Valuing indigenous cattle breeds in Kenya: An empirical comparison of stated and revealed preference value estimates

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Abstract

In this study we compare revealed and stated-preference approaches to value traits of cattle in Kenya. The premise is that much can be learnt about non-market values of indigenous animal genetic resources (AnGRs) from the use of multi-attribute stated-preference methods, if these compare well with revealed-preference results. The objective is to investigate the performance of choice experiments (CEs) in Maasai cattle trading, by conducting an external test of preference consistency. We compare value estimates for cattle attributes from CEs data with those from hedonic analysis of actual transactions by the same population of traders, in the same markets and over the same period. If CEs perform well, they can be used to investigate values of those genetically-determined livestock traits currently not prominent in pastoralists' populations, but desirable candidates for breeding or conservation programmes (e.g. disease resistance). The results indicate that CE estimates pass the external test and appear to be adequately precise in estimating values for cattle traits that are relevant in market transactions for Maasai traders. Accounting for taste and variance heterogeneity does not change this conclusion. CEs may, therefore, be a promising tool for valuing phenotypic traits expressed by indigenous AnGRs.

Key words: Biodiversity values, genetic resources, livestock values, non-market values, East African shorthorn zebu, choice experiments, taste heterogeneity, variance heterogeneity .

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1 Introduction

Of all the forms of biodiversity, the one that is most important to human kind is probably that upon which we rely for food. The conservation and correct assessment of existing biodiversity of plants and animals employed in agriculture is paramount for sustainable development. Following the aims declared in the Convention on Biological Diversity (CBD, 2000), many national and international public agencies are now committed to the challenge of conservation of biodiversity and its genetic base.

The management of animal genetic resources (AnGRs) requires many decisions that would be easier to make if information on the economic value of populations (e.g. breeds), traits and processes (e.g. alternative breeding and/or conservation programmes) were available. In the context of the CBD, valuation is essential for the development of 'benefit-sharing' frameworks. At national levels, governments need economic values of breeds and traits as an input into the development of incentive schemes for *in-situ* conservation programmes.

While some attempts have been made at developing methodologies for placing economic values on genetic resources, this has been limited to plant (including forest) genetic resources (Evenson *et al.*, 1998). Moreover, methodologies for determining to what extent market values reflect the real value of AnGRs are completely lacking. They are particularly needed in developing countries where many important functions of livestock are embedded in traits that are not traded in the market. These include such traits (functions and products) as traction, manure, form of investment, dowry payment, use in traditional ceremonies, etc. A complicating factor in these production systems is that yield stability, which is often more valuable than yield per se, is a manifestation of complex traits, such as adaptive attributes (e.g. disease resistance, drought tolerance).

Thus, nowhere is efficient resource allocation in biodiversity conservation more needed than in developing countries. On one hand, so much of the livelihood of local communities is at stake, and on the other, so meagre is the resource base with which to achieve this objective. In these societies, assessing the role of non-market valuation tools as decision aids is paramount, particularly because of the absence of efficient markets for many of the functions that animals perform.

It is our contention that the difference between the market value of a particular livestock genetic resource and its total economic value to humans is particu-

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larly large in developing countries. Little is known as to the magnitude of this divergence as few empirical studies have attempted to estimate it directly. To compound the problem, estimates of these values are likely to both have great variance and be of more complicated to determine in developing countries. For example, intuitively we can put a very high value on genes determining adaptive fitness in indigenous AnGRs under extreme environmental conditions. However, conventional economic analysis may fail to account for such resilience and reach normative conclusions that favour the adoption of policies encouraging the introduction or promotion of high-input, high-output exotic breeds. Introduction of exotic germplasm, through crossbreeding and breed replacement, can result in extinction of the unique, well-adapted indigenous AnGRs (Hammond and Leitch, 1999).

1.1 Why choice-experiments to value AnGRs?

Because many of the benefits derived from the existence of well-adapted indigenous AnGRs are not transacted in any market, non-market valuation tools are required to identify the magnitude of these benefits.

In the last thirty years valuation methods based on stated preferences have been receiving increased recognition in the context of non-market valuation (Freeman, 1993). Among stated preference methods, the contingent valuation of public programmes is the most frequently employed valuation tool in environmental economics (Bateman and Willis, 1999). However, the contingent valuation method is inadequate to value single attributes of a multi-attribute good, such as the genetic attributes embedded in the phenotype of an animal of a given breed. A promising tool in this field, instead, is choice modeling (choice experiments or CEs) (Louviere *et al.*, 2000), as it allows a systematic investigation of the single attributes of a bundled good.

Preferences regarding phenotypic attributes of livestock differ across regions, countries, communities and production systems. In developing countries, especially in low-input smallholder production systems, the most valuable livestock attributes are often those that successfully guarantee multifunctionality, flexibility and resilience in order to deal with variable environmental conditions. In contrast, in developed countries, livestock attributes maximizing output of specific products are more valuable.

Multi-purpose, rather than specialized breeds, are more suitable to low-output / low-input production systems. For example, Davis (1993) reports results from a Northern Australia case study in which tropical and temperate breeds were compared, and shows marked evidence of the superior ability of tropical breeds to grow and reproduce in conditions of high ambient temperatures, poor feed quality and high parasite and disease incidence. More work done by Moyo (1996) has shown that, under the semi-arid conditions of southern Zimbabwe and for pasture-based beef production, the indigenous breeds, Mashona and Nguni, were more productive in terms of weaner calf produced per kg of body weight of cow per year than the exotic breeds and their crosses.

A successful multi-purpose breed must perform well across many dimensions of use and store value across time, as it is often the main source of wealth to pastoralists. It must also be resilient to environmental and climatic changes. In other words, it must rely on genes that provide a stable bundle of diversified phenotypic attributes.

Research in the development of methods to value genetic resources can therefore benefit greatly from knowledge that a CE approach is indeed a reliable method to estimate preferences over valuable non-market attributes. Valuation methods based on hypothetical rather than factual choices—such as CEs—are looked upon with suspicion by neoclassical economists. They are considered reliable only when they produce value estimates similar to those produced by revealed preference methods, i.e. if they pass a 'criterion validity' test (Bishop *et al.*, 1995).

The decision to study the performance of CEs with respect to cattle, rather than other forms of livestock, stems from the large contribution that this species provides to many developing societies. Compared to other livestock species, cattle stand out across developing countries in terms of provision of non-market services, including draught power, manure, risk management through hedging, asset storage, community bonding, and ceremonial services, amongst others. For example, Winrock International (1992), estimates that livestock contribute 25% of the total agricultural GDP in Sub-Saharan Africa. If the benefits of manure and draught power are included, this figure is estimated to increase to 35% of total agricultural GDP.

But how reliable are CEs as valuation tools in this context? The difficulties involved in using hypothetical valuation methods in developing countries are well documented (Whittington *et al.*, 1990; Köhlin, 2001). In order to address this question, we needed to first validate CE estimates for animal traits that were easily recognizable and objectively verifiable by enumerators. For this reason this study does not include attributes such as 'degrees of disease resistance', but was limited to the identification of the value of an important local breed. So the appropriateness of CE as a valuation tool in this context was tested by comparing the value estimates for breed and other animal traits generally recognized as important in cattle markets. We compared the value estimates for a set of animal attributes obtained from two data-gathering methods applied to the same population of cattle traders. First, a CE survey instrument, designed to elicit traders' preferences for various cattle traits was used. Then a more traditional revealed preference approach was taken, based on actual observed market transactions at the same time and in the same markets as the CE. This was referred to as a hedonic pricing approach.

Testing the methodology was an important goal of this case study, as a CE approach had not been used previously in valuing indigenous AnGRs in developing countries. Although the results presented are only a small component of a larger study on the viability of CEs in valuing AnGR, and do not address the questions some readers will have, such as 'what is the value of single genetic traits' (e.g. higher resilience), they complement other research results that tackle such issues more directly (Scarpa et al. in this issue), and provide important verification of the viability and usefulness (plus the shortcomings) of the approach.

1.2 The challenge of valuing the East African shorthorn zebu.

Although the main objective of this case study is an external test of the CE approach to value cattle attributes, we make an attempt at valuing a typical indigenous cattle breed: the small East African shorthorn zebu found in semi-arid and arid areas of Kenya (and other East African countries).

The decision to try and value the 'breed', as opposed to a specific trait, derives from the fact that this is the most easily, commonly recognized and clearly demarcated unit of a stable genetic resource. In the context of domesticated animals, 'breed' represents an aggregate of genes responsible for a recognizable set of phenotypic traits, which collectively differ from those of other breeds. It therefore lends itself to a first operational approximation of the notion of a 'genetic resource'.

The breed group and production system chosen for this case study provide a particularly significant challenge. Pastoralists in Africa are difficult to survey and their social systems complex to analyze, partly because of their mobility. It is becoming more widely recognized, however, that the cattle they own represent a unique genetic resource (Rege, 1999). The traditional cattle herds kept by the pastoralist Maasai of East Africa belong to a broad sub-group of cattle referred to as 'Small East African shorthorn zebu' (or SEAZ, a member of the broader *Bos indicus* group). Rege and Tawah (1999) have referred to this strain as the Maasai Zebu. The use of 'Maasai Zebu' in the rest of the paper is essentially synonymous with SEAZ.

These animals have been living in harsh, semi-arid conditions for thousands of years, and have a degree of tolerance to drought and endemic diseases not present in recently introduced zebu breeds, such as Sahiwal and/or the East African zebu breeds not native to the area, such as the Boran. These latter breeds of cattle and their crosses are larger animals and therefore produce more meat per animal and can also produce more milk when raised under a high level of management and nutrition. However, under the typical environmental and management conditions of these pastoral systems, and from the medium to long run perspective in production, they do not necessarily perform better than the Maasai Zebu. In fact, in severe drought conditions (an event that has occurred 4-5 times in the last 20 years in parts of Kenya), the non-indigenous breeds are much more likely to perish. This was witnessed in the recent 1999-2000 drought, where pastoralists in southern Kenya incurred severe losses of their herds (Kristjanson *et al.*, 2001).

A comparison of the revealed and stated preference approach to valuing zebu cattle not only allows us to examine whether CEs are a good tool to investigate pastoralists' preferences regarding various cattle attributes, but also provides an analysis of the effect of breed on market prices. Thus, a secondary objective of this case study is to attempt to address some of the following questions:

- Are market transactions reflecting breed type and breed mixtures?
- Is breed recognized as a distinct value in pastoral cattle markets?
- Are CEs adequately precise in estimating values for cattle characteristics that are relevant in market transactions?
- Can breed (as a first proxy for animal genetic resources) be valued by choice experiments in a manner consistent with that observed in market transactions data?

The remainder of the paper is organized as follows. In section 2 we lay out the theory and methodological framework employed in the study. Section 3 describes the area and agro-ecological system where the surveys were conducted, along with the experimental design of the CE. The results of the econometric analysis are reported and discussed in section 4. Some conclusions and directions for further research in this challenging area of work are presented in the last section.

2 Theory and methods

2.1 Hypothetical versus actual choices.

In this study we attempt to characterize the preferences for animal attributes by traders operating in seven markets within Kajiado district in Kenya. We then focus on the Maasai Zebu breed as a first crude proxy for the gene pool found within that indigenous breed. In studies of this kind, the choices supporting the analysis of preference can be hypothetical or they can be real economic choices in which money has actually changed hands.

Hypothetical choices are normally collected by recording choice statements from a representative sample of the relevant population. In choice modelling statements are collected according to an experimental design aimed at characterizing the nature of preferences for the relevant set of attributes of a given choice. The experimental design is developed so as to avoid redundancies in the choice sets and to ease the cognitive task of the respondent to a minimum. This aims at maximizing participation and survey completion rates and is particularly important in our context, where surveys had to take place in eventful cattle markets, where respondents were likely to be distracted by a number of factors during survey administration.

The hypothetical nature of this kind of choice can result in *hypothetical bias*. In other words, since the choices recorded are only statements (no money changed hands), they are implicitly considered as being a *looser* link to individual preferences than revealed preferences are, since the latter are based on actual purchases/sales. Value estimates based on revealed-preferences are therefore considered a superior 'criterion' to stated preference approaches for valuing non-market goods.

Hypothetical bias may be expected to play an important role in populations displaying undesirable attitudes towards interviewers, and it is a problem frequently encountered in the contexts of developing countries (Whittington *et al.* , 1990; Köhlin, 2001). For example, because of cultural reasons, it might be held socially undesirable to displease the interviewer. Hence the respondents may be expected to try to double-guess a possible 'expected right answer', rather than revealing their true preferences about the choice at hand. This, for example, may have implications for the application of contingent valuation in the discrete-choice referendum format. In this respect, however, CEs ought to perform better, although they also need a closer scrutiny in these contexts than they do in developed countries. For these reasons, each interview included a set of 'warm-up' questions during which consistency checks were performed.

2.2 Testing for difference in preferences.

Stated preference methods, such as CE, can be carried out to assess internal and external preference consistency (Carlsson and Martinsson, 2001). The former refers to tests of properties such as rationality, transitivity, effects of elicitation formats, etc. (Ben-Akiva *et al.*, 1992; Adamowicz *et al.*, 1994). In contrast, the latter concentrates on whether or not preferences expressed in statements are consistent with real market transactions (Wardman, 1988; Loomis *et al.*, 1996; Carson *et al.*, 1996). Our study contributes to the debate by providing some empirical evidence using the external consistency test of the robustness of the CE approach.

Another potential test for validating the use of CEs is based on the convergence of the value estimates obtained for the same attribute of the good from the same population of agents. Using a Lancasterian approach (Lancaster, 1966), one can define the market value assigned by cattle traders to an animal as the summation of the values of the animal's most significant attributes. If the value decomposition hypothesis is supported by the evidence in the samples and the two methods are equally good in determining values, then their value estimates should be invariant to the method — stated or revealed — with which the preferences are investigated.

More practically, a base-line hedonic valuation of cattle traits can be conducted from market prices, by simply identifying the determinants of market price in real transactions. Market prices are clearly the 'hardest' form of revealed preference evidence, and hedonic regressions are desirable analytical tools because of their simplicity and wide acceptance among economists.

The same population of traders can then be sampled for the collection of hypothetical choices between alternative animals. From this set of discrete choices a random utility model can be estimated, with market price of the animal as one of the relevant attributes of choice. If the set of value estimates for the attributes is found to be not significantly different, then the CE approach can be considered to be not inferior to the more desirable revealed-preference approach.

2.3 Multi-attribute valuation methods.

Multi-attribute valuation methods attempt to derive the economic value of a given qualitative or quantitative attribute of a good by means of statistical analysis of observed choices.

When the observed choice i takes the form of market prices p_i for a given animal with a set of given measurable attributes and $\mathbf{q}_i = \{q_1, ..., q_k, ..., q_K\}_i$, (e.g. slaughter weight, gender, body condition etc.), then there is an immediate relationship between the amount paid and the attribute measures: $p_i = f(\mathbf{q}_i)$, which can be estimated statistically. Of particular interest to this study are the marginal effects of the above function:

$$p^k = \frac{\partial f(\mathbf{q})}{\partial q_k} \tag{1}$$

They describe how price varies when a given animal attribute varies, keeping everything else constant. Economic theory is silent about the functional form, but not about the sources of data. In fact, revealed preference data, when available, are clearly deemed to be superior.

Equation (1) can be estimated easily starting from both revealed and stated preference data from market transactions. We assume that price is linear in the relevant attributes of the cattle head transacted, plus a constant effect α and an i.i.d. zero mean homoskedastic error term ϵ so that:

$$p_i = \alpha + \sum_k \beta_k q_k + \epsilon_i = \beta' \mathbf{q}_i + \epsilon_i, \tag{2}$$

where k indices the attributes and i the observations. It is a classic result that eq.(1) for the specification in eq.(2) is simply represented by the estimated parameter $\hat{\beta}_k$, which may be derived using ordinary least squares.

Let's now turn to the CE design. In the experimental application of choice-modelling, one paramount objective is that of easing the choice task for respondents. This is particularly important in the busy context of a cattle market because of the distracting environment in which cattle dealers operate. One way of simplifying choice tasks is to make the choice context discrete, as this is known to require smaller cognitive efforts from the respondent, and still provides the required information to elicit economic preference. The respondent is therefore asked to identify one preferred choice j^* amongst a given set of alternatives $j \in J$. These data are then analyzed by employing the theoretical framework of random utility models (McFadden, 1974; BenAkiva and Lerman, 1985; Anderson *et al.*, 1992), where it is postulated that the observed choice is the one associated with the highest (expected) utility.

The seminal paper on conditional logit by McFadden (1974), shows that if the unobservable component in each choice occasion is identically and independently distributed as extreme value type I, then:

$$Pr(j^*) = \frac{\exp(\Delta\theta' \mathbf{q}_{j^*}/\sqrt{\kappa})}{\sum_j^J \exp(\Delta\theta' \mathbf{q}_j/\sqrt{\kappa})}. \tag{3}$$

where $\sqrt{\kappa} = \pi/(\lambda\sqrt{6})$ is the standard deviation of the error term and λ is the usual scale parameter (Train, 2002, pages 28-30).

The objective of the study is to collect hypothetical choices through a CE in order to derive an estimate for $\Delta\theta$ from which to compute estimates of eq.(1). These are to be compared with their analogue obtained from revealed preference data in market transactions. As long as the price p for the animal described in the profile is included in the vector of attributes, then eq.(1) can be derived as a marginal rate of substitution (MRS):

$$p_i^{q_k} = \frac{\partial g(q_i)}{\partial q_{i,k}} = \frac{\partial \Delta\nu / \partial q_{i,k}}{\partial \Delta\nu / \partial p_{i,k}} = \frac{-\Delta\theta_{i,k}}{\Delta\theta_{i,k=p}}. \tag{4}$$

In our context, the preferred choice is one particular animal, described according to a procedure that provided information about the relevant attributes q_k at a given market price. 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 for not buying either animal (zero option) and retain income. This constitutes the third alternative. Respondents were asked to repeat the choice task 8 times and the arrangement of the profiles across choice tasks was randomised from a set of 16 orthogonal main-effects.

The estimated taste parameters are then employed to compute the value of each attribute using eq.(4). Approximate confidence intervals of this ratio of ML estimates can be obtained in various ways, here we use the delta method.

2.4 Variance heterogeneity.

When dealing with a single data set, the dispersion parameter $\sqrt{\kappa}$ is commonly normalized to 1. However, it is sometimes recognized that the researcher's specification of the deterministic component of utility works better for some groups of respondents than for others. In other words, the dispersion of the unobserved component can be expressed as a function of the covariates defining type of traders to account for variance heterogeneity (Swait and Louviere, 1993; Bradley and Daly, 1994; Bhat, 2000).

For example, in the Kenyan cattle markets surveyed, very diverse agents engage in transactions, some of whom have more familiarity than others with buying and selling cattle. Hence the accuracy with which they trade-off animal traits may also vary. For this reason we investigate how sensitive the value estimates for animal attributes are to variance-heterogeneity.

Our parameterization is:

$$[Var(u_i)]^{0.5} = \sqrt{\kappa_i} = \exp(\sum_h^H \gamma_h s_{ih}) \tag{5}$$

where u_i is the unobservable error, s_h are respondent-related covariates thought to have an impact in the variance of the unobserved component u_i. This is convenient because when $\gamma_h = 0, \forall h$ then $\sqrt{\kappa_i} = 1$, which is the common assumption and hence easy to test empirically.

2.5 Taste heterogeneity.

One of the limits of analyzing choices by means of multinomial logit specifications is that all traders are assumed to share the same set of taste parameters for the various attributes of cattle. In contexts of choice where agents buy for diverse purposes — such as African cattle markets — this is a strong limitation. Recent developments in choice modelling via mixed logit make it possible to account for unobserved taste variation (McFadden and Train, 2000; Train, 2002). Mixed logit estimation requires simulated maximum likelihood methods (Sim-ML) and the specification of distributions for taste parameters.

The simulation can be greatly reduced by using Halton rather than pseudo-random draws. Because of their improved equi-dispersion properties these achieve good approximations with a lower number of simulation. We use 100 Halton draws which produce the same approximation as 1000 pseudo-random draws (Train, 1999, 2002).

Rather than independent distributions, we assume a multivariate normal for all taste attributes. Taste for price is assumed log-normally distributed, so as to constrain the parameter to be negative. All other attributes may plausibly have both positive or negative values.

Assuming a log-normal distribution for the price parameter θ_p has implications on the choice of measures of central tendency of the distributions of the MRS. This is because the mean value differs from the median value. In our case we compute them at both the mean and the median values of the estimated log-normal. That is:

- At the mean : $\hat{\mu}_{\theta_j} / \exp(\hat{\mu}_{\theta_p} + 0.5\hat{\sigma}^2_{\theta_p})$
- At the median : $\hat{\mu}_{\theta_j} / \exp(\hat{\mu}_{\theta_p})$

We assume an unrestricted variance-covariance matrix, which in turns allows one to estimate correlation between tastes, which are informative with respect to the proportion and degree of 'jointness' with which these intensities of preference occur in the population.

A second shortcoming of conventional fixed logit estimation is that it does not recognize dependence across repeated choices by the same agent, as it explicitly requires the assumption of choice independence. It is obvious that in CE preferences remain fixed in the sequence of choices made by the same respondent. To account for this we employ the panel version of mixed logit models (Revelt and Train, 1998), where this taste-permanence is explicitly recognized.

Accounting for heterogeneous taste may also vary the estimates of the MRS (Layton, 2000) between animal traits and money, and hence our measure of marginal value. It is therefore appropriate to assess these estimates' robustness to taste-heterogeneity in the econometric analysis.

2.6 The selection of market relevant attributes for cattle.

For the selection of cattle attributes we relied on market information previously collected by researchers in Kenya Agricultural Research Institute (Ruto, 1999) in Kajiado district. The results from the statistical analysis of these data showed that the following cattle attributes explained most of the variation observed in transaction prices:

(1) Estimated slaughter weight;
(2) Sex;
(3) Body condition;
(4) Sexual maturity;
(5) Age group.

Unfortunately, no breed records were collected for these transactions, and no background information on the effect of breed on market price was available in these markets. It was therefore unclear from this earlier analysis if and how the addition of the variable 'breed' would perform.

3 Cattle markets description and survey approach

The surveys were carried out in 7 livestock markets in the district of Kajiado, southern Kenya (Figure 1). The area (19,600 square km) runs from just south and west of Nairobi to the border with Tanzania. Most of Kajiado district lies in the semi-arid and arid zones, and only 8% of its land has some potential for cropping (Bekure *et al.*, 1991). Mean annual rainfall ranges from 300 to 800 mm, and open grasslands predominate with small areas of bush and woodland. There are few permanent natural sources of surface water. Livestock and wildlife co-exist in much of this area, with several major National Parks (Nairobi, Amboseli, Tsavo) bordering or falling within the district.

FIGURE 1 ABOUT HERE

Human population in Kajiado has increased significantly over the last 20 years, from 149,000 in 1979 to 260,000 in 1989 and 406,054 in 1999 (GOK, 2001). The economy of the area has historically been dominated by the Maasai pastoralists who are in the midst of on-going significant socio-cultural and economic changes. For example, Kajiado's cattle population was estimated to be around 475,800 head in 1988 (Rutten, 1992) with 639,000 sheep and goats, in the hands of some 124,100 pastoralists, implying an average livestock ownership of 3.2 TLU/capita (where one TLU, or tropical livestock unit, is equivalent to a 250 kg animal). By 1997, the cattle population of Kajiado was estimated to have increased to 623,000 head and TLU/capita to have fallen to 2.1 (GOK, 1997). Several researchers reported declining livestock/people ratios over the last 10-20 years and attributed it to diversification of the Maasai economy, increasing human population pressure, several severe droughts, and land tenure changes such as the subdivision of group ranches (Rutten, 1992; Bekure *et al.*, 1991).

There are several reasons for concern for the Maasai and their cattle. One is due to the historical existence of indigenous breeds of cattle, sheep and goats in ecosystems with the richest biodiversity of wildlife on the African continent (Marshall, 1990; Reid *et al.*, 1999). Indigenous livestock are more resistant to diseases carried by wildlife (e.g. wildebeest, zebra). Tourism revenues, largely based on wildlife, are extremely important for Kenya's overall economic performance.

A second reason is that pastoralists have become less food secure over the last 20 years, and improving the productivity of their livestock production-based systems is an important poverty alleviation goal (GOK, 2001). The 1999-2000 drought vividly demonstrated the relative hardiness of the indigenous breeds compared to exotic breeds (Kristjanson *et al.,* 2001). Implicitly it also demonstrated the potentially huge costs associated with the loss of livelihood resulting from losses of domestic cattle breeds amongst pastoralists.

The seven markets (Emali, Kiserian, Bissel, Sajiloni, Oldonyonyokie, Kimana, Rombo) were selected because they are the key livestock markets used by pastoralists in southern Kenya. Their spatial distribution reflects the local structure of cattle marketing and, in particular, the movement of livestock from primary to secondary markets. They were therefore expected to represent reasonably well the reality of cattle trade in inland Kenya, especially in terms of indigenous breed mixture.

3.1 *Market transactions survey*

The market transactions survey was aimed at cattle producers and traders who were observed in the process of negotiating for and purchasing cattle. The following information was collected regarding each purchased head:

- Sex of the animal
- Age group
- Reason for purchasing the animal (slaughter, rearing, re-selling)
- Body condition (poor, good, excellent)
- Estimated weight (kgs)
- Breed (Maasai Zebu, Boran, Sahiwal, or cross)
- Price

For each of the 7 markets, local enumerators — familiar with livestock marketing — were recruited and trained. Because of the difficulty associated with standardizing breed recognition, enumerators were given special training. Finally, particular emphasis was dedicated to random sampling techniques. In this type of survey it was not possible to obtain a true random sample, as no complete list of potential respondents existed. However, a concerted effort was made by enumerators to choose the respondents as randomly as possible.

Enumerators collected information from buyers on over 450 observed transactions during the period September through November, 2000. Just over half (51%) of the observed transactions involved cattle classified as Small East African Zebu (specifically, the Maasai Zebu). The second largest fraction were Maasai Zebu crosses (20 % Sahiwal, 13% Boran and less than 2% Boran-Sahiwal crosses). Finally, only 6% of the cattle were pure Sahiwal and 4% pure Boran breeds.

With regard to sex, 42% of the cattle transactions involved cows, 31% mature males, 13% immature males, and 14% heifers. In this atypical drought year, almost half of the animals (46%) were purchased for slaughter, only 19% (and 31% of these were the Maasai Zebu breed or its crosses) for rearing purposes, while 34% were targeted for resale. While all categories of body condition were uniformly represented among heads of cattle purchased for slaughter purposes, this was not the case for those purchased with the intention of rearing the animals. No animals in excellent condition were purchased for rearing, and only 22% were considered to be in good condition; the remainder were in fair or poor condition.

For buyers interested in reselling animals, body condition was clearly important. Fifty-seven percent of animals classified as being in excellent body condition were bought for resale. Forty-four percent of cattle in good condition, 33% of those in fair, and 21% of those in poor condition were purchased with the intention of re-selling.

The average price per kilogram of estimated slaughter-weight was 74 KShs (roughly $1), with a standard deviation of 25.6 and an empirical distribution similar to a normal one, with a Kolmogorov-Smirnov z-value of 1.133.

3.2 The choice experiment

The enumerators that implemented the market transactions survey were further trained to administer the CE survey. This aimed at the same category of market participants, i.e. those purchasing cattle. The interview was made up of the following steps:

(1) A short introduction; where the selected respondent was approached and debriefed as to the nature and the motivation of the interview;
(2) An initial set of 'warm-up' choice-task questions; designed to assess the understanding of the respondents of the choice-mechanism, as well as providing him with some practice with the typical choice-tasks;
(3) A sequence of eight choice-tasks from the experimental design; the outcome of which constitute the CE data analyzed in this study.

The typical choice context of the survey consisted of two hypothetical cattle purchase choices (A and B). Each choice was described to the respondent in terms of five attributes: sex, slaughter weight, breed, body condition and price. They were then asked to choose A, B or neither. For example, Buyer 1 was asked the following: Would you buy animal A: a male Zebu-Sahiwal crossbreed that weighs 120 kgs, is in poor condition and costs KSh 12,000, or animal B, a female Maasai Zebu that weighs 100 kgs, is in good condition and costs KSh 10,000, or neither?

Each animal profile presented to a respondent was represented on a separate laminated card (explained in the local language and with symbols), and in some cases, photographs of cattle were used to demonstrate the variable 'body condition' to respondents (i.e. poor, good, excellent). In the cases where photographs were not used, examples of cattle in the marketplace that were representative of the body condition in question were pointed out to respondents. The enumerators completed more than 310 surveys for a total of nearly 2,500 choice tasks, usually undertaking 4 interviews per market day. In order to ensure preference stability across revealed and stated preference data this survey, like that of the market transactions, was also administered from September through November, 2000.

4 Results

4.1 Results of revealed preference approach

The results of the hedonic analysis of the market transactions data, estimated using ordinary least squares (OLS), are shown in Table 1. Log-linear specifications were rejected by likelihood ratio tests based on the Box-Cox transformation and normal errors ($\lambda = 0.998$), therefore a linear specification was employed.

TABLE 1 ABOUT HERE

In all 7 markets slaughter weight was the principal factor in describing the market price recorded for the transacted animals. Not only was it strongly significant, but this variable alone explained more than 66 percent of the variation in market price.

The different descriptors of body condition were the second group of variables with strong explanatory power. With dummy variables included for 'excellent' and 'good' along with 'slaughter weight', the regression equation explained more than 71 percent of the observed variation

When a dummy for the variable 'market of transaction' was added, the explanatory power exceeded 74 percent. Next came the group of variables for sex classes, where dummies were used for 'mature males' and 'cows', bringing the maximum explanatory power to around 76 percent.

To control for specific-market effects, dummies for 5 out of the 7 markets were included in the regression. Transaction price was significantly lower only in Oldonyonyokie and Sajiloni, compared to the two baseline markets of Rombo and Bissel, which displayed similar price patterns.

Various combinations of 'breed descriptors' were tried, none of which ever appeared to significantly improve the fit, suggesting that these were not significant determinants of market value. Nor did the addition of descriptors for the purpose of buying (slaughter, rearing, resale) help towards increasing the fit of the hedonic equation. Various joint significance F-tests were conducted and supported the same conclusion.

For the purpose of the validity test with the choice experiment data, the part-whole value estimates from the OLS regression were estimated for the set of attributes employed in the experimental design of the CE. These were being a 'cow', being in 'excellent' or 'good' body condition, 'slaughter weight in kg' and being a 'pure Maasai Zebu' animal. The OLS estimates slightly vary according to the type of hedonic regression considered. As can be seen in Table 1, a cow is expected to be purchased for a price which is KSh 541 ($6.94) lower than the other sex/age classes. Cattle in 'excellent' body condition are expected to command a premium of approximately KSh 5,000 ($64.10), and of KSh 2,300 ($29.49) if they are in 'good' body condition. The value of 'one kg of slaughter weight' is approximately Ksh 80 ($1.02). As mentioned earlier, the only variable of relevance lacking significance was the breed variable.

Although animals with good and excellent body condition would typically be of higher weight, collinearity — as measured by the variance inflation factors — was not detected to be a significant problem. The significance of estimates was robust to the dropping and adding of regressors, and so were the value estimates. This is possibly due to the high observed variation in size, body condition and breed due to the large polimorphism that characterizes African cattle. However, all the standard errors were derived using White's robust estimator.

4.2 Results of the choice experiment

4.2.1 Multinomial logit results.

Maximum likelihood estimates for the multinomial logit models estimated from the CE data are shown in Table 2. Because differential prices were employed in different markets in the experimental design, dummies for markets are omitted from the specification of indirect utility.

TABLE 2 ABOUT HERE

For a nonlinear model of this type, the level of explanatory power is noteworthy (Pseudo-R^2 of 23.6%). In fact, the contribution to the sample log-likelihood of each observed choice weighted for the number of choices in the choice set compares well with recent studies. [1]

The estimates of the taste parameter imply that cows are valued KSh 470 less than other gender/age classes (which is similar to the 541 estimate from the hedonic OLS regression); a positive value of KSh 6,000 for animals in excellent or good body condition (also quite similar to the KSh 5,000 estimate above); a slaughter weight value of about KSh 100 per Kg, which is quite close to the estimates KSh 80 per Kg; and finally, a negative value for a pure Maasai Zebu animal of KSh 600. Judging by the p-values computed from standard errors

[1] For example, Carlsson and Martinsson (2001) reported a value of -0.30 (Table II, page 186, Last column), while in our model it is even higher, with a value per observation of -0.28.

approximated using the delta method, all the value estimates for the cattle attributes included in the CE were quite significantly different from zero.

4.2.2 Variance heterogeneity logit results.

The full information maximum likelihood (FIML) estimates of the model with variance heterogeneity (eq. 5) are presented in Table 3. Model selection for the specification of $\sqrt{\kappa}$ was conducted by testing down a vector of covariates that included dummies for market locations, the three main purposes of purchase ('rearing', 'resale' and 'slaughter') and the order of the choice in the respondents' choice sequence.

TABLE 3 ABOUT HERE

Expressing $\sqrt{\kappa}$ as a function of four parameters significantly increases the log-likelihood by 159 points. So the null hypothesis of presence of variance heterogeneity cannot be rejected. It is clear that purchasing for 'rearing' is systematically associated with a large variance in the unobserved error. This is not surprising for two reasons. Firstly, this type of buyer tends to have lower familiarity with market transactions as they engage more rarely in selling and buying than those traders buying for 'resale' and 'slaughter' do. Secondly, 'rearers' evaluate cattle with many different purposes in mind, and therefore the five cattle attributes used in the choice experiment are less likely to capture as much of the preference structure as they do for other types of traders. As a result these choices are 'noisier', and more variation is observed in the error term.

Three markets significantly affect the variance: Bissel, Emali and Rombo. While choices from respondents in Bissel show a significantly lower variance, those from the other two markets show larger variance. This is consistent with the fact that Emali and Rombo, although for different reasons, are both markets attracting a very heterogeneous pool of traders, while Bissel attracts a relatively homogenous pool of traders because it has a slaughter facility. Since many choices are made with slaughter in mind it is likely that the attributes employed in CE (body condition and weight are classic ones) captures most of the taste variation and hence there is significantly less unobserved noise.

Once these systematic effects on the variance of the error are accounted for, the estimates for the MRS are more precise. The one for the main explanatory factor in the hedonic regression – slaughter weight – is Ksh 89, quite close to the value of Ksh 78 estimated from the hedonic regression. The estimates for the 'Cow effect' is Ksh 610 and not significantly higher than that of Ksh 541 obtained in the hedonic regression. However, the estimated effect of cattle being in excellent/good body condition is much higher, Ksh 6,960. This slight discrepancy is difficult to comment upon, because some enumerators used different ways of illustrating body condition to respondents. [2]

4.2.3 Panel mixed logit results.

The simulated maximum likelihood estimates for the mixed logit model are reported in Table 4. Seven choices (one interview) were discarded for incomplete panel information. It is noteworthy that these estimates fit the data significantly better as their joint effect decreases by 25% the average log-likelihood, from 0.839 in the fixed logit down to 0.625 in the panel mixed logit with correlation.

TABLE 4 ABOUT HERE

Because a multivariate normal correlation structure was assumed, all the 15 elements of the 5×5 variance-covariance matrix need estimation. The elements of $\hat{\Sigma}$ can be re-arranged to estimate the correlation matrix for tastes (Table 5). Such matrix reveals that the log of (the negative of) the taste parameter for money is negatively correlated with the intensity of preferences for female animals, with that for heavy animals and for pure zebus. So marginal utility of income is positively correlated with preference for cows, heavier animals and the indigenous breed. It is very weakly negatively correlated with taste for animals in good and excellent conditions. This may indeed be the structure of preference of many buyers: as cash becomes increasingly scarce they wish to buy heavier heavy zebu cows and shun away from cattle with exotic blood showing better than average body conditions, but relatively more vulnerable to extreme environmental conditions.

TABLE 5 ABOUT HERE

Preference for female animals are positively correlated with animals in good or excellent conditions and of higher weight, but these are uncorrelated with breed. Surprisingly, traders attracted to animals in good or excellent conditions tend not to be those attracted to animals of high weight or of indigenous breed.

The estimated MRSs between attributes and money for this model are computed at both the estimated mean and median of the taste distribution of

[2] To illustrate body conditions to respondents some enumerators systematically used laminated photographs, while others chose to point to an animal within view as an example of a particular body condition. Because of the strong and prolonged drought it can be argued that those that used photos were showing respondents examples of cattle whose body condition must have been much better than those of even the best cattle in the market. As a result the body condition effect may well have been systematically overvalued.

price and reported in Table 6.[3] Both computations produce very similar value estimates to those obtained in the other logit models and in the hedonic regression. However, the estimate for the effect of sex of the animal is now no longer significant.

TABLE 6 ABOUT HERE

5 Discussion and conclusions.

The Convention on Biological Diversity is encouraging a series of actions aimed at supporting or promoting conservation, sustainable use and fair and equitable sharing of the benefits arising from the use of genetic resources. These necessitate assessment of the economic value of biological diversity, particularly of biological resources important for livelihood.

The valuation of AnGRs is necessary to fulfill this objective, but very problematic. Little work has been done in this specific field and this study moves into uncharted territory. Much of the indigenous livestock in developing countries, although extremely well adapted to local environments, is relatively unproductive if meat and milk are the only outputs considered. As a result, conventional economic analysis may tend to promote the introduction of exotic breeds. These exotic breeds often fail to deliver the expected long-term production improvements for a variety of reasons including their inferior resilience and adaptability. Yet, their introduction may dangerously displace or dilute indigenous AnGRs, eroding the genetic integrity of well-adapted indigenous breeds.

Further, we argue that since it is the animals that are traded in markets, and their market value depends largely on their perceived ability to perform various unspecified functions for the owner (both buyer and seller), multi-attribute non-market valuation methods are required to assess the net value of these functions. However, such methods were developed and have been well tested in developed economies, and the studies included in this issue of the journal represent the first attempt, to our knowledge, to test them in the context of livestock in developing countries.

A choice-experiment appears to be the appropriate stated-preference multi-attribute tool for this particular valuation challenge. An external test with revealed-preference value estimates represents a good starting point to assess CEs performance in valuing important and objectively verifiable cattle traits,

[3] Because a joint distribution of taste parameters is estimated here, the choice of values to report is somewhat arbitrary.

such as estimated slaughter weight, sex, and body condition. The study we designed is aimed also at investigating the value of AnGRs in the form of a particular breed of cattle: the Maasai Zebu. While ultimately we would like to be able to value specific traits such as disease tolerance, we chose to use breed as a proxy for such 'desirable' traits in this study, since the type of breed can be identified by enumerators, but the degree of disease resistance is not something they can verify during market transactions. So, as a first approximation to AnGRs, we chose to include breed amongst the investigated cattle traits.

We first valued these traits by collecting data from transactions in seven markets in Kenya. We then used this data to provide an external test for CEs estimates from surveys of traders from the same markets. We find that value estimates for slaughter weight, sex and body condition from the hedonic function compare well in magnitude with those implied by the basic random utility model reported in Table 2, by the variance heterogeneity model in Table 3, and by the mixed logit estimates in Tables 4-6. Thus 3 out of the 4 value estimates for animal attributes obtained approximate well their counter-parts from a conventional hedonic approach. The remaining one, Maasai Zebu breed, is not significantly different from zero in the revealed preference analysis, but it is significantly negative in the stated preference approach. Since neither result supports our hypothesis that Maasai Zebu breeds are valued positively within the marketplace, we took a closer look at why this may be the case. It only became clear after the data collection was well underway that we were dealing with an unusual year with respect to weather (i.e. severe drought). Because of this, a majority of the recorded sales would be desperate attempts to sell animals for slaughter before they died of starvation. It stands to reason that in these harsh circumstances, what the particular breed of animal was would not play a major role in either buyer or seller preferences.

In order to test this new hypothesis - i.e. that the results for those buying for slaughter purposes would differ from those purchasing for rearing, the analysis was repeated for a subset of 448 choices from the 56 out of 312 traders who stated that they were buying for rearing purposes. The sign of the coefficient for the breed variable was still negative, but not significant. This result does not resolve the uncertainty about this hypothesis, and it must be interpreted with caution because the experimental design of this subset of the data was incomplete. The frequency of these cases might have been too low for breed to be a significant factor influencing buyers' choices. It remains apparent however, that when buying for slaughter traders should not be expected to consider breed as an important criterion.

A second factor that might have caused the statistical significance of breed in the CE results, but not in the transactions data analysis, is the larger sample size available for CE observations. While the CE estimates relied on a large set of orthogonalized choices (nearly 2,500), the hedonic regression was estimated on 430 transactions. So, the preference of cattle traders buying animals destined to slaughter may well be, on average, negative as supported by the larger sample CE results. Unfortunately the category of buyers that is most likely to be attracted to the Maasai Zebu — those buying for rearing — was least represented in the sample. Finally, it can be suggested that Maasai Zebu animals are indeed less valuable than other cattle breeds, or even that traders are ignorant of their desirable traits, which would point to yet another market failure. This hypothesis is in contrast with the sheer number of transactions recorded in the seven markets, where 51% of the animals were classified as Maasai Zebu.[4] So, given the extent of the market for the indigenous breed, perhaps it is more apt to say that there is a premium for exotic breeds and their crosses, rather than a penalty price for Maasai Zebu cattle. This may be in keeping with the notion of this breed being such an efficient and fit animal to this environment. These attributes make it an animal that can be produced at a comparatively low marginal cost. A producer should be more likely to accept a lower payment for Maasai Zebu cattle than for cattle of exotic breeds, which in turn require more input and hence a higher final price. If this is the case, future research should concentrate on addressing willingness to accept payments amongst producers for different animals.

Further research with a focus on breed as a factor input for the production or re-stocking of herds could refute or corroborate these hypotheses, for example by providing evidence that the Small East African Zebu cattle (of various strains) are indeed negatively valued by market agents (as is suggested by the choice experiment results). The implications for 'in situ' conservation efforts of the genetic resources found within this breed will then need to be considered. Confirmation of a negative relationship would imply that there is currently a lack of economic incentives for the maintenance of this indigenous breed. As Maasai livestock systems continue to change, there is a danger of losing or diluting their indigenous livestock breeds.

We contend that the degree of convergence between the value estimates for the set of animal attributes is sufficient to claim that the external test of 'criterion validity' of CEs is passed, as it produces estimates of marginal values similar to those obtained by the theoretically more valid method of hedonic regression on observed transaction prices. As a consequence, the hypothesis that pastoralists engaged in cattle trading would display a different set of economic preferences when answering hypothetical questions about cattle purchases than they do when actually buying an animal is not supported by the results of this study.

In conclusion, the study supports the use of multi-attribute stated-preference methods — such as choice experiments — as a way to investigate non-market

[4] We are thankful to an anonymous reviewer for pointing this fact to our attention.

preferences over livestock attributes in developing countries. The issue of whether or not the ‘breed’ is a useful operational concept for AnGRs in this context remains open to further investigation. Findings in this respect will have important implications for the valuation of new breeding programmes and AnGRs conservation efforts.

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6 Tables

List of Variables for OLS regression.

(1) WEIGHT = estimated slaughter weight in Kg;
(2) EXCEL, GOOD, FAIR = 0-1 dummies for excellent, good and fair body conditions (baseline 'poor');
(3) OLDONY,SAJILONI ,KISERIAN ,EMALI ,KIMANA = 0-1 dummy variables for market places (baseline Bissel or Rombo);
(4) ZEBU,BORAN,SAHIWAL = 0-1 dummy variables for pure bred animals;
(5) ZEB_BOR,ZEB_SAH,BOR_SAH = 0-1 dummy variables for cross-bred animals (Zebu, Boran, Sahiwal);
(6) SLAUGHT,RESALE = 0-1 dummies for declared purpose of purchase (baseline 'rearing');
(7) COW = 0-1 dummy for the sex of animal (not cows).

Table 1
OLS estimates of marginal values of cattle attributes.

Variable	β	St.Err. of β	p-values of t
WEIGHT	78.15	3.48	0.000
EXCEL	4,845.96	628.33	0.000
GOOD	2,339.28	320.87	0.000
FAIR	1,205.34	270.99	0.000
OLDONY	$-1,232.78$	341.17	0.000
SAJILONI	-961.46	358.92	0.008
KISERIAN	-523.82	282.64	0.065
EMALI	334.87	419.08	0.425
KIMANA	-431.92	354.22	0.223
ZEBU	163.70	601.83	0.786
BORAN	-486.21	786.73	0.537
SAHIWAL	-324.13	694.94	0.641
ZEB_BOR	1.83	659.14	0.998
ZEB_SAH	-363.38	620.60	0.559
BOR_SAH	-270.34	1012.81	0.790
SLAUGHT	30.59	290.63	0.916
RESALE	290.81	291.33	0.319
COW	-541.51	219.12	0.014
(Constant)	-989.08	712.39	0.166

R^2 0.760, Adj.R^2 0.750 St. Err. 1936.383 , F = 72.54, N = 430.

List of variables for logit models.

(1) PRICE = price in of the animal in Kenyan Shilling;
(2) LogPRICE = log of the price of the animal in Kenyan Shilling;
(3) COW = 0-1 dummy for the sex of animal (not cows);
(4) PURE_ZEBU = 0-1 dummy for pure Maasai Zebu (baseline 'other breeds or crosses');
(5) GOOD_EXC = 0-1 dummies for 'good or excellent' body conditions (baseline 'other');
(6) WEIGHT_KG = estimated slaughter weight in Kg.

Table 2
ML estimates from choice experiment, multinomial logit.

Variable	$\Delta\theta$	St.Err. of $\Delta\theta$	p-values of z
PRICE	$-2.6E-4$	$1.7E-5$	0.000
COW	-0.122	0.074	0.100
GOOD_EXC	1.582	0.098	0.000
WEIGHT_KG	0.028	0.001	0.000
PURE_ZEBU	-0.156	0.065	0.017
	$-\Delta\theta_{i,k}/\Delta\theta_{i,k=p}$	*St.Err. of $-\Delta\theta_{i,k}/\Delta\theta_{i,k=p}$	p-values of z
COW	-470	293	0.108
GOOD_EXC	6,113	334	0.000
WEIGHT_KG	107	5	0.000
PURE_ZEBU	-601	260	0.021

Pseudo-R^2 0.236, Adj. Pseudo-R^2 0.235, L-lik. $-2,094.55$, N=2,495, *delta method.

Table 3
FIML estimates from choice experiment, MNL logit with variance heterogeneity.

Variable	$\Delta\theta$	*St.Err. of $\Delta\theta$	p-values of z
PRICE†	−0.406	0.023	0.000
COW	−0.248	0.086	0.004
GOOD_EXC	2.829	0.148	0.000
WEIGHT_KG‡	0.362	0.018	0.000
PURE_ZEBU	−0.161	0.033	0.000
Estimates of parameters in $\sqrt{\kappa}$.			
BISSEL	−0.307	0.100	0.002
EMALI	0.357	0.133	0.007
ROMBO	0.342	0.099	0.000
REARING	2.394	0.375	0.000
	$-\Delta\theta_{i,k}/\Delta\theta_{i,k=p}$	**St.Err. of $-\Delta\theta_{i,k}/\Delta\theta_{i,k=p}$	p-values of z
COW	−610	210	0.004
GOOD_EXC	6,960	315	0.000
WEIGHT_KG	89	3	0.000
PURE_ZEBU	−395	80	0.000

L-lik. −1935.43, N=2,495, *from the secant update, **delta method.
†variable scaled by 1,000; ‡variable scaled by 10.

Table 4
Sim-ML estimates from choice experiment, mixed logit.

Variable	$\Delta\theta$	St.Err. of $\Delta\theta$	p-values of z
LogPRICE	−7.447	0.062	0.000
COW	−0.121	0.172	0.478
GOOD_EXC	4.442	11.452	0.000
WEIGHT_KG	0.065	17.052	0.000
PURE_ZEBU	−0.442	3.224	0.001
Diagonal values in Cholesky matrix, $\hat{L}$.			
LogPRICE	0.438	0.050	0.000
COW	0.674	0.212	0.002
GOOD_EXC	2.167	0.491	0.000
WEIGHT_KG	0.023	0.003	0.000
PURE_ZEBU	0.431	0.344	0.211
Below diagonal values in $\hat{L}$ matrix. $\hat{\Sigma} = \hat{L}\hat{L}^T$.			
COW-LogPRICE	1.363	0.192	0.000
GOOD_EXC-LogPRICE	−0.214	0.430	0.619
GOOD_EXC-COW	5.552	0.434	0.000
WEIGHT_KG-LogPRICE	0.021	0.003	0.000
WEIGHT_KG-COW	-0.028	0.003	0.000
WEIGHT_KG-GOOD_EXC	0.003	0.004	0.490
PURE_ZEBU-LogPRICE	0.137	0.197	0.486
PURE_ZEBU-COW	−0.280	0.209	0.179
PURE_ZEBU-GOOD_EXC	0.245	0.329	0.457
PURE_ZEBU-WEIGHT_KG	−0.385	0.226	0.089
Standard deviations of parameter distributions.			
LogPRICE	0.438	0.050	0.000
COW	1.521	0.167	0.000
GOOD_EXC	5.964	0.429	0.000
WEIGHT_KG	0.042	0.003	0.000
PURE_ZEBU	0.701	0.240	0.003

Pseudo-R^2 0.430, Adj. Pseudo-R^2 0.428, L-lik. $-1,556.68$, N=2,488.
100 Halton Draws.

Table 5
Simulated maximum likelihood estimates from choice experiment.

Mixed logit correlation matrix for taste parameters.

	LogPRICE	COW	GOOD_EXC	WEIGHT_KG
COW	−0.896	1.0	—	—
GOOD_EXC	0.036	0.380	1.0	—
WEIGHT_KG	−0.505	0.156	−0.619	1.0
PURE_ZEBU	−0.195	−0.002	−0.252	0.091

Table 6
Simulated maximum likelihood estimates from choice experiment.

Mixed logit estimates of MRS at the *average* of the price coefficient.			
	$-E[\Delta\theta_{i,k}]/E[\Delta\theta_{i,k=p}]$	*St. Error	p-values of z
COW	−189	273	0.487
GOOD_EXC	6,922	606	0.000
WEIGHT_KG	101	5	0.000
PURE_ZEBU	−688	218	0.002
Estimates of Marginal values at the *median* of the price coefficient.			
	$-E[\Delta\theta_{i,k}]/M[\Delta\theta_{i,k=p}]$	*St. Error	p-values of z
COW	−208	300	0.487
GOOD_EXC	7,621	698	0.000
WEIGHT_KG	112	6	0.000
PURE_ZEBU	−758	241	0.002
Descriptive statistics of coefficient ratios from simulated distribution.			
	$M[-\Delta\theta_{i,k}/\Delta\theta_{i,k=p}]$	$E[-\Delta\theta_{i,k}/\Delta\theta_{i,k=p}]$	St. Dev.
COW	−201	$-1,357$	3,964
GOOD_EXC	8,566	7,017	13,147
WEIGHT_KG	102	105	76
PURE_ZEBU	−701	−947	1,611

*delta method.