
7	no buy	0	0	0	0	0	0	0
8	choice1	1	-1	-1	-1	1	-1	-1
8	choice2	-1	1	1	1	-1	1	1
8	no buy	0	0	0	0	0	0	0
9	choice1	-1	-1	1	-1	-1	-1	1
9	choice2	1	1	-1	1	1	1	-1
9	no buy	0	0	0	0	0	0	0
10	choice1	1	-1	1	1	1	1	0
10	choice2	-1	1	-1	-1	-1	-1	0
10	no buy	0	0	0	0	0	0	0
11	choice1	-1	1	-1	-1	1	1	1
11	choice2	1	-1	1	1	-1	-1	-1
11	no buy	0	0	0	0	0	0	0

Table 4: Cows choice set

Choice task	Choice alternative	Tryps	Milk yield	Reproduction ability	Feed need	Purchase price	Watering frequency	Coat color	Live-weight
1	choice1	1	-1	-1	-1	-1	0	-1	-1
1	choice2	-1	1	1	1	1	0	1	1
1	no buy	0	0	0	0	0	0	0	0
2	choice1	-1	-1	1	-1	1	-1	1	-1
2	choice2	1	1	-1	1	-1	1	-1	1
2	no buy	0	0	0	0	0	0	0	0
3	choice1	1	1	1	-1	0	1	-1	0
3	choice2	-1	-1	-1	1	0	-1	1	0
3	no buy	0	0	0	0	0	0	0	0
4	choice1	1	-1	1	1	1	0	-1	1
4	choice2	-1	1	-1	-1	-1	0	1	-1
4	no buy	0	0	0	0	0	0	0	0
5	choice1	1	1	-1	-1	1	-1	1	1
5	choice2	-1	-1	1	1	-1	1	-1	-1
5	no buy	0	0	0	0	0	0	0	0
6	choice1	-1	1	-1	1	0	-1	-1	-1
6	choice2	1	-1	1	-1	0	1	1	1
6	no buy	0	0	0	0	0	0	0	0
7	choice1	-1	1	1	1	-1	0	1	0
7	choice2	1	-1	-1	-1	1	0	-1	0
7	no buy	0	0	0	0	0	0	0	0
8	choice1	-1	-1	-1	-1	1	1	-1	0
8	choice2	1	1	1	1	-1	-1	1	0
8	no buy	0	0	0	0	0	0	0	0
9	choice1	-1	-1	1	-1	0	0	-1	1
9	choice2	1	1	-1	1	0	0	1	-1
9	no buy	0	0	0	0	0	0	0	0
10	choice1	1	-1	-1	1	0	0	1	0
10	choice2	-1	1	1	-1	0	0	-1	0
10	no buy	0	0	0	0	0	0	0	0
11	choice1	1	-1	1	1	-1	-1	-1	0
11	choice2	-1	1	-1	-1	1	1	1	0
11	no buy	0	0	0	0	0	0	0	0
12	choice1	1	-1	1	1	-1	1	1	1
12	choice2	-1	1	-1	-1	1	-1	-1	-1
12	no buy	0	0	0	0	0	0	0	0

The numerical design codes have then been replaced with the descriptive trait level labels in order to construct pictorial, descriptive profiles for presentation to respondents. The trait levels for qualitative traits have been described using simple terms and pictures to ensure that they portray the same meaning to all respondents. The levels for quantitative traits such as purchase price and live-weight have been replaced with their respective quantitative values. The choice experiment profiles with pictorial presentations were then pre-tested on a sample of 100 respondents in Magadi division of Kajiado district in Kenya, a predominantly pastoral system. The pre-test exercise revealed that though pictorial profiles make the choice experiment instrument easy to understand, respondents tended to get carried away with the pictures and were trying to link the pictures to specific cattle breeds to which they seem to have a high affinity. Even in situations where trait levels were varied, respondents tended to concentrate their choices on pictorial profiles of their "favorite" breeds without due consideration of the changing trait levels. The choice experiment pictorial presentations were therefore adjusted to simple diagrammatic illustrations. Appendix 1 presents two sample choice profile scenarios for cows and bulls that have been used for the choice experiment survey.

4.3 Survey Design and Implementation

Data collection was conducted in two phases; a baseline survey covering Mara, Magadi and Lambwe divisions in Kenya and the Ghibe valley area in Ethiopia was conducted between January and March, 2004. This was followed by a choice experiment household survey between September and December 2004 in Kenya and April to May 2005 in the Ghibe valley in Ethiopia. Selection of the sites for the baseline survey was based on spatial mappings of tsetse fly distributions presented in figures 3 and 4 in chapter one, targeting trypanosomosis prevalent areas. Besides the identification of cattle traits for use in the design of the choice experiments, the objectives of the baseline survey was to identify existing cattle production systems to be used in targeting research areas for the household choice experiment survey and to assess prevailing cattle disease incidences (Ouma et al., 2004). A variety of participatory rural appraisal (PRA) tools were used, including scoring and ranking techniques, timeline and trend analysis, seasonal calendar analysis as well as community institutional maps. The household level choice experiment survey, hereinafter referred to as the main survey was then conducted in five divisions of Narok and Suba districts in Kenya, and four Woreda in the upper and lower Ghibe Valley in Ethiopia. These areas represent different cattle production systems and areas with varying trypanosomosis prevalence. A description of the study sites is presented in section *1.5*.

4.3.1 Sample Size Determination and Sampling Methods

The sampling frame for the main survey was cattle keeping households in the survey sites. The calculation of the sample size followed the layout and description by Hensher et al (2005) for choice data. For simple random samples, the minimum acceptable sample size, n, is determined by the desired level of accuracy of the estimated probabilities, $\hat{p}$. If p is the true choice proportion of the relevant population, a is the level of allowable deviation as a percentage between $\hat{p}$ and *p*, and β is the confidence level of the estimations such that $\Pr(|\hat{p} - p| \leq ap) \geq \beta$ for a given *n*, where $\beta = 1 - \alpha$. The minimum sample size is defined as:

$$n \geq \frac{q}{pa^2}\left[\Phi^{-1}(1-\frac{\alpha}{2})\right]^2 \tag{42}$$

where *q* is defined as $1 - p$ and $\Phi^{-1}(1-\frac{\alpha}{2})$ is the inverse cumulative distribution function of a standard normal, that is $N \sim (0,1)$ taken at $1-\frac{\alpha}{2}$. The minimum sample size calculated using equation (42) represents sample size required if each decision maker is shown a single choice set. As such, it is not strictly the minimum population sample size necessary for the study, but rather the minimum number of choices that are required to replicate the true population proportions within the acceptable error. For stated preference studies where decision makers may be shown more than one choice set, the minimum number of decision makers required for a given choice study, is equal to the minimum number of choices divided by the number of choices each decision maker is to be shown as part of the choice study.

In this study, a true population proportion *p*, of cattle in tsetse challenge areas is approximated to be 23% in Narok and Suba districts in Kenya and 30% in Ethiopia based on Rushton et al. (2002). An 8% and 6% level of allowable deviation of the drawn sample proportions from the true population proportions is assumed for Kenya and Ethiopia respectively. Substituting this into equation (42), yields 3,207 and 2,293 number of choices for Kenya and Ethiopia samples respectively. Since each respondent is given at least 12 choice scenarios, this yields a minimum sample size of 267 cattle keepers in Kenya and 191 in Ethiopia. The actual sample size used in the survey was 304 and 204 cattle keeping households[26] in the Kenyan and Ethiopian sites respectively, following a purposive simple random sample. Sampling was done within the lowest government administrative units in the two countries. The lowest government administrative unit in Kenya is the sub-location while in Ethiopia it is referred to as the Kebele. The exact number of households sampled per sub-location in Kenya or Kebele in Ethiopia was taken as a proportion of the total number of households in the administrative units. For the Kenyan sites, this was based on the 1999 population census figures (Government of Kenya, 2001) while for Ethiopia, the information was drawn from the official records of the Kebele through the committee members. Tables 5 and 6 present the sampling structure for the Kenyan and Ethiopian sites.

[26] A household in this study refers to individuals who live in the same dwelling and share resources. In most cases the household members are related by blood or marriage.

Table 5: Sampling structure for the Kenyan sites

District	Division	Sub-location	Human Population (1999 Census)	No. of households (1999 Census)	Calculated Proportion to be sampled	Adjusted and actual sample size
Narok	Mara	Siana	5,311	1,155	17.3	25
		Nkoilale	3,264	876	13.1	28
		Koyaki	4,046	824	12.4	27
		Sekenani	1,946	443	6.6	18
	Ololunga	Ololunga	16,214	3,541	53.1	13
		Lemek	7,988	1,820	27.3	20
		Melelo	7,834	1,466	21.9	11
	Mau	Sakutiek	6,039	1,361	20.4	30
Suba	Lambwe	God Jope	4,545	889	48.9	53
		Ogongo	3,375	677	37.2	33
	Central	Nyatoto	2,797	548	30.1	31
		Nyadenda	1,207	273	15.0	15
Total number of sample households in Narok district						172
Total number of sample households in Suba district						132

There were cases of ethnic clashes in parts of Ololunga division in Narok district of Kenya during the survey period, consequently the sample size was adjusted downwards for sub-locations in Ololunga division due to security concerns. This sample size loss was compensated by adjusting the sample size upwards for sub-locations in Mara and Mau divisions. The reduction in sample size for Ololunga division was also deemed necessary since some of the sub-locations in the division mainly comprised of large scale cash crop farmers, not rearing livestock. In Ethiopia, the sample size was also adjusted upwards for some Kebeles in order to capture many cattle keeping households in high trypanosomosis challenge areas. Although Walga Kebele had the highest number of households as indicated in table 6, majority were agricultural households, mainly growing pepper as a cash crop and not keeping cattle. Consequently, the sample size for Walga was adjusted downwards.

Table 6: Sampling structure for the Ghibe Valley, Ethiopia

Woreda	Kebele	Area	No. of households	Calculated Proportion to be sampled	Adjusted and actual sample size
Abeshiga	Ghibe	Lower Ghibe	321	7.5	18
	Walga	Lower Ghibe	3,057	71.2	20
	Borere	Upper Ghibe	1,011	23.6	25
Sokoro	Bede	Lower Ghibe	942	21.9	25
	Abbalti	Lower Ghibe	503	11.7	19
Nono	Medallo	Upper Ghibe			18
	Gullele	Upper Ghibe	616*	14.4	19
	Wayu (Bilo)	Upper Ghibe	600	13.9	18
Limu Kosa	Wayu-Tolley/Wedesa	Upper Ghibe	1,064	24.8	42
Total number of sample households in the Ghibe valley					204

*This includes number of households in Medallo as well

The random sampling procedure was carried out in the following manner: Sub-location or Kebele sketch maps were drawn with the help of sub-location chiefs or peasant association committee members marking major landmarks such as schools, dispensaries, shopping centers, churches and boreholes. Four pairs of landmarks were then randomly selected for each sub-location or Kebele and line transects drawn joining each pair. The pairs of landmarks were selected in such a way that most parts of the sub-location and Kebele areas were covered. Sampling was then done along the line transects. Every third household on the left and on the right was interviewed alternately only if it was a cattle keeping household. In cases where there were insufficient number of cattle keeping households along the selected transects, more pairs of landmarks were selected and sampling conducted until the required sample size for the sub-location or Kebele was achieved. In Mara division, the sampling procedure was slightly modified. The Maasai pastoral communities who inhabit the area live communally in structures commonly known as "manyattas". A "manyatta" refers to a collection of huts (hamlet), which usually contain one large, extended family, with one head of manyatta and several households, each with several wives and many children. Human population in a manyatta ranges from 10 to 50 people. The sampling procedure employed in the pastoral sub-locations of Mara division involved randomly selecting a manyatta, then randomly selecting 2 to 3 households in each manyatta. Since the manyattas are sparsely distributed across the sub-locations, every second manyatta on the left and on the right of each transect was selected alternately.

4.3.2 The Survey Instrument

The choice experiment was administered by enumerators as part of a questionnaire survey using in-person interviews in respondents' homes. The enumerators could speak the native language of the local communities, and in some cases were residents of the respective divisions where the survey was implemented. The enumerators were trained prior to the survey to ensure that they understood the choice experiment well and the contents of the questionnaire. This was followed by a period of questionnaire pre-tests to ensure its adequacy and to assess whether it was well understood by the enumerators. The questionnaire was divided into sections covering the choice experiment, household composition, livestock inventory, land size and tenure, cattle breed preferences and sources, livestock management practices including health and breeding services, milk production, labor resources, membership to farmer groups, household income sources, credit access and extension services. In most cases, the enumerators targeted the head of the household for interviews since s/he is the main decision maker regarding purchase of cattle and therefore better placed to articulate preferred traits[27]. The questionnaire is presented in appendix 2. Each completed questionnaire was checked for errors and omissions before entry into Microsoft Office Access database management forms. In addition to the survey data, each sampled household was geo-referenced using Global Positioning System (GPS) units in order to enable accurate estimations of location and market access variables using Geographic Information Systems (GIS).

The administration of the choice experiment part of the questionnaire was conducted in the following manner: Each respondent was first introduced to the type of choice task and asked whether s/he would prefer to buy a cow or a bull. For each choice task, the respondent was asked to assume that there were cows/bulls available in the market possessing the traits presented in the choice experiment profiles. The respondent was then presented with choice sets for either bulls or cows and shown two descriptive profiles at a time based on each choice alternative. In each case, a "no buy" option was also available for respondents who preferred neither of the two choice experiment profiles presented. The respondent was then asked to

[27] It is assumed that the trait preference articulated by the household head is representative of the household's preference structure.

choose the animal profile that he most prefers to buy for rearing. Each respondent was presented with either twelve choice sets in the case of cows or eleven choice sets in the case of bulls. Each choice set decision was taken as an independent decision to the decisions made in all other choice sets. Therefore, the respondents were asked to treat each choice scenario as a separate situation from the other scenarios. Respondents were also asked a number of debriefing questions in the fashion suggested by the NOAA panel after each choice decision (Arrow et al., 1993). Such questions included asking the respondents the reasons for their choice in order to assess the trade-offs they make across choice alternatives and to ensure that they understood the choice problem.

4.4 The Empirical Model Specification

The mixed logit model discussed in the previous chapter is used in this study to investigate the existence of cattle trait preference heterogeneity while the latent class model is used to examine the sources of heterogeneity across segments of cattle keepers. Estimation of the models requires a specification of the functional form of the utility function. In this study, a linear in parameters utility function is assumed. In mixed logit, the parameters that enter the utility function as random parameters need to be identified as well as the population distribution from which they are drawn. A zero-based, asymptotic *t*-test for individual parameter standard deviations has been used following Hensher et al. (2005) to determine the set of random parameters in the model. The vector X_{njt} in equation (22) contains cattle traits and trait levels of the bull and cow profiles from the choice experiment. Estimated coefficients β, may be interpreted in terms of the relationship between the explanatory variables and the probability of choice[28]. Each person makes repeated choices for either eleven choice experiment bull profiles or twelve choice experiment cow profiles. The repeated choices enable one to examine how the levels of various traits influence individual utility and compare them with *a priori* expectations. Hypotheses can be drawn regarding the general expected direction of influence.

Table 7 presents the cattle trait levels that enter the deterministic portion of the utility functions for the mixed logit and latent class models and their expected direction of influence on the utility function. What is observable by the analyst is the choice made by the decision maker, which is assumed to be the utility maximizing alternative. Choice is a binary

[28] Besides the mean coefficients of variables from the sample population, mixed logit also estimates the amount of spread that exists around the mean of the random parameter and provides estimates of individual specific parameter estimates.

dependent variable which takes the value of 1 for the chosen alternative and 0 for the non-chosen alternatives. From an a priori perspective, the trait levels; trypanotolerance, high fertility in bulls, high reproduction potential in cows and high milk yield are expected to increase an individual's utility, as should an increase in live weight. Trypanotolerant animals are expected to increase competitiveness of the cattle enterprise by reducing the costs associated with treatment of trypanosomosis disease. A high reproductive performance in cows and high fertility in bulls have a positive impact on herd productivity and herd size. Similarly, low watering requirement for the animals is expected to increase utility especially in production systems where water is a constraining factor. Pastoral systems are expected to particularly prefer this trait due to the harsh climatic conditions associated with the system. The coefficient values for coat color may plausibly take either negative or positive sign depending on an individual's preference and beliefs. For instance in the Ghibe valley, the coefficient sign may be negative due to preference for light-coat colored animals while in Kenya, especially the pastoral systems it may take a positive sign due to preference for dark-coat colored bulls.

Table 7: Choice experiment variable coding and expected signs

Variable	Units	Expected sign
Trypanosomosis	1=tolerant, -1= susceptible	positive
Purchase price	Price in US $	negative
Low watering frequency	1=once in 2 days, 0= once a day, -1= twice a day	positive
Moderate watering frequency	0 = once in 2 days, 1 = once a day, -1 = twice a day	positive
Coat color	1=dark, -1= light	negative/positive
Traction (bulls)	1=good, -1=poor	negative/positive
Fertility (bulls)	1=high, -1=low	positive
Reproduction (cows)	1=calf every year, -1=calf once in 2 years	positive
Live weight in kg	Live-weight in Kg	positive
Milk yield (cows)	1=2 Lt. per day, -1=less or equal to 1Lt. per day	positive
Purchased feed supplements (cows)	1=needed, -1=not needed	negative

The traction potential coefficient may also take either positive or negative sign depending on the production system. In the cropping systems, farmers rely on draft power from bulls and oxen for cultivating crop fields. On the other hand, for some pastoral communities use of cattle for draft power is a taboo. The main effect of animal traction shown in Africa for cropping systems has been to reduce field labor inputs and facilitate area expansion. Other studies such as Reardon et al. (1996) have also shown a strong positive farm-level impact of animal traction on land productivity and labor returns in West Africa. Finally, the trait coefficients associated with monetary expenditure, that is, purchase price of the animal and the need for purchased feed supplements is expected to have a negative sign due to the positive marginal utility for income generally exhibited by most individuals. Rational economic behavior stipulates that an increase in utility arises when the cost of the associated alternative falls, since money is a limited resource.

Several socio-economic factors influence preference and choice behavior as presented in the choice model framework in figure 9. These factors enter into the latent class model of class membership function in equation (35) and as interactions with the $X's$ in the utility function in equation (22). Prime candidates for such variables are production system characteristics, access to tsetse fly control methods, gender, age and human capital of the decision maker, household wealth indicators and market access factors. Human capital theory suggests that education and experience are important factors in enhancing human capital through acquisition and learning of skills. It enhances the efficiency of human beings to perceive, to interpret correctly and to undertake actions that will appropriately reallocate their resources (Schultz, 1975). This implies that cattle keepers who have more schooling will be able to conceptualize and comprehend the effects and trade-offs of different trait levels better in their choice decisions.

In addition, a dummy variable for production system to represent different production environments has often been used and shown to be significant in a number of preference studies (e.g. Zander et al., 2005; Tano et al., 2003). Different production systems are often characterized by different environmental constraints which influences the production systems needs, objectives of production and consequently, preferences. Other socio-economic attributes of cattle keepers such as gender, household size and composition, age of the household head and household wealth may also influence preferences in a number of ways. Household off farm income, land size and cattle herd size variables are often used as indicators of wealth in preference studies (e.g. Irungu et al., 2006). High income or wealth is hypothesized to influence a decision maker's choice alternatives by determining the feasible choice sets. It also influences the decision maker's perception of traits that condition the household's financial resources. Household size and composition reflect labor availability and constraints which impact on the utility derived from certain traits that may be labor intensive. The household size variable has often been used in livestock technology adoption studies such as Abdulai and Huffman (2005) and Makokha (2006) as an indicator of availability of labor resource.

Gender of the household head is important because female headed households may be labor constrained especially if some of the cattle traits require special type of labor. For instance, a trait such as traction potential in bulls which often requires bulky animal-drawn ploughing instruments may be unfeasible for female headed households especially if there is no male adult labor in the household. In addition, studies such as Blackden et al. (2006) indicate that female headed households in rural areas of sub-Saharan Africa are wealth constrained. This is sometimes due to prevailing customs and traditions that do not allow for females to inherit or control resources associated with wealth such as land or other property. This has an impact by limiting the choice alternatives that may be feasible to them.

Lack of market access for livestock or livestock products may adversely affect utilities for high yielding traits such as milk production. Longer distances to the market can reflect increased cost of marketing products especially for perishable products such as unprocessed milk which is associated with high risks of spoilage (Staal et al., 2002). It is therefore hypothesized that cattle keepers who are closely located to a market or an urban centre are most likely interested in increased milk or meat production because there is a secure opportunity to market their products. Longer distances to market centers also reflect barriers to livestock inputs and services such as veterinary services and drugs, especially in disease-prone areas. This may influence the utilities associated with disease tolerance such as trypanotolerance. Preference for cattle traits, especially trypanotolerance may also be influenced by the availability of tsetse fly control measures. It is hypothesized that cattle keepers who have access to low-cost tsetse fly control alternatives, are more likely to trade off trypanotolerance trait for high yielding traits especially if they have access to markets.

4.4.1 Sample Characteristics and Data Description

The sample population represents three distinct cattle production systems, presented in table 8. Forty percent of the sample populations are agro-pastoralists from the lower and upper Ghibe valley in Ethiopia. Twenty two percent are pastoralists, mainly from Mara division and parts of Ololunga division in Narok district of Kenya, practicing transhumance and nomadism. Thirty eight percent are mixed crop-livestock farmers from Lambwe and Central divisions of Suba district as well as Mau division and parts of Ololunga division in Narok district.

Table 8: Production systems

Production system	Division/Area	Frequency	Percent
Agro-pastoral	Lower Ghibe	82	16.1
	Upper Ghibe	122	24.0
Total agro-pastoral		*204*	*40.1*
Pastoral	Mara	102	20.1
	Ololunga	10	1.9
Total pastoral		*112*	*22.0*
Crop-livestock	Mau	26	5.1
	Ololunga	34	6.7
	Lambwe	86	16.9
	Central	46	9.1
Total crop-livestock		*192*	*37.8*

Source: Survey data

The socio-economic variables, some of which have been used for the econometric modeling are presented in table 9.

Table 9: Socio-economic variables

Variable name	Variable description	Mean	S.D.
Type of production system			
Agropast	Dummy (1 = if production system is agro pastoral, 0 otherwise)	0.40	0.49
Pastoral	Dummy (1 = if production system is pastoral, 0 otherwise)	0.22	0.41
Cropliv	Dummy (1 = if production system is crop-livestock, 0 otherwise)	0.38	0.49
Household characteristics			
Male	Dummy (1 = if household head is male, 0 otherwise)	0.93	0.26
Yrsexp	Years of cattle keeping experience	21.7	12.3
Hhage	Age of head of household (years)	47.9	15.1
Educyrs	Number of years of formal education of the head of household	4.9	5.1
Hhinc (US$)	Total average monthly income in US$	39.2	57.8
Catherd	Cattle herd size	30.4	64.5
Hhsize	Household size	6.6	2.6
Resources and Market access variables			
Drywaterpt	Distance to the nearest livestock watering point during dry season (Km)	3.0	3.5
Mktdist	Distance to the nearest market point (Km)	4.8	5.5
Travtimurb*	Travel time taken to the nearest large urban centre (Hours)	3.1	2.1
Travtimnrb	Travel time to Nairobi (Hrs)	4.1	1.4
Popdens5km	Human population density within a radius of 5km	64.1	47.1
Trypanosomosis disease			
Trypfreq	Frequency of trypanosomosis attacks per year	55.6	123.5
Tsecont	Dummy (1=household applies tsetse fly control methods)	0.5	0.5

Source: Survey data

*The urban areas are defined on the basis of population densities, that is, population densities of more than 250 people km^{-2}

Household characteristics

Ninety three percent of the sampled households are headed by males, and the average age of the household head is 48 years[29]. Generally, there are high illiteracy levels of household heads in the sample population; the average number of formal schooling years for a household head is 4.9 years. However, this is significantly different between the production systems at the 1% level. Table 10 shows the average years of education of the heads of households, across the production systems. In pastoral systems, the average number of schooling years for the household head is 1.5 years compared to 8.4 and 3.4 years in crop-livestock and agro-pastoral systems respectively.

Table 10: Number of years of education of household head, by production system

Production system	Mean	S.D.	Minimum	Maximum
Crop-livestock	8.38	4.52	0	18
Pastoral	1.48	3.57	0	14
Agro-pastoral	3.38	4.24	0	13

Source: Survey data

Further descriptive statistics indicate that 82% of household heads in pastoral systems have no formal education compared to 11% and 53% in crop-livestock and agro-pastoral systems respectively. The lack of formal education among head of households in pastoral system is probably due to the high degree of mobility in pastoral systems as a survival strategy due to the harsh environmental conditions. The average monthly household income in the sample is US$ 39, though the variation is high. Households in pastoral systems have a significantly higher average monthly income of US$ 46 at the 5% level mainly from livestock sales, compared to the crop-livestock farmers whose average income is US$ 30 (t = -2.08).

Average cattle herd size per household is 30 animals with a wide variation as indicated by the high standard deviation in table 9. The average herd size is significantly different between the production systems at the 1% level. Table 11 presents the average cattle herd size across the production systems. The pastoral system has the highest average cattle herd size of 84 animals per household, though with a high standard deviation. In the crop-livestock and agro-pastoral systems, a household owns an average cattle herd size of 25 and 6 animals

[29] A household head refers to the reference person in the household who is responsible for decision making in the household. Since Ethiopia still uses the Julian calendar, dates data from the Ethiopian dataset were converted into Gregorian calendar to enable uniformity with the Kenyan dataset.

respectively. In the agro-pastoral system of Ghibe valley, the cattle herd is mainly comprised of male stocks which are used for traction.

Table 11: Cattle herd size, by production system

Production system	Mean	S.D.	Minimum	Maximum
Crop-livestock	25.3	40.6	1	332
Pastoral	84.4	109.7	2	600
Agro-pastoral	5.7	4.6	1	30

Source: Survey data

The average herd size of the crop-livestock system households varies depending on the location of the farmer. For instance, crop-livestock system farmers from Suba district have an average herd size of 13 cattle while in Mau and Ololunga divisions of Narok district, the average cattle herd size is 53 animals, reflecting the cattle accumulation culture among the Maasai community. The Maasai communities are the main inhabitants of Narok district practicing pastoralism in Mara division and mixed crop-livestock production in Mau and Ololunga divisions. Livestock keeping is a central component of the Maasai community's livelihood system and are closely linked to their cultural and social lives, where livestock numbers are an important means of demonstrating wealth and a source of social status in the society. The pastoral communities also accumulate livestock during favorable climatic conditions to balance high losses usually experienced during major droughts and disease outbreaks (Lybbert et al., 2001).

Resources and market access

Generally, households are located far from livestock watering points. During the dry seasons they have to travel an average distance of 3 km to the nearest livestock watering point, as indicated in table 9. This differs across the production systems, with households in pastoral systems having to travel an average distance of 3.9 km compared to 2.4 and 3.1 km for crop-livestock and agro-pastoral system household respectively in search of livestock watering points. Table 12 presents the watering sources for the animals during the dry season.

Table 12: Source of water for cattle during dry seasons

Source	Frequency	Percent
Water well	60	11.8
Pond	99	19.5
River	314	61.8
Spring	35	6.9

Source: Survey data

The main source of water during the dry season is rivers as reported by 60% of the households. Other sources include water wells and ponds. In terms of access to markets, the households are located relatively far from market centers at an average distance of 4.8 km. This differs across the production systems as indicated in table 13.

Table 13: Distance to the nearest market centre in km, by production system

Production system	Mean	S.D.	Minimum	Maximum
Crop-livestock	2.96	2.70	0.04	20
Pastoral	3.31	2.47	0.1	10
Agro-pastoral	7.23	7.46	0.02	35

Source: Survey data

The t-test statistic of mean difference indicates a statistically significant difference in average distance to the nearest market centre between the crop-livestock and agro-pastoral systems at the 1% level (t = -7.43) and also between the pastoral and agro-pastoral systems at the 1% level (t = -5.35). It is however not significantly different between the crop-livestock and pastoral production systems. The distance measure is based on responses from respondents, mainly from farmer judgment, and is likely to suffer from imprecision. In order to overcome this and also to incorporate the effects of poor quality roads, common in rural areas of sub-Saharan Africa, total traveling time variables have been used, that is, time taken to reach the nearest large urban centre as well as time taken to reach Nairobi, Kenya's capital centre. These variables are GIS derived and have been calculated by ILRI's Smallholder Dairy (R&D) Project using the methods developed in Staal et al. (2000). The travel time variables are available for the Kenyan study sites only due to the availability of digitized road network data and other data layers for Kenya, from the International Livestock Research Institute's GIS team. Table 14 presents descriptive statistics for the GIS derived market access indicators for the two production systems in Kenya.

Table 14: GIS derived market access indicators for the Kenyan production systems

	Crop-livestock system(n=192)		*Pastoral system (n=112)*	
	Mean	S.D.	Mean	S.D.
Time taken to reach nearest large urban centre (hrs)	1.59	0.51	3.35	0.25
Time taken to reach Nairobi (hrs)	4.76	1.47	5.74	0.88
Human population density (5 km radius)	94.75	31.36	11.71	6.53

Source: Survey data

The average travel time to the nearest large urban centre is 1.6 and 3.4 hours for the crop-livestock and pastoral systems respectively. This is significantly different between the two systems at the 1% level (t = 33.9). Large urban centers are important demand centers for agricultural and livestock produce from rural areas. The time taken to reach such centers therefore has repercussions on the types of produce that can be sold in such markets due to the highly perishable nature of some livestock products. Average travel time to Nairobi is 4.8 and 5.7 hours for the crop-livestock and pastoral systems respectively. Travel time to Nairobi is an important market access indicator since higher livestock product prices are usually available in Nairobi relative to centers farther away from Nairobi, due to the high demand for the products arising from Nairobi's high human population (Kijima et al., forthcoming). The cattle keepers who are closer to Nairobi may therefore focus on highly productive traits to take advantage of the high product prices in Nairobi. The human population density measure in the cattle keeper's neighborhood (popdens5km) in table 9 is also an indicator of market access to some extent since a high population density potentially implies availability of demand for livestock products. The average human population density within a 5 Km radius is 64.1 persons. However, this differs significantly between the production systems at the 1% level. The pastoral production systems are sparsely populated with an average population density of 11.7 persons within a 5 Km radius compared to 94.7 in crop-livestock systems.

Trypanosomosis disease

Trypanosomosis occurrence is high in the sample population, with an average incidence per household of fifty six times in a year, though the standard deviation is large as reported in table 9, indicating a high variation in number of occurrences. Table 15, shows the average number of times of trypanosomosis occurrence in a year across the production systems. Trypanosomosis occurrence is highest in the pastoral systems, with some households reporting its occurrence throughout the year. The reason for the apparently high presence of the disease in the pastoral system is due to the proximity of the sample households to the Maasai Mara game reserve. The reserve houses a variety of wildlife species, some of which are important reservoirs of trypanosomosis infection in livestock.

Table 15: Trypanosomosis occurrence per year, by production system

Production system	Average number of times	S.D.	N	Minimum	Maximum
Crop-livestock	3.3	26.3	192	0	365
Pastoral	221.9	178.7	112	0	365
Agro-pastoral	13.7	18.5	204	0	220

Source: Survey data

The main source of treatment of trypanosomosis disease is self-administration of purchased drugs from village pharmacies. Figure 12 shows that 79% of the sample population use self administered purchased drugs to treat trypanosomosis disease while only 21% obtain the services from government or private veterinarians. In the pastoral areas, animal health service providers are scarce and households usually rely on experience and indigenous knowledge to know the type of drugs to use for treatment of trypanosomosis and other livestock diseases.

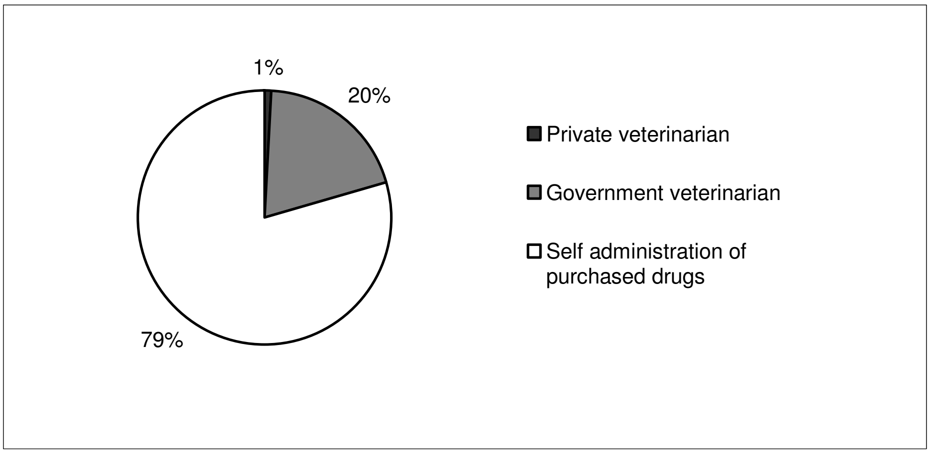


Figure 12: Source of treatment of trypanosomosis disease

Fifty percent of the sample households use tsetse fly control methods to contain trypanosomosis disease. Common tsetse fly control methods include spraying and use of traps as presented in table 16. A small proportion of the sample population, about 2% rub insecticides on the animals coat as a control strategy. In the crop-livestock and agro-pastoral production systems, spraying is a common control strategy while in the pastoral areas, use of traps, local herbs and clearing bush land are common.

Table 16: Tsetse fly control methods

Tsetse fly control measures	Frequency	Percent
Spraying	150	59.5
Use of pour-on/insecticides	7	2.7
Use of local herbs	15	5.9
Use of traps	55	21.8
Clearing bush land	25	9.9

Source: Survey data

4.5 Chapter Conclusions

The choice experiment method is a useful tool for valuing non-priced traits or traits without market values. Although a demand curve is not observable for such traits, there still exists a latent demand curve that can be teased out through methods such as choice experiments. In order for the choice experiments to be effective, the experimental design and profile presentation to the decision makers need careful consideration. Experimental designs are fundamental components of choice experiments as they are mainly used to construct the choice profiles. Careful consideration is therefore needed to ensure that the designs are optimal or statistically efficient. Besides, it is also necessary to ensure that the choice experiment profiles do not place a significant level of cognitive burden on respondents since this is likely to result in response unreliability. In order to ensure that the choice experiment presentation to the target population is effective, it is necessary to follow the NOAA panel recommendations on stated preference surveys such as the use of debriefing and follow-up questions to ensure that the respondents understand the scenarios. For instance, the choice experiment pre-tests in the present study showed that simple descriptive cattle profiles utilizing diagrams and simple statements for the trait levels were more effective compared to pictorial profiles for the targeted sample population. This is because there were tendencies for respondents to get carried away with the pictures of their favorite cattle breeds without due consideration of the changing trait levels.

Chapter 5

Cattle Trait Preferences: Results and Discussions

5.1 Introduction

This chapter is divided into two main sections. The first section presents the cattle enterprise objectives as well as breed composition, using descriptive analyses carried out in Stata™ statistical software version 9.2 (StataCorp, 2005). The second section discusses the results of the econometric modeling estimations of choice behavior and cattle trait preferences from the choice experiments. Empirical estimations from conditional logit, mixed logit and latent class models are presented.

5.2 Cattle Enterprise Objectives and Breed Composition

The cattle enterprise objectives provide insightful information about the traits cattle keepers would potentially prefer in order to meet the enterprise objectives. The objective of the cattle enterprise is influenced by a number of factors and varies across the production systems due to the varying production environments and the production system needs. Figure 13 presents the households' cattle enterprise objectives across the production systems.

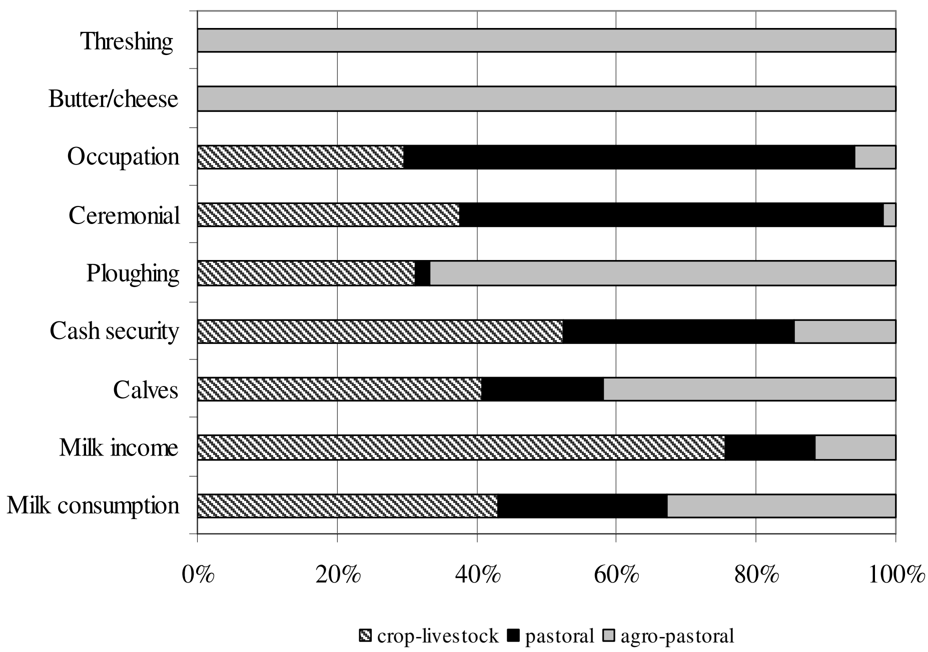


Figure 13: Cattle enterprise objectives

The proportion of respondents indicating various cattle enterprise objectives has been compared across different production systems using a chi-square test. Common cattle enterprise objectives across the three production systems include household milk consumption, calf production and cash security. The proportion of respondents indicating milk consumption as a cattle enterprise objective differs significantly across the three production systems $(\chi^2(2) = 63.9,\ p < 0.01)$. About 42% of the crop-livestock farmers indicate that milk consumption is an important cattle enterprise objective, compared to about 30% and 28% from agro-pastoral and pastoral systems respectively. The rankings also differ across the production systems with pastoral households ranking milk consumption highest as indicated in figure 14. In crop-livestock and agro-pastoral systems, milk consumption ranks second after draft power. In the pastoral systems, calves production ranks second after milk consumption while in the agro-pastoral and crop-livestock systems it ranks third and fourth, respectively.

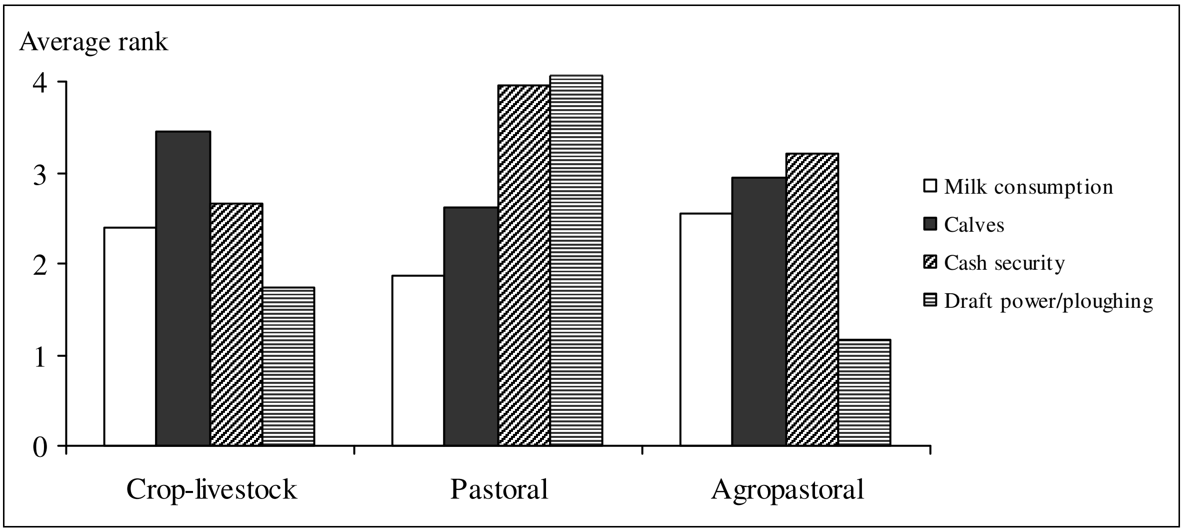


Figure 14: Average ranks of the cattle enterprise objectives, by production system

Note: 1=high rank 4=low rank

The proportion of respondents indicating milk income as a cattle enterprise objective also differs significantly across the three production systems $(\chi^2(2) = 64.1,\ p < 0.01)$. A relatively high proportion of crop-livestock system farmers indicate milk income as an important cattle enterprise objective in comparison to the pastoral and agro-pastoral households as indicated in figure 13. This difference may be attributed to disparities in market orientation across the production systems or the varying production environments which influence milk production and availability of surplus for sale. The role of cattle as a form of cash security is different from regular cash income from milk and other products. Cash security guarantees opportunities for meeting future planned and emergency needs while income from milk or other products are important for meeting regular expenses. A high proportion of crop-livestock farmers indicate this as an important cattle keeping objective and ranks it relatively high as illustrated in figures 13 and 14. This differs significantly across the production systems at the 1% level ($\chi^2 = 252.4(2)$).

The use of cattle for traction is an important objective for the cropping systems. The proportion of respondents indicating this as an important objective differs significantly across the production systems ($\chi^2(2) = 226.6,\ p < 0.01$). A significantly high proportion of agro-pastoralists indicate the use of cattle for ploughing as a cattle keeping objective relative to the crop-livestock and pastoral systems as illustrated in figure 13. Figure 14 shows that this cattle keeping objective is ranked highest in both agro-pastoral and crop-livestock systems. In these systems, male cattle are used for ploughing crop fields and threshing grains such as teff. The important use of cattle for traction is reflected in the cattle herd composition of agro-pastoral systems where the average number of bulls and oxen per household is as high as 4 compared to 2 for cows and heifers.

In crop-livestock and pastoral systems, cattle are also used for ceremonial purposes as illustrated in figure 13. Such ceremonies include payment of dowry and age-set graduation ceremonies[30]. Households in the pastoral system also indicate the role of cattle keeping as a form of occupation. This is mainly because livestock keeping is the main activity and preoccupation in the pastoral systems due to the harsh agro-climatic conditions that deem the cropping enterprises unfeasible. In the agro-pastoral system of Ghibe valley, traditional milk products such as home-made cottage-cheese, commonly referred to as "ayib" and butter are important for home consumption and are indicated in figure 13 as important reasons for keeping cattle.

Cattle breeds kept in the pastoral and crop-livestock production systems in the Kenyan study sites mainly comprise of the Kenyan Zebu breed which is kept by 98% and 79% of the pastoral and crop-livestock system households respectively. The breed is preferred by the households due to its adaptability to local environmental conditions. Relative to the exotic breeds, the Kenyan Zebu is more tolerant to drought and tick-borne diseases. Other breeds kept in small proportions in the crop-livestock system include crosses of Kenyan Zebu with Borana, Ayrshire or Guernsey breeds. In the agro-pastoral system of Ghibe valley, 98% of the households keep indigenous cross-bred cattle which are difficult to distinguish. Only 2% keep the Ethiopian Borana cattle breed which has its origins in the southern Borana plateau of

[30] Age sets are important social structures among the Maasai community. Movement of an individual from one age set to the next is marked by graduation ceremonies which signify an important transition in the life of an individual and in the wider life of the community.

Ethiopia. The agro-pastoral households indicate preference for the indigenous breeds due to their adaptability to climatic conditions and good traction ability.

5.3 Empirical Results from Choice Experiments

A total of 253 complete choice experiment interviews were carried out for bulls and another 253 for cows yielding panel data of 2,783 complete choice sets for bulls and 3,036 for cows. Information from two questionnaires was excluded from the choice experiment econometric models due to incomplete data. The mixed logit and latent class models were estimated using NLOGIT version 3.0 (Econometric Software, Inc., 2002).

5.3.1 Conditional Logit Estimation Results

Estimation of mixed logit model first involves the estimation of a conditional logit model to derive initial start values for each of the parameters in the mixed logit model. This allows an assessment of the parameter signs and the relative performance of the conditional logit and mixed logit models to be compared. The maximum likelihood estimates of the conditional logit model for bulls and cows are presented in tables 17 and 18, respectively. Preference stability for the three production systems has been tested using likelihood ratio tests. This has been done by checking if the log-likelihood function from the conditional logit estimation for the different production system sub-samples is significantly larger than the pooled sample log-likelihood function. The hypotheses tested are:

a) $H_0^1 : \beta_{pooled} = \beta_{Crop-Livestock\ Kenya}$ versus $H_A^1 : \beta_{pooled} \neq \beta_{Crop-Livestock\ Kenya}$

b) $H_0^2 : \beta_{pooled} = \beta_{Agro-pastoral\ Ethiopia}$ versus $H_A^2 : \beta_{pooled} \neq \beta_{Agro-pastoral\ Ethiopia}$

c) $H_0^3 : \beta_{pooled} = \beta_{Pastoral\ Kenya}$ versus $H_A^3 : \beta_{pooled} \neq \beta_{Pastoral\ Kenya}$

d) $H_0^4 : \beta_{Agro-pastoral\ Ethiopia} = \beta_{Crop-Livestock\ Kenya}$ versus $H_A^4 : \beta_{Agro-pastoral\ Ethiopia} \neq \beta_{Crop-Livestock\ Kenya}$

e) $H_0^5 : \beta_{Crop-Livestock\ Kenya} = \beta_{Pastoral\ Kenya}$ versus $H_A^5 : \beta_{Crop-Livestock\ Kenya} \neq \beta_{Pastoral\ Kenya}$

f) $H_0^6 : \beta_{Agro-pastoral\ Ethiopia} = \beta_{Pastoral\ Kenya}$ versus $H_A^6 : \beta_{Agro-pastoral\ Ethiopia} \neq \beta_{Pastoral\ Kenya}$

For instance, results from hypothesis test *d*, indicate that the crop livestock system in Kenya and agro-pastoral system in Ethiopia are statistically different and consequently should not be pooled together:

$L_{Agro-pastoral\ Ethiopia} = -365.9$ and $L_{Crop-livestock\ Kenya} = -691.3$.

$L_{Crop-livestock\ Kenya} + L_{Agro-pastoral\ Ethiopia} = -1057$, while the restricted

$L_{pooledcroplivestock+agropastoral} = -1221.6$ with a $\chi_7^2 = 329$ which is much larger than the critical value of 20.1 for the conventional one tailed test with probability of type I error of 1%. In the same way, the other hypotheses for preference stability have been rejected. Consequently, the conditional logit estimations have been done separately for the three systems.

Most of the trait coefficients for bulls' estimation in table 17 have the expected signs apart from purchase price which has an unexpected positive sign for the pooled sample and crop livestock system estimations. However, the coefficient is not statistically significant for the pooled sample but is significant for the crop-livestock production system estimation at the 5% level. The magnitude of the coefficients tends to vary by the type of production system. For instance, the traction trait coefficient for bulls in table 17 is positive and statistically significant for the cropping systems (crop-livestock and agro-pastoral systems), although it is strongly positive for the agro-pastoral system in Ethiopia relative to Kenya's crop-livestock system. This reflects the production system needs and the high contribution of good traction potential trait in bulls to the cropping system farmers' utility function. The result is in line with findings from Tano et al. (2003) where farmers practicing mixed crop-livestock production have a high preference for good traction potential in bulls relative to milk and beef systems. The mixed crop-livestock farmers produce both food and cash crops and use bulls for ploughing crop fields. Zander et al. (2005) also find similar results in their Ethiopian study where agro-pastoral system farmers have higher preference for good traction potential in bulls relative to the pastoralists. Trypanosomosis trait coefficient is statistically significant for both bulls and cows estimation in tables 17 and 18 and has the expected positive sign across all production systems, indicating that respondents prefer trypanotolerant cattle relative to trypanosusceptible ones.

In the pastoral systems, trait coefficients associated with fecundity, that is, fertility in bulls and reproduction potential in cows are strongly positive and significant as tables 17 and 18 indicate. This may be attributed to high preference for large herd sizes in pastoral systems, given that fecundity traits have a positive impact on herd increase. The trait coefficient for live-weight is positive and strongly significant for bulls in crop-livestock and pastoral systems in Kenya, reflecting preference for heavy bulls, while for the cow estimations, it is statistically significant for the pastoral system only. Preference for heavy bulls/cows in the Kenyan sites may be due to the high market prices usually associated with heavy cattle with good body condition (Aklilu et al., 2002).

Table 17: Maximum likelihood estimates from choice experiment for bulls, conditional logit

	Production system			
Bulls Traits	Pooled	Crop-livestock	Agro-pastoral	Pastoral
Trypanosomosis	0.341***	0.446***	0.472***	0.593***
	(0.029)	(0.047)	(0.101)	(0.090)
Purchase price (US$)	0.016	0.095**	-0.371	-0.037
	(0.034)	(0.043)	(0.234)	(0.070)
Low watering frequency	0.091***	0.093**	0.092	0.093
	(0.029)	(0.046)	(0.088)	(0.083)
Moderate watering frequency	0.073	0.078	0.076	0.072
	(0.082)	(0.091)	(0.083)	(0.078)
Coat color	0.053**	0.053	-0.063	0.060
	(0.024)	(0.038)	(0.063)	(0.066)
Fertility	0.289***	0.191***	0.024	0.987***
	(0.025)	(0.038)	(0.068)	(0.085)
Live-weight in Kg	0.118***	0.142***	0.004	0.200***
	(0.024)	(0.035)	(0.062)	(0.071)
Traction	0.714***	0.557***	1.649***	0.100
	(0.031)	(0.048)	(0.103)	(0.082)
Constant	-2.477***	-1.867***	-2.812***	-3.349***
	(0.161)	(0.239)	(0.412)	(0.598)
Log-likelihood function	-1701.987	-691.323	-365.985	-262.814
N	2783	1012	1177	594
Hausman test statistic (restricted alternative 1(χ^2 (8)) = 114.5 *p*-value = 0.0000				
Hausman test statistic (restricted alternative 2 (χ^2 (8)) = 59.3 *p*-value = 0.0000				

***, **, * indicate that coefficients are statistically significant at the 1, 5 and 10 % levels, respectively, using P-values in maximum likelihood estimation. Robust standard errors in parenthesis.

Purchased feed supplements coefficient for cows in table 18 is negative across the production systems albeit statistically significant for the crop-livestock and pastoral production systems only. This reveals the reluctance of cattle keepers to have cows that require externally purchased feed inputs. This may be attributed to financial resource constraints faced by the households.

Table 18: Maximum likelihood estimates from choice experiment for cows, conditional logit

	Production system			
Cows Traits	Pooled	Crop-livestock	Agro-pastoral	Pastoral
Trypanosomosis	0.786***	0.649***	1.179***	0.489***
	(0.031)	(0.048)	(0.066)	(0.063)
Purchase price (US$)	-0.011*	0.012	-0.011	0.025**
	(0.007)	(0.009)	(0.023)	(0.012)
Milk yield	0.224***	0.254***	0.261***	0.309***
	(0.026)	(0.041)	(0.055)	(0.057)
Reproduction	0.363***	0.295***	0.439***	0.420***
	(0.030)	(0.045)	(0.064)	(0.060)
Purchase feed	-0.228***	-0.403***	-0.014	-0.340***
supplements	(0.031)	(0.048)	(0.068)	(0.065)
Low watering frequency	0.154***	0.140**	-0.030	0.196**
	(0.039)	(0.058)	(0.094)	(0.083)
Moderate watering	0.098	0.093	0.097	0.096
frequency	(0.137)	(0.110)	(0.156)	(0.114)
Coat color	-0.030	-0.063	-0.009	-0.040
	(0.030)	(0.043)	(0.073)	(0.064)
Live-weight in Kg	0.049	0.005	0.135	0.388***
	(0.054)	(0.089)	(0.098)	(0.127)
Constant	-2.315***	-1.464***	-3.440***	-0.935**
	(0.195)	(0.306)	(0.477)	(0.464)
Log-likelihood function	-1788.483	-820.655	-412.041	-431.001
N	3036	1188	1164	684
Hausman test statistic (restricted alternative 1 (χ^2 (9)) = 115.7 p-value = 0.0000				
Hausman test statistic (restricted alternative 2 (χ^2 (9)) = 159.5 p-value = 0.0000				

***, **, * indicate that coefficients are statistically significant at the 1, 5 and 10 % levels, respectively, using P-values in maximum likelihood estimation. Robust standard errors in parenthesis.

The constant variable in the model results in tables 17 and 18 represent the “no buy” choice alternative, which is the base for the choice model, as it is associated with “zero” utility. It takes a value of one if the option is “no buy” and zero otherwise. The results indicate a strong negative preference for this option, implying that the respondents preferred to select the other two choice alternatives associated with various trait levels.

5.3.1.1 Simulation Results from Conditional Logit Estimates

Simulations have been performed using the conditional logit estimates in tables 17 and 18 as a basis of comparison to test how changes in the trait levels impact upon the choice probabilities for each of the alternatives across the production systems. This provides a useful indicator of the trait levels that are important drivers of choice. Table 19 presents simulation results for bulls if trypanosomosis trait is changed to -1, representing the trypanosusceptible level.

Table 19: Simulations of probability model for trypanosomosis

Choice	Base		Scenario		Scenario-Base	
	% Share	Number	% Share	Number	Δ Share	Δ Number
Pastoral system						
Option1	47.73	284	47.61	283	-0.12%	-1
Option2	51.59	306	51.22	304	-0.38%	-2
No-buy	0.67	4	1.17	7	0.50%	3
Total	100.00	594	100.00	594	0.00%	0
Crop-livestock system						
Option1	49.88	505	49.78	504	-0.09%	-1
Option2	46.96	475	45.39	459	-1.57%	-16
No-buy	3.16	32	4.82	49	1.66%	17
Total	100.00	1012	100.00	1012	0.00%	0
Agro-pastoral system						
Option1	52.28	615	52.51	618	0.23%	3
Option2	45.60	537	44.65	526	-0.95%	-11
No-buy	2.12	25	2.84	33	0.71%	8
Total	100.00	1177	100.00	1177	0.00%	0

Source: Survey data

The results indicate an estimated share increase for the no-buy alternative of 1.2% up from 0.7% for the pastoral system, 4.8% up from 3.3% for the crop-livestock system and 2.8% up from 2.1% for the agro-pastoral system, all other factors held constant. Thus, a change in the trypanosomosis trait to trypanosusceptible level is predicted to result in 0.5% switches from other alternatives to the no-buy alternative in the pastoral systems and 1.7 and 0.7% in the crop-livestock and agro-pastoral systems respectively. This translates to 28 choice-switches to the no-buy alternative if trypanosomosis trait has only one level, representing trypanosusceptibility, that is, trypanosomosis =-1. Choice switches to the no-buy alternative are predicted to be even higher for the cropping systems if trypanosomosis=-1 and traction=-1 concurrently (trypanosusceptible bull which also has poor traction ability), all other factors held constant. Table 20 presents the simulation results.

Table 20: Simulations of probability model for trypanosomosis and traction potential

Choice	Base		Scenario		Scenario-Base	
	% Share	Number	% Share	Number	Δ Share	Δ Number
Pastoral system						
Option1	47.73	284	47.59	283	-0.14%	-1
Option2	51.59	306	51.10	304	-0.49%	-2
No-buy	0.67	4	1.30	7	0.63%	3
Total	100.00	594	100.00	594	0.00%	0
Crop-livestock system						
Option1	49.88	505	46.45	470	-3.43%	-35
Option2	46.96	475	44.45	450	-2.51%	-25
No-buy	3.16	32	9.09	92	5.94%	60
Total	100.00	1012	100.00	1012	0.00%	0
Agro-pastoral system						
Option1	52.28	615	35.34	416	-16.93	-199
Option2	45.60	537	35.85	422	-9.75	-115
No-buy	2.12	25	28.81	339	26.68	314
Total	100.00	1177	100.00	1177	0.00	0

Source: Survey data

The results indicate predictions of 0.6% switches to the no-buy alternative for the pastoral systems compared to 5.9% in the crop-livestock system and a substantial 27% in the agro-pastoral system. This indicates that good traction potential is an important driver of choice in the cropping systems, especially in agro-pastoral systems of the Ghibe valley where initial 314 choices from other choice alternatives are predicted to switch to the no-buy alternative resulting from bull trait changes to both trypanosusceptible and poor traction potential levels, *ceteris paribus*.

Table 21 presents simulation results for changes in purchase price of bulls. A doubling of the purchase price is predicted to decrease the shares of the two choice alternatives in agro-pastoral systems by 1.4% which translates to 16 of the original 1,136 choices for the two alternatives switching to the no-buy alternative. In the pastoral and crop-livestock systems of Kenya, a doubling of the purchase price results in slight changes of the choice shares and reallocation to other choice alternatives. This implies that price is not an important determinant of choice, and high prices do not necessarily discourage choice but results in reallocations to other preferred choice alternatives.

Table 21: Simulations of probability model for purchase price

Choice	Base		Scenario		Scenario-Base	
	%Share	Number	%Share	Number	Δ Share	Δ Number
Pastoral system						
Option1	47.73	284	48.14	286	0.41%	2
Option2	51.59	306	51.12	304	-0.48%	-2
No-buy	0.67	4	0.74	4	0.07%	0
Total	100.00	594	100.00	594	0.00%	0
Crop-livestock system						
Option1	49.88	505	49.89	505	0.02%	0
Option2	46.96	475	47.62	482	0.66%	7
No-buy	3.16	32	2.48	25	-0.68%	-7
Total	100.00	1012	100.00	1012	0.00%	0
Agro-pastoral system						
Option1	52.28	615	51.39	605	-0.89%	-10
Option2	45.60	537	45.13	531	-0.47%	-6
No-buy	2.12	25	3.48	41	1.36%	16
Total	100.00	1177	100.00	1177	0.00%	0

Source: Survey data

This finding is in line with focus group discussion results during the baseline surveys in Kenya where group members indicated that good quality animals are the main determinants of choice even though the price may be high. This is because expensive, high quality animals may result in even higher returns to the cattle keeper since livestock have a capacity for value increase overtime through growth and reproduction. Table 22 presents simulation results if reproduction potential trait in cows=-1, representing low reproduction potential trait level (1 calf in 2 years).

Table 22: Simulations of probability model for reproduction potential

Choice	Base		Scenario		Scenario-Base	
	% Share	Number	% Share	Number	Δ Share	Δ Number
Pastoral system						
Option1	58.75	402	55.71	381	-3.04%	-21
Option2	37.01	253	37.71	258	0.69%	5
No-buy	4.24	29	6.58	45	2.34%	16
Total	100.00	684	100.00	684	0.00%	0
Crop-livestock system						
Option1	56.82	675	53.47	635	-3.35%	-40
Option2	36.70	436	37.86	450	1.16%	14
No-buy	6.48	77	8.68	103	2.20%	26
Total	100.00	1188	100.00	1188	0.00%	0
Agro-pastoral system						
Option1	59.34	691	57.85	673	-1.55%	-18
Option2	39.83	464	40.99	477	1.17%	13
No-buy	0.77	9	1.16	13	0.38%	4
Total	100.00	1164	100.00	1163	0.00%	-1

Source: Survey data

The results indicate predictions of 2.3% and 2.2% switches to the no-buy alternative for the pastoral and crop-livestock production systems respectively. However, for the agro-pastoral systems, it results in only 0.4% switches to the no-buy alternative. An examination of the simulation results for low milk yield in cows (milk yield = -1) presented in table 23 reveals similar results. For the pastoral and crop-livestock systems, simulation of choices for low milk yield results in 1.7% and 2.1% switches to the no-buy alternative respectively, while for the agro-pastoral system, this results in only 0.3% switches to the no-buy alternative. This indicates that reproduction potential and milk yield in cows may not be important drivers of choice for the agro-pastoral system, where only about 4 initial choices from other alternatives are predicted to switch to the no-buy alternative, *ceteris paribus*.

Table 23: Simulations of probability model for milk yield

Choice	Base		Scenario		Scenario-Base	
	%Share	Number	%Share	Number	Δ Share	Δ Number
Pastoral system						
Option1	58.75	402	53.31	365	-5.44%	-37
Option2	37.01	253	40.71	278	3.69%	25
No-buy	4.24	29	5.98	41	1.74%	12
Total	100.00	684	100.00	684	0.00%	0
Crop-livestock system						
Option1	56.82	675	51.31	610	-5.51%	-66
Option2	36.70	436	40.13	477	3.43%	41
No-buy	6.48	77	8.56	102	2.08%	25
Total	100.00	1188	100.00	1189	0.00%	0
Agro-pastoral system						
Option1	59.39	691	57.34	667	-2.06%	-24
Option2	39.83	464	41.64	485	1.81%	21
No-buy	0.77	9	1.02	12	0.25%	3
Total	100.00	1164	100.00	1164	0.00%	0

Source: Survey data

5.3.1.2 Influence of Socio-Economic Characteristics on Trait Preferences

Several socio-economic variables have been interacted with the trait levels to assess their influence on trait preferences using conditional logit models. The results are presented in tables 24 and 25 for bulls and cows respectively. The results indicate statistical significance of some of the socio-economic characteristics. The number of education years of the household head and the age of the household head show positive significant interactions with trypanosomosis and bull traction potential traits at the 1% level of significance as indicated in table 24. This implies that more educated and older household heads tend to prefer trypanotolerant bulls with good traction potential. This is probably because the educated household heads are better able to conceptualize the benefits of trypanotolerance and good traction potential traits in bulls, such as the benefits that arise due to low production costs associated with trypanotolerant cattle. Similarly, older heads of households may have accumulated years of experience with trypanosomosis disease challenge and may also have a better understanding of the relationship between good traction potential and crop productivity.

Table 24: Conditional logit estimates for bulls with socio-economic factors

	Coefficient	Standard error	P-value
Number of education years of household head			
Trypanosomosis	0.0289	0.0092	0.0016
Traction	0.0268	0.0094	0.0045
Low watering frequency	-0.0037	0.0087	0.6736
Coat color	0.0030	0.0072	0.6757
Live-weight	-0.0005	0.0067	0.9392
Fertility	-0.0058	0.0073	0.4316
Constant	0.0802	0.0400	0.0448
Age of household head			
Trypanosomosis	0.0072	0.0025	0.0035
Traction	0.0178	0.0025	0.0000
Low watering frequency	-0.0012	0.0023	0.5996
Coat color	-0.0008	0.0019	0.6678
Live-weight	-0.0003	0.0018	0.8789
Fertility	-0.0014	0.0020	0.4673
Constant	-0.0067	0.0113	0.5544
Gender of household head(male=1, 0 otherwise)			
Trypanosomosis	-0.0206	0.1020	0.8401
Traction	0.4139	0.1035	0.0001
Low watering frequency	0.1193	0.1035	0.2491
Coat color	0.0276	0.0863	0.7488
Live-weight	-0.1247	0.0804	0.1207
Fertility	0.1270	0.0872	0.1454
Constant	-1.9313	0.5014	0.0001
Distance to the nearest market (Km)			
Trypanosomosis	0.0253	0.0108	0.0196
Traction	0.0347	0.0111	0.0017
Low watering frequency	0.0037	0.0090	0.6814
Coat color	-0.0041	0.0070	0.5525
Live-weight	-0.0021	0.0067	0.7574
Fertility	0.0016	0.0074	0.8253
Constant	-0.1017	0.0422	0.0160
Household income (US$)			
Trypanosomosis	-0.0035	0.0017	0.0400
Traction	-0.0066	0.0017	0.0001
Low watering frequency	0.0005	0.0018	0.7790
Coat color	-0.0013	0.0015	0.3842
Live-weight	0.0007	0.0014	0.5985
Fertility	0.0032	0.0015	0.0394
Constant	0.0021	0.0109	0.8441
Log likelihood function=-1336.919			
N=2783			

Source: Survey data

The significant and positive coefficient on the interaction term between traction potential in bulls and gender of the household head indicate that male household heads tend to prefer bulls with good traction potential relative to their female counterparts. This may be attributable to the bulkiness and weight of the animal drawn implements, restricting handling of the traction bulls or oxen to men. This is particularly striking since it has implications on availability and access of tillage power for female headed households and consequently on crop productivity. Concerns about access of female headed households to tillage power and its effects on crop productivity have been corroborated empirically in several studies in sub-Saharan Africa. For instance, Lawrence et al. (1993) find evidence of scarcity of tillage power by female headed households in a Lesotho/Swaziland study where such households have to rely on adult males in the household to do the cultivation for them. In the absence of adult household males, they are forced to cash hire, contract and sharecrop for ploughing services or use hand hoes which is very slow, thereby adversely affecting crop productivity. The constant (no-buy alternative) variable interacts significantly and negatively with gender of the household head, implying that male headed households are less likely to choose the no-buy option relative to the female headed households.

Distance to the nearest market centre show positive significant interaction with trypanosomosis and bull traction potential traits but negative interactions with the no-buy alternative as indicated in table 24. This shows that households far from market centers tend to prefer trypanotolerant bulls with good traction potential and are less likely to choose the no-buy choice alternative. This may be attributed to poor access to veterinary services and treatment drugs by households far from market centers, where such services are often available, thereby resulting in higher preference for disease tolerant traits. In developing countries, long distances translate into high transaction costs due to increased travel costs (Abdulai and Delgado, 1999). Koma (2003) reports results that tend to support the significance of distance to the nearest veterinary services on demand for animal health service providers. The results based on a study in Uganda reveal declining demand for animal health service providers in Uganda as distance increases.

Households with higher incomes tend to downplay adaptive traits such as trypanotolerance and good traction potential in bulls and tend to prefer highly fertile bulls as indicated by the negative and statistically significant coefficients representing interactions of household income with trypanosomosis and traction potential traits but positive significant interactions with the fertility trait. Such households may be able to afford treatment drugs for trypanosomosis and would therefore be willing to trade-off trypanotolerance for high fertility. Traction potential may not be an important trait for them especially if they do not practice cropping.

Table 25: Conditional logit estimates for cows with socio-economic factors

	Coefficient	Standard error	P-value
Number of education years of household head			
Trypanosomosis	0.0011	0.0067	0.8673
Milk yield	0.0054	0.0055	0.3305
Reproduction	-0.0075	0.0063	0.2331
Purchase feed supplements	-0.0077	0.0065	0.2364
Low watering frequency	0.0019	0.0082	0.8124
Coat color	0.0050	0.0062	0.4159
Live-weight (Kg)	0.0040	0.0115	0.7279
Constant	0.0414	0.0408	0.3091
Age of household head			
Trypanosomosis	0.0023	0.0017	0.1790
Milk yield	0.0007	0.0014	0.6459
Reproduction	0.0013	0.0016	0.4230
Purchase feed supplements	-0.0039	0.0017	0.0199
Low watering frequency	0.0004	0.0021	0.8517
Coat color	-0.0020	0.0015	0.1864
Live-weight (Kg)	-0.0033	0.0030	0.2726
Constant	-0.0227	0.0108	0.0350
Gender of household head (male=1, 0 otherwise)			
Trypanosomosis	0.3578	0.0774	0.0000
Milk yield	0.0671	0.0690	0.3306
Reproduction	0.1405	0.0753	0.0620
Purchase feed supplements	-0.0637	0.0777	0.4122
Low watering frequency	0.1492	0.0973	0.1251
Coat color	0.0754	0.0728	0.3004
Live-weight (Kg)	0.1481	0.1516	0.3284
Constant	-1.2904	0.5066	0.0109
Distance to the nearest market (Km)			
Trypanosomosis	0.0270	0.0074	0.0002
Milk yield	0.0039	0.0059	0.5114
Reproduction	0.0153	0.0071	0.0315
Purchase feed supplements	-0.0138	0.0070	0.0483
Low watering frequency	-0.0099	0.0099	0.3172
Coat color	0.0013	0.0075	0.8619
Live-weight (Kg)	0.0064	0.0107	0.5510
Constant	-0.1614	0.0513	0.0017
Household income (US$)			
Trypanosomosis	-0.0074	0.0015	0.0000
Milk yield	0.0045	0.0016	0.0055
Reproduction	0.0010	0.0014	0.4909
Purchase feed supplements	-0.0020	0.0018	0.2635
Low watering frequency	0.0008	0.0022	0.7132
Coat color	-0.0017	0.0018	0.3551
Live-weight (Kg)	0.0067	0.0040	0.0924
Constant	0.0359	0.0133	0.0069
Log likelihood function=-1741.774			
N=3036			

The socio-economic characteristics interactions with cow traits in table 25 indicate negative interactions of age of the household head with purchased feed supplements trait and the no-buy choice alternative. This implies that older people are reluctant to have cows that require externally purchased feed inputs. This is probably because the older household heads may be more financially constrained relative to the younger household heads and therefore display a positive marginal utility for money. Scarpa et al. (2003b) also find positive interactions between respondents' age and marginal utility for money which increases with age at a slowly decreasing rate.

Households far from market centers display a positive marginal utility for income as indicated by the negative interaction coefficient of the distance to the nearest market and purchase feed supplements trait. They are less likely to choose the no-buy choice alternative and tend to prefer trypanotolerant cows with high reproduction potential. Household income on the other hand, interacts significantly and negatively with trypanosomosis just like in the case for bulls in table 24. However, it interacts positively and significantly with milk yield and live-weight traits. The constant term interaction is also significantly positive implying that high income households are likely to choose the no-buy alternative. This preference structure indicates that high income households may afford trypanosomosis treatments and may be willing to trade-off trypanotolerance for productive traits such as milk yield and live-weight. The different cattle trait preference patterns exhibited through interactions with socio-economic characteristics in tables 24 and 25 are indicative of the potential sources of preference heterogeneity.

Some of the traits have been interacted with the GIS-derived market access indicators for the Kenyan data set to examine their impacts. The results are presented in table 26. The variable, travel time to the nearest large urban centre, shows positive significant interactions with live-weight, fertility and reproduction traits. However, it has a negative and significant interaction with the traction and milk yield traits. This shows that households with poor market access tend to prefer fecundity and high live weight traits and are least likely to prefer bulls with good traction potential and cows with high milk yield. The negative interaction effect on traction trait may imply poor access to cropping inputs and outlets for the crop products. Since the pastoral systems have lower market access relative to the crop-livestock system on average, the negative preference for traction trait may result from harsh agro-climatic conditions rendering crop production unfeasible. The negative interaction effect with milk yield trait in cows may be attributed to the perishable nature of milk, rendering it costly for households far from large demand centers such as urban centers to market surplus milk production. This may be different for meat production where there are possibilities of selling live-animals at the farm gate to livestock traders to avoid the high transport, handling and transactions costs that would otherwise be involved if sales are made directly to the slaughter houses. Transport constitutes a major cost factor in livestock trading. In Kenya, Aklilu et al. (2002) indicate that 25 to 40% of the total cost of livestock brought to terminal markets from the Northern pastoral areas accounts for transport, since truck owners charge more for livestock than consumer goods. Due to the high transactions costs, producer prices tend to be relatively low. Some livestock traders have tried to avoid the high transport costs by trekking the cattle to the markets. However, this often results in animal weight loss and reduced prices (*ibid.*).

Table 26: Conditional logit estimates for bulls and cows with market access factors

	Coefficient	Standard error	P-value
Bulls			
Travel time to nearest large urban centre			
Trypanosomosis	-0.0408	0.1162	0.7252
Traction	-0.5927	0.1103	0.0000
Live-weight	0.1635	0.0597	0.0062
Fertility	0.4980	0.0944	0.0000
Human population density			
Trypanosomosis	0.0021	0.0021	0.3146
Traction	0.0032	0.0020	0.1072
Live-weight	-0.0002	0.0012	0.8604
Fertility	-0.0049	0.0019	0.0099
Constant	-1.5740	0.3463	0.0000
Log likelihood function = -310.8			
N = 1606			
Cows			
Travel time to nearest large urban centre			
Trypanosomosis	0.0470	0.0700	0.5022
Milk yield	-0.1547	0.0692	0.0253
Reproduction	0.3736	0.0732	0.0000
Human population density			
Trypanosomosis	0.0019	0.0015	0.1933
Milk yield	0.0027	0.0014	0.0640
Reproduction	0.0036	0.0015	0.0186
Constant	-2.2388	0.1580	0.0000
Log likelihood function =-507.5			
N = 1872			

The human population density variable interacts negatively and significantly with fertility in bulls and positively with reproduction potential and milk yield in cows. The positive interaction with milk yield is expected since high human population density within the cattle keepers' neighborhood provides a potential market for milk and its products. The negative interaction with fertility trait in bulls may be due to problems of uncontrolled breeding if the human population density is high, especially if communal grazing is practiced.

5.3.2 Mixed Logit Estimation Results

The Independence of Irrelevant Alternatives (IIA) test procedure developed by Hausman and McFadden (1984) has shown IIA violations for both bulls' and cows' conditional logit estimations at the 1 percent level. Simulated maximum likelihood estimates for the flexible mixed logit model that allows correlated random parameters using 100 Halton draws are reported in tables 27 and 28 for bulls and cows, respectively. A zero-based, asymptotic *t*-test for individual parameter standard deviations have been used, following Hensher et al. (2005) to determine the set of random parameters in the model. From this, the traits; trypanosomosis, traction, fertility, live-weight, purchase price, feeding requirement, and reproduction have been entered as random parameters in the mixed logit estimations, while watering frequency and coat color have been entered as fixed. The random parameters with the exception of purchase price are assumed to be drawn from a multivariate normal distribution with vector mean, b and variance-covariance matrix, Ω. This allows for correlations since some coefficients are generally expected to be correlated. For instance, cattle keepers who have preference for trypanotolerant animals may also have preference for high reproduction potential and milk yield for cows. This is because one of the impacts of trypanosomosis disease is low milk yield and poor reproduction potential. The coefficient vector is expressed as, $\beta_n = b + L\eta_n$, where L is a lower triangular Cholesky factor of Ω, such that $LL' = \Omega$ and η_n is a vector of independent draws from a standard normal density. The normal distribution allows coefficients of both signs.

The parameter trait "purchase price" is assumed to be drawn from a tented or triangular distribution. For traits with an explicit sign assumption such as cost parameters like purchase price, log-normal distributions have been widely used in past studies in order to constrain the sign of the coefficient to be negative. However, the drawback of the log-normal distribution is that it is characterized by a long tail, which potentially leads to overestimated expected values. In addition, there is very slow convergence of models using log-normally distributed coefficients. The triangular distribution overcomes the long-tail problems since it has the advantage of being bounded on either side (Hess et al., 2006). For a triangular distribution, if b is the center and s the spread, the density starts as b-s, rises linearly to b, and then drops linearly to *b+s*. The mean and mode are *b* while the standard deviation is spread/√6, hence the spread is standard deviation multiplied by √6.

A likelihood ratio test has been performed to test the null hypotheses that the conditional logit fits the data better than the mixed logit for both bulls and cows estimations. Given the likelihood ratio critical values of $\chi^2_{20,\,0.01} = 37.6$ and $\chi^2_{27,\,0.01} = 46.9$ for bulls and cows respectively, the null hypotheses are rejected with likelihood ratio test statistics of 941.8 and 846.4 for bulls and cows, respectively. This finding clearly indicates that mixed logit model which allows random taste variation fits the data better than the conditional logit model which assumes fixed taste parameters. Further, the mixed logit model decreases the log-likelihood by 28% and 24% for bulls and cows respectively; from -1702 and -1788 in the conditional logit model down to -1231 and -1365 in the mixed logit for bulls and cows respectively, indicating a better model fit with mixed logit.

The mixed logit results for bulls presented in table 27 indicate a strong statistical significance of the mean coefficients of the bull traits apart from coat color and moderate watering frequency. The coefficients of the random parameters are of the expected signs and are all significant at the 1% level apart from purchase price which is significant at the 10% level. The model reveals preference for bulls that are trypanotolerant, cheap, highly fertile, have good traction potential and high live-weight. The mean coefficients in the mixed logit model are larger than the fixed coefficients in the conditional logit model presented in table 17. Revelt and train (1998) note that the large coefficient values often obtained from mixed logit estimates relative to the conventional logit reflects the fact that the mixed logit decomposes the unobserved portion of utility and normalizes parameters on the basis of part of the unobserved portion. For instance, if true utility is given by the mixed logit, $U_{njt} = bX_{njt} + \eta_n sX_{njt} + \varepsilon_{njt}$, the parameters *b* are normalized such that ε_{njt} has the appropriate variance for an extreme value error. The conventional logit treats utility as $U_{njt} = bX_{njt} + \xi_{njt}$ with *b* normalized such that ξ_{njt} has the variance of an extreme value error. The extreme value term in the conventional logit incorporates any variance in the parameters as well while for mixed logit, the variance in parameters is treated explicitly as a separate component of the error, $\eta_n sX_{njt}$, such that the remaining error, ε_{njt}, is net of this variance. This makes the variance in the extreme value component of the error term in the mixed logit lower than the variance in the error term of the conventional logit and the normalization makes the parameters in the conventional logit smaller in magnitude than those in mixed logit.

Table 27: Mixed logit model of bull trait preferences

	Coefficient	Standard Error	P-value
Random parameters in utility function			
Trypanosomosis	0.4556	0.0842	0.0000
Traction	1.6838	0.1302	0.0000
Fertility	0.3747	0.1209	0.0019
Live-kg	0.2772	0.0956	0.0037
Purchase price	-0.2319	0.1278	0.0695
Non-random parameters in utility function			
Low watering frequency	0.1831	0.0501	0.0003
Moderate watering frequency	0.1463	0.1645	0.2368
Coat color	-0.0278	0.0535	0.6035
Constant	-2.4696	0.2792	0.0000
Diagonal values in Cholesky matrix, L			
NsTrypanosomosis	0.6684	0.0812	0.0000
NsTraction	1.0789	0.1243	0.0000
NsFertility	0.4235	0.1344	0.0016
NsLive-kg	0.3301	0.0523	0.0000
TsPurchase price	0.5462	0.3073	0.0755
*Below diagonal values in L matrix. V = L*Lt*			
Traction:Trypanosomosis	0.9283	0.1338	0.0000
Fertility:Trypanosomosis	0.1571	0.1296	0.2254
Fertility:Traction	-0.5652	0.1108	0.0000
Live-kg:Trypanosomosis	0.0772	0.1027	0.4521
Live-kg:Traction	-0.0032	0.0656	0.9610
Live-kg:Fertility	-0.1353	0.0780	0.0828
Purchase price :Trypanosomosis	-0.2135	0.1265	0.0916
Purchase price :Traction	-0.2726	0.0891	0.0022
Purchase price:Fertility	0.3439	0.0903	0.0001
Purchase price:Live-kg	-0.1874	0.1091	0.0860
Standard deviations of parameter distributions			
Trypanosomosis	0.6684	0.0812	0.0000
Traction	1.4233	0.1181	0.0000
Fertility	0.7235	0.1053	0.0000
Live-kg	0.3650	0.0529	0.0000
Purchase price	0.3087[c]	0.2425	0.0018
Likelihood ratio test[a]	941.8 ($\chi^2_{20,0.01} = 37.6$)		
Log likelihood at start values (MNL)	-1701.9868		
Simulated log likelihood at convergence	-1231.072		
McFadden R^{2b}	0.277		
Halton draws	100		
Number of observations	2783		

[a] The likelihood ratio test is given by $2(L_\Omega - L_\omega)$, where L_Ω is the unrestricted maximum log-likelihood from the mixed logit estimation and L_ω is the restricted maximum log-likelihood from the multinomial logit estimation. It has an asymptotic $\chi^2(k)$ distribution where k is the number of required restrictions.
[b] McFadden R^2 is computed as $R^2 = 1 - L_{\Omega/}\ L_\omega$
[c] The value from the model estimates are spread values. Reported standard deviation is calculated as spread/√6

Associated with each of the mean coefficient estimates of the random parameters are derived standard deviations calculated over the *R* Halton draws, indicating the amount of spread that exists around the sample population. At first sight, the standard deviations of all random parameter coefficients in table 27 are highly significant, indicating that the coefficients are indeed heterogeneous in the population. This implies that different individuals possess individual-specific parameter estimates that may be different from the sample population mean parameter estimate. However, the standard deviations of the random parameters may not be independent if the parameters are correlated. Under such conditions, the independent standard deviation contribution of each random parameter would need to be estimated. The non-random parameter, low watering frequency is positive and highly significant, implying that there is preference for bulls that are drought tolerant. The constant parameter representing the no-buy option is also negative and strongly significant like in the conditional logit model, indicating a negative preference for this option.

Similar to the bull mixed logit parameter estimates, the mean coefficient estimates for the random parameters for cow traits in table 28 are significantly different from zero at the 1% level apart from purchase price and live-weight which are significant at the 5% level. The results indicate preference for cows that are cheap, trypanotolerant, have high milk yield and high reproduction ability. Cows that need supplementary purchased feeds are not preferred, as indicated by the negative coefficient on feeding requirement. Just like the case for bulls, the non-random parameter, low watering frequency is positive and highly significant, implying that there is preference for cows that are drought tolerant. The constant parameter is also negative and strongly significant indicating a negative preference for the “no-buy” alternative. The standard deviations are also highly significant, implying that the coefficients are heterogeneous in the population.

Table 28: Mixed logit model of cow trait preferences

	Coefficient	Standard Error	P-value
Random parameters in utility function			
Purchase price	-0.0327	0.0157	0.0366
Trypanosomosis	1.6229	0.1237	0.0000
Purchase feed supplements	-0.4865	0.0986	0.0000
Milk yield	0.4508	0.0849	0.0000
Reproduction ability	0.4686	0.0959	0.0000
Live-kg	0.2490	0.1266	0.0491
Non-random parameters in utility function			
Low watering frequency	0.1310	0.0651	0.0440
Moderate watering frequency	0.1960	0.2743	0.3520
Coat color	-0.0591	0.0520	0.2558
Constant	-3.0727	0.3716	0.0000
Diagonal values in Cholesky matrix, L			
TsPurchase price	0.2504	0.0329	0.0000
NsTrypanosomosis	0.7070	0.1087	0.0000
NsPurchase feed supplements	0.4132	0.0952	0.0000
NsMilk yield	0.2764	0.0716	0.0001
NsReproduction ability	0.2699	0.1128	0.0167
NsLive-kg	0.0398	0.1404	0.7769
*Below diagonal values in L matrix. V = L*Lt*			
Trypanosomosis:Purchase price	2.3705	0.2802	0.0000
Feed supplements: Purchase price	-0.5237	0.2416	0.0302
Feed supplements:Trypanosomosis	-0.4122	0.1002	0.0000
Milk yield:Purchase price	-0.3810	0.1835	0.0379
Milk yield:Trypanosomosis	0.0581	0.0930	0.5323
Milk yield: Feed supplements	0.2066	0.0863	0.0166
Reproduction ability:Purchase price	-0.5762	0.2181	0.0082
Reproduction ability:Trypanosomosis	0.1677	0.1104	0.1288
Reproduction ability: Feed supplements	0.1786	0.0952	0.0608
Reproduction ability:Milk yield	0.3778	0.0913	0.0000
Live-kg: Purchase price	-0.6524	0.3201	0.0416
Live-kg: Trypanosomosis	-0.4284	0.1153	0.0002
Live-kg: Feed supplements	-0.3837	0.1154	0.0009
Live-kg: Milk yield	0.1292	0.1200	0.2818
Live-kg:Reproduction	0.1292	0.1200	0.2818
Standard deviations of parameter distributions			
Purchase price	0.1022	0.0329	0.0000
Trypanosomosis	2.4737	0.2702	0.0000
Feed supplements	0.7842	0.1808	0.0000
Milk yield	0.5173	0.1550	0.0008
Reproduction ability	0.7795	0.1742	0.0000
Live-kg	0.8896	0.2374	0.0002
Likelihood ratio test[a]	846.4 ($\chi^2_{27,0.01} = 46.9$)		
Log likelihood at start values (MNL)	-1788.483		
Simulated log likelihood at convergence	-1365.306		
McFadden R^{2b}	0.237		
Halton draws	100		
Number of observations	3036		

[a] The likelihood ratio test is given by $2(L_\Omega - L_\omega)$, where L_Ω is the unrestricted maximum log-likelihood from the mixed logit estimation and L_ω is the restricted maximum log-likelihood from the multinomial logit estimation. It has an asymptotic $\chi^2(k)$ distribution where k is the number of required restrictions.
[b] McFadden R^2 is computed as $R^2 = 1 - L_{\Omega /} L_\omega$

Rearrangement of the elements of the variance-covariance matrix reveals several numerically large correlations between the random parameters. The correlation matrix for the random parameters is presented in table 29. Traction coefficient for bulls is strongly negatively correlated to the fertility and purchase price coefficients but positively correlated to the live-weight coefficient. This suggests that cattle keepers who value traction potential in bulls are also likely to prefer heavy bulls and exhibit a positive marginal utility for income. This may indeed be the preference structure for some cropping systems where traction bulls are castrated in order to gain weight and to be more effective for draft purposes. The trypanosomosis coefficient is also strongly positively correlated to the traction coefficient. Purchase price coefficient is negatively correlated to trypanosomosis, traction and live-weight coefficients but positively correlated to fertility. This indicates that marginal utility for income is positively correlated with preference for trypanotolerance, traction ability and high live-weight but negatively correlated with preference for fertile bulls.

Table 29: Correlation matrix for random parameters for bulls and cows

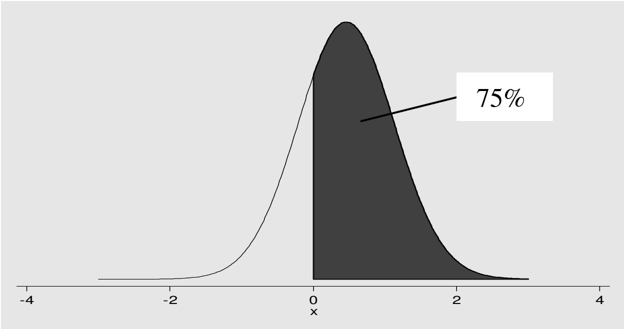
	Trypanosomosis	Traction	Fertility	Live-kg	Price	
Bulls						
Traction	.65224	1.00000				
Fertility	.21717	-.45049	1.00000			
Live-kg	.21164	.13138	-.16409	1.00000		
Price	-.28237	-.45751	.48659	-.44927	1.00000	
Cows	Price	Trypanosomosis	Purchased feed	Milk yield	Reproduction	Live-kg
Trypanosomosis	0.9583	1.0000				
Purchased feed supplements	-0.6678	-0.7902	1.0000			
Milk yield	-0.7364	-0.6736	0.6432	1.0000		
Reproduction	-0.7392	-0.6469	0.5013	0.9190	1.0000	
Live-kg	-0.7333	-0.8404	0.5156	0.3913	0.4603	1.0000

Interestingly, purchase price coefficient for cows is strongly positively correlated to trypanosomosis coefficient and negatively correlated with feeding requirement, milk yield, reproduction ability and live-weight coefficients. This suggests that marginal utility for income is positively correlated with preference for cows that need to be fed on externally purchased feeds, high milk yielding, high live-weight and good reproduction ability but negatively correlated with preference for trypanotolerance. This may indeed be the preference structure for some segments of the population where trypanosomosis prevalence is relatively low and there is preference for a more market-oriented production where returns may be used to meet treatment costs associated with trypanosomosis while still making some profit.

The Cholesky decomposition matrix[31] unconfounds the correlation structure over the random parameter estimates, making it possible to calculate the independent standard deviations associated with each random parameter. The significant below-diagonal elements in the Cholesky decomposition matrix for both bulls and cows estimations in tables 27 and 28 suggest significant cross-parameter correlations. The diagonal values in the Cholesky matrix L (where $L'L = \Omega$) are statistically significant for all random parameters at the 1% level for both bulls and cows apart from reproductive ability for cows and purchase price parameter which is significant at the 10% level for bulls and 5% level for cows. This implies that most of the random parameters are actually independently heterogeneous in the population. The magnitudes of the diagonal value parameters are much lower than their reported standard deviations, revealing possibilities of confoundment with other parameters. For instance, the diagonal value of live-weight parameter for cows, 0.0398 is not statistically significant but its standard deviation, 0.8896 is large and highly significant. The below diagonal values in the Cholesky matrix reveal that its significant standard deviation results from its significant cross-correlation with trypanosomosis, purchased feed supplements and purchase price parameters. Otherwise, its individual dispersion without the confoundment is not statistically significant implying lack of heterogeneity in the parameter estimate in the population, that is, all information in the distribution is captured within its mean. The actual standard deviation parameters have been recalculated by making use of the elements of the Cholesky decomposition matrix.

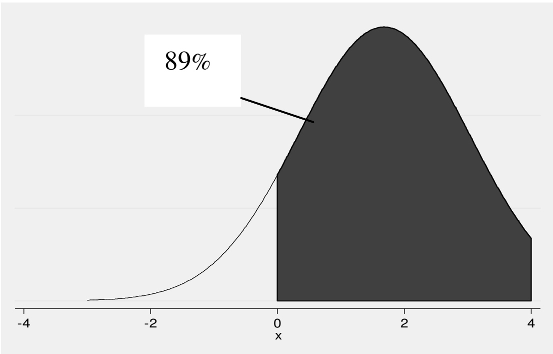
The estimated means and recalculated standard deviations of the random coefficients provide information on the shares of the population that place a positive or negative value on the bull and cow traits. This is obtained by calculating the proportion of observations covered by the standard deviation above and below the mean, for a normal distribution. Preferences for trypanotolerance trait and traction ability are skewed to the positive orthant, with 75% of the sample population preferring trypanotolerant bulls or cows as indicated in figure 15. A bull with good traction ability is preferred by 89% of the cattle keepers as presented in figure 16.

[31] The Cholesky matrix is a positive definite matrix. The diagonal values represent the amount of variance attributable to a random parameter when the correlations with subsequently named random parameters have been removed. The below diagonal values represent the amount of cross-parameter correlations which are confounded with the standard deviation parameters of the model (Hensher et al., 2005).



Trypanotolerance
Mean: 0.46
Standard deviation: 0.67

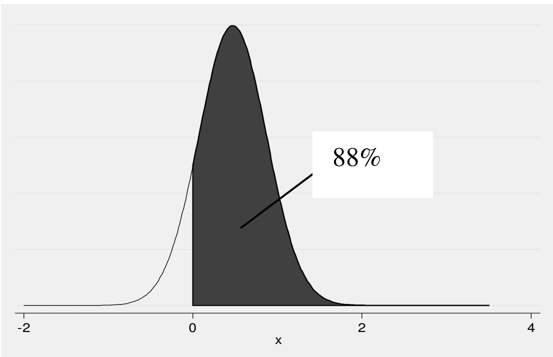
Figure 15: Preference distribution for trypanosomosis



Traction potential
Mean: 1.68
Standard deviation: 1.35

Figure 16: Preference distribution for traction

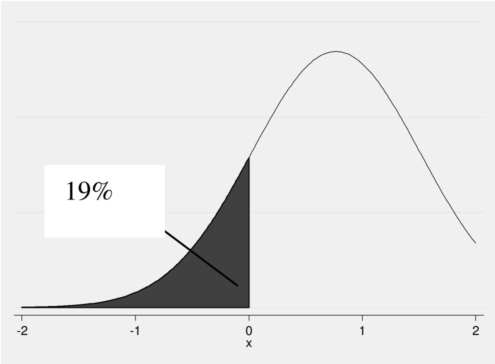
Figure 17 reveals preference for cows with high reproduction potential. Eighty eight percent of the population prefers cows that can calve down annually. The mean coefficient is 0.47 with a low standard deviation of 0.40.



Reproduction potential - cows
Mean: 0.47
Standard deviation: 0.40

Figure 17: Preference distribution for reproduction potential

The estimated mean and standard deviation coefficients for purchase price for bulls reveal that 19% of the distribution is below zero and 81% above zero as depicted in figure 18.



Purchase price – bulls
Mean: -0.23
Standard deviation: 0.26

Figure 18: Preference distribution for purchase price

This indicates that one-quarter of the population displays a negative marginal utility for income, implying that for this group, purchasing a bull may result in an increase in utility which outweighs the decrease in utility from spending monetary resources on the purchase of the animal. For cows, 37% of the population displays a negative marginal utility for income. A plausible interpretation for the seemingly irrational preference behavior is that cattle keepers may view the cost of purchasing cattle as a worthwhile expense, due to the multiple benefits associated with owning a cow or a bull. In addition, cattle ownership might be providing some of the same functions that monetary resources would provide, such as savings due to the potential of livestock to increase in value overtime through growth and reproduction.

5.3.3 Implicit Prices from Mixed Logit Estimates

Implicit trait prices from the mixed logit model have been derived using individual conditional constrained parameter estimates and are presented in table 30. The estimates are validated using the household level survey data and past studies. Estimates of WTP for trait parameters indicate that a trypanotolerant animal is valued at US$ 25 more than a trypanosusceptible one. This value compares well with the costs associated with treatment of trypanosomosis. The most commonly used drugs for prevention and cure of trypanosomosis in the field is Veriben®Sanofi or Berenil®Hoechst in double dose to clear infection at a price of US$ 1.58 per animal[32].

[32] Personal communication with Mwai Okeyo of the International Livestock Research Institute, Nairobi.

Table 30: Implicit price estimates of cattle traits in US$ from mixed logit models

Trait	$E(\beta_k / -\beta_p)$	Standard Deviation
Trypanotolerance	24.7	16.7
Good traction potential (bulls)	58.4	47.4
Watering frequency	6.8	0.8
Purchased feed supplements (cows)	-10.7	9.7
High fertility (bulls)	22.6	17.1
Live-weight (per 10Kg)	10.5	6.2
Reproduction potential (cows)	9.4	6.9
Milk production (cows)	8.1	5.5

According to the survey data, the average cost of treatment or control of trypanosomosis per year varies from US$ 6 to US$ 37 in the agro-pastoral systems of the Ghibe valley, while in Kenya it is an average of US$ 36 in crop-livestock systems but can be as high as US$219 in pastoral systems depending on the number of treatments per year. Therefore, the choice experiment estimate of US$ 25 appears plausible, although more information can be gained by assessing the distribution of the estimate in the population.

An adaptive boundary kernel density approach has been utilized to examine the distribution of the WTP for the various traits that have values that are inherently bounded from below by zero. The standard kernel density estimator has considerable bias near the support boundary at the origin and in general, assigns probability mass outside the support (Jones, 1993). Gaussian kernels with adaptive kernel density estimator that supports boundary correction for variables with bounded domain have been used to overcome the boundary effects problem and to take into consideration the bounded WTP traits variables. The adaptive kernel density estimator has less bias than the ordinary estimator as it adapts the amount of smoothing to the local density of the data. It is defined as;

$\hat{f}_K(x;h) = \frac{1}{W}\sum_{i=1}^{n}\frac{w_i}{h\lambda_i}K\left(\frac{x - X_i}{h\lambda_i}\right)$, where w_i are the associated weights, $W = \sum_{i=1}^{n} w_i$, K[.] is a kernel function, h is the smoothing parameter and λ_i are the local bandwidth factors (Jann, 2005).

The kernel density distributions in figures 19 to 22 provide useful information about the distributions of the implicit trait values. The distribution of WTP values for trypanotolerance presented in figure 19a, shows a bimodal distribution having two peaks at

US$ 19 and 36. This indicates presence of heterogeneity in trypanotolerance trait valuations. Although little is reported in the literature about valuation of trypanotolerance using stated preference methods, Tano et al. (2003) show that disease resistance can be ranked very highly under similar types of production system to those covered in this study.

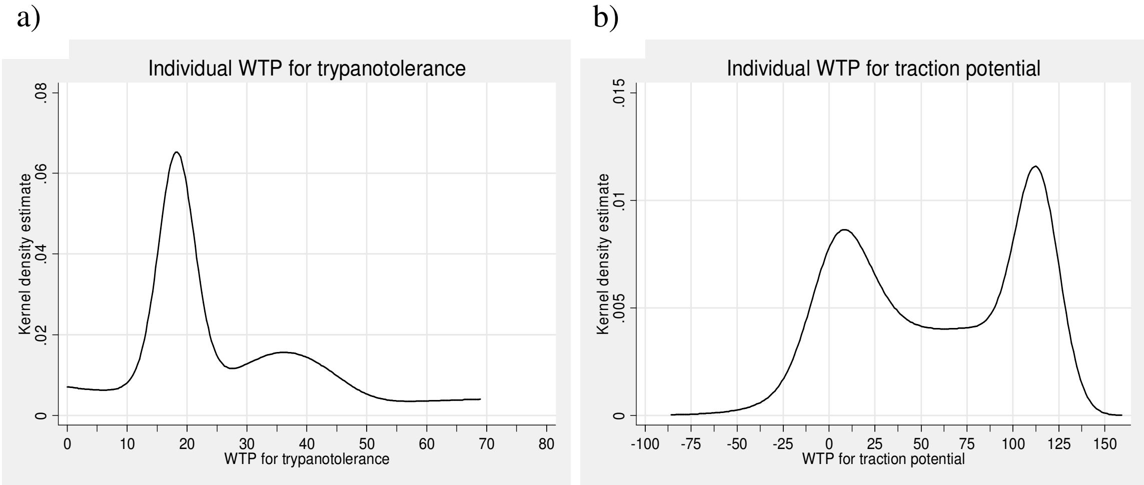
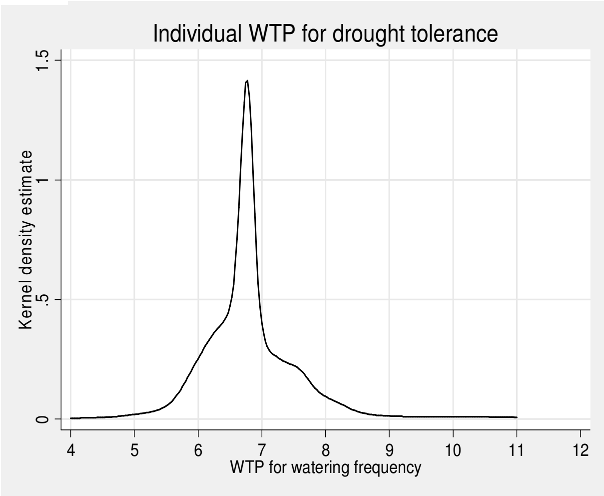


Figure 19: WTP kernel density plot for trypanotolerance and traction potential

The kernel density plot in figure 19b for traction potential also provides evidence of heterogeneous preferences for traction potential in bulls, indicated by the substantial negative values and the bimodal distribution density having two peaks above zero. The mean of the WTP distribution is US$ 58 for a bull with good traction potential. This finding is consistent with the finding by Tano et al. (2003) who found fitness to traction to be the highest ranked trait for bulls in West Africa. Zander et al. (2005) also find substantially high WTP trait value of 37 Euros (about US$ 44.4) for a Borana bull with good traction potential in Ethiopia from their choice experiment study. Fitness to traction has a direct link to crop production in crop-livestock systems and is one of the main reasons for keeping cattle. The draught animals are also an important source of revenue since their services can be hired off-farm. The negative WTP values for traction potential trait may be due to the negative preference for this trait by some pastoral communities who view use of cattle for draft power as a taboo.

An animal that needs to be watered only once every 2 days, used as a proxy for drought tolerance, is valued at US$ 6.8 more than one that needs to be watered twice per day. Water is a constraint in the study areas especially during the dry seasons; therefore there is preference for animals that can withstand drought. The kernel density distribution of WTP values for low watering frequency in figure 20a, is tight with values concentrated around the mean, indicating homogeneity in preference for this trait.

a) b)



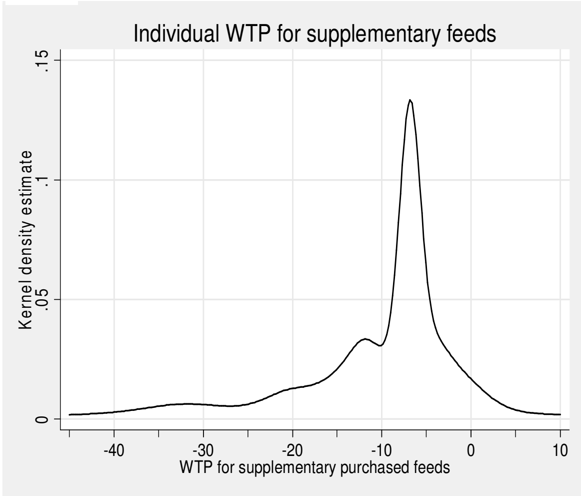


Figure 20: WTP kernel density plot for drought tolerance and supplementary feeding

The value of purchased supplementary feeds for cows that cattle keepers would be willing to accept as compensation for utility reduction is US$ 10.7. Cattle keepers are reluctant to raise cows requiring purchased supplementary feeds to boost milk production. Due to scarce financial resources, the cattle keepers prefer cattle that do not require externally acquired inputs. The kernel distribution associated with the implicit price for supplementary feeds in figure 20b, has a mean substantially in the negative range indicating significant aversion to this trait, though there is a small fraction in the positive orthant.

An important attribute in cows is the ability to calve every year instead of once in two years. The Zebu cattle breeds, kept by most of the respondents in the study sites tend to have relatively longer calving intervals of about 1.8 years. A calving interval trait of one year is valued at US$ 9.4 relative to one of two years while a cow with high milk production is valued at US$ 8.1 relative to one with low milk production. The kernel density distribution of WTP for milk yield and reproduction ability in figures 21a and 21b indicate large variance for positive values. Tano et al. (2003) find a comparable preference structure where cows with high reproduction potential are highly valued relative to those with high milk yield. This is probably because the cattle keepers in these systems are not market oriented but more subsistence oriented, consequently placing less emphasis on milk production for the market.

a) b)

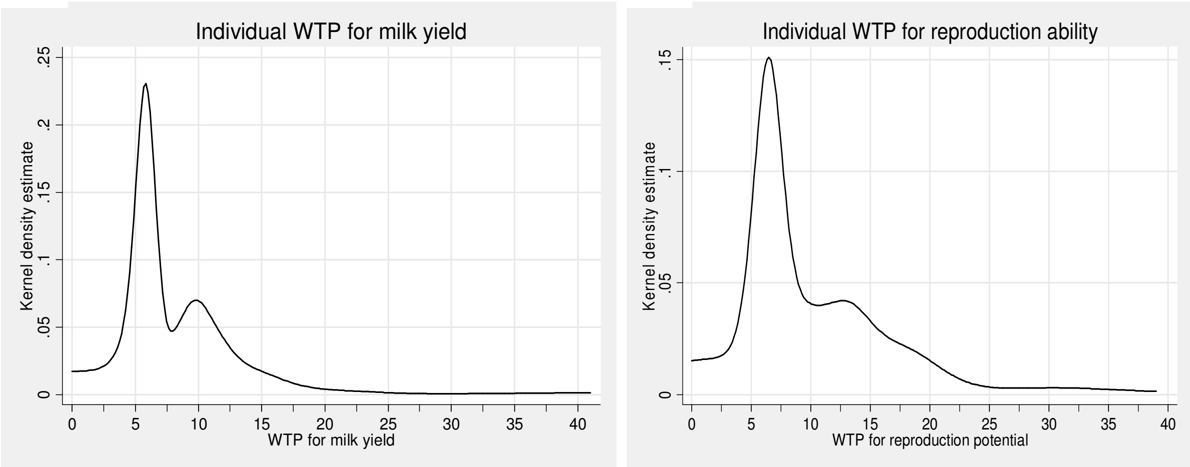


Figure 21: WTP kernel density plot for milk yield and reproduction potential in cows

Live-weight increase, which is associated with meat production, is valued at US$ 1.05 per Kg. This is close to the average slaughter weight of US$ 1.02 per kg found in Scarpa et al. (2003b) for a pastoral system in Kenya. In Kenya, the value of 1Kg of slaughter weight is approximately US$ 1.07 (Aklilu et al., 2002).

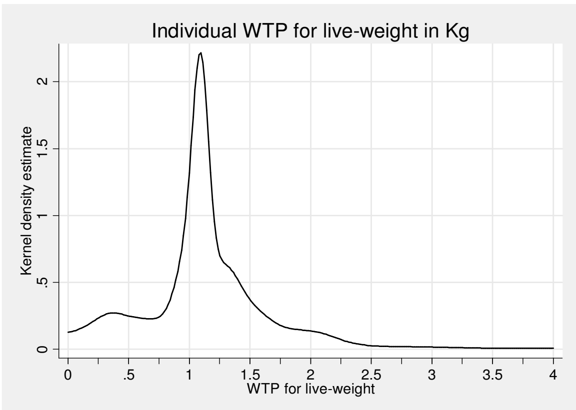


Figure 22: WTP kernel density plot for live-weight

The kernel density distribution of WTP values for live-weight in figure 22 is tight with values concentrated around the mean, indicating homogeneity in preference for this trait.

The mixed logit results indicate presence of preference heterogeneity for most of the traits. However, the sources of heterogeneity is better captured by using finite mixing through latent class modeling to assess possible existence of identifiable preference segments within the population and the factors influencing membership to each segment.

5.3.4 Latent Class Model Estimation Results

In order to determine the optimal number of latent classes for the latent class model estimation, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) proposed by Boxall and Adamowicz (2002) have been used. Latent class models for 1, 2, 3, 4 and 5 classes have been attempted. The 5-class model for cows failed to converge. Table 31 summarizes the aggregate statistics for these models.

Table 31: Determination of number of classes based on the converged latent class model[a]

No. of latent classes	No. of parameters (P)	Log likelihood (LL) at convergence	Log likelihood evaluated at (LL(0))	AIC[c]	BIC[d]	ρ^{2b}
Cows						
1	9	-1788.5	-3335.4	3594.9	1804.2	0.464
2	20	-1584.3	-3335.4	3208.7	1619.2	0.525
3	30	-1402.4	-3335.4	2864.8*	1454.6*	0.580
4	40	-1354.7	-3335.4	2789.3	1424.3	0.594
Bulls						
1	8	-1701.9	-3057.4	3419.9	1715.8	0.443
2	18	-1361.5	-3057.4	2758.9	1392.5	0.555
3	27	-1290.9	-3057.4	2635.9*	1337.4*	0.578
4	36	-1249.8	-3057.4	2571.7	1311.8	0.591
5	45	-1223.0	-3057.4	2536.1	1300.5	0.600

* Optimal number of latent classes.
[a] Sample size is 2,783choices for bulls and 3,036 for cows from a total of 506 individuals (N).
[b] ρ^2 is calculated as 1-(LL)/LL(0).
[c] AIC (Akaike Information Criterion) is calculated using {-2(LL-P)}.
[d] BIC (Bayesian Information Criterion) is calculated using {-LL+[(P/2)*ln(N)]}.

The log likelihood values at convergence reveal improvement in the model fitness as classes are added to the model, more so with 2, 3, and 4 classes for both cows and bulls. This is evident in the ρ^2 values which increase rapidly up to the 4 class model. Inspection of the AIC and BIC values suggest that the 3 class model for cows is more intuitive since the change in AIC and BIC values is markedly smaller for the 3 to 4 class model than the 1 to 2 and 2 to 3 class models. This suggests that adding an additional class beyond the 3rd may not be gaining much improvement. For bulls, a similar pattern is observed, where the change in AIC and BIC values is lower for the 3 to 4 and 4 to 5 class models compared to the 1 to 2 and 2 to 3 class models. Therefore, a three class latent class model for cows and bulls has been estimated. The maximum likelihood estimates for the latent class model for bulls and cows are reported in tables 32 and 33 respectively. A likelihood ratio test has been performed to test the null hypothesis that the conditional logit model fits the data better than the latent class model. The sample values of the likelihood ratios are 995.4 and 675.9 with a critical value of $\chi^2_{24,0.01} = 42.9$ and $\chi^2_{28,0.01} = 48.3$ for bulls and cow traits respectively, thus rejecting the null hypothesis. This implies that the latent class logit fits the data better relative to the conditional logit model.

The latent class model results indicate significant heterogeneity in preferences across latent classes as revealed by the differences in magnitude and significance of the utility function parameter estimates. For instance, table 32 indicates strongly positive trypanotolerance trait coefficient for class 3 in comparison to the other two classes while traction coefficient is strongly positive for class 1. The class membership coefficients for the third class have been normalized to zero in order to be able to identify the remaining coefficients of the model. The class membership coefficients for bulls and cows estimations indicate that the probability of being in a class is significantly related to the cattle keepers' production system. The decision on the covariates to be included in the model as determinants of class membership has been based on evaluations of likelihood ratio tests across competing models. Table 32 shows that 54% of the respondents who participated in the choice experiment for bulls have a fitted probability to belong to class 1. On the other hand, 27% and 19% of the respondents have a fitted probability to belong to class 2 and 3, respectively.

The estimation results in table 32 reveal that individuals in latent class 1 have a preference for bulls that are trypanotolerant, drought tolerant, highly fertile with good traction potential. They also show a low likelihood to choose the no-buy choice alternative. The class membership coefficient for the agro-pastoral system dummy variable is strongly positively significant at the 1% level, indicating that members of this class are likely to be agro-pastoralists. Class 2 membership coefficients for bulls indicate that members of this class are likely to be pastoralists, as indicated by the negative and statistically significant coefficients for agro-pastoral and crop-livestock systems dummy variables. The class is also associated with younger household heads with low levels of education and high income relative to class 3. Members of this class have a preference for bulls that are trypanotolerant, drought tolerant, highly fertile and with high live-weight. They also display a negative marginal utility for money as indicated by the positive and significant purchase price coefficient. Members of class 3 have preference for trypanotolerant bulls with high live-weight and good traction potential. They also display a negative marginal utility for money like members of class 2. This class may subjectively be associated with crop-livestock farmers.

Table 32: Maximum likelihood estimates of bull traits from latent class model

	Class 1	Class 2	Class 3
Utility function coefficients			
Trypanosomosis	0.2101***	0.2605***	1.1483***
	(0.0743)	(0.0476)	(0.0687)
Purchase price	-0.1089	0.0964**	0.0952**
	(0.1116)	(0.0422)	(0.0434)
Low watering frequency	0.1456**	0.1785***	0.0992
	(0.0746)	(0.0471)	(0.0684)
Coat color	-0.0399	0.0523	-0.0143
	(0.0642)	(0.0423)	(0.0555)
Live_kg	0.1040	0.2682***	0.1241**
	(0.0692)	(0.0386)	(0.0498)
Traction	1.6664***	0.0851*	0.5099***
	(0.0823)	(0.0480)	(0.0626)
Fertility	0.2322***	0.7916***	0.0099
	(0.0645)	(0.0366)	(0.0572)
Constant	-2.6555***	-1.8350***	-1.1524***
	(0.3512)	(0.2318)	(0.2498)
Class membership coefficients			
Constant	-1.2965	4.0756***	
	(1.2525)	(1.4888)	
EDUCYRS	-0.0028	-0.1307*	
	(0.0500)	(0.0788)	
HHAGE	0.0149	-0.0424*	
	(0.0165)	(0.0236)	
AGROPAST	3.2523***	-3.4592***	
	(0.9236)	(0.9821)	
CROPLIV	0.8570	-2.2791***	
	(0.9260)	(0.7600)	
HHINC (US$100)	-0.0433	0.0437***	
	(0.0304)	(0.0171)	
Number of observations	1474	770	528
Latent class probability	0.5394***	0.2719***	0.1886***
	(0.0332)	(0.0310)	(0.0276)
Log likelihood	-1204.281		
Number of groups	253		
Likelihood ratio test = 995.4 ($\chi^2_{0.99}(24) = 42.9$)			

[a] Standard errors in parentheses

[b] The likelihood ratio test is given by $2(L_\Omega - L_\omega)$, where L_Ω is the unrestricted maximum log-likelihood from the latent class logit estimation and L_ω is the restricted maximum log-likelihood from the conditional logit estimation. It has an asymptotic $\chi^2(k)$ distribution where k is the number of required restrictions.

Note: ***, **, * indicate that coefficients are statistically significant at the 1, 5 and 10 % levels, respectively, using P-values in maximum likelihood estimation.

Forty percent of the respondents who participated in the choice experiment for cows have a fitted probability to belong to class 1, while 51% and 9% have a fitted probability to belong to class 2 and 3 respectively as indicated in table 33. The class membership coefficients reveal that members of class 1 are likely to be agro-pastoralists as indicated by the strongly positive agro-pastoral system dummy. Members of this class have a lower income relative to class 3 members. This class has preference for cows that are trypanotolerant and with high reproduction ability. They display a positive marginal utility for money as indicated by the negative and strongly significant purchase price coefficient. Members of class 2 have preference for trypanotolerant cows with high milk yield. They have low preference for cows that need externally purchased feed supplements. The class membership coefficients for class 2 show that this class is likely to be associated with crop-livestock farmers, as indicated by the negative coefficients on pastoral and agro-pastoral system dummy variables. Members of this class also have a lower income relative to class 3 and practice some tsetse fly control measures to control trypanosomosis disease. Members of class 3 exhibit negative marginal utility for money and have preference for trypanotolerant and drought tolerant cows with high milk yield, high reproduction potential and high live-weight. They are reluctant to have cows that require externally purchased feed inputs. This class could subjectively be associated with being a pastoralist.

Table 33: Maximum Likelihood estimates of cow traits from latent class model

	Class 1	Class 2	Class 3
Utility function coefficients			
Trypanosomosis	2.1989***	0.9798***	0.3410***
	(0.1706)	(0.0912)	(0.0317)
Purchase price	-0.0756***	0.0123	0.0412***
	(0.0293)	(0.009)	(0.0067)
Milk yield	0.1944	0.2380***	0.4125***
	(0.1233)	(0.0736)	(0.0298)
Reproduction ability	0.4960***	0.0732	0.4864***
	(0.1481)	(0.0833)	(0.0266)
Purchase feed supplements	0.1505	-1.3381***	-0.3019***
	(0.1699)	(0.0976)	(0.0343)
Low watering frequency	-0.5464**	0.1368	0.1372***
	(0.2570)	(0.1046)	(0.0444)
Coat color	-0.1121	0.0377	-0.0424
	(0.1474)	(0.0719)	(0.0364)
Live_kg	0.1984	0.3574*	0.3718***
	(0.2264)	(0.2021)	(0.0721)
Constant	-5.1054***	0.8428	-2.4925***
	(0.9945)	(0.5398)	(0.3028)
Class membership coefficients			
Constant	-0.0038	-0.9184**	
	(0.3216)	(0.4545)	
AGROPAST	1.2205***	-1.9657**	
	(0.3589)	(1.0184)	
PASTORAL	-2.1813***	-0.5922	
	(0.6669)	(0.5562)	
HHINC (US$100)	-0.0341**	-0.0491*	
	(0.0155)	(0.0274)	
TSECONT	-0.0609	0.9857**	
	(0.3468)	(0.4890)	
N	1248	408	1368
Latent class probability	0.3998***	0.0900***	0.5101***
	(0.0318)	(0.0186)	(0.0328)
Log likelihood	-1362.695		
Number of groups	253		
Likelihood ratio test = 675.1 ($\chi^2_{0.99}(28) = 48.3$)			

[a] Standard errors in parentheses

[b] The likelihood ratio test is given by $2(L_\Omega - L_\omega)$, where L_Ω is the unrestricted maximum log-likelihood from the latent class logit estimation and L_ω is the restricted maximum log-likelihood from the conditional logit estimation. It has an asymptotic $\chi^2(k)$ distribution where k is the number of required restrictions.

Note: ***, **, * indicate that coefficients are statistically significant at the 1, 5 and 10 % levels, respectively, using P-values in maximum likelihood estimation.

Calculations of implicit prices of the traits across the latent classes show marked differences in preference structure as presented in table 34. Cattle keepers in class 1 attach a high value to good traction potential in bulls, which is even higher than the value they attach to trypanotolerance and high fertility in bulls. This is not totally unexpected since agro-pastoralists, the most likely members of this class consider draft power capacity in bulls for ploughing and threshing grains an important reason for keeping cattle. This is reflected in their herd composition, which is predominantly male stock. Reproductive potential in cows is also an important trait for this class, while milk production is not statistically significant, suggesting that the trait is not important for this class.

Table 34: Class-specific implicit prices of cattle traits (US$)

Trait	Class 1	Class 2	Class 3
Bulls			
Trypanotolerance	22.7 (15.1)[a]	29.6(7.6)	115.9(7.6)
Good traction	159.1 (27.7)	11.1 (6.9)	54.5 (6.4)
High fertility	23.4 (12.1)	81.4 (5.5)	NS[b]
Live-weight (per 10 Kg)	NS	27.9 (1.3)	13.5 (1.0)
Watering frequency	14.3 (4.5)	18.7 (1.1)	NS
Cows			
Purchased feed supplements	NS	-102.8 (11.5)	-8.4 (4.2)
High milk yield	NS	20.2 (17.2)	11.1 (7.8)
High reproduction potential	6.8 (0.8)	NS	13.3 (11.4)

[a] Standard deviations in parenthesis

[b] NS-trait not statistically significant

Class 2, mainly associated with pastoralists (for bull traits) exhibits a different preference structure from the other two classes. In this class, high fertility in bulls is a highly valued trait, while trypanotolerance and live-weight have the same weight. Traction fitness is not highly valued in this class, a finding that is in line with expectations, since pastoralists do not use cattle for traction. They are more concerned with obtaining larger herd sizes which is linked to high fertility trait in bulls. Besides prestige purposes, large herd sizes and accumulation of stock are important for pastoral communities as a strategy of balancing the high losses usually experienced during major droughts or disease outbreaks. Live weight increase is also an important trait for the pastoral system given that the system is an important source of meat for domestic consumption in sub-Saharan Africa, accounting for about 50% of local beef consumption (Institute of Policy Analysis and Research, 2004). However, the estimated value of US$2.79 per kg is much higher than the slaughter weight value of US$ 1.07 per kg. This may imply that the market value results in lower welfare values for the producers. This class also values drought tolerance in bulls. This is an important trait for the pastoral systems since water is an important constraint, especially during dry seasons. Class 2 for cow traits has been associated with crop-livestock farmers who exhibit negative preferences for cows that need supplementary purchased feeds and would be willing to accept up to US$ 103 as compensation for utility reduction. High milk production is highly valued in this class relative to class 3, though reproduction potential is not found to be significant for this class. This is probably because the system may be more milk market-oriented relative to the rest.

Class 3, comprising mainly of the crop-livestock farmers (for bull traits), place high value on trypanotolerant animals and bulls with good traction potential. The high valuations on trypanotolerant animals may be due to high levels of trypanosomosis prevalence in this system. Bulls are mainly used for ploughing crop fields in this system. High fertility in bulls is not a significant trait in this class. This class which is associated with pastoralists for the cow traits place almost equal values on high milk yield and high reproduction potential.

Chapter 6

Pathways for Cattle Keeping Households to Access Genetically Improved Cattle

6.1 Introduction

Cattle breed improvement programs have been identified as a potential pathway for improving cattle productivity by utilizing trypanotolerance trait and other preferred traits through organized breeding. The chapter discusses the alternative dissemination pathways of genetically improved livestock to cattle keepers and then focuses on communal livestock breeding initiatives based on collective action, since it provides a potentially sustainable pathway for poor cattle keepers to access improved livestock. The framework for collective action and factors influencing successful collective action is also discussed. The chapter also highlights the institutions that can be effectively involved in generation of improved livestock genetic materials.

6.2 Dissemination Pathways of Improved Livestock Genetic Materials

The basic practical step for a breed improvement program is to identify and select superior breeding animals to be used, based on the traits to be improved or introduced, and the production systems opportunities and constraints. The structure could be either in the form of a non-nucleus scheme or a nucleus scheme characterized by a herd of superior breeding animals. The superior breeding animals could be obtained by screening and selection within a particular breed that show high levels of trypanotolerance and also known to possess other desirable traits for on-station breeding or village based breeding schemes. Another alternative is through creation of a hybrid from crossing a trypanotolerant breed with another breed that contains other preferred traits such as high milk or meat production and traction potential. Developing a synthetic breed is a long-term process that needs many resources such as a large number of animals, detailed recording and analytical facilities (Rege et al., 2001). Therefore, development of synthetic breeds has often been carried out on one unit with many cattle, where feeding and management is likely to be better than in the field.

Selection of breeding animals from within the existing breeds in village herds for village based breeding schemes has been identified as a viable alternative to obtain breeding animals since the animals are already adapted to the environment (Van der Waaij, 2001; Sölkner et al., 1998). In such a case, there is no external breeding organization, and cows are selected from amongst the cows in the village and those can be mated to the best bulls in the village to breed the bulls for the next generation. The unselected bulls are castrated, sold or kept in a separate herd so that they cannot mate with the cows. Inbreeding can be prevented by exchange of bulls between villages. Village breeding programs are usually organized by communities at subsistence level, especially in low input systems and its advantage is the minimal dependency on external inputs (Bruns, 2000). The organizational level is usually low, and detailed data recording is often missing. The village breeding programs may only be practical in situations where the existing cattle herds in the village have the desired traits. A study being carried out by the International Livestock Research Institute in the Ghibe valley of Ethiopia has been continually monitoring some indigenous breeds of cattle for indicators of relative trypanotolerance[33]. The indigenous breeds have been identified as trypanotolerant by their owners and selected from within the village herds. Village level meetings have been carried out to introduce the essential breeding concepts and practices. The ultimate objective is to develop the initiative into a community-based breeding scheme in the Ghibe valley aimed at enhancing trypanotolerance (Ayalew et al., 2004). The success of such village based breeding schemes is dependent on access to advisory services and communities which are well organized to facilitate record keeping by setting up of simple recording schemes (Sölkner et al., 1998). Some of the economic studies that have focused on utilization of cattle trait preferences for design of breeding programs such as Tano et al (2003) have failed to address pertinent economic issues regarding appropriate intervention measures needed for breed improvement program sustainability. Lack of performance recording, common in developing countries partly because of low literacy levels is a major drawback to village-based breed improvement schemes, thus requiring appropriate intervention measures.

In nucleus breeding programs carried out by public or commercial breeding organizations, performance recording of the breeding animals is conducted at the nucleus. The cattle keepers can then access the improved genetic material through artificial insemination using semen from the superior breeding bulls from the nucleus herd or by buying the breeding bulls or pregnant cows which have been inseminated with semen from superior breeding bulls (Van der Waaij, 2001). In this way, there is a gradual increase in genetic potential. The use of artificial insemination by the cattle keepers in trypanosomosis-prone areas of Africa is however limited since the areas are remote and may not be accessible due to inadequate infrastructure. Electricity may not be available, making it difficult to store and distribute semen, which usually needs to be deep-frozen in liquid nitrogen. The alternative of

[33] Parasitaemia and Packed Red Cell Volume (PCV), together with clinical signs of ill-health and history of trypanocidal drug treatments, serve as indicators of relative trypanotolerance.

purchasing breeding bulls or pregnant cows may be limited to only a few cattle keepers who can afford it, locking out the more resource-constrained cattle keepers.

An alternative pathway for cattle keepers who cannot individually afford to purchase breeding animals from a nucleus herd is through communal based initiatives based on collective action. This has been identified in economic literature, (e.g. Wollny, 2003) as a potential pathway to access improved genetic material and achieve measurable genetic gains of livestock traits in subsistence systems of developing countries. Besides, formation of communal breeding groups is an important way of empowering local communities through participation and decision making in the processes. There are a number of communal based livestock breeding strategies that have been initiated in developing countries. Most of the successful ones are characterized by support of other integral services such as extension advisory services on record keeping, herd management, feeding and disease management. Some of the communal breeding strategies are reviewed in the section that follows in order to draw some lessons that may be applied for the production systems under study.

6.3 Communal Livestock Breeding Initiatives: A Review

A communal breeding programme with the objective of exploiting the existing local gene pool for goats to achieve higher productivity of goats has been set up in the semi-arid area of Kathekani located in eastern Kenya (Njoro, 2003). The indigenous goat reared by the Kathekani community is the East African goat, which is adapted to the harsh environmental conditions. The objective of the group is to upgrade the East African goat by cross breeding with the Galla goat which is highly prolific, has a faster growth rate and high milk production relative to the East African goat. The farmers have organized themselves into nine groups, each with an average of 15 members. Each farmer selects the best performing East African buck and does from his/her flock. The poor performing bucks are castrated while the females are culled. It is also a pre-requisite for each group member to put up a housing structure for all his/her goats to protect them against extreme weather and predators. Each group then procures a Galla buck from the neighboring districts from the monetary contributions of each member as stipulated in the group by-laws. The Galla buck is then allocated to each group member for one month on a rotational basis. During this period, the farmer is responsible for its feeding and health management. Inbreeding is minimized by exchanging the Galla bucks between the nine groups once a full rotation has been achieved within the group. The communal breeding groups receive support from the Ministry of Livestock in the form of technical information through extension services, especially regarding the identification of good breeding bucks, animal health and proper goat management practices. The anticipated and realized monetary benefits of the project have encouraged farmers to adopt the breeding initiative since the Galla - East African goat crosses have a higher market value than the East African goat. So far, the communal breeding project has been successful, though it is still at its nascent stages. One of the main challenges that have been highlighted in the project is lack of proper record keeping due to high illiteracy levels and lack of a clear breeding strategy and long-term objectives. Some of the farmers are upgrading their goats without a firm idea of the levels they want to achieve.

A nationally funded Djallonké sheep breeding program had been initiated by the Government of Côte d'Ivoire in 1983 with the objective of improving the performance of the Djallonké sheep breed since it is adapted to the physical environment of Côte d'Ivoire (Yapi-Gnoare et al., 2000). A selection program had been carried out in the country with the objective of improving growth and live-weight of pure-bred Djallonké sheep and to provide smallholder sheep farmers with improved breeding animals. A total of 209 farmers had been selected to participate in the program and registered with the extension service. The selection of the farmers was based on several criteria such as ability to keep records, ability to follow the prophylactic program and give supplements during critical periods, accessibility to the farm by car or motor cycle and access to a water source. Each farm had received at least 150 breeding Djallonké ewes, which were automatically included in the selection programme. The farmers were taught how to castrate unwanted rams, keep records and build night enclosures, shelters, collecting yards and footbaths.

The breeding strategy for the Djallonké sheep breeding program in Côte d'Ivoire has followed that of an open-nucleus breeding scheme[34] with selection based on individual performance of the rams. Open nucleus breeding systems have been recommended by animal breeders for genetic improvement in developing countries that lack the money, expertise and structure required to operate an efficient improvement programme based on artificial insemination and field recording throughout the entire cattle population (Bosso, 2006). Such programmes do not require expensive infrastructure because recording is only done in the nucleus herd. The structure of the Djallonké sheep breeding program is composed of one central performance evaluation station for selected rams (which forms the nucleus), and farmers' flocks of only breeding ewes, referred to as the base population. Selected breeding rams are brought to the farms for a mating period of about 45 days. Participating farmers use

[34] An open nucleus allows selection of replacements of superior breeding animals from the participating village herds.

the selected rams from the nucleus for mating. In return, ram lambs born on those farms are bought and brought to the nucleus for evaluation and eventual selection to be sires. Such an open-nucleus breeding pyramid is presented in figure 23. The price offered for the ram lambs constitutes substantial revenue for the farmers. Replacement females are produced within the flocks. The second-best non-selected ram lambs are sold to non-participating farmers while all other non-selected ram lambs are either castrated or culled. So far the breeding program has been successful, however, critical lessons learnt are that farmers are motivated to participate as long as funds are available and inputs are available at subsidized prices. When the government withdrew subsidies on veterinary products and fencing material in 1990, the number of participating farmers declined. In addition, the flock sizes have been declining since 1998 when new rules requiring farmers to deposit their recording sheet with the nearest extension office and pay for the use of rams for mating were initiated.

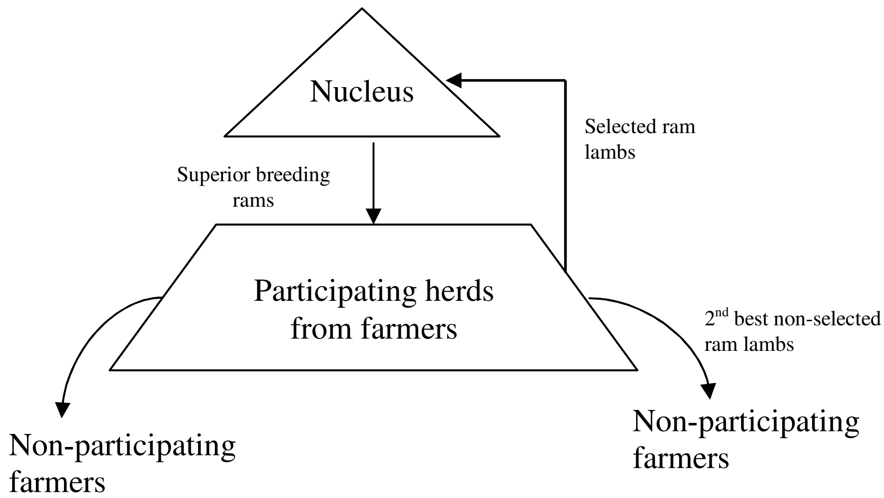


Figure 23: Schematic presentation of the two-tier breeding program
Source: Adapted from Van der Werf (2000).

The N'dama cattle genetic improvement program initiated in 1994 at the International Trypanotolerance Centre (ITC) in The Gambia with funding from BMZ and the EU, and implemented in a low input production system is yet another communal livestock breeding program that has so far been successful. The objective of the improvement program is to improve the welfare of livestock owners through better performance and increased productivity of their livestock (Bosso, 2006). The focus is on the N'dama cattle breed due to its adaptability to the conditions of the low-input system and ability to tolerate trypanosomosis disease. The breeding strategy follows an open nucleus breeding scheme like the Djallonké sheep breeding program in Côte d'Ivoire, though it is a three-tier scheme with a nucleus herd from the ITC. Superior genes from the nucleus herd are disseminated through multiplier herds to the village herds by selected bulls[35]. The multiplier receives superior breeding males from the ITC nucleus herd, uses these breeding males for a specified period and sells the male offspring of these breeding males to commercial farmers in the lower tier. The dissemination program started in 2001. Upward migration of selected females from multiplier and commercial herds to the nucleus is allowed. The multiplier tier consists of individual herds that have been selected after several meetings with farmers and communities. To become a multiplier, the farmer needs to fulfill certain conditions and criteria. This mainly includes sound management in terms of improved health care, feeding, reproduction and housing in order to minimize mortality and reproduction losses. Since 2002, livestock farmer organizations have formed multiplier associations with the objective of disseminating the genetic materials to the village herds. To ensure that farmers understand the importance of using the superior genetic material from the nucleus, training and awareness creation has been conducted through a series of workshops, training, open days, farm visits and livestock shows, which demonstrate the benefits from the production of the N'dama cattle breed (ibid.). The implementation and support of other integral activities such as herd management, feed production and feeding system has also been indicated as a contributing factor to the success of the program. In addition, regular meetings by stakeholders, such as the ITC, farmer groups, individual farmers, Department of Livestock Services have been useful in providing platforms for problem discussions and charting the way forward.

This section has highlighted the challenges and successes of some of the existing communal livestock breeding initiatives in sub-Saharan Africa. It also shows the importance of formation of communal breeding programs as a pathway to disseminate improved livestock genetic material. However, there exists a knowledge gap on the factors that influence an individual's choice to take up a collective action decision. Such information would be useful in developing appropriate interventions to enable facilitation and success of collective action initiatives.

6.4 Theoretical Framework for Collective Action and Empirical Model

The theory of collective action is based on the institutional approach to the solution of societal problems and is thus concerned with the conditions under which groups of people with a common interest will perceive that interest and act on it (Clague, 1997). The foundational work in collective action in the economic sense was by Olson (1965). Collective

[35] The nucleus and multiplier herds represent the "seed stock sector" responsible for generation and multiplication of superior animals.

action leads to creation of peoples organizations, commonly referred to as groups which brings together individuals with common problems and aspirations and who cannot, as individuals, meet certain goals as effectively, if at all (Kariuki and Place, 2005). By pooling their capital, labor and other resources, members are able to access certain resources or carry out profitable activities, which if undertaken by individuals alone, would involve greater risk and effort. This implies that group members have a common objective and means to achieve those objectives. In the context of communal breeding programs, a breeding bull from a nucleus herd may be purchased by a group for use within the group on a rotational basis. The breeding bull then becomes a collective good. According to Olson (1965), a collective good is non-excludable; therefore if it is provided to one member of the group, it cannot be withheld from any other member. Any attempt to acquire this good is considered collective action. If only a few members of the group pay for the collective good, yet it is provided to the whole group, then the free-rider problem develops[36]. The free-rider problem can be overcome through peer pressure from the group members and by having smaller group sizes (Sethi and Somanathan, 2006). The classic study by Olson (1965) suggests that collective action is more difficult to organize in larger groups relative to smaller ones.

The concept of social capital is closely related to collective action, and is often taken as an indicator of capacity for collective action. As such, empirical research usually incorporates both concepts when analyzing collective action. Social capital has been described as a combination of networks of individuals and sets of collective norms embedded in those networks (Ostrom et al., 1994). It deals with relations of trust, reciprocity and exchanges, common rules, norms and sanctions, as well as networks and groups, which are important mechanisms for building social capital assets (Meinzen-Dick et al., 2004). Such social ties are commonly viewed as important assets, a form of capital at par with physical, financial, human and political capital, and a potential instrument for building the other forms of capital (ibid.). Several studies such as Ramos-Pinto (2006) and Sandler (1992) have shown that social capital facilitates collective action. Elements of social capital have potentials to make collective action more or less likely. For instance, the degree to which close interactions or networks that characterizes a group can make cooperation more likely. The collective action and social capital concepts have been applied in several economic studies such as Fujiie et al. (2005) and Sakurai and Palanisami (2001) to analyze the factors influencing successful collective action at individual and group level.

[36] Free riders are economic agents who benefit from or consume a good but do not contribute to its provision.

An individual decision maker makes a choice decision whether to participate in a collective action initiative or not. Though choices are made under conditions of uncertainty, in this study, the decision maker is assumed to be risk neutral and aims at maximizing expected utility of profits. The decision maker is assumed to weigh up the expected utility of profits from the collective good or service through participation in a collective action initiative, represented as $E[U(\pi^P)]$ and the expected utility of profits from non-participation, represented as $E[U(\pi^N)]$. The decision to participate in a collective action initiative occurs when:

$$E[U(\pi^P)] - E[U(\pi^N)] > 0 \tag{43}$$

Where,

$$\begin{aligned} &E[U(\pi^P)] = U[E(PQ(X^P, Z^P) - W^P X^P)] \\ &and\ E[U(\pi^N)] = U[E(PQ(X^N, Z^N) - W^N X^N)] \end{aligned} \tag{44}$$

E is the expectation operator given the constraints facing the decision maker, *P* is the output price, *Q* is the expected output level, *X* is a column vector of inputs, *W* is a column vector of the input prices and costs associated with collective action such as financial contributions and transport costs to attend group meetings in case of W^P, and *Z* is a vector of household and other socioeconomic characteristics. The individual's expected utility of profits associated with participation and non-participation in collective action as presented in equation (43) is unobserved and can be represented by the latent variable Y^* which defines the propensity for the decision maker to participate in a collective action initiative:

$$Y^* = E[U(\pi^P)] - E[U(\pi^N)] \tag{45}$$

Y^* is unobservable to the analyst. What is observed is whether a decision maker participates in a collective action initiative or not. This can be presented as *Y* and is linked to Y^* as follows;

$$\begin{aligned} &Y = 1\ if\ Y^* > 0, \\ &and\ Y = 0\ if\ Y^* \le 0. \end{aligned} \tag{46}$$

When $Y^* > 0$, the decision maker decides to participate in collective action and $Y = 1$ is observed. Otherwise, if $Y^* \le 0$ the decision maker decides not to participate in collective action and $Y = 0$ is observed. For an individual decision maker *i*, the latent variable Y^* is assumed to be related to observed characteristics through a structural model as follows (Greene, 2003):

$$Y_i^* = \beta X_i + e_i, \qquad (i = 1, \ldots, N) \tag{47}$$

Where X_i is a vector of household and other socioeconomic characteristics, β is a coefficient vector, and e_i is a random disturbance term. From (46) and (47), the probability of decision maker *i*, participating in a collective action initiative is given by the following probability model:

$$\begin{aligned} \Pr[Y_i = 1] &= \Pr[Y_i^* > 0] \\ &= \Pr[\beta X_i + e_i > 0] \\ &= 1 - F(-\beta X_i) \\ &= F(\beta X_i) \end{aligned} \tag{48}$$

Where $\Pr[.]$ is a probability function and $F(.)$ is the cumulative distribution function. The exact distribution of *F* depends on the distribution of the error term e_i. If e_i is distributed as a logistic random variable, then the logit statistical model results. In this study, the binary choice model for participation in a collective action initiative has been estimated using a logit model. The cumulative distribution function in equation (48) can thus be presented as a logistic distribution;

$$F(\beta X_i) = \frac{e^{\beta X_i}}{1 + e^{\beta X_i}} = \Lambda(\beta X_i) \tag{49}$$

Where $\Lambda(.)$ represents the logistic cumulative distribution function. The log-likelihood function for a sample of independent observations is then presented as;

$$\begin{aligned} \log(L(\beta)) &= \sum_{i=1}^{n} y_i \log(\Lambda(\beta X_i)) + \sum_{i=1}^{n} (1 - y_i) \log(1 - \Lambda(\beta X_i)) \\ &= \sum_{i=1}^{n} y_i \log\left(\frac{e^{\beta X_i}}{1 + e^{\beta X_i}}\right) + \sum_{i=1}^{n} (1 - y_i) \log\left(1 - \frac{e^{\beta X_i}}{1 + e^{\beta X_i}}\right) \\ &= \sum_{\{i; y_i = 1\}} \log\left(\frac{e^{\beta X_i}}{1 + e^{\beta X_i}}\right) + \sum_{\{i; y_i = 0\}} \log\left(1 - \frac{e^{\beta X_i}}{1 + e^{\beta X_i}}\right) \end{aligned} \tag{50}$$

The parameters of the logit model are estimated by maximum likelihood methods.

6.5 Data and Variable Description

The data used for the binary logit estimation of participation in a collective action initiative have been obtained from the main survey (choice experiment survey) using the Kenyan data set only due to the lack of GIS-derived variables for the Ethiopian data set. Table 35 presents descriptive statistics for variables used in the empirical analysis. The means and standard deviations are presented separately for households who participated in collective action through welfare group membership and those who did not participate in a collective action initiative.

Table 35: Descriptive statistics based on welfare group membership

Variable	Member of a welfare group (n =123)		Non-member of a welfare group (n =181)	
	Mean	S. D.	Mean	S. D.
Age of household head (years)	56.2	14.8	46.3	15.7
Gender of household head (1 = male, 0 otherwise)	0.8	0.4	0.9	0.3
Years of education of household head	8.1	4.8	4.7	5.3
Number of adult female household members (above 18 years old)	1.8	1.1	1.5	1.2
Human population density (within a 5 Km radius)	93.7	39.5	48.2	43.7
Access to off-farm income (1 = yes, 0 otherwise)	0.1	0.3	0.2	0.3
Tenure system of owned land (1 = with title deed, 0 otherwise)	0.2	0.1	0.4	0.1
Cattle herd size	26.0	46.4	58.4	90.5
Distance to the nearest market (Km)	3.1	3.2	3.1	2.3
Travel time to the nearest large urban centre* (Hrs)	2.0	0.1	3.8	0.2
Narok district (1, if household is located in Narok district, 0 otherwise)	0.2	0.4	0.8	0.4

Source: Survey data

*The urban areas are defined on the basis of population densities, that is, population densities of more than 250 people km^{-2}

The dependent variable is membership to a welfare group. Forty percent of the surveyed households in the Kenyan sites were members of at least one welfare group, some of which were informal, unregistered organizations. Figure 24 presents the proportion of households who are members of various types of welfare groups.

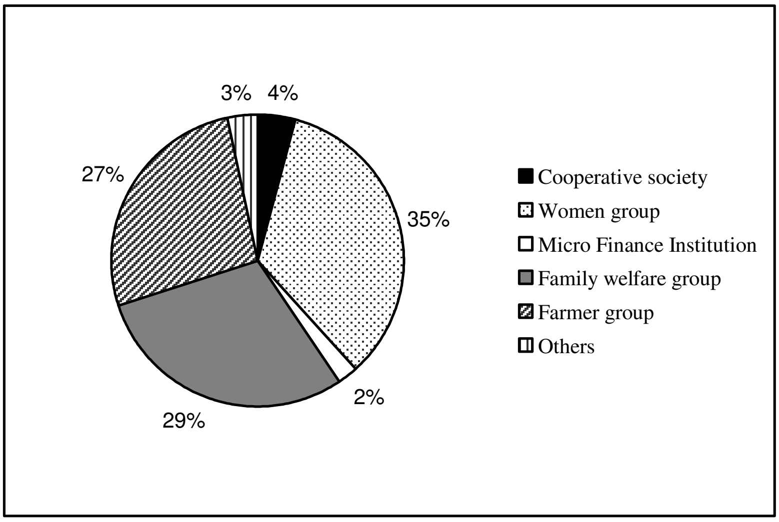


Figure 24: Membership to different types of welfare groups

Thirty five percent of the households are members of women groups while 27% belong to farmer groups. The services obtained from women groups are mainly agricultural extension advice and rotational savings while the farmer groups provide pooled farm labor services such as weeding and harvesting on a rotational basis. In Kenya, women group formation has been encouraged as a means of improving rural livelihoods through income generation and informal credit access (Karega, 1996). Twenty nine percent of the welfare group member households belong to family welfare groups. The services obtained from such groups include rotational purchases of income-generating equipments such as bee hives and emergency assistance of members to offset bills such as hospital and funeral expenses.

The independent variables used include farm and household characteristics, geographic location and market access variables. Household characteristics include access to off farm income, age, gender and education of the household head as well as number of adult female household members. The average age of the household head differs significantly between members and non-members of welfare groups, with an average of 56 and 46 years for the member and non-member households of welfare groups respectively ($p<0.01$). The proportion of male heads of households in the sample population is an average of 80% and does not differ significantly between members and non-members of welfare groups. The average number of education years for heads of households differs significantly between member and non-member households of welfare groups at $p<0.01$. For households who are members of welfare groups, the average number of education years is 8.1 years compared to 4.7 years for non-members of welfare groups. Education enhances the ability of an individual to perceive and conceptualize the effects of collective action, thus permitting a critical evaluation and trade-offs of the costs, which may be in terms of both time and money, and gains from a collective good through collective action. In addition, education influences the depth and richness of social networks and produces skills in relating to others and effective contributions to group developments (Kilpatrick et al., 2003). If this hypothesis is true, then household heads who have more schooling will have a higher probability of being members of organizations such as community welfare groups. Presence of an adult female in the household is hypothesized to increase the probability of membership to a welfare group. More than a quarter of the sample households who are members of welfare groups actually belong to women groups. Most women in the rural areas of Africa have a tendency to organize themselves into welfare groups to meet their financial and material obligations, especially in the absence of stable income. Table 35 indicates the average number of adult female members to be 1.8 for households who are members of some welfare group and 1.5 for the non-welfare group members.

Membership to welfare groups may also be influenced by the intensity of social interactions. The human population density variable has been included as an independent variable to proxy the intensity of social interactions. It is expected that social interactions among people tend to be more intense if they are concentrated within a smaller area (Fujiie et al., 2005). The average human population density variable differs considerably between the member and non-member households of welfare groups. The variable is strongly correlated with the type of production system, with a positive correlation for crop-livestock system and a negative correlation for the pastoral system. The hamlets, where the pastoral communities live are generally sparsely distributed in comparison to the crop-livestock farmers.

Access to off farm income and other farm characteristic variables such as security of tenure of land owned and cattle herd size are used as wealth indicators. The average values of these variables differ between the member and non-member households of welfare groups as indicated in table 35. Lower mean values are reported for households who are members of welfare groups, implying that households that are members of welfare groups may be resource constrained and therefore have incentives to join welfare groups in order to improve their conditions. On the other hand, wealthy households with access to off-farm income and security of tenure of land may have alternative channels to meet their needs and may not have the incentives to join the communal welfare groups. Land tenure security in the form of individual property rights influences access to formal or informal credit since land is often used as collateral.

Market access may also influence the household's decision to undertake collective action. Distance to the nearest market and time taken to reach the nearest large urban centre have been used as measures of market access. The average distance to the nearest market is about 3 Km and does not differ significantly between members of welfare groups and non-members. Conversely, average time taken to reach the nearest large urban centre differs significantly between member households of welfare groups and non-members at $p<0.01$. This may be attributed to the poor road infrastructure common in most rural areas of Africa. The effect of market access on participation in collective action initiatives has been widely debated. On the one hand a negative relationship between market distance and participation may be expected since areas closer to the market may have lower costs for interaction with the government for purposes of registering a society and for making their demands heard (Meinzen-Dick et al., 2000). However, Fujiie et al. (2005), note that in rural communities with little exposure to urban market activities, members expect to continue their interaction indefinitely, and hence have incentives to cooperate. Access to markets often decreases this interdependence, and therefore might reduce the likelihood of collective action.

6.6 Results and Discussion

Table 36 presents the maximum likelihood parameter estimates of the binary logit model for membership to welfare groups. The model was estimated using Limdep statistical package. The marginal effects measure the change in the probability of being a member of a welfare group given a one-unit change in the explanatory variable. It is computed as $\beta\Lambda(\beta X_i)[1-\Lambda(\beta X_i)]$ at the mean values of the *X's* (Greene, 2003). To measure the model fitness, McFadden's R^2 and the log-likelihood function values are reported. McFadden's R^2 is calculated as R^2=1- L_Ω/L_ω, where L_Ω is the unrestricted maximum log-likelihood and L_ω is the restricted maximum log-likelihood with all slope coefficients set equal to zero (Train, 2003). The percent of correct predictions is calculated as the total number of predictions as a percentage of the number of observations. The model correctly predicts welfare group membership decision for 77% of the sample. The McFadden's R^2 value of 0.266 shows a moderately good fit[37].

Table 36: Binary logit model results for welfare group membership

Variable	Coefficient	Standard Error	Marginal Effects
Constant	-1.2881	1.0474	-
Human population density	0.0132**	0.0055	0.0030
Access to off-farm income	-0.6351*	0.3544	-0.1474
Age of household head	0.0251***	0.0100	0.0056
Years of formal education of household head	0.0804**	0.0357	0.0181
Number of adult female household members	0.2721*	0.1470	0.0611
Distance to the nearest market (Km)	-0.0003	0.0015	-0.0001
Travel time taken to the nearest large urban centre	0.0473	0.1454	0.0106
Tenure system of owned land (1 = with title deed, 0 otherwise)	-0.0014***	0.0004	-0.0003
Gender of household head (1=male, 0 otherwise)	-0.6543	0.4279	-0.1559
Cattle herd size	-0.0003	0.0033	-0.0001
Narok (1= Narok district, 0 otherwise)	-0.0205*	0.0156	-0.0105
Narok*Human population density	-0.0163***	0.0056	-0.0037
McFadden R^2	.2662		
Log likelihood function	-154.991		
Correct predictions	77.2%		
N	304		

Note: ***, **, * indicate that coefficients are statistically significant at the 1, 5 and 10 % levels, respectively, using P-values in maximum likelihood estimation.

The estimated coefficients have the expected signs though the market access variables, gender of the household head and cattle herd size are not statistically significant. The coefficient on human population density has the expected positive sign and is statistically significant at the 5% level. This result is consistent with the hypothesis that a high human

[37] The independent variables included in the model may not be exhaustive. Other variables such as group characteristics and policy factors (government regulations for groups) could also have significant influences but were not captured during the surveys.

population density strengthens social interactions as a basis for organizing collective action. This finding is similar to that found by Fujiie et al. (2005) in their study on collective action in the Philippines. The coefficients on education level and age of the household head are also positive and statistically significant as expected, indicating that more educated and older heads of households are more likely to be members of welfare groups. Sakurai (2002) also finds a positive relationship between education level and membership to welfare groups. Older heads of households may have no alternative access to monetary resources especially as they may have retired from formal employment and may not have access to social welfare benefits. Consequently, the welfare groups may be important avenues for meeting their needs and cushioning against shocks. Similarly, the coefficient on number of female adult household members is positive and significant at the 10% level, indicating a higher probability of membership to welfare groups for households with female adult members. This is expected since a high proportion of sample households who are welfare group members belong to women groups.

The coefficients of the two variables representing wealth endowments that is; access to off farm income and tenure system of owned land, have the expected negative signs and are statistically significant at the 10% and 1% levels, respectively. This indicates that the probability of being a member of a welfare group is lower for households with access to off-farm income relative to households without off-farm income. The marginal effect of off-farm income indicates that access to off farm income reduces the likelihood of being a member of a welfare group by a substantial 15%. Similarly, the probability of being a welfare group member is lower for households with security of land tenure in the form of title deeds relative to those without tenure security. These results imply that households who are wealth constrained are more likely to be members of welfare groups. The wealthier households may have alternative channels to meet their needs and may not have the incentives to join the welfare groups. The dummy variable coefficient for Narok district is negative and statistically significant at the 10% level. This finding indicates a lower probability of households in Narok district relative to Suba district to be members of a welfare group. This is probably because the district is dominated by pastoralist households making it difficult to participate in collective action due to frequent mobility. An interaction term between human population density and Narok district dummy variable has been introduced in the model in order to examine the effect of population density and location of the household on welfare group membership. The interaction term is negative and statistically significant at the 1% level. The marginal effects show that a unit increase in population density reduces the probability of membership to welfare groups by 0.0007 (0.0030 - 0.0037) in Narok district.

The binary logit results reveal that most of the households who belong to welfare groups may be the resource-poor households who pool their resources together to meet their needs. This has important implications for communal livestock breeding initiatives since resource poor cattle keepers may not individually afford to purchase improved breeding bulls and may be willing to participate in a communal breeding initiative in order to access improved genetic material. Interested cattle keepers may form breeding groups that act as multipliers which receive bulls of proven genetic merit from a nucleus herd for rotational mating among herds of group members. The proven bulls could be obtained through purchases from monetary contributions of group members or through alternative payments in the form of offsprings from the proven bulls. Just like the communal breeding programs previously reviewed, members of the breeding groups would need to fulfill the necessary criteria for sound management such as health care, feeding, reproduction and housing in order to minimize mortality and reproduction losses. In addition, other bulls would have to be castrated or culled to ensure that mating only takes place with the bulls from the nucleus herd. The nucleus may be opened so that potential bull replacements which are superior offsprings from the communal breeding groups may be selected and taken back to the nucleus to be sires. Incentives ought to be provided in order to enable the participating group members to be willing to give up their best offsprings for selection into the nucleus. Such incentives may include purchasing the replacement bulls at a fee.

A communal breeding program may be easy to organize for sedentary cattle keepers such as those in mixed crop-livestock systems where human population densities are high and social interactions are strong. However, it may be difficult to organize for the pastoral systems due to the high level of mobility of pastoralists as they search for water and pasture with changing seasons. Van der Waaij (2001) suggests that for such systems, cattle keepers ought to individually purchase the improved cattle for upgrading their own. Since artificial insemination may not be feasible in such areas, purchases may be in the form of pregnant heifers or proven bulls. A separate study carried out by the International Livestock Research Institute (ILRI) in Mara division of Narok district in Kenya in 2005 to assess the perceptions of the Maasai pastoralist community regarding some experimental animals which could potentially act as foundation stock for a breed improvement program produced interesting results. The experimental animals were F1 crosses and backcrosses of trypanotolerant N'dama and trypanosusceptible but highly productive Kenyan Boran breeds which had been produced through a collaborative project between ILRI and KARI with the objective of validating the QTL values of disease tolerance and production traits under natural field conditions (Ouma, 2005). The trypanotolerant N'dama breed had been introduced into Kenya from the Gambia in 1985 for experimental purposes by the International Livestock Research Institute (Jordt et al., 1986). The study results revealed that the communities are interested in obtaining the experimental cattle to upgrade their own but most of the respondents would not be willing to participate in a communal breeding group. The main reasons given for the lack of interest to participate in a communal breeding group include potentials for quarrels due to individual member differences in terms of cattle management and group management difficulties.

The respondents were then asked to indicate and rank their most preferred method of obtaining the experimental animals in case KARI and ILRI were willing to avail them to the community. The average rankings are presented in table 37.

Table 37: Rankings of preferred mode of obtaining initial animals from the KARI herd

Mode of obtaining animals from ILRI-KARI herd	Average rank*	S. D.
Purchase at market price	1.5	0.7
Obtain on credit at market price. Credit to be repaid over a one year period	1.3	0.5
Obtain in the form of an animal loan. One offspring to be repaid within two years	1.7	0.7

Source: Ouma, 2005

*1 represents the highest rank

The results indicate that the most preferred method of obtaining the animals is to individually obtain them at the market price on credit and repay the credit over a period of one year. The second preferred method is to purchase the animals at the market price, while the least preferred method is to obtain them in the form of an animal loan, with the agreement that one offspring is to be repaid within two years. Repayment in the form of offspring is not preferred as the respondents indicate potential difficulty in releasing the first offspring from the ILRI-KARI experimental animals. Although the respondents in the ILRI study do not prefer animal loaning with repayments in the form of offsprings, this type of arrangement has been very successful in smallholder dairy production systems in Africa where poor cattle keepers who cannot afford to own a cow are loaned in-calf heifers under the heifer-in-trust scheme. In most cases, the repayment arrangement is in the form of the first calf produced or the first two female calves which are passed on to fellow smallholder farmers (Dieckmann, 1994).

6.7 Institutional Aspects

An essential issue that merits attention is identification of the institutions that can be effectively involved in generation of improved livestock genetic materials. Animal breeding is a long-term venture which requires adequate investments in breeding research before meaningful results can be achieved. Modern biotechnology methods can identify and introduce the genes that control desirable traits into animal strains with far greater precision and control than conventional methods. This facilitates the creation of a hybrid breed that possesses desirable characteristics through breeding. Few livestock breeding programs exist in sub-Saharan African countries capable of applying biotechnology methods such as molecular breeding and genomics, through marker-assisted selection and gene-assisted selection, as an aid in selection of improved livestock breeds (FAO, 2000). This is largely due to the potentially high costs of such programs and the limited public investment in animal biotechnology research in most sub-Saharan African countries.

Trypanosomosis disease is concentrated in remote areas of sub-Saharan African countries where majority of the populations are poor and low-input livestock production system is the norm. Such areas may not easily attract private sector investment in breeding research and development of breed improvement programs (Omamo and d'Ieteren, 2003). This points to the need to reinforce national and international public agricultural research in developing countries in investing in and applying modern biotechnologies in livestock breeding where private sector investment is unlikely to be commercially attractive. However, the financial and technological constraints facing most sub-Saharan African countries suggest that such huge investments in National Agricultural Research Systems (NARS) may not always be feasible. This highlights the need for sub-Saharan African governments to consider supporting private-public sector collaborations in animal breeding research, especially for research targeted at low-input livestock production systems to generate improved genetic materials that are available to the public. Such collaborations however, need to clearly stipulate the intellectual property rights (IPR), for instance, who can use the findings and where public research may freely use the products and techniques. Private sector motivation in collaborative animal breeding research could be done through development of appropriate incentive structures such as tax incentives and effective intellectual property regimes to facilitate animal biotechnology research. The lack of intellectual property protection, common in developing countries constrains private-sector investment in research.

Most of the private-public sector collaborations for agricultural biotechnology have occurred and succeeded in developed countries. However, some developing country initiatives have already had some effect, especially in the field of plant biotechnology. For instance, Kameri-Mbote et al. (2001) note the important role played by the International Service for the Acquisition of Agri-biotech Applications (ISAAA) in transfer of agricultural technology to developing countries. ISAAA is a non-profit organization established in 1992 with an objective of delivering the benefits of agricultural biotechnologies to the poor in developing countries. It has regional network centers in different countries and usually acts as a middleman between the private sector and the recipient institutions in developing countries. The AfriNet is the network for Africa and is located in Nairobi, Kenya. It has been involved in brokering the transfer of tissue culture techniques for rapid multiplication of bananas in Kenya. ISAAA-AfriNet has also made arrangements for scientists from Jomo Kenyatta University of Agriculture and Technology, a public university, to be trained in a commercial tissue culture laboratory for banana multiplication in Costa Rica. In addition, the network office has identified private sector investors to both finance commercial tissue culture laboratory work in Kenya and to commercialize the products of that work. One rare and successful private-public sector partnership in the field of animal biotechnology has occurred between the International Livestock Research Institute and the Institute for Genomic Research (TIGR), a non-profit research institute based in the USA. The partnership has successfully developed a vaccine for East Coast Fever, a common tropical livestock disease through application of cutting edge science of genomics (Consultative Group on International Agricultural Research, 1996). Each partner brought in different areas of expertise and resources to focus on the common goal of reducing livestock mortality from East Coast Fever disease through development of a vaccine. The goal would have been unattainable by a single party acting alone.

At the national level, public research institutes like the NARS and public universities have been working in collaboration with the Consultative Group on International Agricultural Research (CGIAR) centers. Mechanisms of collaboration include joint research proposals and activities involving the institutions. An example is a collaborative project between the International Livestock Research Institute (ILRI) and the Kenya Agricultural Research Institute (KARI) in Kenya, funded by USAID to validate QTL that control trypanotolerance in crossbreeds of N'Dama-Boran cattle under natural field challenge in order to assess correlated effects of production traits and other diseases (ILRI, 2004). The project is a follow up on experiments conducted at the ILRI in collaboration with other international scientists from Hebrew University and Wageningen Institute for Animal Science that had been able to identify QTL of potential value controlling trypanotolerance in crosses of trypanotolerant N'dama and susceptible but more productive Kenyan Boran using genomic technologies (ibid.). Such invaluable research that identifies QTL controlling desirable traits are useful in generating improved genetic materials that can be used as inputs into public livestock breeding programs. Progeny testing and field testing of synthetic breeds for adaptation to local environments may also be done through collaborative efforts. For instance, Centro Internacional de Agricultura Tropical (CIAT), a CGIAR centre has been involved in field testing of new agro-chemical technologies developed by private firms (Binenbaum et al., 2001).

Chapter 7

Conclusions

The analyses conducted in this study aimed at examining households preferences for cattle traits in trypanosomosis prevalent cattle production systems of eastern Africa. Due to the constraints posed by trypanosomosis disease, the study was partly intended to contribute towards the design of appropriate and sustainable cattle breed improvement programs aimed at encouraging the adoption and use of trypanotolerant breeds. The main motivation for studying the households' cattle trait preference behavior is the potential contribution of breed interventions through breed improvement programs that utilize trypanotolerance trait and other preferred traits in improving livestock productivity and enhancing competitiveness of the cattle enterprise in low input systems. The primary benefit from improved livestock productivity is a sustainable improvement in the livelihoods of livestock producers, many of whom are resource poor. The study further aimed to identify potentially sustainable dissemination pathways of improved livestock genetic materials from the breed improvement programs to cattle keepers. This chapter summarizes the impetus of the study along with a review of the methods used. A summary of the results is then presented along with the implications of the results on policy. Finally suggestions for future research in the area are discussed.

7.1 Study Focus and Review of Methods

Calculation of economic values of traits by animal breeders for inclusion in breed improvement programs often focus on profit function approaches utilizing single, market driven traits such as milk and meat production. This often results in genotypes that are not suited to the conditions of the local environment and the exclusion of traits without market values yet they may be considered important by cattle keepers especially in small scale and low-input systems, where cattle also perform non-income and social cultural functions. In this study, the socio-economic reasons for keeping cattle were determined and preferred phenotypic cattle traits identified through focus group discussions. Choice experiment method was then employed to assess preferences for cattle traits on a random sample of 506 cattle keeping households in Kenya and Ethiopia. The advantage of choice experiments over profit function approaches is that preferences are measured directly and then related to utility making it possible to estimate economic values of traits without market values as well as prospective traits which may be of interest to animal breeders. Moreover, the involvement of cattle keepers in breed improvement efforts may contribute to high adoption rates of improved breed technologies, aimed at increasing productivity.

Past studies that have utilized the choice experiment method or conjoint analyses have mainly employed ordered probit or multinomial logit models to empirically model preference behavior. A limitation of these models is that they do not explicitly account for heterogeneity of preferences among cattle keepers, yet preferences often vary among individual decision makers according to their socio-economic characteristics, tastes, environment and production systems. This renders them less useful for analysis aimed at providing policy recommendations for different environments and production systems. This study overcomes this limitation by employing a mixed logit model to investigate the existence of preference heterogeneity and a latent class model to examine the sources of heterogeneity across segments of cattle keepers.

The study also focused on identifying potentially sustainable dissemination pathways of improved livestock genetic materials to cattle keepers. Different alternatives have been discussed and then emphasis has been placed on the communal breeding initiatives through collective action as it provides a potentially sustainable pathway for poor cattle keepers to access improved livestock. A binary logit model was employed to investigate factors that influence an individual's choice to take up a collective action decision on a sub-sample of 304 cattle keeping households. Such information is useful in developing appropriate interventions to enable facilitation and success of collective action initiatives.

7.2 Summary of Results and Implications for Policy

The summary of results is discussed under two main sub-sections: preferences for cattle traits and cattle enterprise objectives, and pathways for cattle keeping households to access genetically improved cattle.

7.2.1 Preferences for Cattle Traits and Cattle Enterprise Objectives

The empirical results from mixed logit and latent class models provide several insights to understand cattle keepers' choice behavior. The results from the mixed logit model revealed significant preference heterogeneity among cattle keeping households. Good traction potential, fertility, and trypanotolerance were found to be the most preferred traits in the model of bull preferences. The most valued traits in the cow preference models were trypanotolerance and reproductive performance.

Quite significant and interesting was the finding that traits related to beef and milk yield were ranked below the other factors such as traction, fertility, and tolerance to trypanomosis disease. This is probably because the cattle keepers in these systems are subsistence oriented and consequently place less emphasis on meat and milk production for the market. These findings are particularly interesting because traditional economic analyses on livestock and cattle breeding programs often focus on raising milk and meat productivity, with little emphasis on the non-income traits such as traction potential and disease resistance. However, the results clearly suggest that the breeding programs, as currently practiced in eastern Africa may be focusing on traits that are not highly valued by cattle keepers, especially for smallholders and low input systems in the region. In particular, improved milk production, achieved mostly by cross-breeding with European dairy breeds, does not appear to be of high significance to most cattle keeping households. For instance, the Kenya National Sahiwal Stud was established in 1962 with an objective of improving the breed for milk and meat production in marginal areas. The selection criteria for the breeding stock has mainly focused on traits associated with meat and milk production such as lactation milk yield, age at first calving, calving interval, and growth rate without consideration of adaptation traits which may be useful for the marginal areas (Mpofu and Rege, 2002).

The findings indicated existence of heterogeneous preferences mainly driven by the underlying cattle production systems. Agro-climatic conditions of an environment partly determine the type of production system, the production objectives and priorities since they differ in exhibiting various stress factors. The results of the latent class model, which was used to reveal the presence of identifiable segments within the population, indicated that cattle keepers' preferences are clustered around the production systems under which cattle production takes place. Specifically, three distinct classes of cattle keepers in the sample population, each displaying differing preferences for the same set of cattle traits emerged. The classes mainly comprised the agro-pastoralists, pastoralists and crop-livestock farmers. For the class comprising agro-pastoralists, traction fitness and high reproduction potential were found to be the most preferred traits in bulls and cows, respectively. For the pastoralists, high-fertility in bulls and high reproduction potential in cows were the most important traits. The crop-livestock system farmers placed high values on trypanotolerance and traction fitness in bulls and high milk yield in cows, indicating that preferences are associated with the farming system that is predominant in a particular environment. The differing cattle trait preferences across the production systems reflect the different cattle keeping objectives between production systems. For instance, one of the main objectives of cattle keeping for agro-pastoral and crop-livestock system households is traction capacity in bulls for ploughing and threshing grains. In the crop-livestock systems, milk production is also indicated as an important cattle keeping objective while in the pastoral systems, cattle are kept for socio-economic as well as cultural or ceremonial reasons. The findings from the latent class model indicates the importance of considering heterogeneity within population segments as it provides a useful framework for adapting breeding policy interventions to specific producer segments.

Given that most breeding programs in eastern Africa tend to focus on traits related to milk and beef production, the results from this study offer some explanation for the low adoption rates of exotic breeds in some livestock production systems. A more effective strategy along the lines suggested by Dalton (2004) would seek to refocus national agricultural development and international development cooperation agencies on evaluating a broader set of cattle traits beside beef and milk yield. Animal traction fitness is one example of a highly valued trait by cattle keepers that is often ignored in genetic improvement programs because of difficulties in definition of the trait, testing of the trait and the general feeling that the economic importance of a genetic improvement of the trait is not so high (Tano, 1998). However, the study results indicate that traction potential is one of the most preferred traits in bulls and therefore ought to be included in genetic improvement programs targeted at cropping systems.

For breeding programs to be more effective and sustainable, breeding research and policies should focus on the different production environments and ensure that improved genotypes maintain the traits that are preferred by the cattle keeping households such as trypanotolerance in trypanosomosis prone areas, high reproductive performance and fitness to traction, in addition to increasing milk and beef productivity. Although utilization of trypanotolerance trait in a breed improvement program offers potentially sustainable opportunities for controlling trypanosomosis disease, the results from this study reveal the necessity to integrate this trait with other traits of preference since some traits are even relatively highly valued than trypanotolerance by the cattle keeping households.

In order for productivity improvements resulting from trypanotolerance and other preferred traits to have an impact on the livelihoods of the cattle keeping households, there is need for development of supportive infrastructure. Infrastructural developments such as improvement of road infrastructure to reduce transaction costs and establishment of abattoirs close to the communities need to be considered so as to improve market access for the cattle keepers. An option would be to support entrepreneurs investing in slaughterhouses, cold storages and other premises in order to improve livestock marketing. These policy issues are in line with the policy options identified at the Angola/Mozambique animal genetic resources (AnGR) conferences of 2002/2003.

7.2.2 Pathways for Cattle Keeping Households to Access Genetically Improved Cattle

Community based cattle breeding initiatives, based on collective action were identified as potentially sustainable pathways for poor cattle keepers to access genetically improved cattle, whether from nucleus breeding herds from on-station breeds or existing breeds in village herds for village based breeding schemes. An alternative pathway of access through artificial insemination using semen from superior breeding bulls from nucleus herds was found to be infeasible due to the remoteness of the study areas and inadequate infrastructure such as electricity, necessary for storing semen in liquid nitrogen. The alternative of purchasing breeding bulls or pregnant cows which have been inseminated with semen from superior breeding bulls may be limited to only a few cattle keepers who can afford it, locking out the more resource-constrained cattle keepers.

The results from the binary logit model to investigate factors that influence an individual's choice to take up a collective action decision through membership to welfare groups revealed that socio-economic and location factors play a significant role. The results were consistent with the hypothesis that a high human population density strengthens social interactions as a basis for organizing collective action. In addition, presence of adult females in the household as well as higher education level and age of the head of the household increases the probability of being a member of a welfare group. Older heads of households may not have access to income or economic safety nets in the form of social welfare benefits to deal with economic shocks. They may therefore have to rely on the communal welfare groups to meet their needs and cushion against shocks. Similarly, women in the rural areas of Africa have a tendency to organize themselves into welfare groups to meet their household needs. Therefore the presence of an adult female in the household increases the probability of the household to be a member of a welfare group.

The results also revealed that wealthy households have a lower probability of belonging to welfare groups relative to the wealth constrained. This has important implications for communal livestock breeding initiatives since resource poor cattle keepers may not individually afford to purchase improved breeding bulls and may be willing to participate in communal breeding initiatives in order to access improved livestock. The binary logit results suggest that a communal breeding program may be easy to organize for sedentary cattle keepers such as those in mixed crop-livestock systems where human population densities are high and social interactions are strong. However, it may be difficult to organize for the pastoral systems due to the high level of mobility of pastoralists as they search for water and pasture with changing seasons. Such systems may access improved genetic material through purchases of the improved cattle for upgrading their own. Although communal livestock breeding initiatives were identified as potentially sustainable pathways for poor sedentary cattle keepers to access improved livestock genetic materials, their success is highly dependent on integration of intervention programs such as extension advisory services on simple record keeping, herd management, breeding, feeding and disease management.

Modern biotechnology methods can identify and introduce the genes that control desirable traits into animal strains with far greater precision and control than conventional methods. This facilitates the creation of a hybrid breed that possesses desirable characteristics through breeding. However, few livestock breeding programs exist in sub-Saharan African countries capable of applying biotechnology methods such as molecular breeding and genomics, through marker-assisted selection and gene-assisted selection, due to the high costs of such programs. This highlights the need for sub-Saharan African governments to consider supporting private-public sector collaborations in animal breeding research, especially for research targeted at low-input livestock production systems to generate improved genetic materials that are available to the public.

7.3 Directions for Future Research

The main objective of this study was to assess the phenotypic cattle trait preferences in trypanosomosis-prevalent production systems of eastern Africa and draw implications for sustainable cattle breeding programs. Three study areas were selected in Kenya and Ethiopia to represent the different production systems. The economic values of the traits derived from the choice experiment and econometric models reflect the relative importance of the traits to the cattle owners. Since the choice experiment method applied was mainly hypothetical in nature, future research may consider providing real cattle breeds with different traits in an enclosure to the respondents to validate the choice experiment results. However, due to time and financial constraints, this was not possible in the present study. Instead, the presentation of the choice experiment to the respondents was done using simple illustrations to ensure that the respondents understood the trade-offs between traits. Therefore, the choice experiment results were deemed to be satisfactory. Secondly, although the emphasis of the study was on cattle trait preferences, a prediction of the impact of breeding programs that utilize preferred traits on livelihoods of the cattle keepers was not provided by the analysis, yet it would have reflected the potential economic benefits to cattle keepers from genetic improvement of the traits. Future research can focus on this area.

The study was carried out using cross-sectional choice experiment data and provides interesting results on trait preferences of the cattle keeping households. It may be interesting to further investigate whether the preferences are time variant, especially as agro-climatic conditions which influence the production systems are inherently characterized by seasonal fluctuations. This would have important implications for a long-term breeding program.

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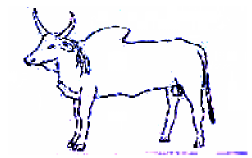
Appendices

Appendix 1: Choice Experiment Profiles

Bulls - Choice Task 1 (Option 1)

Susceptible to Tryps: Poor condition after infection, need treatment drugs

Weight at 4 yrs: 320 Kg



Highly fertile: Semen results in pregnancy **after 1-2 sessions with cow**

High watering frequency: Need to be watered **twice in** a day

Dark coat colour

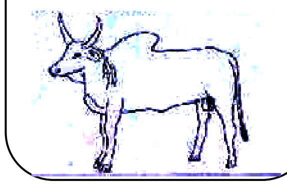
Purchase price of bull at 4 years

KSh 11,000

Bulls - Choice Task 1 (Option 2)

Tolerant to Tryps: able to be in good condition despite infection. No need for treatment drugs

Weight at 4 yrs: 320 Kg



Low fertility: Semen does not easily result in pregnancy **(success after more than 3 sessions with cow)**

Low watering frequency: Need to be watered **only once in two days day**

Light coat colour

Purchase price of bull at 4 years

KSh 27,000

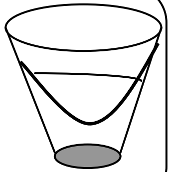
Bulls - Choice Task 1 (Option 3)

Don't Buy

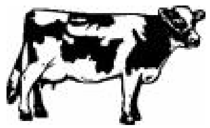
Cows: Choice task 1 (Option1)

Tolerant to Tryps able to be in good condition despite infection. No need for treatment drugs

Average milk Yield per day (2lts)



Weight at 2 yrs: 120 Kg



Reproductive potential: One calf every **two years**

Yr 1	Yr 2	Yr3	Yr4	Yr 5
√		√		√

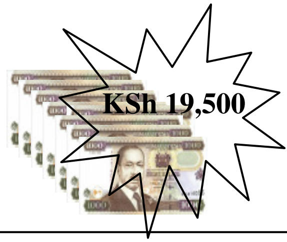
Moderate watering frequency: Need to be watered **once** a day

Dark coat

Feeding

No need for supplementary purchased feed rations

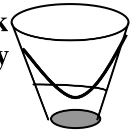
Purchase price of cow



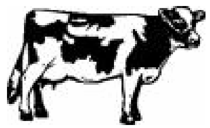
Cows: Choice task 1 (Option2)

Susceptible to Tryps: Poor condition after infection, need treatment drugs

Average milk Yield per day (up to 1lt.)



Weight at 2 yrs: 250 Kg



Reproductive potential: One calf **every year**

Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
√	√	√	√	√

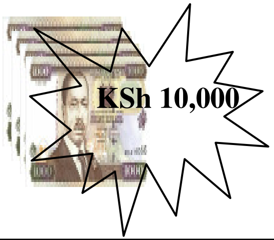
Moderate watering frequency: Need to be watered **once** a day

Light coat

Feeding

Need for supplementary purchased feed rations

Purchase price of cow



Choice task 1 (Option3)

Don't Buy

Appendix 2: Field Questionnaire

DEVELOPING OPTIMISED CATTLE BREEDING SCHEMES, WITH A SPECIAL FOCUS ON TRYPANOTOLERANCE, BASED ON THE DEMANDS AND OPPORTUNITIES OF SMALLHOLDER LIVESTOCK KEEPERS IN EASTERN AFRICA

HOUSEHOLD LEVEL QUESTIONNAIRE

Collaborative Research Project of the Swiss Centre for International Agriculture (ZIL), Swiss Federal Institute of Technology (ETH) and International Livestock Research Institute (ILRI)

Name of Enumerator: ____

Date of interview: [__ __/__ __/ __ __] (DD/MM/YY)

Time started: _________ Time ended: ________

Reviewed by: ________________________ Date: [___/___/___]

Area (*Tick appropriately*) New settlement [ ] Native [ ]

The overall objective of the survey is to identify and understand producers' cattle breeding objectives and practices, and assess the important traits that they take into consideration when selecting breeds of cattle to keep and rear. The collected data from the survey will be used to generate baseline information on farmer preferences for cattle traits in different production environments. This information is useful for cattle breed improvement programs.

Note: For the Ethiopian sites, use the Ethiopian calendar for all questions related to dates and year.

COUNTRY	DISTRICT	DIVISION	SUB-LOCATION	
KENYA	1. Kajiado	11=Magadi	1101=Ngurumani 1102=Lenkobei 1103=Pakase 1104=Olkiramatian	1105=Musenke 1106=Entosopia 1107=Oloika
	2. Narok	21=Mau	2101=Sakutiek 2102=Nairage Enkare	
		22=Mara	2201=Siana 2202=Nkoilale	2203=Koyaki 2204=Sekenani
		23=Ololunga	2301=Ololunga 2302= Lemek	2303=Melelo
	3. Suba	31=Lambwe	3101=God Jope 3102=Ogongo	
		32=Central	3201=Nyatoto 3202=Nyadenda	
ETHIOPIA	**WEREDA**		**KEBELE**	
	1. Abeshiga		11 = Ghibe 12 = Walga	13 = Borar
	2. Sokoro		21 = Abbalti	22 = Bede
	3. Nono		31 = Medallo 32 = Gullele	33 = Bilo Wayu
	4. Limu Kosa		41 = Wayu Tolley	

District: [______]

Division: [______]

Sub – location: [______]

Wereda: [______]

Kebele: [______]

Household questionnaire Number: [______]

A. BACKGROUND INFORMATION

A/1. Name of household head ________________________________

A/2. Type of homestead [_____] (Use codes below)

1 = Monogamous (married)

2 = Polygamous (married)

3 = Single household head (unmarried)

A/3. What part of the polygamous household is being interviewed? [_____] (Use codes below)

1 = Entire homestead

2 = Only the "household" (property and activities) of one co-wife, who is wife number [___]

A/4. Who is the main decision maker in relation to cattle sales and purchases (ownership) by the household? (Use codes below)

Name(s) of decision maker (s)	Relationship to household head
1.	[_____]
2.	[_____]

Relationship to household head

1 = Household head	5 = Co - wife
2 = 1st wife to household head	6 = Son
3 = 2nd wife to household head	7 = Daughter
4 = 3rd wife to household head	8= Other (specify) ________________

Any of the decision makers in A/4 should be the respondent.

A/5. Name of respondent ________________________________

B. HOUSEHOLD CHARACTERISTICS

B/1. Give details of the household members (including household head) living permanently on the compound and are dependent on the household (Use codes below)

Name (first name)	Gender 1 = Male 2 = Female	Year of birth	Relationship to hh head	Highest education level attained	Primary activity
Household head	[_____]	[_____]	[_____]	[_____]	[____][___]
	[_____]	[_____]	[_____]	[_____]	[____][___]
	[_____]	[_____]	[_____]	[_____]	[____][___]
	[_____]	[_____]	[_____]	[_____]	[____][___]
	[_____]	[_____]	[_____]	[_____]	[____][___]
	[_____]	[_____]	[_____]	[_____]	[____][___]
	[_____]	[_____]	[_____]	[_____]	[____][___]
	[_____]	[_____]	[_____]	[_____]	[____][___]
	[_____]	[_____]	[_____]	[_____]	[____][___]
	[_____]	[_____]	[_____]	[_____]	[____][___]

* A person is in permanent residence if he/she sleeps in the house a majority of nights per week

Relationship to hh head
1=Household head
2=1st wife
3=2nd wife
4=3rd wife
5=Co- wife
6=Son
7=Daughter
8=Daughter-in-law
9=Son-in-law
10=Grandchild
11=Niece/Nephew
12=Farm employee
13=Grandparent
14=Sister
15=Brother
16=Cousin

Education level
0=No formal education
1=Pre-school age
2=Preparatory school/Nursery school
3=Standard 1 through 4
Elementary school – Grade1-4
4=Standard 5 through 8
Elementary school – Grade 5-8
5=Form 1 or 2 (Grade 9-10)
6=Form 3 or 4 (Grade 11-12)
7=Post-secondary school (“A” level)
8=Technical college (2-3 years)
9=University (Undergraduate)
10=University (Postgraduate)
11=Adult literacy education
12=Muslim religious education
13=Orthodox religious education

Primary Activity
0=None
1=Farmer/animal husbandry
2=Civil servant
3=Employee in private business
4=Engaged in own business
5=Labourer on-farm
6=Labourer off-farm
7=Religious leader
8=In school
9=Pre-school age
10=Other (Specify)

B/2. Ethnic affiliation [_____] (Please use codes below)
B/3. Religion [_____] (Please use codes below)

B/2. Ethnic Affiliation

1 = Maasai	8 = Luo
2 = Kalenjin	9 = Kisii
3 = Kikuyu	10 = Amhara
4 = Kamba	11 = Oromo
5 = Meru	12= Tigri
6 = Embu	13 = Gurage
7 = Luhyia	14 = Other (Specify) ________

B/3. Religion

1 = Catholic
2 = Protestant Christian
3 = Muslim
4 = Orthodox Christian
5 = Indigenous
6 = Other (specify)________

B/4. How **far** is the household **from** (in Km):

		Distance from homestead (Km)
A road open to vehicles all year		[____.__] Km
A road passable only during the dry season		[____.__] Km
	Name of market	
Nearest market centre	______________	[____.__] Km
Nearest livestock market	______________	[____.__] Km

B/5. Which of the following means of transportation does the household or farm have for marketing their farm products? (**Tick** where appropriate)

Transportation items		**Tick**
1=Bicycle		
2=Wheelbarrow		
3=Handcart		
4=Animal drawn cart (donkeys, mules, horses)		
5=Motorcycle		
6=Tractor		
7=Pick-up		
8=Car		
9=Other (specify) ____________		

B/6. What is the household's major farming activity? (*Tick one box*)

Faming activity	**Tick**
1 = Livestock production	
2 = Crop production	
3 = Both	

B/7. Do you grow crops? [____] 1 = Yes 2 = No

B/8. If yes, please list crops grown and crop area in the table below:

List crops grown	Own (acres)	Rented (acres)
a)	[_____]	[_____]
b)	[_____]	[_____]
c)	[_____]	[_____]
d)	[_____]	[_____]
e)	[_____]	[_____]
f)	[_____]	[_____]
g)	[_____]	[_____]

B/9. Please fill in the household's overall land holding details below for land owned or rented.
If only communal land is used, then go to B/12.

	Own land (acres)	**Rented land (acres)**
1. Land for crops		
2. Land for grazing		
3. Land for planted pasture		
4. Others ___________		
Total land size		

B/10. What is the tenure system of the land **owned** by the household? [_____] (Please use codes below)

B/9. Land Tenure system

1 = Freehold (with title deed)   3 = Other (specify) _______________

2 = Freehold (without title deed)

B/11. If land is rented from others, what is the rental value? _______ KSh/Birr/acre

Note: If payment is in-kind Please describe:_________________________________

B/12. Do you use communal/public land? [___] 1 = Yes 2 = No

B/13. If yes, **how much** communal or public land do you use for;

	Acres
1. All crops	
2. Grazing	
4. Others ___________	
Total communal land used	

C. HERD STRUCTURE, MORTALITIES, CATTLE KEEPING OBJECTIVES and CATTLE TRAITS

C/1.When did the household start keeping cattle? Please give **month** and **year**.
Month [______] Year [______]

C/2. What types of livestock does the household have and how many are they?

Livestock type	Total Number
a) Cattle	[_____]
b) Sheep	[_____]
c) Goats	[_____]
d) Poultry	[_____]
e) Donkeys/mules	[_____]
f) Horses	[_____]
g) Pigs	[_____]
h) Camels	[_____]
i) Others (specify) _____	[_____]

C/3. Indicate the **total number** of cattle **owned** by the household

Category	Owned and kept on-farm Number	Breed Types		Owned but kept off-farm Number	Breed Types
Cows (calved at least once)	[____]	[__] [__]		[____]	[__] [__]
Heifers (post-weaned, pre-calving)	[____]	[__] [__]		[____]	[__] [__]
Oxen (Castrated adult males >3yrs)	[____]	[__] [__]		[____]	[__] [__]
Bulls (> 3 yrs)	[____]	[__] [__]		[____]	[__] [__]
Immature males (< 3 yrs)	[____]	[__] [__]		[____]	[__] [__]
Pre-weaners	[____]	[__] [__]		[____]	[__] [__]

C/3. Breed Type

1 = East African Zebu
2 = Boran
3 = Boran cross
4 = Sahiwal
5 = Sahiwal cross
6 = Jersey (cross)
7 = Ayrshire (cross
8 = Guernsey (cross)
9 = Holstein-Friesian
10 = Sheko
11 = Kuri
12 = Abigar
13 = Danakil
14 = Horro
15 = Arado
16 = Borana
17 = Holstein Friesian
18 = Local x local cross (specify)
19 = Others (specify)_____

C/4. Number of calves born in the **last 12 months (since October 2003)**: [_____]

C/5. What reasons influenced the choice of cattle breed(s) kept (Use breed codes in C/3)?

Breed Type	**Reason for breed choice**
[___]	[___] [___] [___]
[___]	[___] [___] [___]
[___]	[___] [___] [___]
[___]	[___] [___] [___]

C/5. Reason for breed choice

1 = High milk production
2 = Disease resistance __________
3 = Ease of handling (docile)
4 = Size of the animal
5 = Non-selective feeding
6 = Highly fertile (bulls)
7 = Good reproductive ability (cows)
8 = Good traction ability
9 = Heat tolerance
10 = Drought tolerance
11 = Only breed available in the market
12 = Sale ease (marketability)
13 = Aesthetic attributes (colour etc)
14 = Weight gain
15 = Ability to walk long distances
16 = Other (specify) __________________

C/6. What is the origin or source of the cattle breeds kept by the household?

Breed type	**Origin/source of breed (s)**
a)	[___]
b)	[___]
c)	[___]
d)	[___]
e)	[___]

C/6. Origin/Source of breed

1=Inherited
2=Bought from neighbour
3=Gift/bride price
4=Born on-farm
5 = Market
6 = NGO/Project
7 = Cooperative
8 = Large - scale farm
9 = Other ___________

C/7. How many cattle have **left** the herd in the **last 12 months**?

Animal type	**Number**	**Mode of disposal**	**Reasons for disposal**
Cows (calved at least once)	[___]	[___] [___]	[___] [___]
Heifers (post weaned, pre-calving)	[___]	[___] [___]	[___] [___]
Oxen (Castrated adult males>3yrs	[___]	[___] [___]	[___] [___]
Bulls (> 3 yrs)	[___]	[___] [___]	[___] [___]
Immature males (< 3 years)	[___]	[___] [___]	[___] [___]
Pre-weaners	[___]	[___] [___]	[___] [___]

C/7. Mode of disposal

1=Sold
2=Slaughtered
3=Died
4=Stolen
5=Still birth
6=Give away
7=Others _____

C/7. Reasons for disposal

1=Cash needed (sales)
2=Colour
3=Temperament
4=Health/body condition
5=Old age
6=Production performance
7=Fertility
8=Disease
9=Others _____________

C/8. Please provide details of the animals that **died in the past 12 months**.

Cattle Type	**Number**
a) Cows (calved at least once)	[____]
b) Heifers (post weaned, pre-calving)	[____]
c) Oxen (Castrated adult males>3yrs	[____]
d) Bulls (> 3 yrs)	[____]
e) Immature males (< 3 years)	[____]
f) Pre-weaners	[____]

C/9. Reasons for death (*Tick where appropriate*)

1. Predators		
2. Disease		
3. Accident		
4. Poisoning		
5. Unknown		
6. Drought		
7. Other (specify) ____________		

C/10. If the cause of death was disease in C/9 above, what disease(s) was it? [___][___][___]

1 = Trypanosomosis ("Gandi")
2 = Black Leg ("Abagorba/Goleba")
3 = Anthrax ("Abasanga")
4 = Bloat disease ("Mura/Kurba")
5 = FMD ("Masaa")
6 = Pasturolosis ("Wanaraba")
7 = Skin Disease
8=Unknown disease
9= Others (specify ______________

C/11. Why do you keep cattle?

Reasons for keeping cattle	**Tick (√) if mentioned**	**Rank (1= most important)**
a) Source of milk for household consumption		[___]
b) Milk income (sale of milk)		[___]
c) Meat production		[___]
d) Source of manure		[___]
e) Source of calves		[___]
f) Cash security		[___]
g) Draft power		[___]
h) Store of wealth (savings)		[___]
i) Prestige (social status)		[___]
j) Dowry payment		[___]
k) Breeding		[___]
l) Ceremonial purposes		[___]
m) As a way of life (occupation)		[___]
n) Others (specify) ____________		[___]
0) Butter ("Kibe)		[___]
p) Cheese ("Ayib")		[___]
q) Threshing grains		[___]
r) Others (specify) __________		[___]

Note for C/11. **Do not suggest** reasons to the respondent, let him/her answer. Rank in the second column the most important reasons why they keep cattle, with 1 being the most important.

C/12. Have you ever purchased cattle? [___]   1 = Yes   2 = No

If yes, what traits are important when you buy male and female cattle?

	Male		**Female**	
Cattle traits	**Tick (√) if mentioned**	**Rank**	**Tick (√) if mentioned**	**Rank**
a) Disease resistance		[__]		[__]
b) Heat tolerance		[__]		[__]
c) Body condition		[__]		[__]
d) Traction ability		[__]		[__]
e) Temperament		[__]		[__]
f) Fertility		[__]		[__]
g) Growth rate		[__]		[__]
h) Feed requirement		[__]		[__]
i) Drought tolerance		[__]		[__]
j) Colour (specify)		[__]		[__]
k) Tail length		[__]		[__]
l) Breed		[__]		[__]
m) Size of prepuce		[__]		
n) Size of navel flap		[__]		[__]
o) Length of neck		[__]		[__]
p) Milk yield				[__]
q) Pregnancy				[__]
r) Milk taste				[__]
s) Teat/udder size and condition				[__]
t) Horns		[__]		[__]
u) Meat quality		[__]		[__]
v) Walking ability		[__]		[__]
w) Size of the animal		[__]		[__]
x) Price of the animal		[__]		[__]
y) Weight gain		[__]		[__]
z) Size of		[__]		[__]
a1) Strong legs		[__]		[__]
a2) Curved back		[__]		[__]

C/13. CHOICE EXPERIMENT

Use the choice cards provided in the file. Each farmer is to answer profiles for **either bulls only** or **cows only.**

<u>**Scenario**</u>**:** For **each choice task**, ask the respondent to assume that he wants to buy a bull or a cow. In the market, there are only 2 types of cows or bulls to be bought. Explain the traits of each animal and show them the advantages and disadvantages of each, from the pictures in the file. S/he can choose to buy one of them or s/he can choose to buy none and go back home without buying any. Then tick the appropriate box for the choice the farmer has made for each task and ask the main reason for the choice.

A: BULLS – Tick appropriate box for farmer choice profile for BULLS for each choice task

	Farmer Choice			**Main reason for choice**
Choice task 1	1 [__]	2 [__]	3 [__]	
Choice task 2	1 [__]	2 [__]	3 [__]	
Choice task 3	1 [__]	2 [__]	3 [__]	
Choice task 4	1 [__]	2 [__]	3 [__]	
Choice task 5	1 [__]	2 [__]	3 [__]	
Choice task 6	1 [__]	2 [__]	3 [__]	
Choice task 7	1 [__]	2 [__]	3 [__]	
Choice task 8	1 [__]	2 [__]	3 [__]	
Choice task 9	1 [__]	2 [__]	3 [__]	
Choice task 10	1 [__]	2 [__]	3 [__]	
Choice task 11	1 [__]	2 [__]	3 [__]	

B: COWS – Tick appropriate box for farmer choice profile for COWS for each choice task

	Farmer Choice			**Main reason for choice**
Choice task 1	1 [__]	2 [__]	3 [__]	
Choice task 2	1 [__]	2 [__]	3 [__]	
Choice task 3	1 [__]	2 [__]	3 [__]	
Choice task 4	1 [__]	2 [__]	3 [__]	
Choice task 5	1 [__]	2 [__]	3 [__]	
Choice task 6	1 [__]	2 [__]	3 [__]	
Choice task 7	1 [__]	2 [__]	3 [__]	
Choice task 8	1 [__]	2 [__]	3 [__]	
Choice task 9	1 [__]	2 [__]	3 [__]	
Choice task 10	1 [__]	2 [__]	3 [__]	
Choice task 11	1 [__]	2 [__]	3 [__]	
Choice task 12	1 [__]	2 [__]	3 [__]	

D. PRODUCTION SYSTEM CHARACTERISTICS

General

D/1. Type of production system [___]

D/1. Production system
1 = Crop-livestock system
2 = Agro-pastoral
3 = Pastoral
4 = Other (specify) ___________

D/2. Mobility of livestock [___]

D/2. Mobility
1 = Sedentary
2 = Transhumance (transfer of livestock from one grazing ground to another, with the changing of seasons)
3 = Nomadic (Leading the life of a person without a fixed domicile; moving from place to place according to the seasons in search of food, water and grazing land)
4 = Other (specify) ___________

Cattle Feeding Systems

D/3. What are the household's main cattle feeding systems for the various seasons? (Tick where appropriate)

	Dry season	Wet season
1 = Herder grazing		
2 = Tethered grazing		
3 = Unherded grazing		
4 = Stall feeding		
5 = Semi-zero grazing		
6 = Others (specify) _________		

D/4. If cattle are grazed, how many hours per day do your cattle graze? ________hours

D/5. Type of pasture which the cattle graze [___] 1=Natural 2= Cultivated

D/6. What is the source of water for the animals and the distance to the water source?

(i) Dry season [___] Distance to watering point _________ Km

(ii) Wet season [___] Distance to watering point _________Km

D/6 Source of water for the animals

1 = Borehole/water well	3 = River	5 = Rain water	7 = Other (specify)___
2 = Dam/pond	4 = Piped water	6 = Spring	

D/7. Do you use commercial feeds, Agro-industrial by-products or crop residues as supplementary feeds for your cattle? [___]
1 = Yes 2 = No

D/8. If **yes**, which ones do you use and on which cattle type(s)? (Use codes below)

	Tick if used	Unit of purchase	Price per unit	Cattle type	Feeding unit	No. of units PER DAY PER animal (quantity)
1 = Dairy meal		[___]	[___]	[___]	[___]	[___] [___]
2 = Maize bran		[___]	[___]	[___]	[___]	[___] [___]
3 = Wheat bran		[___]	[___]	[___]	[___]	[___] [___]
4 = Maize germ		[___]	[___]	[___]	[___]	[___] [___]
5 = Pollard		[___]	[___]	[___]	[___]	[___] [___]
6 = Calf pellets		[___]	[___]	[___]	[___]	[___] [___]
7 = Poultry waste		[___]	[___]	[___]	[___]	[___] [___]
8 = Brewer's waste		[___]	[___]	[___]	[___]	[___] [___]
9 = Minerals		[___]	[___]	[___]	[___]	[___] [___]
10 = Other ____		[___]	[___]	[___]	[___]	[___] [___]
Crop Residue Type (List)						
				[___]	[___]	[___] [___]
				[___]	[___]	[___] [___]
				[___]	[___]	[___] [___]
				[___]	[___]	[___] [___]
				[___]	[___]	[___] [___]

D/8. Unit of purchase

1 = Kgs
2 = Standard sacks
3 = Donkey cartload
4 = Handcart/wheelbarrow load
5 = Pick-up load
6 = I kg Kasuku tin
7 = 2 kg Kasuku tin or gorogoro
8 = Others (Specify) ______

D/8. Cattle Type

1 = Bulls (> 3 years)
2 = Castrated adult males (>3 yrs)
3 = Immature males (< 3 yrs)
4 = Cows
5 = Heifers
6 = Preweaners

D/8. Feeding Units

1 = Kgs
2 = Standard sacks
3 = Donkey cartload
4 = Handcart/wheelbarrow load
5 = I kg Kasuku tin
6 = 2 Kg Kasuku tin or gorogoro
7= Handful
8 = Others (Specify) ______

Housing and Housing materials

D/9. Housing/enclosure for cattle (*Tick one or more boxes*)

With roof	1. In family house	
	2. Separate house	
	3. Veranda	
	4. Shed	
Without roof	5. Kraal	
	6. Yard	
	7. Other (specify) ____________	

D/10. Type of housing materials (*Tick one or more boxes*)

	Roof	Wall	Floor
1. Iron sheets			
2. Grass/bushes			
3. Wood/branches			
4. Stone/bricks			
5. Earth/mud			
6. Concrete			
7. Dung			
8. Others (specify)____________			

D/11. Animals housed under one roof (*Tick appropriately*)

	Tick	**Comments**
1. Cows		
2. Bulls		
3. Oxen		
4. Calves (< 1 year)		
5. Other young stock (1 to 3 years)		

D/12. If you have **a paddock, a boma or a stall to enclose your cattle**, when did you build it? [_ _ _ _] (Year)

How much did it cost you?

(Include costs of expansion and separate dairy shed from boma)

Materials	Cost of dairy shed (zero grazing unit-KSh/Birr)	Cost of boma or paddock (KSh/Birr)
Wood	[______]	[______]
Cement/stone/sand	[______]	[______]
Thatch	[______]	[______]
Mabati (iron sheet)	[______]	[______]
Nails	[______]	[______]
Fences	[______]	[______]
Transport	[______]	[______]
Total	[______]	[______]

	Dairy shed	Boma/paddock	Comments
How much do you spend per year for its maintenance?	[___] (KSh/Birr)	[___] (KSh/Birr)	
From time of construction, how many years do you think it can last?	[___] (years)	[___] (years)	
If you sold the materials now, how much do you estimate you can get?	[___] (KSh/Birr)	[___] (KSh/Birr)	

Animal Power and Manure

D/13. What animals do you use for work (*Tick appropriately*)?

1. Male cattle	
2. Donkeys	
3. Cows	
4. None	

D/14. If you use cattle for work, what work do you use them for? ((*Tick appropriately*)

1. Ploughing	
2. Threshing	
3. Transport (of goods)	
4. Pulling water	
5. Other (specify) _________	

D/15. Do you use animal manure? [___] 1 = Yes 2 = No

If yes, how is the animal manure used?

	(Tick)	(Remark)
a) Fertilizer		
b) Fuel		
c) Building		
d) Not used		
e) Sold*		** Price/Unit
f) Other (specify) ___________		

Milk Production, Sales, Prices and Breeding Services

D/16 For **two cows** in the herd, fill out the following information **Note:** If the household has **more than 2 cows in the herd, then ask the farmer to give details of some *randomly selected* two.**

COW		No. of calvings	Cow age (years)	Age at 1st calving (Months)	Pregnant now? 1 = Yes 2 = No	Source of last service	Last service date (MM/YY) (most recent)	Last calving date MM/Y Y	Second last calving date MM/Y Y	**TOTAL MILK PRODUCTION (Morning plus evening milk) MILK UNITS [__] [__]**			
Name	Breed									At calving	Yesterday	When stopped milking	Comments
__________	[__]	[____]	[____]	[____]	[____]	[____]	[__/ __]	[__/__]	[__/__]	[____]	[____]	[____]	
__________	[__]	[____]	[____]	[____]	[____]	[____]	[__/ __]	[__/__]	[__/__]	[____]	[____]	[____]	
__________	[__]	[____]	[____]	[____]	[____]	[____]	[__/ __]	[__/__]	[__/__]	[____]	[____]	[____]	
__________	[__]	[____]	[____]	[____]	[____]	[____]	[__/ __]	[__/__]	[__/__]	[____]	[____]	[____]	

D/16. Breed Type

1 = East African Zebu
2 = Boran
3 = Boran cross
4 = Sahiwal
5 = Sahiwal cross
6 = Jersey (cross)
7 = Ayrshire (cross
8 = Guernsey (cross)
9 = Holstein - Friesian (cross)
10 = Sheko
11 = Kuri
12 = Abigar
13 = Danakil
14 = Horro
15 = Arado
16 = Others______

D/16. Source of Last Service

1 = Own bull
2 = Other farmer's bull
3 = Government AI
4 = Private AI
5 = Self Help Group AI
6 = Project AI
7 = Community bull
8 = Unknown bull
9 = Other (Specify)

D/16. Milk Unit

1 = Litre
2 = Treetop bottle (750ml)
3 = Bottle (330ml)
4 = Cup (250ml)
5 = Glass
6 = Other (specify)

D/17. Do you consume milk or milk products from your cows? [___] 1 = Yes   2 = No

D/18. If yes, please indicate how much of **fresh milk and other milk products** are currently consumed by your household **per day**? (Use codes for milk units below)

Milk and milk product type	**Unit**	**Quantity per day**
Fresh milk	[___]	[___]
Sour milk	[___]	[___]
Cheese ("Ayib")	[___]	[___]
Butter ("Kibe")	[___]	[___]
Other (specify) ____________	[___]	[___]

D/19. Do you sell milk and milk products? [___]   1 = Yes   2 = No

D/20. If yes, please indicate where and how much of the milk and milk products you **sell** currently, specifying the average amount to each buyer type per day and the price received.

Milk and milk product type	**Buyer Type**	**Unit**	**Average quantity sold per day**	**Price per unit (KSh/Birr)**
Fresh milk	[___]	[___]	[________]	[_____]
Sour milk	[___]	[___]	[________]	[_____]
Yoghurt	[___]	[___]	[________]	[_____]
Cheese ("Ayib")	[___]	[___]	[________]	[_____]
Butter ("Kibe")	[___]	[___]	[________]	[_____]
Other (specify)	[___]	[___]	[________]	[_____]

Milk and milk product units

1 = Litre
2 = Cup (250ml)
3 = Glass
4 = Bottle (330ml)
5= Kg
6 = Other (specify) _____

Buyer Type

1 = Neighbours
2 = Private milk traders
3 = Private dairy processor
4 = Farmer group/club
5= Retail shop/kiosks
6 = Hotels/restaurants
7 = Institutions (e.g. schools)
8 = Market place
9 = Others (specify)

Mating and Breeding Services

D/21. What kind of mating-practice do you perform? (Tick where appropriate)

		Comments
Controlled	[__]	
Uncontrolled	[__]	
Both	[__]	

D/22. What type of mating did you use in the last 12 months? (Tick where appropriate)

Bull service [__]
Artificial insemination [__]
Both [__]

D/23. If bull service was used, what was the source of bull? (Tick where appropriate)

1 = Own-bred [__]
2 = Bought [__]
3 = Donated [__]
4 = Borrowed [__]
5 = Bull from neighbour [__]
6 = Communal bull [__]
7 = Unknown [__]

D/24. If you use your own bull for breeding, what are the criteria for the selection/choice of that particular bull? (Tick where appropriate)

1. No particular choice [__]
2. Body condition [__]
3. Size [__]
4. Coat colour [__]
5. Horns [__]
6. Character [__]
7. Availability [__]
8. Breed [__]
9. Performance of mother [__]
10. Performance of grandmother [__]
11. Performance of father [__]
12. Performance of grandfather [__]
13. Performance of other relatives specify: ______________________ [__]

D/25. Refer to D/22 above on breeding services used, if you do not have your own bull, how far (on foot) do you go to get the bull service or AI service?

	Distance (Km) (One way)	Time taken (One way) (hh:min)
Bull service	________________	[__:__]
AI service	________________	[__:__]

D/26. Do you have a problem obtaining bull service or the AI service at the time your cow is on heat? [_____] 1=Yes 2 = No

D/27. If Yes above, what is the problem? [__] [__]

D/27. Source of problem obtaining bull service or AI service

1 = Long distance — 3 = Service too expensive

2 = Unavailability of service provider — 4 = Others (specify) ____________

D/28. Are there specific reasons why you use **bull service**?

Reasons for preference:
(i) ____________________
(ii) ____________________
(iii) ____________________

D/29. Are there specific reasons why you use **AI service**?

Reasons for preference:
(i) ____________________
(ii) ____________________
(iii) ____________________

D/30. How much do you pay for one AI service or bull service?

	Cost (KSh/Birr)	**Comments**
Bull service	___________________	
AI service	___________________	

D/31. Are you satisfied with the;

bull service you are using? [___] 1=Yes 2 = No

AI service you are using? [___] 1=Yes 2 = No

D/32. If No in D/31 what are the problems?
(i) ____________________
(ii) ____________________

D/33. Do you raise your own replacement stock? [___] 1 = Yes 2 = No

D/34. If No in D/33 above, what is your source of replacement stock? [___]

D/34. Source of replacement stock

1 = Purchased from livestock markets
2 = Neighbours
3 = Friends
4 = Commercial breeders
5 = Projects/NGOs
6 = Others (specify) ________

D/35. Do you castrate your own bulls? [___] 1 = Yes 2 = No

D/36. At what age do you castrate your own bulls? (Tick where appropriate)

Age of castration	3-6 months	6-9 months	> 9 months
	[___]	[___]	[___]

D/37. Reasons for castration: (Tick where appropriate)

1. Fetch better market prices [___]
2. Improve draft power [___]
3. Improved temperament [___]
4. Control breeding [___]
5. Fattening [___]

D/38. What is the average age at sexual maturity (first mating) in months for male cattle?
[___] months.

E. LABOUR RESOURCES

E/1. Do you hire labour for your farm activities? [___] 1 = Yes 2 = No

E/2. What is your source of labour for farm activities and how much do you pay for hired labour?

Activity	Source of labour	No. of days per year	Hours per day	No. ofhired laborers	Amount paid for hired labor (KSh/Birr) per unit	Unit 1= day 2= month 3= acre 4= other	In-kind payment (describe
Land preparation	[__]	[__]	[__]	[__]	[___]	[__]	
Planting	[__]	[__]	[__]	[__]	[___]	[__]	
Weeding	[__]	[__]	[__]	[__]	[___]	[__]	
Harvesting	[__]	[__]	[__]	[__]	[___]	[__]	
Cutting fodder and feeding cattle	[__]	[__]	[__]	[__]	[___]	[__]	
Herding cattle	[__]	[__]	[__]	[__]	[___]	[__]	
Milking	[__]	[__]	[__]	[__]	[___]	[__]	
Spraying/dipping	[__]	[__]	[__]	[__]	[___]	[__]	
Milk sales	[__]	[__]	[__]	[__]	[___]	[__]	
Other_______	[__]	[__]	[__]	[__]	[___]	[__]	

E/2. Source of labor

1 = Adult members of the house (≥ 16 years)
2 = Female adult members of the house (≥ 16 years)
3 = Male adult members of the house ((≥ 16 years)
4 = Child labour from the house (< 16 years)
5 = Hired casual labourer (short - term)
6 = Hired permanent labourer (long-term)
7 = Farmer group/community group
8 = Tractors
9 = Others ___________________

F. ANIMAL HEALTH and MANAGEMENT PRACTICES

F/1. Have you had any cases of sick cattle in your herd in the last **three** years? [___]
1 = Yes 2 = No

F/2. If yes, please give the details:

Diseases	Frequency of disease (number of times per year)	Clinical signs	Breed of animal affected	Source of treatment	No. of treatments per year	Cost per treat-ment per animal	Effect of non-treat-ment
a) [__]	[____]	[__] [__]	[__]	[___]	[___]	[____]	[_] [_]
b) [__]	[____]	[__] [__]	[__]	[___]	[___]	[____]	[_] [_]
c) [__]	[____]	[__] [__]	[__]	[___]	[___]	[____]	[_] [_]
d) [__]	[____]	[__] [__]	[__]	[___]	[___]	[____]	[_] [_]
e) [__]	[____]	[__] [__]	[__]	[___]	[___]	[____]	[_] [_]
f) [__]	[____]	[__] [__]	[__]	[___]	[___]	[____]	[_] [_]

Diseases

1 = Trypanosomosis
2 = FMD
3 = Anaplasmosis
4 = Blackwater
5 = Bloat disease
6 = Pasturolosis
7 = CBPP
8 = ECF
9 = Lumpy Skin Disease
10 = Black water
11 = Redwater (Babesiosis)
12=Heartwater
13= Malignant Catarrhal Fever
14=Mastitis
15=Anthrax
16=Brucellosis
17=Unknown
18= Others (specify ______

Clinical signs

1=Diarrhoea
2=Cough
3=Fever
4=lack of appetite
5=Skin problems
6=Swollen lymph node
7=Weight loss
8=Lameness
9=Swollen body parts
10=Blindness
11=Salivation
12=Lachrimation
13=Rough coat
14=Miscarriage in cows
15=Shivering
16=Bloody dung
17=Dyspnoea
18=Abrupt death
19=Ulcerations in hoof
20= Others__________

Breed of animal affected

1 = East African Zebu
2 = Boran
3 = Boran cross
4 = Sahiwal
5 = Sahiwal cross
6 = Jersey (cross)
7 = Ayrshire (cross
8 = Guernsey (cross)
9 = Holstein-Friesian (cross)
10 = Sheko
11 = Kuri
12 = Abigar
13 = Danakil
14 = Horro
15 = Arado
16 = Borana
17 = Others (specify)

Treatment source

1 = AHA
2 = Other farmer (s)
3 = Private veterinarian
4 = Govt veterinarian
5 = Extension worker
6 = Self (bought drugs)
7 = Traditional healer
8 = Other (specify)

Effect of non-treatment

1=Reduced milk yield
2=Reduced traction
3=Death
4=Low reproduction rate
5=Loss of weight
6= Others (specify) ___

F/3. Do you control ticks? [___] 1 = Yes   2 = No

F/4. If yes, which methods do you use? [___]

1 = Use of cattle dips   3 = Use of local herbs (specify) __________
2 = Spraying   4 = Other (specify) ___________

F/5. Do you control tsetse flies? [___] 1 = Yes   2 = No

F/6. If yes, which methods do you use? [___][___]

1 = Dipping   4 = Clearing bush land
2 = Spraying   5 = Other (specify) _________
3 = Use of Traps

G. ACCESS TO CREDIT, EXTENSION SERVICES AND MEMBERSHIP TO FARMER GROUPS

G/1. Have you ever obtained credit (loans) for your cattle enterprise activities in the last 5 years? (**From 2000**) [___]
1 = Yes 2 = No

G/2. If **Yes**, indicate for **which needs** credit was obtained, **when and from what credit source**? (List each loan separately)

Credit needs (check codes)	Year obtained	Source of credit (check codes)	Form of credit 1=Money 2=In-kind (specify)	Was it adequate? 1=Yes 2=No
[___][___]	[___ ___]	[___]	[___]	[___]
[___][___]	[___ ___]	[___]	[___]	[___]
[___][___]	[___ ___]	[___]	[___]	[___]
[___][___]	[___ ___]	[___]	[___]	[___]
[___][___]	[___ ___]	[___]	[___]	[___]

G/2. Credit needs
1=Purchase cattle
2=Cattle housing
3=Purchase feed
4=Veterinary services
5=Establishing fodder
6=Loan of cattle
7=Other specify)

G/2. Source of credit
1 = Government bank/agency
2 = Agricultural Finance Corporation (AFC)
3 = Micro Finance Institutions e.g. WEDCO
4 = Savings and Credit Cooperative (SACCO)
5 = Farmer group (Self help group)
6 = Friends/relatives
7 = Others (specify)____________

G/3. If **No** credit was obtained, why not? [___] [___]

G/3. Reason for not obtaining credit

1 = Credit required but didn't get
2 = Credit not available
3 = Credit was too costly
4 = Lack of collateral
5 = Not aware/do not have such information
6 = Fear of being unable to pay
7 = Not needed
8 = Other (specify) ___________

G/4. Have you been visited by an extension agent in the last **12 months**? [___]

1 = Yes 2 = No

G/5. If **Yes**, what is the frequency of contact? [___]

G/5. Frequency of Contact

1 = Once a week
2 = Fortnightly
3 = Once a month
4 = Thrice a year
5 = Twice a year
6 = Other (specify) ________

G/6. What is the source of extension service and what is the content of the extension message?

Source of Extension	**Extension message (s)**
[___]	[___] [___]
[___]	[___] [___]

G/6. Source of Extension Contact

1 = Government
2 = Private
3 = Other (specify) __________

G/6. Extension message

1 = Cattle management
2 = Land use
3 = Crop management
4 = Input use
5 = Disease control
6 = Others ________

G/7. Is anyone in the household a member of the following organisations?

Organisation	**Membership** **1 = Yes** **2 = No**	**Services obtained from organisation**
Cooperative society	[___]	[___] [___]
Women Group	[___]	[___] [___]
Micro Finance Institution	[___]	[___] [___]
Welfare group	[___]	[___] [___]
Farmer group	[___]	[___] [___]
Others (specify) ________	[___]	[___] [___]

G/7. Services obtained from organisation

1 = Credit (cash)
2 = Credit (in – kind)
3 = Marketing
4 = Extension advice
5 = Purchases from rotation savings
6= Others (specify) _________

H. HOUSEHOLD INCOME SOURCES

H/1. For the different sources of income to the household, **estimate average amount per month or per year**:

	INCOME (KSh/Birr)	FREQUENCY 1 = Month 2 = Year 3= Other ________
Income from cattle/dairy activities	[_______]	[____]
Income from sale of cash crops	[_______]	[____]
Income from sale of food crops	[_______]	[____]
Income from wages/salaries/non-farm, pension and business activities	[_______]	[____]
Income from remittances from absent family members and other external income	[_______]	[____]
Income from rent (plots, house, etc.)	[_______]	[____]
Income from other sources (specify) ___________________________	[_______]	[____]

H/2. If you are asked to keep production performance records of your cattle, would you be willing to do it? [___] 1 = Yes 2 = No

H/3. If No, in H/2 why not?

____

____

H/4. In your opinion which is the best method of obtaining cattle for breeding and why?

____

____

____

This is the end, please thank the respondent for his/her time

GENERAL COMMENTS

____

____

____

Appendix 3: Curriculum Vitae

Name: Emily Awuor Ouma

Date of Birth: 25th October 1973

Place of Birth: Nairobi, Kenya

Nationality: Kenyan

Marital status: Married

Education

2004 – 2007: **PhD student** at the Department of Food Economics and Consumption Studies at the Christian – Albrechts - University Kiel, Germany.
Thesis title: "Economic Valuation of Phenotypic Cattle Trait Preferences in Trypanosomosis Prevalent Production Systems of Eastern Africa: Implications for Sustainable Cattle Breeding Programs".

2000 – 2003: **M.Sc. in Agricultural Economics**, Egerton University Njoro, Kenya.
Thesis title: "An Analysis of the Economic Value of Cattle in Smallholder Livestock Production Systems of Western Kenya".

1993 – 1998: **B.Sc. in Agricultural Economics**, Egerton University Njoro, Kenya.

1988 – 1991: **Secondary school education:** Pangani Girls High School, Nairobi, Kenya.
Qualification: Kenya Certificate of Secondary Education.

1980 – 1987: **Primary school education:** Harambee Primary School, Nairobi, Kenya.
Qualification: Kenya Certificate of Primary Education.

Professional Experience

October 2004 – April 2007

Doctoral student at the Christian – Albrechts - University Kiel, Germany, working on a ZIL-funded project entitled "Developing Optimized Cattle Breeding Schemes, with a special focus on trypanotolerance, based on the demands and opportunities of poor livestock keepers in Eastern Africa".

July 2001 – November 2002: M.Sc. Graduate Fellow at the International Livestock Research Institute.

May 1998 – October 2000

Research Assistant with the Market Oriented Smallholder Dairy (R&D) project and the Eco-regional project at the International Livestock Research Institute, in Nairobi – Kenya.