Valuing Animal Genetic Resources: A Choice Modelling Application to Indigenous Cattle in Kenya

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Abstract

There is increasing global concern about the potential long term consequences of the loss of domestic animal biodiversity. Of particular interest is the situation in developing countries where on one hand, livestock make the greatest contribution to human livelihoods while on the other, genetic erosion has placed important indigenous breeds at risk of extinction. Economic valuation of these animal genetic resources (AGR) would improve decision making regarding their conservation and sustainable utilisation. This paper investigates the valuation of indigenous cattle in Kenya, an example of a genetic resource at risk. Using data from a stated choice experiment survey conducted in Kenya's pastoral livestock markets, a latent class modelling approach is employed to characterise heterogeneity in valuations across and within various segments of buyers. The results provide empirical evidence that suggests that most types of buyer favour exotic rather than indigenous breeds. Such segmented information can help inform the design and targeting of economic incentives for the conservation and sustainable management of AGR in developing countries.

***Key words**: Biodiversity values; Animal genetic resources; Economic valuation; Stated preference; Choice experiment; Latent class models; Indigenous cattle; Maasai Zebu*

JEL Codes: Q12, Q18, Q57

1. Introduction

The primary biological capital for food security and sustainable development is the existing diversity of plants and animals employed in agriculture. Globally, domestic animals supply some 30 percent of total human requirements for food and agricultural production (FAO, 1999). Livestock is particularly vital to subsistence and economic development in developing countries; it provides, not only essential food products, but also sustains the employment and income of millions of people, and contributes draught power and manure for crop production. The majority (over 60 percent) of livestock breeds are found in developing countries (Rege, 1999a). These animals represent a large pool of genetic diversity resulting from thousands of years of domestication in a wide range of environments, subsequent local adaptations and the consequent development of a variety of breeds and strains with very different characteristics. Fundamentally, it is the genetic composition of these animals that enables them to differ in the number, types and quantities of inputs they utilise; the outputs they produce; and in the environmental circumstances that they tolerate. The diversity of this 'genetic resource' is a key component of the ability of a pastoral agricultural system to overcome destabilising factors such as disease, drought or conflict.

Africa is endowed with diverse animal genetic resources (AGR). In the East African state of Kenya, cattle are extremely important in terms of both biomass (73 percent) and the large contribution that this species makes to the local economy compared to the other livestock species (MOA, 1995). Cattle resources in Kenya can generally be classified into three major groups; the indigenous Zebu (*Bos indicus*), the 'exotic' (*Bos taurus*) and those animals that are the result of crossbreeding between and within the two groups (Rege *et al*., 2001). These breeds perform better than their non-native (exotic) counterparts in areas of low input agriculture and in the extreme environments such as in the arid and semi arid lands that characterise 80 percent of Kenya's land mass, a fact that makes their survival particularly important at a time of uncertainty over climate change. They play a vital role in the livelihood of rural communities serving as household assets with multiple functions (Anderson, 2003). While farm animals can be considered as private goods, the AGR embedded in these breeds can be considered as quasi-public goods (Scarpa *et al.*, 2003), from the view point of a pool of genes shared among all individuals belonging to a particular breed given that the benefits from the existence of such a gene pool are shared across society. This is especially the case when the pool is capable of producing phenotypes that are well-adapted to local environmental circumstances. Their degree of excludability is low, as access to animals of a breed carrying the desired AGR may be very inexpensive. Some form of non-rivalry in consumption also exists because if a breed is properly managed above a critical population size, it retains its property as a renewal resource. From this viewpoint, AGR appears to fit the public good definition as the non-rivalry and non-excludability criteria are met.

As for public goods, values are typically not exclusively derived from current private use of the resource, and it appears reasonable that conservation efforts for AGR are often motivated by the desire to preserve a diverse gene pool that can serve as a source for future breeding and by the fact that decision making on breed development is characterised by uncertainty about future market and environmental conditions. In this regard farmers, faced with prices that do not reflect the social cost of resources, may not fully consider the uncertainty over future developments in their decisions. They may rely on others (such as governments) to preserve the desired degree of genetic diversity. This free rider problem relates to the public good character of AGR and is likely to be an important factor in explaining the erosion of animal genetic diversity (Roosen *et al.*, 2005). Of particular interest is the situation in Kenya where on one hand, livestock make a great contribution to human livelihoods while on the other, genetic erosion has placed many indigenous breeds at risk. The Kenya Zebu cattle, and many uniquely adapted indigenous African AGR, are at risk of extinction. Rege (1999b) has estimated that some 22 African cattle breeds have become extinct in the last century and that 27 percent of the remaining estimated 145-150 breeds are at varying degrees of risk. Furthermore, a recent FAO survey found that around 30 percent of the world's AGR is at risk of being lost forever (FAO, 2000).

Considering the importance of indigenous AGR, particularly in developing countries, and their endangered status, there is an urgent need to develop strategies for the conservation and sustainable management of these resources. The economic valuation of AGR could contribute to this need by providing a basis for decision-making and could provide important inputs into priority setting and policy formulation. For example, information on the economic values of populations (e.g. breeds) or traits could help determine incentive structures that may need to be put in place to conserve threatened or endangered breeds that may not be supported by market forces, but which play an important role in the sustainability of farming systems. Indeed, the importance of economic valuation is recognised in the Convention on Biological Diversity (CBD, 1992). The CBD acknowledges that 'economic valuation is an important tool for well targeted and calibrated economic incentive measures for conservation and sustainable use of biodiversity and its genetic base'.

A stated preference multi-attribute method appears to be the most appropriate valuation approach in this context as it permits a systematic investigation of preferences in terms of the benefits that are perceived to result from AGR. Because preferences are measured directly, the results are less likely to be adversely affected by traits that are not priced, as may be the case in indigenous animal agriculture in developing countries. A promising multi-attribute stated preference approach in this case are choice experiments (CE) (Louviere *et. al.,* 2000; Hanley *et. al.*, 2001), which allow a systematic investigation of the single attributes of a bundled good. Although such methods were developed and have been well tested in the context of developed economies, examples of their application in developing countries are extremely limited (Whittington, 2002; Hope and Garrod, 2004).

Scarpa *et. al.* (2003) and Ruto (2004) are among the first attempts to apply the CE methodology in the context of AGR valuation in developing countries. They investigate the performance of the CE approach as a valuation tool in this context by systematically comparing stated and revealed preference value estimates for cattle traits in Kenya. Their results indicate that CE estimates pass the external consistency test and appear to be adequately precise in estimating values for cattle traits that are relevant in market transactions. Building on this initial work, this paper further employs the CE approach to: investigate preferences over cattle traits in Kenyan livestock markets, estimate the value of a typical indigenous breed (Maasai Zebu) as a proxy to the valuation of indigenous AGR, and to characterise heterogeneity in valuations across and within various segments of buyers. We use an endogenous preference segmentation approach via latent class modelling both to account for preference heterogeneity and to *explain* the sources of such heterogeneity. Such information may be useful, not only in targeting incentive measures for breed conservation and the design of breeding programmes, but also in assessing the distributional impact of such policy actions. The remainder of this paper is organised as follows. Section 2 provides an overview of recent developments in the literature on the treatment of heterogeneous preferences in random utility models and then discusses the econometric specification of our latent class model of cattle choice. Section 3 documents the data sources. The results are presented and discussed in section 4, and section 5 draws some conclusions.

2. Theory and methods

2.1 Recent developments in modelling heterogeneous preferences

Although the multinomial logit model (McFadden, 1974) has provided the fundamental platform for discrete choice modelling, its basic limitations, most notably, its assumption of independence of irrelevant alternatives (IIA) and, most importantly, the concomitant assumption of homogeneous preferences have motivated the development of alternative modelling approaches to account for heterogeneity of preferences. A number of studies have shown that failure to account for preference heterogeneity, when it is warranted, can lead to biased utility parameter estimates and potentially misleading attribute valuations or welfare measures (Greene, 2003). In addition, accounting for preference heterogeneity provides a broader picture of the distributional and other impacts of policy actions and promote the policy usefulness of the results.

Among a set of recent innovations to account for heterogeneous preference in discrete choice models, the mixed logit model is probably the most significant development in terms of its flexibility and the range of behavioural assumptions it can accommodate (McFadden and Train, 2000). The mixed logit model explicitly accounts for heterogeneity by allowing utility parameters to vary randomly according to a continuous parametric distribution. The moments of this distribution (such as the mean and variance) are estimated. However, the computational cost of mixed logit models is high and the estimation results may be sensitive to the specific parametric distribution assumed (subjectively) by the researcher. Furthermore, the mixed logit model may not be well-suited to account for the sources of heterogeneity (Boxall and Adamowicz, 2002). These sources often relate to the characteristics of respondents such as the various typologies of buyers or individual motivations for buying livestock in our case.

A promising alternative specification for tackling these issues is to cast heterogeneity as a discrete distribution, a specification based on the concept of endogenous (or latent) preference segmentation (Wedel and Kamakura, 2000; Bhat, 1997). Here, the premise is that the population consists of a finite (and identifiable) number of groups of individuals (segments), each characterised by relatively homogenous preferences. However, these segments differ substantially in their preference structure. A key feature of this approach is that it accommodates preference heterogeneity while allowing the number of segments to be determined (endogenously) by the data. In this context, belonging to a segment with specific preferences is probabilistic, perhaps based on buyer characteristics such as the individual motives for buying cattle. The Latent class model is a classic operationalisation of this approach. These models were originally used in market research (Kamakura and Russel, 1989; Gupta and Chintagunta, 1994; Swait, 1994). According to these studies, latent class models can provide results that are quite 'actionable' in terms of effective product targeting and strategic positioning.

More recently, latent class models have been extended to travel cost revealed preference studies (Provencher *et. al*., 2002; Provencher and Bishop, 2004) and stated preference applications. The latter include a study by Greene and Hensher (2003) in which the merits of mixed logit are systematically contrasted with those of latent class modelling in terms of choice elasticities, distributions of predicted choice probabilities and changes in absolute choice shares. Based on a date set on choice of road types in New Zealand, they conclude that no unambiguous recommendation can be made as to the superiority of either of the two approaches, though they find stronger statistical support overall for the latent class approach with three preference segments.

Boxall and Adamowicz (2002) in an application investigating the choice of outdoor recreation, used factor analysis to provide estimates of motivational determinants of recreational trips to wilderness, that were then used in the specification of the segment membership likelihood function. Their analysis supported the existence of four segments of recreationists and permitted a much richer interpretation of the data than the standard (single segment) multinomial logit model. Such studies generally acknowledge the policy usefulness of accounting for preference heterogeneity at the segment level and have highlighted this approach as an area of potentially novel research that requires further empirical applications in stated choice studies. This paper provides a contribution to the growing literature in this area and represents one of the first empirical applications of the latent class approach to an agricultural problem in a developing country.

2.2 The latent class model of cattle choice

Formally, buyer *n* faces a choice of selecting the preferred alternative amongst a set of J ($j = 1, 2, \ldots, J$) alternatives of cattle in each of the T choice occasions ($t = 1, \ldots, T$). Suppose buyer *n* belongs to latent segment *s*, then his utility function associated with the preferred alternative $i \in J$ can be written as a linear index:

$$U(i \mid s) = \beta_s' X_{int} + \varepsilon_{int \mid s} \tag{1}$$

Assuming a random utility framework as the basis of a buyer's choice and an independent-identically-distributed (IID) extreme value type I stochastic component $\varepsilon_{int|s}$ of a buyer's utility for the preferred choice, the probability that buyer *n* chooses alternative *i* in choice occasion *t* conditional on the buyer belonging to segment *s* takes the familiar multinomial logit (MNL) form:

$$P(i \mid s) = \frac{exp(\beta_s' X_{int})}{\sum_{j=1}^{J} exp(\beta_s' X_{jnt})} \tag{2}$$

where in equations 1 and 2, X_{int} is a vector of observable attributes associated with alternative *i* and buyer *n* observed making a choice on occasion *t*, and β_s is a conformable (segment-specific) vector of taste parameters. Note that the scale parameter is normalised to one. The differences in the β_s vectors enable this approach to capture heterogeneity in preferences for the cattle-choice attributes across segments.

Now consider an individual's segment membership likelihood function M^* that classifies buyers into one of the S latent segments. The classification variables influencing segment membership are perhaps related to observed individual motivations for buying cattle. This is represented by a vector of 'purpose of buying' variables (labelled Z), used here as proxies for individual motivational factors influencing cattle choices. The membership likelihood function for buyer n and segment s can be expressed as: $M^*_{ns} = \lambda_s Z_n + \xi_{ns}$. Assuming the error terms in the individual membership likelihood functions are IID extreme value type I across individuals and segments, the probability that buyer n belongs to segment s can be expressed in a MNL form as:

$$P(s) = \frac{exp(\lambda_s Z_n)}{\sum_{s=1}^{S} exp(\lambda_s Z_n)} \tag{3}$$

Where λ_s (s = 1, 2,…, S) are segment-specific parameters to be estimated that denote the contribution of the various buyer motivational factors to the probability of segment membership: a positive λ implies that the associated buyer descriptor variable Z_n increases the prior probability that buyer n belongs to segment s. The scale factor is normalised to unity. $P(s)$ sums to one across the S (to be determined) latent segments with $0 \leq P(s) \leq 1$. The size of each segment W_s, in terms of the proportions of the population that are predicted to belong to each segment may be obtained as:

$$W_s = \frac{\sum_n P(s)}{N} \tag{4}$$

Recall that equation 2 provides the conditional (on membership of a particular segment s) choice probability. The unconditional probability that any randomly selected buyer n chooses alternative i on choice occasion t is obtained by combining this conditional probability with the segment membership probability from equation 3. Equation 5 (below) shows that the unconditional choice probability is a weighted average of segment-specific choice probabilities $P(i|s)$ where the weights $P(s)$ vary systematically as a function of buyers' (motivational) descriptor variables:

$$P(i) = \sum_{s=1}^{S} [(P(s).(P(i \mid s)] \qquad (5)$$

The assignment of buyers to segments is a critical part of preference segmentation as discussed. This assignment is a probabilistic event and is based on equation 3. Given estimates of λ_s it is possible to compute a probability for buyer n belonging to each of the S segments if information on their motivations for buying animals is available. Hence on the basis of an assignment rule such as 'membership in the segment with the highest probability' it is possible to uniquely assign buyers to segments with differential sensitivity to price and preferences for cattle traits. Thus, the model provides an indirect link between observed buyer motivations for animal purchase, their choice probabilities and their membership of preference segments.

In our survey, respondents provided a sequence of choices. Hence to implement the model, the probability of each sampled buyer's observed sequence of choices is required. The probability of buyer n's sequence of choices over T choice occasions (T= 8 in this case) conditional on membership of group s is given by:

$$P(i_1,\ldots\ldots,i_T \mid s) = \prod_{t=1}^{T} \frac{\exp(\Delta\beta_s^{'} X_{\mathrm{int}})}{\sum_{j=1}^{J} \exp(\Delta\beta_s^{'} X_{jnt})} \qquad (6)$$

The unconditional sample log-likelihood function is given by:

$$L = \sum_{n} \sum_{i \in J} I_i \, ln \sum_{s} P(s) P(i_1,\ldots\ldots,i_T \mid s) \qquad (7)$$

where I_i is an indicator variable for the observed choice. The unknown parameters of segment membership and choice probabilities λ_s and β_s respectively are obtained in a joint and simultaneous estimation procedure by maximising the unconditional log-likelihood of the sample over the parameter space. Once the parameter estimates have been obtained, a measure of economic value ($\rho_{i,k}$) can be derived for each animal attribute using the formula given by equation 8 below (Hanemann, 1984). The coefficient β_y gives the marginal utility of income and is the coefficient of the price attribute and β_k is the coefficient on any of the cattle attributes. These ratios (often referred to as marginal implicit prices) can also be interpreted as a marginal rate of substitution (MRS) between the corresponding attributes.

$$\rho_{i,k} = -\frac{\beta_k}{\beta_y} \tag{8}$$

3. Data collection

A choice experiment (CE) survey was conducted in seven livestock markets in the district of Kajiado, southern Kenya during the year 2000[1]. These were selected because they represent the key livestock markets used by pastoralists in the region and their spatial distribution reflects the local structure of cattle trade in inland Kenya, especially in terms of breed mixture. The objective of the CE was to characterise buyers' preferences for the attributes of the cattle sold at market, taking into account their various motives for buying animals. The attributes identified as being most important and therefore used in the CE design, were those which emerged from an exploratory revealed preference survey as important and objectively verifiable attributes in market transactions (Ruto, 1999): these were breed of animal, gender, body condition, dressed weight and price. The inclusion of price as one of the attributes in the CE was to permit the monetary valuation of the selected cattle attributes.

In the CE design, the breed attribute had two levels: indigenous breed (i.e. Maasai Zebu) and exotic (Non-Zebu) breeds. This attribute was of particular interest from a policy point of view as it provides a proxy for the valuation of indigenous AGR. The body condition attribute was also varied at two levels; good/excellent or poor. Finally, the weight and price attributes were allocated four levels based on the actual prices and weights of animals across gender and body condition classes observed in the exploratory survey. The selection of attributes and levels also made use of information from focus group discussions with cattle buyers and sellers in one of the sampled markets.

[1] The markets were Emali, Kiserian, Rombo, Kimana, Bissel, Sajiloni and Oldonyonyokie. See Ruto (2004) for a detailed description of the survey.

Given the set of attributes and the levels that each attribute would take, experimental design methods (described in Louviere *et. al.,* 2000) were used to structure paired comparisons of 'animal profiles' or choice sets. From the complete factorial design of possible choice sets, the smallest orthogonal main-effects design was extracted using SPSS for Windows (SPSS, 2000) yielding 16 animal profiles. In order to ease the choice task, only two animal profiles were made available to the respondent for each choice task. In addition, the respondent could also opt to buy neither animal (zero option) which constituted the third (constant base) alternative. This was provided to ensure that the choice set was exhaustive and consistent with the theory of utility maximisation underlying CE (McFadden, 1981).

The CE interview and choice elicitation process proceeded in the following chronological stages: (1) a short introduction and briefing where the respondent was asked why he was buying animals that market day (e.g. for slaughter, resale or breeding); (2) an initial set of 'warm-up' choice-task questions; designed to assess the respondent's understanding of the choice mechanism, as well as providing him with some practice with typical choice-tasks. The respondent's ability to perform in the trial choice-task questions was evaluated by the interviewer so that only those who gave consistent choices were allowed to proceed to the third stage; (3) finally the respondent was asked to complete eight choice-tasks randomly allocated from the set of 16 orthogonal main effects.

A typical choice task required respondents to decide which of two hypothetical cattle purchase choices (say A and B) they preferred. Each choice was described to the respondents in terms of the five attributes discussed previously: sex, breed, dressed (slaughter) weight, body condition and price. They were then asked to decide whether they preferred A, B or neither. For example Buyer 1 was asked the following question: "Would you buy animal A: a male non-Zebu breed that weighs 120kg, is in poor condition and costs 12,000 Kenya Shillings (Ksh)[2], or animal B, a female Maasai Zebu that weighs 90kg and costs 10,000 Ksh, or neither?" More than 310 interviews were completed yielding a total of nearly 2,500 choices.

[2] Seventy six Kenya Shillings is equivalent to one US Dollar.

4. Results and Discussion

A latent class model was employed to simultaneously identify the existence and the number of latent segments in the sample, to estimate the preference structure within each segment, and to relate membership in each segment to buyer typologies or to the observed purpose of purchase. Table 1 provides a description of the variables employed in the estimation of the latent class models. The discussion of empirical results is separated as follows. First, the results of the procedure to determine the number of segments are reported. Next, estimates of the 'optimal' model which consists of a set of probabilities defined over segments and segment specific parameters are discussed.

Table 1: Description of variables from choice experiment

Variable	Description
Animal attributes	
Price	Price of animal (Ksh)
Cow	Gender of animal: Cow = 1 if female; 0 otherwise
Zebu	Breed of animal: Zebu = 1 if indigenous (Maasai Zebu) breed ; 0 otherwise
Good-exc	Body condition score of animal: Good-exc = 1 if in 'good or excellent' body condition; 0 otherwise
Weight	Estimated slaughter (dressed) weight of animal
Buyer- specific attributes	
Typology of buyer/purpose of buying animal	Declared purpose /motivation for animal purchase: Slaughter = 1 if buying for slaughter; 0 otherwise Resale = 1 if buying to resell to others, 0 otherwise Breeding = 1 if buying for 'home' breeding/rearing, 0 otherwise

4.1 Estimation of the number of latent segments

One critical quantity in the empirical application of latent class models is the number of segments required to characterise the underlying distribution of heterogeneity. Formal statistical test for the number of segments in the population are not readily available. In particular, neither the likelihood ratio test statistic, nor its Wald test and Langrange Multiplier test counterparts, meets the regularity conditions necessary for a limiting chi-square distribution (McLachlan and Peel, 2000). We use two information theoretic criteria often employed in latent class modelling to determine how many segments to retain, increasing the number of segments until the criterion is minimised. These were: the Consistent Akaike Information Criterion (CAIC) and the Bayesian Information Criterion (BIC) (Boxall and Adamowicz, 2002; Wedel and Kamakura, 2000). A single segment model was calibrated, followed by a series of models with increasing values of *S,* which were systematically estimated while assessing these statistics. Table 2 summarises the results for different multi-segment models ranging from one to seven segment solutions.

Table 2: Comparisons of Fit of Various Latent Class Models[a]

Segments	Number of Parameters(P)	Log likelihood at convergence (LL)	Pseudo-R^2[b]	BIC[c]	CAIC[d]
1	5	−2083.53	0.2377	4206.15	4211.15
2	13	−1766.16	0.3538	3633.96	3646.96
3	21	−1553.65	0.4316	3271.51	3292.51
4	29	−1488.37	0.4555	3203.49	3232.49
5	37	−1446.43	0.4708	3182.17	3219.17
6	45	−1438.36	0.4738	3228.58	3273.58
7	53	−1436.56	0.4744	3287.53	3340.53

[a] Sample size is 2,488 choices from 311 individuals (N); [b] Pseudo-R^2 is calculated as 1-LL/LL(0)

[c] BIC is calculated using $\{-2LL + P \ln(N)\}$; [d] CAIC is calculated using $\{ -2LL + P (\ln N) + 1\}$

The log likelihood values at convergence (column 3) reveal improvement in model fit as segments as are added to the model. This is evident in the pseudo-R^2 which doubles in a seven segment model compared to the initial one segment model (from 0.23 to 0.47). This information supports the existence of heterogeneity in the data and also suggests existence of latent segments, but does not suggest how many segments there are. To answer this question, the other statistics in Table 2 must be inspected. The BIC and CAIC statistics decreases monotonically as the number of segments increases but tend to flatten out from the three segment model.

Both statistics indicate a five segment model as the optimal solution, though there is no significant change in the criteria value between the four and five segment models. However Andrews and Currim (2002), in a Monte Carlo simulation study, find that BIC and CAIC never under-fit the number of segments but sometimes over-fit. They also show that over-fitting the true number of segments produces larger parameter bias than under-fitting. In view of this, a four segment model. This model is also most intuitive and interpretable. Empirical results, which are discussed subsequently, are based on the four-segment latent class model.

4.2 Parameter estimates of the optimal model

Table 3 presents maximum likelihood parameter estimates for the four segment model. The top block of the table, hereinafter referred to as the 'choice model', shows the estimated parameters (β_s) of the segment-specific utility functions while the bottom block, hereinafter referred to as the sub-model, shows the corresponding parameters (λ_s) for the segment membership functions. Examination of Table 3 demonstrates that there is substantial heterogeneity in preferences for cattle attributes across segments, as indicated by differences in the magnitude, significance and signs of choice model parameter estimates. In the sub-model, the parameter estimates which represent the effects of the different buyer motivations on the probability of membership in the various segments are, in general, significant.

Table 3: Parameter estimates of the optimal latent class model

Model	Segment 1	Segment 2	Segment 3	Segment 4
		Choice model		
Attribute X				
Price	–4.30E-4	–6.90E-4	–2.80E-4	–5.1E-4
	(–4.37)[a]	(–6.19)	(–4.80)	(–10.80)
Cow	1.674	–0.181	1.144	–0.316
	(3.79)	(–0.42)	(5.08)	(–2.25)
Good_exc	–0.749	11.420	–1.803	2.663
	(–1.43)	(9.92)	(–5.67)	(8.42)
Weight(Kg)	0.0264	0.018	0.054	0.057
	(3.76)	(2.47)	(10.42)	(15.67)
Zebu	0.0477	–0.516	–0.222	–0.274
	(0.13)	(–1.43)	(–1.25)	(–2.24)
		Sub-model		
Attribute Z				
Slaughter	–3.959	0.061	–2.682	
	(–3.77)	(0.27)	(–2.86)	
Resale	–3.244	–2.860	–1.414	
	(–5.54)	(–5.40)	(–4.43)	
Breeding	1.069	–19.502	1.893	
	(1.93)	(–7.97)	(3.41)	

[a] Asymptotic t-values in parentheses

Summary statistics: Log-likelihood = –1488.37; Pseudo-R^2 = 0.455; Adjusted pseudo-R^2 = 0.445

To characterise the structure of preferences in each segment, it was necessary to determine the 'type' of buyer belonging to the different segments by establishing how the four segments draw their membership from the three main buyer groups (slaughter, resale and breeding). To achieve this, buyers were assigned to each of the four segments based on the sub-model. As noted earlier, this assignment was a probabilistic event and is based on equation 3 after replacing the λ_s terms by their estimated counterparts from the sub-model. Table 4 presents segment membership probabilities conditional on the three main buyer profiles as implied by the parameters of the sub-model.

Table 4: Segment membership probabilities and sizes

Attribute Z	Segment1	Segment2	Segment3	Segment4
Slaughter	0.01	0.49	0.03	0.46
Resale	0.03	0.04	0.18	0.75
Breeding	0.28	0.00	0.63	0.09
Segment size (%)	3.0	1.0	50.0	46.0

The results in Table 4 show the following. Breeders are the most common members of segment 1 (membership probability=0.28); while Segment 2 is most likely to be populated by those buying for slaughter (membership probability=0.50). Interestingly, buyers interested in breeding from their purchases are also associated with segment 3 with a probability of membership in this segment of 0.63 and a significant positive parameter in the sub-model. Finally, segment 4 comprises a 'mixture' of those motivated by resale and slaughter purposes with membership probabilities of 0.75 and 0.46 respectively. Table 4 also presents segment size estimates, obtained by aggregating over the sample segment membership probabilities using equation 4. Segment 3 was the largest and accounted for 50 percent of buyers' choices, followed by segment 4 (46 percent). Segments 1 and 2 were small, comprising only 3 and 1 percent of buyers' choices respectively.

4.3 Characterisation of preferences across segments

The assignment of buyers to segments and the derivation of segment sizes facilitate a more intuitive characterisation of the structure of preferences in each segment. A close comparison of the choice model parameter estimates in Table 3 with the segment membership results in Table 4 is instructive, both in terms of explaining choice behaviour and informing policy. Of particular interest are segment specific MRS values implied by the choice model parameters reported in Table 5. The MRS estimates clearly show the presence of substantial heterogeneity in preferences across the segments.

Table 5: Segment specific marginal values of cattle attributes (Ksh)

Attribute	Segment 1	Segment 2	Segment 3	Segment 4
Cow	3,859.87	–264.53	4,077.14	–625.64
Good-exc	–1,727.88	16,655.69	–6,423.04	5,277.63
Weight	60.91	25.55	191.73	113.91
Zebu	110.08	–752.82	–790.42	–543.49

Buyers in segment 1 (3 percent of the sample population) assign a significantly positive value to both cows and the weight of the animal. MRS estimates imply that buyers value cows by nearly Ksh 4,000 more than other gender classes and are willing to pay Ksh 60 per kilo of slaughter weight. The members of this segment also tend to assign a positive value for indigenous Zebu cattle and are less likely to be concerned with the body condition of the animal, though neither is significant in the model. These results seem reasonable given that this segment is made up of breeders who are likely to favour Zebu animals for breeding. This may be in keeping with the notion of this breed being so well adapted to this environment, an important attribute that make it an animal that can be produced at low marginal cost.

Buyers in segment 2, which is smallest of the four (only 1 percent of the sample population), attach a very high value to good/excellent body condition and a relatively small positive value to weight (Ksh 25.50). However, their preference for cows and indigenous breeds was not found to be significant in the model. Overall these results are consistent with the fact that slaughter buyers (who are the most likely members of this segment) are expected to be primarily concerned with body condition and the dressed weight of the animal.

Segment 3, which comprises half of the buyers, exhibits a similar preference structure to segment 1. For example, both segments assign a significant positive value of Ksh 4,000 to cows and both seem not to be attracted to animals in good or excellent body condition. It is not surprising, therefore, that both segments are expected to draw their membership predominantly from breeders. However, segment 3 seems to be willing to pay more per kilo of dressed weight than segment 1 (Ksh 200 compared to Ksh 60). Though segment 1 tends to prefer indigenous Zebu breeds, while segment 3 seems to be inclined to exotic breeds and their crosses, the breed parameter is not significantly different from zero in either segment. It is likely that segment 1 represents a relatively small 'sub-group' of the 'mainstream' population (segment 3) of breeders.

Segment 4, which comprises predominantly slaughter buyers and resellers, contributes the second largest share of buyers' choices. This segment displays a similar pattern of preferences to the smaller segment 2, which also draws its membership from the same buyer population. The members of segment 4 prefer male animals to cows by a value of Ksh 600, are willing to pay about Ksh 100 per kilo of slaughter weight and a high premium price of Ksh 5000 for animals in good/excellent body condition. It is noted that this is the only segment which is found to significantly discount the indigenous cattle breeds (by a value of Ksh 500) in favour of their exotic counterparts and cross breeds. Judging from the t-values reported in Table 3, all of the choice model taste parameters for the cattle attributes associated with this segment are highly significant.

The endogenous segmentation results suggest that there are two predominant segments in the population of cattle buyers, each holding a very different set of preferences: breeders (segment 3); and slaughter/resale buyers (segment 4). Clearly, the structure of preferences for segments 1 and 2 are generally aligned to those of segments 3 and 4 respectively. Breeders are shown to prefer female animals apparently as breeding stock and for herd re-stocking purposes. Interestingly, they are not attracted to animals in good/excellent body condition. In fact they prefer animals in poor condition. A likely explanation is that many breeders prefer to buy animals in poor body condition at a bargain price (e.g. in the dry season), fattening them at home (e.g. in the wet season or if they are endowed with more land and pasture) and bringing them back to the market to sell at a premium price.

Slaughter and resale buyers, in contrast, prefer male animals to females and are strongly attracted to animals in good or excellent body condition. It is also noteworthy that this group of buyers exhibits a higher sensitivity to price compared to their breeder counterparts. For example, this differential sensitivity to price in turn translates to breeders being willing to pay an additional Ksh 100 per kilo of dressed weight compared to the slaughter/resale group, despite the fact that the taste parameter for weight is similar in magnitude across the two segments. This result seems reasonable given that slaughter/resale traders may be expected to be primarily motivated by 'quick' profits and to hold on to their money more tightly; while breeders may not be primarily motivated by profit (at least in the short term) as they are likely to be more interested in the longer term potential of the animal and hence more willing to pay a higher price to obtain animals with preferred characteristics. Turning to the critical issue of breed value, the results reveal that those who are buying animals destined for slaughter or resale significantly prefer exotic breeds of cattle and their crosses (with a premium price of Ksh 500) to the indigenous Zebu breeds. However, there is no clear evidence from the results that breeders similarly prefer exotic breeds to indigenous ones or impose a penalty price to indigenous cattle.

This empirical application has demonstrated the methodological and substantive merits afforded by endogenous preference segmentation via the latent class model as seen from the following summary of key results: (1) the model builds upon the advantages of the MNL model while alleviating the limitation caused by the assumption of preference homogeneity across buyers. Model fit, judged by pseudo-R^2 values, doubles from 0.23 for the one segment case (which corresponds to the MNL model) to 0.46 for the model with four segments; (2) the segments comprise buyers who hold significantly different preferences over the same set of cattle attributes; (3) the motives underlying purchase decisions are shown to be significantly related to a buyers' probability of belonging to a particular segment and this information can be employed to derive segment-specific (and hence, buyer-group-specific) economic values for cattle attributes; and (4) buyers' preference patterns are shown to be logically consistent with their purchase motives.

5. Conclusions

This paper reports results from a choice experiment study aimed at characterising heterogeneity of buyers' preferences over cattle breeds and traits in Kenyan livestock markets and assessing the economic value of a typical indigenous breed (Maasai Zebu) as a proxy to the valuation of indigenous AGR. A discrete characterisation of taste heterogeneity was employed through the use of an endogenous preference segmentation approach (the latent class model).

The results outlined above show that buyers' preferences are latently clustered around the various motives underlying cattle purchase. They suggest the existence of two predominant segments in the population with distinct preferences; the first comprising those buying for breeding and the second drawing its membership from those buying either for slaughter or resale. Members of the latter segment clearly favour exotic rather than indigenous breeds. However, the nature of breed preferences in the breeder segment remains somewhat uncertain as there is no clear evidence of breeders' preferences for exotic or indigenous breeds. While endogenous segmentation reveals a small segment (comprising breeders) that may have a preference for indigenous cattle, the dominance of slaughter/buyers in the market generally skews preferences toward exotic breeds. This suggest that the short-term commercial demands of slaughter/resale buyers in their choice of cattle, as exemplified by their concentration on a narrower range of traits such as meat output, is not balanced by the longer term objectives underlying the choices of some breeders. Further research with a focus on breed as a factor input for the household production process could provide clear evidence of the net value that livestock producers or breeders place on indigenous breeds.

In general, it emerges that indigenous breeds fail to attract a premium from buyers either ignorant of, or indifferent to, their desirable traits. If it is argued that, in times of uncertainty about future climatic conditions, society should value the attributes of tolerance to drought and poor feeding conditions that are found in indigenous breeds, then such an observation is an example of market failure caused by a lack of appropriate signals or incentives within the market (Bator, 1958) to reflect the potential social benefits of these attributes. The results also demonstrate the methodological and substantive merits of the latent segmentation approach. For example, out-of-sample buyers can be allocated to segments with differential preference structures on the basis of information on the purpose for animal purchase alone. Such stratification can be used to tailor breeding or conservation policies to different buyer groups and/or assess the distribution of the effects of such policy actions among market players. Given that information on individual motivations for buying cattle can be collected easily and relatively cheaply in Kenyan livestock markets, the model's potential practical application is appealing. For example, results from such a model can be used to target incentives for breed conservation and/or to implement policy actions tailored to each particular segment. The results strongly suggest a differentiated strategy with respect to the design of such policy interventions.

Further, an important finding of this study is the comparative lack of economic competitiveness of the indigenous breeds across the buyer population. As pastoral production systems continue to change and as traders specialising in buying animals for slaughter gradually dominate Kenyan cattle markets, there is a very real risk of indigenous breeds being gradually 'pushed' out of the market in favour of exotic breeds. This reflects producers responding rationally to market signals by adopting market-driven breeding objectives which in many cases mean replacing indigenous breeds with the more 'marketable' exotic breeds. By appropriate intervention in the market, Governments or international agencies could provide signals and incentives to make the purchase of indigenous breeds more attractive to these buyers. A successful intervention strategy would ensure that the genetic diversity of the Kenyan cattle population is maintained without compromising the efficient operation of the market. Such an outcome would demonstrate the potential usefulness of economic analysis in improving our understanding of some of the underlying forces that are driving the decline of indigenous breeds (and the concomitant loss of domestic animal biodiversity) and in informing the design of well targeted economic incentives for their conservation and sustainable management.

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