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Valuing Indigenous Cattle Breeds in Kenya: An Empirical Comparison of Stated and Revealed Preference Value Estimates

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SUMMARY

In this study we compare revealed and stated-preference approaches to value live-stock 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. This involves comparing value estimates for cattle attributes derived from CEs data with those obtained using a 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). It is argued that these methods are important in developing countries where livestock are kept for economic reasons and for cultural and risk management functions which are critical to livelihood strategies, but not valued by markets. The results indicate that CEs 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. They may be, therefore, a promising tool for valuing phenotypic traits expressed by indigenous AnGRs.

Keywords: Biodiversity values, genetic resources, stated preference, choice experiments, livestock values, non-market values, shorthorn East African zebu

NON TECHNICAL SUMMARY

A choice experiment (CE) is used to value the phenotypic traits expressed in indigenous breeds of cattle in Kenya. Validation is achieved by comparison with a hedonic analysis of actual transactions. Results indicate that CE can indeed be used to estimate trait values and could be used to investigate values of genetically-determined traits currently not prominent in livestock populations, but desirable candidates for breeding or conservation programs. The data also permits an analysis of how household characteristics determine differences in preferences, information which can be of use in designing policies that counter the present trend towards marginalisation of indigenous breeds.

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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. The conservation of genetic material from which this biodiversity arises is an integral and important component of this going concern.

The management of animal genetic resources (AnGRs) requires a host of decisions, many of these would be much better informed 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 Convention on Biological Diversity, valuation is essential for the development of benefit-sharing frameworks while 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 genetic resources are completely lacking for AnGRs. They are particularly needed in less developed countries (LDCs) 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 the need for efficient resource allocation for the task of biodiversity conservation more demanding than in LDCs. 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.

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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 particularly large in LDCs. 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 determination in LDCs. 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, 2000). 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 CE) (Louviere *et al.*, 2000), as it allows a systematic investigation of the single attributes of a bundled good.

Human preferences regarding phenotypic attributes of livestock differ across regions, countries, communities and production systems. In LDCs, 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 productivity of specific products are more valuable.

Multi-purpose, rather than specialised 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 in Zimbabwe by Moyo (1996) has shown that 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 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 the developing world 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 output 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 stated preference methods in developing countries are well documented (Whittington *et al.*, 1990; Köhlin, 2001). Thus in order to address this question, we needed to first validate CE value estimates for animal traits that were easily recognizable and objectively verifiable by the enumerators, and therefore didn't include things like 'degree of disease resistance'. Identifying breed alone turned out to be challenging and required extensive training of the enumerators. So the appropriateness of CE as a valuation tool in this context was tested by comparing the value estimates for animal traits recognised as important in cattle markets. We did so by comparing 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 the developing world. Although the case study results presented here represents a small component of a larger study on the viability of CEs in valuing AnGR, and don't 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 in this journal that do tackle such issues (Scarpa et al. in this issue), and provide and important verification of the viability and usefulness (plus the shortcomings) of the approach.

1.2 The challenge of valuing the shorthorn East African 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 valuing 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, the 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 farming system chosen for this case study provide a particularly significant challenge. Pastoralists in Africa are difficult to survey and their social systems complex to analyse, partly because of their mobility. It is becoming more widely recognized, however, that the cattle they tend 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' (a member of the broader *Bos indicus* group). Rege and Tawah (1999) have referred to this strain as the Maasai Zebu. In some cases in distinguishing strains of Small East African Zebu (SEAZ) by traders, 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 disease 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 and can also display higher productivity in 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 southern 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 peoples' 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 organised 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 Cattle in Africa: private goods or (quasi-)public non-market goods?

Economic theory draws a line between the allocative performance of atomistic competitive markets for public versus private goods. Further, public economic theory and a large body of evidence suggests that truthful value revelation for public goods is much more problematic than for non-market private goods

(Carson *et al.*, 2001).

It is therefore desirable to seek a classification of African cattle and its genetic resources; are they private or public non-market goods? Strictly speaking, genetic material is not commonly available to users separately from the phenotype. If one considers the genetic endowment of a single head of cattle, this appears to fit the private good definition, as it is clearly excludable and rival in consumption.

However, AnGRs can also be classified as quasi-public goods, since the genetic base determining a phenotypic trait typical of a breed is shared across all the individuals of the population of the breed. Access to several fertile individuals may be very inexpensive, implying low excludability, and consumption of AnGRs is not well defined as it is not the main purpose of herd management. In fact, AnGRs are employed to generate new individuals, and are not used up in any sense, unless the phenotypes carrying them are destroyed. They are a renewable resource so long as they are managed appropriately. This argument suggests the existence of a weak form of non-rivalry in consumption.

From this perspective, AnGRs may be considered quasi-public goods in an economic sense. The public good argument becomes more relevant when the issue of AnGRs management is observed from a different scale, the pool of genes shared among all individuals belonging to a particular breed. Benefits from the existence of such a gene pool are shared across many beneficiaries. This is especially the case when the pool is capable of producing phenotypes that are well-adapted to local environmental circumstances. From this very broad scale viewpoint, then, AnGRs can be considered as pure public goods as both the non-rivalry and non-excludability criteria are met.

This study is concerned with validation of stated preference estimates of marginal values of animal attributes to private cattle dealers. This is clearly a private-good component of AnGRs. However, the method, once persuasively validated, can also be employed to explore the quasi- and pure public good aspects of AnGRs.

2.2 Hypothetical versus actual choices.

In this study we appeal to an anthropocentric, individualistic and utilitarian theory of value. We attempt to characterize the preferences over animal attributes of a group of 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. Choice statements are collected according to an experimental design aiming at characterising 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 what economists call *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 a developing country context (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 an implication to the application of contingent valuation in the discrete-choice referendum format (). In this respect, however, stated preference multi-attribute valuation tools such as CEs ought to perform better, although they also need a closer scrutiny in these contexts than they do in developed countries. For this reason, each interview included a set of 'warm-up' questions during which consistency checks were performed.

2.3 Testing for difference in preferences.

Stated preference methods, such as CEs, 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 different markets. Market prices are clearly the 'hardest' form of revealed preference evidence, and the 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.

Multi-attribute value theory can be related to both continuous and discrete models of choice (see Pendleton and Mendelsohn (2000) for a recent review of this concept in the context of recreational value).

2.4 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. These are interpreted as being generated by utilitarian and individualistic principles.

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 $\mathbf{q}_i = \{q_1, ..., q_k, ..., q_K\}_i$, (i.e. 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. Of course, marginal effects of this type can be linked to the appropriate consumer-behaviour functions, such as Hicksian demand or the indirect utility function, depending on the framework employed and the data available. 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. Once the main determinants of price have been identified and recorded for each transaction, the associated price can be decomposed into its various marginal effects. 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 analysed 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.

Formally, if the respondent is faced with a choice task i of selecting the preferred alternative amongst a set of $j, ..., J$, and the selected choice is j^*, then:

$$U_{j^*} = \max\{U_1, ..., U_j, ..., U_J\}. \tag{3}$$

In a probabilistic setting, this involves the adequate definition of the event for each observed choice i. In other words, the model must be constructed

around a collection of choice events $i, ..., I$, in each of which the probability of observing the preferred choice j^* can be expressed in random utility terms as:

$$Pr(U_{j^*}) = Pr(U_{j^*} \geq U_{\neq j^*}). \tag{4}$$

To implement such a model it is assumed that the (indirect) utility level associated with a given alternative j is only known by the respondents, while the researcher postulates that only a component of it — the deterministic component ν — be observable, while a second unobservable component u is stochastic and its behaviour must be assumed to be following a given probability distribution.

Although other specifications are possible, the observable component is most commonly specified as a linear index. On this basis, the typical random utility model (RUM) is postulated on the following assumptions:

$$U_j = \nu_j + u_j = \sum_k \theta_k q_{j,k} + u_j = \theta' \mathbf{q}_j + u_j, \tag{5}$$

where $j = 1, ..., j, ..., J$ index the alternatives in the choice set, $\mathbf{q}$ are the choice attributes (in our case the cattle head's attributes) and θ is a k-dimensional column vector of taste parameters: $\theta = \{\theta_1, ..., \theta_k, ..., \theta_K\}$. The unobservable component u_j is independently and identically distributed (i.i.d.) with a generic density function $\xi(\cdot)$.

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 equations (4-5) imply [1]:

$$Pr(U_{j^*}) = \frac{\exp(\Delta\theta' \mathbf{q}_{j^*})}{\sum_j^J \exp(\Delta\theta' \mathbf{q}_j)}. \tag{6}$$

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:

$$p_i^{q_k} = \frac{\partial g(q_i)}{\partial q_{i,k}} = \frac{\partial \Delta\nu / \partial q_{i,k}}{\partial \Delta\nu / \partial p_{i,k}} = \frac{\Delta\theta_{i,k}}{\Delta\theta_{i,k=p}}. \tag{7}$$

[1] Here the scale parameter μ is omitted as it cannot be identified in estimation from a single dataset.

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. We call this description the 'animal profile'. In order to ease the choice task, only two animal profiles (or alternatives) 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. Each respondent was asked to repeat the choice task 8 times and the arrangement of the profiles across choice tasks was randomised from a set of profiles obtained by orthogonalizing with respect to the main-effects using the module 'orthoplan' in the software package SPSS.

Since utility is ordinal, one choice can be taken as the reference point, and it is convenient to take the zero option as the baseline. Our choice context involved only three alternatives: choice A, choice B and the 'zero option' of not buying either, with the latter used as the baseline, so eq.(6) can be simplified to:

$$Pr(U_{j^*}) = \frac{\exp(\Delta\theta'\mathbf{q}_{j^*})}{1 + \exp(\Delta\theta'\mathbf{q}_A) + \exp(\Delta\theta'\mathbf{q}_B)} \tag{8}$$

The estimated taste parameters are then employed to compute the value of each attribute using eq.(7). Approximate confidence intervals of this ratio of ML estimates are obtained with the delta method.

2.5 Taste heterogeneity.

One of the peculiarities of African cattle markets is the vast heterogeneity of its agents. Diverse agents have diverse tastes for animal attributes. One of the limits of choice modelling by means of multinomial logit specifications is that the underlying heterogeneity of tastes for the various attributes is ignored. In contexts of choice where agents buy for diverse purposes — such as African cattle markets — this is a strong limitation. This heterogeneity of taste is mostly unobserved to the researcher, as in Kenyan cattle markets in particular, the agent-specific information one can collect for each agent is typically quite poor. Recent developments in choice modelling via mixed logit allow the researcher to account for unobserved taste variation (McFadden and Train, 2000). Mixed logit estimation requires simulated likelihood methods and the specification of taste distributions.

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. For example, we use 100 Halton draws which produce the same approximation as 1000

pseudo-random draws (Train, 1999).

For the distribution of taste we assume a multivariate normal for all taste attributes, except for price, which is assumed log-normally distributed, so as to constrain the parameter to be negative. All the other attributes may plausibly have both positive or negative values. For example, while most agents are expected to like weight and body conditions, some may be in the market to purchase animals to be fattened and then resold. These agents will possibly prefer thinner animals and in comparatively poor condition.

Assuming a log-normal distribution for the taste parameter for price θ_p also has implications for the way one computes the marginal rates of substitution. In our case we compute them at the mean and the median 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 : $\hat{\mu}_{\theta_j} / \exp(\hat{\mu}_{\theta_p})$

Assuming a multivariate normal taste distribution 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. Although this is limitation is conveniently ignored in the discussion of results in most papers, it is obvious that in repeated choice contexts preferences are fixed in repeated choices by the same individual. 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 marginal rates of substitution (Layton, 2000) between animal traits and money, and hence our measure of value. For this reason it is appropriate to investigate how sensitive these estimates are to the omission or inclusion of 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 the Kenyan Agricultural Research Institute (Ruto, 1999). In particular, during a monitoring programme, transactions prices and cattle attributes were recorded by trained enumerators in a number

of markets in Kajiado district of Kenya. The results from the statistical analysis of these data showed that the following cattle attributes explained most of the variation observed in transaction prices, irrespective of the individual market where they had been collected:

(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 Kajiado district of southern Kenya. Kajiado is a vast district running from just south and west of Nairobi to the border with Tanzania, covering an area of 19,600 square km. Most of Kajiado District lies in the semi-arid and arid zones, and only 8% of the District's land is classified as having 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. 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 through much of the district, with several major National Parks (Nairobi, Amboseli, Tsavo) bordering or falling within the district.

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 Kajiado district 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 have noted the declining livestock/people ratios over the last 10-20 years and have attributed it in part due 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 for focusing on the Maasai and their cattle is the fact 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. 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 structure of cattle marketing in the study area 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 where the surveys were carried out local enumerators — familiar with livestock marketing — were recruited and trained. Because of the difficulty associated with standardised breed recognition in Africa, particular training was dedicated to this issue. The training was participatory in nature, and each enumerator was encouraged to contribute suggestions for improving the survey instrument. Finally, particular emphasis was dedicated to the idea of random sampling. 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 with the intention of slaughtering them. The proportion of those purchased for rearing purposes was only 19% (and 31% of these were the Maasai Zebu breed or its crosses), 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 them.

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 analysed 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 actual market transactions data, estimated using ordinary least squares, 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.

Slaughter weight was the principal factor in describing the market price recorded for the transacted animals. This held for all 7 markets. Not only was slaughter weight strongly significant, but this variable alone was able to explain more than 66 percent of the variation in market price.

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

When a dummy for the variable 'market of transaction' was added, the explanatory power exceeded 74 percent. The next group of variables that added explanatory power was the descriptors for sex classes, where the animal purchased was differentiated as being either a 'mature male' or a 'cow', bringing the maximum explanatory power to around 76 percent.

In order to control for specific-market effects, dummies for 5 out of the 7 markets were included in the regression reported in Table 1. 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 combination 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 of cattle in our sample. Nor was the addition of descriptors for the purpose of buying (slaughter, rearing, resale) helping 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 ordinary least squares (OLS) regression were estimated for the set of attributes employed in the experimental design of the choice experiment. 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 value 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, which shows a positive sign.

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 polimorfism that characterizes African cattle. However, all the standard errors were derived using White's robust estimator.

4.2 Results of the choice experiment

The results of the random utility analysis of the choice experiment, estimated using fixed-parameter conditional (multinomial) logit analysis, are shown in Table 2. They show that all 5 of the attributes employed to describe the animals are statistically significant, and together they explain the pattern of observed choices quite well. Because differential prices were employed in different markets in the experimental design, dummies for markets are omitted from the specification.

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. 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.

The maximum likelihood estimates of the taste parameter for the indirect utility function reported in Table 2 imply that cows are valued KSh 470 less than other types (which is similar to the 541 estimate from the hedonic OLS regression); a positive value of KShs 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 approxi-

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

The simulated maximum likelihood estimates for the mixed logit model are reported in Table 3. Because a multivariate normal correlation structure was assumed, all the 15 elements of the 5×5 variance-covariance matrix need estimation. 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. The elements of $\hat{\Sigma}$ can be re-arranged to estimate the correlation matrix for tastes (Table 4). Such matrix reveals that a negative correlation between price and female animals, estimated slaughter weight and of indigenous breed. Traders with higher marginal utility for money tend to prefer male animals which are light, but not indigenous. These may indeed be the structure of preference of many who buy for fattening and reselling.

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 marginal rate of substitution between attributes and money for this model are computed at both the estimated mean and median of the taste distribution of price and reported in Table 5. Both computations produce very similar value estimates to those obtained in the fixed logit model and from those in the hedonic pricing. However, the estimate for the effect of sex of the animal (COW) is now no longer significant. We speculate that once unobserved taste heterogeneity is accounted for the gender of the animal does no longer play a distinct role in its valuation by traders.

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 include assessing 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 the developing world, although extremely well adapted to local environments, is relatively unproductive if meat and milk are the only benefits valued. As a result, con-

ventional 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 well-adapted indigenous traits.

Further, we argue that since it is the animals that are traded in markets, and their market value depends largely on their perceived ability fo 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 journal represent the first attempt, to our knowledge, to test them in the context of livestock in the developing world.

A choice-experiment thus 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, 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 Maasai 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 and by the mixed logit estimates in tables 3-5. 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 criteria.

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 orthogonalised choices (nearly 2,500), the hedonic regression was estimated on 430 transactions. So, the preference of cattle traders buying animals destined to slaughter for the Maasai Zebu 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 AnGRs of 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.[2] 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

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

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 the associated AnGRs.

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 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 fixed and mixed 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
Maximum likelihood estimates from choice experiment.

Variable	$\Delta\theta$	St.Err. of $\Delta\theta$	p-values of z
PRICE	-2.6E-4	1.7E-5	0.000
COW	-0.1218	0.074	0.100
GOOD_EXC	1.5824	0.098	0.000
WEIGHT_KG	0.0279	0.001	0.000
PURE_ZEBU	-0.1556	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	-470.569	293.080	0.108
GOOD_EXC	6,112.868	334.868	0.000
WEIGHT_KG	107.825	5.128	0.000
PURE_ZEBU	-601.293	260.500	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
Simulated max. lik. (100 Halton Draws) estimates from choice experiment.

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.

Table 4
Simulated maximum likelihood estimates from choice experiment.

Estimated 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 5
Simulated maximum likelihood estimates from choice experiment.

Estimates of Marginal values at the *average* of the price coefficient.			
	$\Delta\theta_{i,k}/\Delta\theta_{i,k=p}$	St.Err.* of $\Delta\theta_{i,k}/E[\Delta\theta_{i,k=p}]$	p-values of z
COW	-189.791	273.167	0.487
GOOD_EXC	6,922.874	606.106	0.000
WEIGHT_KG	101.998	5.282	0.000
PURE_ZEBU	-688.546	218.387	0.002
Estimates of Marginal values at the *median* of the price coefficient.			
	$\Delta\theta_{i,k}/\Delta\theta_{i,k=p}$	St.Err.* of $\Delta\theta_{i,k}/M[\Delta\theta_{i,k=p}]$	p-values of z
COW	-208.945	300.395	0.487
GOOD_EXC	7,621.529	698.687	0.000
WEIGHT_KG	112.291	6.308	0.000
PURE_ZEBU	-758.034	240.936	0.002

*delta method.

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(xxxvi) This paper was presented at the Second EFIEA Policy Workshop on "Integrating Climate Policies in the European Environment. Costs and Opportunities", organised by the Fondazione Eni Enrico Mattei on behalf of the European Forum on Integrated Environmental Assessment, Milan, March 4-6, 1999

(xxxvii) This paper was presented at the Fourth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei, CORE of Louvain-la-Neuve and GREQAM of Marseille, Aix-en-Provence, January 8-9, 1999

(xxxviii) This paper was presented at the International Conference on "Trade and Competition in the WTO and Beyond" organised by the Fondazione Eni Enrico Mattei and the Department of International Studies of the University of Padua, Venice, December 4-5, 1998

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(xl) This paper was presented at the conference on "Distributional and Behavioral Effects of Environmental Policy" jointly organised by the National Bureau of Economic Research and Fondazione Eni Enrico Mattei, Milan, June 11-12, 1999

(xli) This paper was presented at the Fifth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CODE, Universitat Autonoma de Barcelona, Barcelona January 21-22, 2000

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(xliv) This paper was presented at the International Workshop on "Green National Accounting in Europe: Comparison of Methods and Experiences" organised by the Fondazione Eni Enrico Mattei within the Concerted Action of Environmental Valuation in Europe (EVE), Milan, March 4-7, 2000

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