Contribution of Economics to Design of Sustainable Cattle Breeding Programs in Eastern Africa: A Choice Experiment Approach

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1. Introduction

Livestock forms an important component of the livelihoods of majority of developing countries' rural populations and are closely associated with the social fabric and welfare of rural households. These rural populations live in complex, diverse and risk-prone environments where livestock are mainly raised in low-input systems and perform multi-faceted functions ranging from income, non-income to socio-cultural functions (Anderson, 2003). In African rural areas, livestock is an important source of food and cash, crucial for the purchase of consumer goods and procurement of farm inputs. In addition, they are a means of demonstrating wealth, storing savings and act as substitutes for missing financial and insurance markets in developing countries (Moll, 2005).

Despite the high significance of livestock production in developing countries, productivity remains low. In sub-Saharan Africa as in other developing countries, livestock producers continue to face a number of technical, institutional and infrastructural constraints related to feeding, animal health and genotype, leading to low livestock productivity levels. The severity of these constraints varies by the various production systems under which livestock production takes place. The production systems are determined by agro-ecology and commonly differ in exhibiting various stress factors, such as water shortages, disease and parasites as well as temperature extremes. In order for improved livestock productivity to be realized, there is need to overcome or minimize the constraints faced by livestock keepers.

Animal diseases, especially those caused by parasites, are severe constraints on animal production in sub-Saharan Africa. Trypanosomosis is arguably one of the most important of these, with effects hardest felt by poor livestock keepers in sub-Saharan Africa. Trypanosomosis is endemic in seven million square kilometers of Africa, comprising more than one third of the land area across Africa. It is one of the major constraints of livestock productivity, with forty six million cattle at constant risk of infection (FAO, 1991; Kristjanson et al., 1999). The disease represents a major constraint to increased food production as it reduces livestock productivity due to poor growth, weight loss, low milk yield, infertility and abortion. Other losses emanate from farmer's 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. It is estimated that control of trypanosomosis would result in substantial increases of milk and meat supply in sub-Saharan Africa by a substantial 17 percent (De Haan and Bekure, 1991).

Control of trypanosomosis in Africa currently relies largely on the use of chemotherapeutic drugs, tsetse vector control or an integrated control approach combining several strategies. In most cases, such control remains costly and only partially effective. The control of trypanosomosis using trypanocidal drugs to treat or prevent the disease is limited by drug costs and availability, and by the development of drug-resistance in target parasites.
Genetically controlled tolerance of livestock is a highly promising route for control of trypanosomosis (d'Ieteren et al., 1998). The advantage of genetic control over other methods of control is that genetic changes are cumulate and permanent, and there are no recurring costs to the end users. The prospects for producing cattle with genetic tolerance to trypanosomosis in combination with other suitable characteristics are high given that trypanotolerance is known to exist in several cattle populations.

Breed improvement, provides key entry points for increasing productivity in cattle populations especially those susceptible to trypanosomosis. However, there are tendencies for breed improvement programs to focus on single, market driven traits such as milk or meat production in isolation of broader livestock system functions and constraints. The focus of livestock development policies in developing countries has often been on improvement of livestock productivity through substitution of large-frame, higher yielding exotic breeds for indigenous breeds. This has repercussions on potential loss of indigenous livestock breeds, which are more adaptable to the harsh climatic conditions in some environments and capable of fulfilling the multiple roles that cattle assume in developing countries.

There is little evidence and information regarding animal breeding programs that allow priority setting that is driven by cattle keepers' preferred traits. Yet, their participation may contribute to development of sustainable breeding programs. This paper aims to fill this gap by deriving economic values for cattle traits in pastoral and crop-livestock production systems in eastern Africa, using choice experiments. The focus is on farmer preferences for trypanotolerance, relative to other traits which could be introduced through breeding programs that utilize resistant genotypes. The rest of the paper is organized as follows. Section 2 presents a brief description of the characteristics of the study sites, while section 3 provides a background on choice experiments as well as a description of the process used to collect the choice experiment data and the estimation methods. The empirical results are discussed in section 4 and concluding remarks presented in section 5.

2. Study Area

Spatial mappings of tsetse fly distribution in Kenya and Ethiopia was done as an initial attempt at targeting research areas with trypanosomosis challenge, given that the major pathogenic trypanosome species in livestock are transmitted by the tsetse fly. Two districts, Suba and Narok were then selected in Kenya to represent crop-livestock systems and pastoral systems respectively. In Ethiopia, the study was carried out in Ghibe valley, a trypanosomosis prevalent area where crop-livestock production system is predominant. Pastoral systems are characterized by low input management for the cattle enterprise; large cattle herd sizes of about 72 animals per household and practice of some level of semi-nomadism. Livestock are moved based on seasonal rotation in search of water and pasture. No crop production is undertaken due to the harsh agro-climatic conditions. Land ownership is predominantly in the form of communal group ranches. In crop-livestock systems, both crop and livestock production takes place. There exist strong crop-livestock interactions in this system. Cattle act as agricultural inputs in crop production, in terms of provision of draught power for ploughing crop fields and manure for fertilization of agricultural plots. On the other hand, crop harvest left-over is used to feed livestock. The use of manure for fertilization is important in this system because inorganic fertilizers are unaffordable to the farmers as their costs keep escalating.

3. Choice Experiments

Calculations of economic values by animal breeders for inclusion in breeding goals have often utilized profit functions. However, there are some important traits to cattle keepers that do not have prices or market values. This therefore calls for employment of a non-market valuation method that captures traits with and without market values or price. Price in the market is simply the willingness to pay for an additional unit of a good. Without markets we do not have prices, but trade-offs that people make often demonstrate a willingness to pay (Loomis, 2005). In this study, choice experiments are employed to capture these values. Choice experiments are a multiple trait stated preference method that applies the probabilistic theory of choice, where choices made by individuals from a non-continuous set of alternatives are modeled in order to reveal a measure of utility for the traits of the choices (Ben-Akiva and Lerman, 1985). Few studies that have used this method to estimate preferences for animal traits including Scarpa et al. (2003a), Scarpa et al. (2003b) and Tano et al. (2003), indicate that it is a highly promising method in valuing single traits of bundled goods such as livestock.

3.1 Data

In order to identify the cattle traits to be included in the choice experiment, farmer group discussions were held in the study sites. Farmers were asked to indicate their objectives of cattle keeping and then asked to identify the cattle traits that they consider important, based on their prevailing local and environmental conditions. Pairwise ranking technique for the traits was then applied to select the highly preferred traits. A total of eight preferred traits were identified for cows and seven for bulls. These were then used to design the choice experiment, with each trait having two to three levels. Table 1 presents the traits and their levels. The choice experiment was administered through a household questionnaire survey, on a sample of 303 cattle keeping households in Kenya and 204 in Ethiopia using in-person interviews. Cards with pictorial presentations of the differences in the levels of traits were used to demonstrate each cattle profile to survey respondents. The administration of the choice experiment was conducted in the following manner. Each respondent was first introduced to the type of choice task required and then he/she was presented with either twelve sets of pair-wise choices for cows or eleven for bulls drawn from a main effects only fractional factorial design. Each choice task required the respondent to choose one animal profile he would prefer to buy for rearing from the two profiles presented for each choice task. If neither of the profiles was found satisfactory, the respondent could choose the "none" option and state that he preferred neither. The household questionnaire also covered other aspects on the household and farm characteristics as well as market and resource access.

3.2 Estimation Methods

The theoretical foundation of choice experiments derives from Lancasterian consumer theory (Lancaster, 1966) and the random utility framework developed by Marshak (1960). In this study, the assumptions supporting the multinomial logit model are applied, the most prominent being that each error term is independently and identically distributed extreme value with a cumulative distribution**;** $F(\varepsilon_n) = e^{-e^{-\varepsilon_n}}$ (Train, 2003). The probability of individual *n*, choosing alternative *i* is specified thus;

$$P_{ni} = \frac{e^{\alpha_{ni} + \lambda_j s_n + \beta_n x_{ni}}}{\sum_j e^{\alpha_{nj} + \lambda_j s_n + \beta_n x_{nj}}} \tag{1}$$

while the sample log-likelihood function is;

$$LL(\alpha_{nj}, \beta_n, \lambda_j) = \sum_{n=1}^{N} \sum_{i=1}^{J} y_{nj} \ln P_{nj} \tag{2}$$

Where α_{ni} is the intercept or individual *n's* intrinsic preference for choice *i*, s_n contains the socio-economic characteristics of the individual, and the coefficient λ_j captures the systematic heterogeneity among the individuals in the sample. X_{nj} is a vector of the attributes and β_n the coefficients of the attributes. Maximum likelihood estimates for the parameter vector can be obtained by maximizing the likelihood function. The limitation of the multinomial logit model lies in its assumption of constant variance, which results in the independence of irrelevant alternatives (IIA) property and the assumption of fixed taste parameters in the population, which is rather limiting if taste actually varies in the population. This is a rather restrictive assumption since cattle keepers face varying sets of constraints and incentives, and are likely to exhibit different preference patterns. To relax this restrictive assumption, mixed logit model has been employed in this study, making it possible to account for unobserved taste variation.

In mixed logit, the taste parameters β, are allowed to vary in the population with density $g(\beta_n \mid \theta)$, where θ are the parameters of the population distribution. Each individual's coefficient β_n, differ from the population mean β, by some unobserved amount, constituting an additional source of randomness (Ben-Akiva and Lerman, 1985). The estimates for the location and spread parameter of the specified population distributions can also be obtained by maximizing the likelihood function in Equation 2. The value is simulated from random parameter draws from the postulated distribution $g(\beta|\theta)$. In the case of repeated choices per respondent as in our case, the same random draw is used across all the choices made by the same respondent in order to account for correlation across repeated responses (Train and Revelt, 1998; Garrod et al., 2002). The joint probability of a set of *t* repeated choices by respondent *n* and conditional on the drawn value for β is a product of logits;

$$L_n = \prod_t \exp(x_{n(t)j}\beta).\sum_j \exp(x_{n(t)j}\beta) \qquad (3)$$

The unconditional probability for the sequence of the choices for the *n*th individual is:

$$P_n(\theta) = \int L_n(\beta) g(\beta|\theta) d\beta \tag{4}$$

Since there is no closed form solution for equation 4 in the estimation, $P_n(\theta)$ is approximated by simulations by summing over values of β generated by Halton draws. Halton draws are superior to random draws in simulations. 100 Halton draws produce the same approximation as 1000 pseudo-random draws (Train, 2003). The simulated probability is presented thus;

$$\tilde{P}_n(\theta) = \frac{1}{r} \sum_{r=1,\ldots,R} S_n(\beta^{r|\theta}) \tag{5}$$

Where r is the number of draws of β from $g(\beta_n \mid \theta)$ and $\tilde{P}_n$ is the simulated probability of person *n's* choices. The simulated log-likelihood function is $SLL(\theta) = \sum_n \ln(\tilde{P}_n(\theta))$ and the estimated parameters are those that maximize the function. Various population distributions from which β is drawn can be assumed; this includes normal, lognormal, triangular and uniform distributions. In this paper, we assume normally distributed random parameters apart from purchase price which is drawn from triangular distributions.

3.3 Production Systems and Preference Heterogeneity

Producers from different production systems and countries, may face different constraints and opportunities in terms of livestock production activities, and may exhibit different preferences for cattle traits. We therefore tested for preference stability in the two cattle production systems in our study sites; crop-livestock in Kenya and Ethiopia and pastoral systems in Kenya using likelihood ratio tests. This was done by checking if the log-likelihood function from the multinomial logit (MNL) estimation from the different sub-samples is significantly larger than the pooled sample log-likelihood. The hypotheses to be tested were:

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

b) $H_0^2 : \beta_{pooled} = \beta_{Crop\,Livestock\,Ethiopia}$ Versus $H_A^2 : \beta_{pooled} \neq \beta_{Crop\,Livestock\,Ethiopia}$

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

d) $H_0^4 : \beta_{Crop\,Livestock\,Ethiopia} = \beta_{Crop\,Livestock\,Kenya}$ Versus $H_A^4 : \beta_{Crop\,Livestock\,Ethiopia} \neq \beta_{Crop\,Livestock\,Kenya}$

e) $H_0^5 : \beta_{Crop\,Livestock\,Kenya} = \beta_{Pastoral\,Kenya}$ Versus $H_A^4 : \beta_{Crop\,Livestock\,Kenya} \neq \beta_{Pastoral\,Kenya}$

For instance, results from hypothesis test *d*, indicate that the crop livestock systems in Kenya and Ethiopia are statistically different and consequently should not be pooled together: $L_{Ethiopia}$ =-366 and L_{Kenya} =-692. $L_{Ethiopia}$+ L_{Kenya} =-1059 while the restricted $L_{pooled\ crop\ livestock}$ =-1223 with a $\chi_7^2 = 329$ which is much larger than the critical value of 14.1 for the conventional one tailed test with probability of type I error of 5%. In the same way, the other hypotheses for preference stability were rejected. Consequently, the MNL estimations were done separately for the pastoral system in Kenya and the crop livestock systems of Kenya and Ethiopia.

4. Results and discussions

Maximum likelihood estimates for the multinomial logit models estimated for bulls and cows from the choice experiment data is presented in Table 2. Since the traits had 2-3 levels each, one level was left out as base during estimation. A total of 2,783 choices made by 253 households was collected for bulls and 3,036 choices made by another 253 households collected for cows. Most of the trait coefficients are statistically significant and have the expected signs, though their magnitude varies by the type of production system. For instance, trypano-tolerance trait coefficient has the expected positive sign across all production systems, indicating that respondents prefer trypano-tolerant cattle relative to trypano-susceptible ones. Traction potential for bulls is strongly positive and significant for crop livestock systems, indicating a high contribution of good traction potential trait in bulls to the crop-livestock farmers' utility function. In the pastoral systems, trait coefficients associated with fecundity (high fertility and reproductive potential) is strongly positive. The trait for liveweight is positive and strongly significant for bulls in crop-livestock and pastoral systems in Kenya. It is however not significant in the crop-livestock system in Ethiopia. Supplementary purchased feeds coefficient for cows is negative across the production systems albeit only statistically significant for the Kenyan production systems revealing the reluctance of the cattle keepers to have cows that require externally purchased feed inputs. The purchase price coefficients are not statistically significant for both cows and bulls traits. The Independence of Irrelevant Alternatives (IIA) test procedure developed by Hausman and McFadden showed IIA violations for both bulls and cows at the 1 percent level. Consequently, mixed logit, a less restrictive model, was estimated.

The results of the simulated maximum likelihood estimates for the mixed logit model are presented in Table 3. The overall model is statistically significant and fit the data slightly better than the fixed, multinomial logit model, with a Pseudo R-squared of 31% for bulls and 22% for cows. The likelihood ratio tests also result in rejection of the null hypothesis that the multinomial logit models fit the data significantly better than the mixed logit models. The mean coefficients of the random parameters are statistically significant, with the expected signs. The standard deviations of the random parameters are also statistically significant indicating significant preference heterogeneity within the sampled population. The non-random parameter, low watering frequency is positive and highly significant for bulls, implying that there is preference for bulls that are drought tolerant (need to water only once in two days), it is however, not significant for cows. The constant variable in tables 2 and 3 represent the “none” choice option and is the base for the choice model, as it is associated with “zero” utility. It takes a value of one if the option is “none” and zero otherwise. The results indicate a strong negative preference for this option, implying that the respondents preferred to select the other two choice options associated with various trait levels.

The marginal rate of substitution between the traits and the purchase price coefficient $(\hat{\beta}_k / \hat{\beta}_p)$ provides an estimation of implicit prices of the traits, also known as willingness to pay (WTP) values. The estimated implicit prices are computed using conditional[2] parameter estimates and the average values are reported in Table 4. Calculations of implicit prices from conditional individual parameter estimates rather than from draws of population distribution is reported by Hensher et al. (2005) to be advantageous since it produces behaviourally realistic value estimates. Estimates of WTP for traits parameters indicate that a trypano-tolerant bull or cow is valued at US$ 25 more than a trypano-susceptible one. According to the household survey data, the average cost of treatment or control of trypanosomosis per year per animal varies from US$ 6 to US$ 37 in Ethiopia while in Kenya it is an average of US$ 36 in crop-livestock systems. This depends on the number of treatments per year, influenced by the level of trypanosomosis challenge of the area. The implicit value for a bull with good traction potential is a high value of US$ 58. Tano et al. (2003), also find high preference for this trait, through highest rankings for bulls that are fit for traction in Burkina Faso. Fitness to traction has a direct link to crop production in crop-livestock systems and is one of the main reasons for keeping cattle.

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. An important attribute for cows is the ability to calve every year instead of once in two years. This trait is valued at US$ 9.4 which is even higher than the value of US$ 8.1 for a cow with high milk production. A bull that needs to be watered only once in 2 days, used as a proxy for drought tolerance, is valued at US$ 7 more than one that needs to be watered twice in a day. Water is an important constraint in the study areas especially during the dry seasons; therefore a drought tolerant animal is relatively highly valued by the cattle keepers.

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[2] The estimates are simulated conditioned on the choices observed to have been made by an individual.

5. Concluding Remarks

The basis of this study in estimating the economic value of cattle traits is to provide an input in designing sustainable cattle breeding programs in Africa based on cattle keepers' preferences in trypanosomosis disease prevalent areas. Results of the choice experiment conducted indicate that the values estimated are of reasonable magnitude and compares relatively well with computations from the household survey and previous research. A likelihood ratio test indicates that the mixed logit model, with random taste parameters provides better information about the utility function than the multinomial logit model.

Differences in preferences are observed across production systems. In as much as trypanotolerance is an important trait across the production systems, other traits are also of significant importance. For instance, in the crop-livestock system, traction ability for bulls contributes more to utility compared to trypanotolerance while in the pastoral systems, high fertility is more important. Therefore, breeding for trypanotolerance ought to integrate other preferred productive traits such as traction fitness, fecundity as well as other adaptability traits such as drought tolerance. Preference differences are also observed within the crop livestock systems of Kenya and Ethiopia. This may be attributed to taste heterogeneity across respondents. This reveals the need to further characterize households based on their tastes differences. This may be achieved through latent class analysis, which we will pursue.

From this study, we suggest the need to design a breeding program within a framework that may work for the target communities, taking into consideration production system differences and cattle keepers preferences and circumstances. Conservation and use of already existing trypanotolerant breeds with desirable qualities as breeding stock in a breeding program may be a viable strategy. In order for the breeding program to be sustainable, intervention programs related to breeding, feeding, record keeping and general management would need to be in place.

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Table 1: Traits and Trait Levels used for bulls in Choice Experiments

Cows		**Bulls**	
Traits	**Levels**	**Traits**	**Levels**
Trypanotolerance	1. Tolerant 2. Susceptible	Trypanotolerance	1. Tolerant 2. Susceptible
Milk yield	1. 1-2 litres/day 2. 2-4 litres/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 colour	1. Light-coloured 2. Dark-coloured	Coat colour	1. Light-coloured 2. Dark-coloured
Purchase price at 2 yrs (Kenya)	1. KSh 10,000 2. KSh 15,000 3. KSh 19,500	Purchase price at 4yrs (Kenya)	1. KSh 11,000 2. KSh 20,000 3. KSh 27,000
Purchase price at 2 yrs (Ethiopia)	1. Birr 550 2. Birr 900 3. Birr 1200	Purchase price at 4yrs (Ethiopia)	1. Birr 850 2. Birr 1200 3. Birr 1500
Watering frequency	1. Once in 2days 2. Once a day 3. Twice in a day	Watering frequency	1. Once in 2days 2. Once 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 purchased supplementary feeds 2. No need for purchased supplementary feeds		

Table 2: Maximum Likelihood estimates from choice experiment, multinomial logit

	Production system			
Bulls Traits	Pooled	Crop-livestock (Kenya)	Crop-livestock (Ethiopia)	Pastoral (Kenya)
Trypanotolerance	0.341***(0.029)	0.446***(0.047)	0.472***(0.101)	0.593***(0.090)
Purchase price (US$)	0.016 (0.034)	0.095*(0.043)	-0.371 (0.234)	-0.037 (0.070)
Low watering frequency	0.091***(0.029)	0.093*(0.046)	0.092 (0.088)	0.093 (0.083)
Dark coat colour	0.053*(0.024)	0.053 (0.038)	-0.063 (0.063)	0.060 (0.066)
Fertility	0.289***(0.025)	0.191***(0.038)	0.024 (0.068)	0.987***(0.085)
Liveweight in Kg	0.118***(0.024)	0.142***(0.035)	0.004 (0.062)	0.200**(0.071)
Traction potential	0.714***(0.031)	0.557***(0.048)	1.649***(0.103)	0.100 (0.082)
Constant	-2.477***(0.161)	-1.867***(0.239)	-2.812***(0.412)	-3.349***(0.598)
L-likelihood function	-1701.987	-691.3227	-365.985	-262.814
N	2783	1012	1177	594

Cows Traits	Pooled	Crop-livestock Kenya	Crop-livestock Ethiopia	Pastoral (Kenya)
Trypanotolerance	0.786***(0.031)	0.649***(0.048)	1.179***(0.066)	0.489***(0.063)
Purchase price (US$)	-0.011 (0.007)	0.012 (0.009)	-0.011 (0.023)	0.025*(0.012)
Milk yield	0.224***(0.026)	0.254***(0.041)	0.261***(0.055)	0.309***(0.057)
Reproduction ability	0.363***(0.030)	0.295***(0.045)	0.439***(0.064)	0.420***(0.060)
Supplementary feeds	-0.228***(0.031)	-0.403***(0.048)	-0.014 (0.068)	-0.340***(0.065)
Low watering frequency	0.154***(0.039)	0.140*(0.058)	-0.030 (0.094)	0.196*(0.083)
Dark coat colour	-0.030 (0.030)	-0.063 (0.043)	-0.009 (0.073)	-0.040 (0.064)
Liveweight in Kg	0.049 (0.054)	0.005 (0.089)	0.135 (0.098)	0.388** (0.127)
Constant	-2.315***(0.195)	-1.464***(0.306)	-3.440***(0.477)	-0.935*(0.464)
L-likelihood function	-1788.483	-820.655	-412.041	-431.001
N	3036	1188	1164	684

***, **, * indicate that coefficients are statistically significant at the 0.1, 1 and 5 % levels, respectively, using P-values in maximum likelihood estimation. Robust standard errors in parenthesis.

Table 3: Simulated ML estimates from choice experiment, mixed logit

Bulls traits	Mean coefficient	Standard deviation coefficient
Random parameters in utility function		
Trypanotolerance	0.4556***	0.6684***
	(0.0842)	(0.0812)
Traction potential	1.6838***	1.4233***
	(0.1302)	(0.1181)
Fertility	0.3747***	0.7235***
	(0.1209)	(0.1053)
Liveweight in Kg	0.2772***	0.3650***
	(0.0956)	(0.0529)
Purchase price (US$)	-0.2319*	0.3087***
	(0.1278)	(0.2425)
Non-random parameters in utility function		
Low watering frequency	0.1831***	
	(0.0501)	
Dark coat colour	-0.0278	
	(0.0535)	
Constant	-2.4696***	
	(0.2792)	
Simulated log likelihood at convergence	-1231.072	N=2783
Likelihood ratio test[a] 941.8 ($\chi^2_{0.99}(20) = 37.6$); McFadden R^{2b} = 0.312; Halton draws=100		
Cows traits		
Random parameters in utility function		
Purchase price (US$)	-0.0333*	0.1161***
	(0.0145)	(0.0279)
Trypanotolerance	1.5671***	2.1548***
	(0.0988)	(0.1933)
Supplementary feeds	-0.4217***	0.7299***
	(0.0908)	(0.1656)
Milk yield	0.4429***	0.4422***
	(0.0741)	(0.1294)
Reproduction ability	0.4866***	0.7166***
	(0.0965)	(0.1744)
Non-random parameters in utility function		
Low watering frequency	0.0991	
	(0.0606)	
Dark coat colour	-0.0359	
	(0.0505)	
Liveweight in Kg	0.2911***	
	(0.0942)	
Constant	-2.4601***	
	(0.3169)	
Simulated log likelihood at convergence	-1391.685	N=3036
Likelihood ratio test[a] 793.6 ($\chi^2_{0.99}(20) = 37.6$); McFadden R^{2b} =0.222; Halton draws=100		

[a] The likelihood ratio test is given by 2(L_Ω-L_ω), 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_ω

***, **, * 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.

Table 4: Implicit price estimates (US$) of Cattle Traits from Mixed Logit Models

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