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**Lexicographic Preferences in
Discrete Choice Experiments:
Consequences on Individual-
Specific Willingness to Pay
Estimates**

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NOTA DI LAVORO 128.2006

OCTOBER 2006

SIEV – Sustainability Indicators and Environmental
Valuation

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Summary

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Keywords: Continuity axiom, Discrete Choice Experiments, Lexicographic Preferences, Mixed logit, Individual-Specific Willingness to Pay

JEL Classification: C35, Q24, Q51

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Lexicographic preferences in discrete choice experiments: consequences on individual-specific willingness to pay estimates

Abstract

In discrete choice experiments respondents are generally assumed to consider all of the attributes across each of the alternatives, and to choose their most preferred. However, results in this paper indicate that many respondents employ simplified lexicographic decision-making rules, whereby they have a ranking of the attributes, but their choice of an alternative is based solely on the level of their most important attribute(s). Not accounting for these simple decision-making heuristics introduces systemic errors and leads to biased point estimates, as they are a violation of the continuity axiom and a departure from the use of compensatory decision-making. In this paper the implications of lexicographic preferences are examined. In particular, using a mixed logit specification this paper investigates the sensitivity of individual-specific willingness to pay (WTP) estimates conditional on whether lexicographic decision-making rules are accounted for in the modelling of discrete choice responses. Empirical results are obtained from a discrete choice experiment that was carried out to address the value of a number of rural landscape attributes in Ireland.

1.0 Introduction

Since their introduction by Louviere and Hensher (1982) and Louviere and Woodworth (1983) there has been a growing number of studies using the discrete choice experiment methodology. Discrete choice experiments are consistent with the Lancasterian microeconomic approach (Lancaster, 1966), whereby individuals derive utility from the different characteristics, or attributes, that a good possesses, rather than directly from the good *per se*. Accordingly, a change in one of the attributes can cause a discrete switch from one alternative to another that will provide a superior combination of attributes. In discrete choice experiments, respondents are asked to choose their preferred alternative among several hypothetical alternatives in a choice set, and are typically asked to perform a sequence of such choices (Alpízar *et al.*, 2001). Experimental design theory is used to construct the alternatives, which are defined in terms of their attributes and the levels these attributes would take (Louviere, 2001).

A central principle of the discrete choice experiment methodology is the continuity axiom which implies respondents make trade-offs between the attributes across each of the alternatives, and choose their most preferred. Thus the continuity axiom rules out lexicographic orderings whereby respondents have a tendency to rank alternatives solely with reference to a sub-set of attributes, ignoring all other differences between the alternatives. However, evidence from a number of studies (see, for example, Rosenberger *et al.*, 2003; DeShazo and Fermo, 2002; Sælensminde, 2001) suggests that many respondents violate the continuity axiom and hold non-compensatory preference structures such as lexicographic preferences for attributes within the choice set. Lexicographic choices occur when the respondent always chooses the alternative that is best, or worse, with respect to a specific attribute, or subset of alternatives. This may be due to an information processing strategy whereby respondents ignore attributes as a coping strategy in order to deal with the perceived complexity of the discrete choice experiment or because the attribute is truly not relevant in influencing the respondent's choice (Hensher *et al.*, 2005b).

Lexicographic preferences are non-compensatory and, therefore, discontinuous which poses a problem for neoclassical analysis. Without continuity, there is no trade-off between two different attributes (McIntosh and Ryan, 2002; Rosenberger *et al.*, 2003). Without a trade-off, there is no relative price and thus no tangency with the production frontier (Gowdy and Mayumi, 2001). Since lexicographic decision-making rules are a violation of the continuity axiom and a departure from the use of compensatory decision-making, discrete choice experiment studies should incorporate procedures to account for such heuristics (Sælensminde, 2002). Furthermore given that accounting for such preferences has been shown to influence welfare estimates (see, for example, Hensher *et al.*, 2005b; Sælensminde, 2001; Rizzi and Ortúzar, 2003) research is warranted. Reported in this paper are the results from an empirical study that investigated the implications of a violation of the continuity axiom on welfare estimates. In particular, a mixed logit specification is used to highlight the sensitivity of individual-specific willingness to (WTP) estimates conditional on whether lexicographic decision-making rules are accounted for in the modelling of the discrete choice responses. Results from the analysis provide further evidence that modelling discrete choice without accounting for lexicographic preferences leads to biased WTP estimates.

The remainder of this paper is organised as follows. Section 2.0 provides a background on lexicographic decision-making rules, while Section 3.0 outlines the design of the empirical application, including the attributes, experimental design and tests for lexicographic

preferences. Section 4.0 details the mixed logit specification and reports the relevant results. Finally Section 5.0 draws conclusions and provides a number of recommendations.

2.0 Lexicographic decision-making rules

A basic assumption within the discrete choice experiment framework is that of unlimited substitutability between the attributes within the choice set. However, there is growing evidence that many respondents use non-compensatory decision-making rules when reaching their decisions in choice experiments. That is, some respondents have a ranking of the attributes, but their choice of an alternative is based solely on the level of their most important attribute(s). Respondents who have a hierarchy of values may express their preferences lexicographically (Rosenberger *et al.*, 2003). Lexicographic preferences are defined as a tendency for respondents to rank alternatives solely with reference to a sub-set of attributes, ignoring all other differences between the alternatives (Foster and Mourato, 2002).

Lexicographic preferences constitute a violation of the continuity axiom in the neoclassical framework. Such preferences can be classified according to either ‘strict’ lexicographic procedures where attributes are hierarchically ordered from the most important to the least important one and the preference is determined only by the most important attribute or ‘modified’ lexicographic preferences where choice is based on thresholds and minimum levels of an attribute are necessary (Lockwood, 1996). For a comprehensive survey on the literature of non-compensatory preferences see Spash (2000) and Rekola (2003).

While the incidence of lexicographic preferences is likely to be an indication that attributes within the choice set are not behaviourally relevant, that is, where respondents have indifferent preferences associated with those attributes not considered, there are many factors which can give rise to respondents employing lexicographic decision-making rules in discrete choice experiments. Internal factors, such as the complexity of the experiment (DeShazo and Fermo, 2002; Heiner, 1983; Swait and Adamowicz, 2001) or a consequence of the attributes within the experiment (Blamey *et al.*, 2001), are possible explanations for respondents employing such simplifying heuristics. External factors, such as the cognitive ability of the respondent, the strength of attitudes, beliefs, or dispositions that the respondent holds and other demographic characteristics of the respondent, are also likely to influence the use of lexicographic decision-making rules (Rosenberger *et al.*, 2003).

Discrete choice experiments impose a significant cognitive burden on respondents, which can compromise choice consistency (Sælensminde, 2001). Typically task complexity and cognitive burden facing respondents in a discrete choice experiment depends *inter alia* on the number of alternatives in each choice set, the number of attributes to describe the alternatives, the correlation structure of the attributes among alternatives, and the number of repetitions (Bennett and Blamey, 2001; Caussade *et al.*, 2005). In complex situations respondents adopt simplified decision rules (DeShazo and Fermo, 2002). Moreover, increasing choice complexity widens the gap between a respondent's cognitive ability and the cognitive demands of the decision and thus leads to a restriction of the range of factors considered (Heiner, 1983). Respondents shift towards more lexicographic strategies in situations where there is correlation among the attributes or where they consider an attribute is of relatively high importance (Luce *et al.*, 2000; Blamey *et al.*, 2002). As a form of protest vote, respondents may also focus on a specific attribute for which they have a strong negative preference, whereby they place an absolute value on the attribute and refuse to make tradeoffs between it and another attribute (Spash and Hanley, 1995).

3.0 Empirical application

3.1 Defining the attributes

Reported in this paper are the results from a discrete choice experiment that was carried out to address the value of a number of rural landscape attributes in Ireland. The landscape attributes in question are the improvement of Wildlife Habitats, Rivers And Lakes, Hedgerows and Pastures. Three levels were used to portray these attributes according to varying levels of landscape improvement. To minimise respondent confusion the levels for each of the landscape attributes were denoted using the same labels: A Lot Of Action, Some Action and No Action. While the A Lot Of Action and Some Action levels represented a high level and an intermediate level of landscape improvement respectively, the No Action level represented the unimproved or status-quo condition. Image manipulation software was used to prepare photo-realistic simulations representing the landscape attributes under different management practices and levels of agricultural intensity. This involved the manipulation of a 'control' photograph to depict either more of or less of the attribute in question. This method was used so that on the one hand the changes in the attribute levels could be easily identified while holding other features of the landscape constant. On the other hand the respondent would not perceive as ostensibly unrealistic the computer generated landscape

illustrations. For the Wildlife Habitats attribute, a farmland landscape was depicted with different degrees of biodiversity. A range of eutrophication levels in a lake were used to represent the Rivers And Lakes attribute. The Hedgerows attribute was shown under different management practices. The effect on the landscape of different stocking densities was used to depict the Pastures attribute. All images and accompanying wording were tested in the focus group discussions and pilot study to ensure a satisfactory understanding and scenario acceptance by respondents.

The cost attribute was described as the expected annual cost of implementing the alternatives represented in the choice questions. This attribute was specified as the value that the respondent would personally have to pay per year, through their Income Tax and Value Added Tax contributions, to implement the alternative. Employing a sequential experimental design strategy enabled the levels of the monetary attribute to be adjusted in response to the preliminary findings following each phase of the survey. Altogether, seven price levels, ranging between €15 and €80 per year, were used to represent the cost attribute. As shown in Table 1, five tax levels were used in the first phase of the survey, two in the second and four in the final phase.

Table 1: Expected Annual Cost attribute price levels used during each phase of the survey

	€15	€20	€35	€40	€50	€65	€80
Phase 1		✓	✓		✓	✓	✓
Phase 2		✓					✓
Phase 3	✓	✓		✓	✓		

3.2 *Experimental design*

Since different experimental designs can significantly influence the accuracy of WTP estimates (Lusk and Norwood, 2005), it is important to use an experimental design that minimises an efficiency criterion. Given the national scope of this study, and the cost of surveys of this kind, sample size was also an issue. To increase sampling efficiency a sequential experimental design with a Bayesian information structure was employed (Sándor and Wedel, 2001).

A review of recent studies on experimental design (see, for example, Ferrini and Scarpa, 2005) reveals that the values in the matrix of attribute levels should be chosen so as to minimize some expected measure of variance, such as the D_p -optimality criterion:

$$D_p\text{-criterion} = \det \left\{ I(\beta)^{-1} \right\}^{1/p}, \quad (1)$$

where $I(\cdot)$ is the information matrix of the multinomial logit model and p is the number of attributes. A more informative Bayesian measure, the D_b -optimal criterion, suggested in Sándor and Wedel (2001), which is the expected value of the D_p -criterion with respect to its assumed distribution over β or $\pi(\beta)$, was adopted with the arrangement of values in the matrix of attribute levels such that:

$$D_b\text{-criterion} = E_{\beta} \left[\left\{ \det I(\beta)^{-1} \right\}^{1/p} \right] = \int_{\mathbb{R}^p} \left\{ \det I(\beta)^{-1} \right\}^{1/p} \pi(\beta) d\beta. \quad (2)$$

As a prior an informative multivariate normal distribution centred on β was used with a variance-covariance matrix, both of which were derived initially from the first phase of the survey, and subsequently updated at each phase by the pooled dataset from previous phases of sampling. This is achieved in practice by simulating the value of this criterion by drawing from the assumed distribution of β s, computing the value of the criterion for each draw, and then averaging it out. The best allocation of values is found by using heuristic algorithms, such as *swapping* and *relabelling* (Huber and Zwerina, 1996) and *cycling* (Sándor and Wedel, 2001):

$$\tilde{D}_b = \frac{1}{R} \sum_{r=1}^R \left\{ \det I(\beta)^{-1} \right\}^{1/p}, \quad (3)$$

where R is the number of draws.

Starting from a conventional main effects fractional factorial in the first phase, a Bayesian design was employed in the second wave of sampling. The design for the final phase incorporated information from the first and second phases. However, not all values of the attributes were allocated in the design by the above approach. The numerical values of cost were assigned on the basis of realism and so as to balance the probabilities of choices across alternatives in the choice set (Kanninen, 2002). For further information and an evaluation of the efficiency of the sequential experimental design approach used in this study see Scarpa *et al.* (2005).

Each choice set consisted of two experimentally designed alternatives, labelled Option A and Option B, and a status-quo alternative, labelled No Action, which portrayed all the landscape attributes at the No Action level with zero cost to the respondent. An example choice set is shown in Figure 1.

3.3 *Determining lexicographic decision-making rules*

In total, the choice experiment was administered by experienced interviewers to a representative sample of 600 respondents drawn from the Irish adult population in 2003/4. With a further 166 potential respondents refusing to complete the interview, the overall response rate was 78 percent. During the choice experiment each respondent was asked to indicate their preferred alternative in a panel of repeated choice sets. Following the discrete choice experiment, respondents who did not always choose the No Action alternative were asked to identify the attribute, or attributes, they considered in making their choices. Although this did not provide the precise weight respondents attached to the attributes, it identified the attributes that they ignored.

In total 36 respondents always choose the No Action alternative. The attributes or combinations of attributes considered by the remaining 564 respondents during the discrete choice experiment are reported in Table 2. Table 2 shows that 61 (11 percent) respondents focused solely on the Rivers And Lakes attribute. Collectively 48 (9 percent) respondents focused solely on one of the remaining attributes. Hence around one-fifth of respondents considered only one attribute in the discrete choice experiment, thus providing no information on their willingness to make trade-offs among the attributes. When reaching their decisions in the choice experiment 60 (11 percent) respondents took into account two attributes. Three and four attributes were considered by 27 (5 percent) and seven (1 percent) respondents respectively. All of the attributes were considered in the choice experiment by 361 (64 percent) respondents. Further investigation of Table 2 reveals that the Rivers And Lakes attribute was considered by 500 (89 percent) respondents. This high proportion may be due to the fact that the Rivers And Lakes attribute was perceived as a 'causal' attribute (Blamey *et al.*, 2002) in which it was considered to an important indicator of the overall state of the rural environment. It was also likely to be associated with the quality of drinking water. Furthermore, respondents who participate in water-based recreational activities are likely to attach higher attention to the Rivers And Lakes attribute. The Wildlife Habitats, Pastures and Hedgerows attributes were taken into account in the choice experiment by 437 (77 percent), 416 (74 percent) and 399 (71 percent) respondents respectively. The Cost attribute was considered by 391 (69 percent). Thus the Cost attribute was the attribute least taken into account in the choice experiment which is an important finding in a study that is primarily concerned with deriving WTP estimates. This result would suggest that many respondents wanted rural landscape improvements irrespective of the costs involved.













	Option A	Option B	No Action
Wildlife Habitats	 Some Action	 A Lot Of Action	 No Action
Rivers And Lakes	 No Action	 Some Action	 No Action
Hedgerows	 Some Action	 A Lot Of Action	 No Action
Pastures	 A Lot Of Action	 No Action	 No Action
Expected Annual Cost	€ 20	€ 80	€ 0
Which do you prefer?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 1: Example choice set

While the incidence of lexicographic preferences may have been a result of the complexity of the experiment or a consequence of the levels of the attributes within the experiment (Heiner, 1983; Ryan and Bate, 2001), the development of the discrete choice experiment exercise reported here involved several rounds of design and testing. This process began with a qualitative review of expert opinions to establish the range over which the landscape attribute vary. Further qualitative research was then carried out to refine the definitions of the

landscape attributes and define an appropriate payment vehicle and levels thereof. An important aim of the focus group discussions was also to identify the appropriate level of choice task complexity (that is, the number of alternatives and attributes). This was achieved through a series of focus group discussions with members of the public. Following the focus group discussion pilot testing of the survey instrument was conducted in the field. This allowed the collection of additional information, which along with expert judgement and observations from the focus group discussions, was used to design the discrete choice experiment used in the public survey. Therefore the incidence of attributes not taken into account during the choice experiment is most likely because they were truly not relevant in influencing the respondent's choice. Despite this, lexicographic preferences as a coping strategy in order to deal with the complexity experiment cannot be ruled out completely.

4.0 Mixed logit specification and results

Mixed logit models provide a flexible and computationally practical econometric method for any discrete choice model derived from random utility maximisation (McFadden and Train, 2000). The mixed logit model obviates the three limitations of standard logit by allowing for random taste variation, unrestricted substitution patterns, and correlation in unobserved factors (Train, 2003). Mixed logit does not exhibit the strong assumptions of independent and identically distributed error terms and its equivalent behavioural association with the independence of irrelevant alternatives property. Mixed logit panel estimation also affords a desirable avenue for highlighting the implications of lexicographic decision-making rules on WTP, where one can derive individual-specific estimates conditional on the observed individual choices x^n and y^n (Train, 2003; Hensher and Greene, 2003; Sillano and Ortúzar, 2005). This can be achieved by applying Bayes' theorem to derive the expected value of the ratio between the landscape attribute parameter estimate (*land*) and the parameter estimate for the Cost attribute (*cost*):

$$E\left[\text{WTP}^n\right] = E\left[-\frac{\beta_{land}^n}{\beta_{cost}^n}\right] = \int \beta^n P(\beta^n | y^n, x^n) d\beta^n. \quad (4)$$

It is well known that given two outcomes A and B, Bayes' theorem relates $P(B|A)$ to the conditional probability of $P(BA)$ and the two marginal probabilities $P(A)$ and $P(B)$ as follows:

$$P(B|A) = \frac{P(A|B)P(B)}{P(A)}. \quad (5)$$

Table 2: Attributes and combinations of attributes taken into account by the respondents during the discrete choice experiment

Attributes and combinations of attributes taken into account	Number	Percent
Wildlife Habitats	14	2.48
Rivers And Lakes	61	10.82
Hedgerows	2	0.35
Pastures	18	3.19
Cost	14	2.48
Wildlife Habitats and Rivers And Lakes	26	4.61
Wildlife Habitats and Hedgerows	2	0.35
Wildlife Habitats and Pastures	6	1.06
Wildlife Habitats and Cost	1	0.18
Rivers And Lakes and Hedgerows	5	0.89
Rivers And Lakes and Pastures	12	2.13
Rivers And Lakes and Cost	3	0.53
Hedgerows and Pastures	2	0.35
Pastures and Cost	3	0.53
Wildlife Habitats, Rivers And Lakes and Hedgerows	14	2.48
Wildlife Habitats, Rivers And Lakes and Pastures	3	0.53
Wildlife Habitats, Rivers And Lakes and Cost	3	0.53
Rivers And Lakes, Hedgerows and Pastures	2	0.35
Rivers And Lakes, Hedgerows and Cost	2	0.35
Rivers And Lakes, Pastures and Cost	1	0.18
Hedgerows, Pastures and Cost	2	0.35
Wildlife Habitats, Rivers And Lakes, Hedgerows and Pastures	6	1.06
Wildlife Habitats, Rivers And Lakes, Hedgerows and Cost	1	0.18
Wildlife Habitats, Rivers And Lakes, Hedgerows, Pastures and Cost	361	64.01
Total	564	100.00

So, substituting in

$$E\left[\text{WTP}^n\right] = E\left[-\frac{\beta_{land}^n}{\beta_{cost}^n} \mid y^n, x^n\right] = \int \frac{\beta_{land}^n}{\beta_{cost}^n} \frac{P(y^n, x^n \mid \beta^n) P(\beta^n)}{P(y^n, x^n)} d\beta^n,$$

$$\begin{aligned}
&= \int_{\beta^n} \frac{\beta_{land}^n}{\beta_{cost}^n} \frac{P(y^n, x^n | \beta^n) P(\beta^n)}{\int_{\beta^n} P(y^n, x^n | \beta^n) P(\beta^n) d(\beta^n)} d\beta^n, \\
&= \frac{\int_{\beta^n} \frac{\beta_{land}^n}{\beta_{cost}^n} P(y^n, x^n | \beta^n) P(\beta^n) d(\beta^n)}{\int_{\beta^n} P(y^n, x^n | \beta^n) P(\beta^n) d(\beta^n)}. \tag{6}
\end{aligned}$$

With knowledge of the β estimates this can be approximated by simulation as follows:

$$\hat{E}[\text{WTP}^n] = \frac{\frac{1}{R} \sum_R \frac{\hat{\beta}_{land}^n}{\hat{\beta}_{cost,r}^n} L(\hat{\beta}_r^n | y^n, x^n)}{\frac{1}{R} \sum_R L(\hat{\beta}_r^n | y^n, x^n)}. \tag{7}$$

where L is the logit probability. In this way the individual WTP estimates are obtained conditional on all the information from the choice experiment interview.

Computation of mixed logit choice probabilities using classical estimation procedures typically requires Monte Carlo integration. The basis of this computation is the generation of pseudo-random sequences that are intended to mimic independent draws from the underlying distribution of the random variable of integration. An alternative approach proposed by Bhat (2001) and Train (1999) replaces these pseudo-random sequences with sequences based on a deterministic Halton sequence. One-dimensional Halton sequences are created using any prime number $p(\geq 2)$. The unit interval $[0,1]$ is divided into p equally-sized segments, and the endpoints or breaks of these segments form the first p numbers in the Halton sequence. Successive numbers in sequence are generated by further subdividing each segment into p equally-sized segments and adding the breaks in a particular order. The resulting Halton draws thus achieve greater precision and coverage for a given number of draws than pseudo-random draws, since successive Halton draws are negatively correlated and therefore tend to be self-correcting (Train, 2003). Accordingly many fewer draws are needed to assure reasonably low simulation error in the estimated parameters. In fact both Bhat (2001) and Train (1999) demonstrate that for a mixed logit model, 100 Halton draws provides results that were more accurate than 1,000 pseudo-random draws. Overall the application of Halton draws allows a decrease in computation time without sacrificing precision. However while multi-dimensional Halton sequences generally provide better coverage than the corresponding pseudo-random number sequences, problems with high correlation can occur between

sequences constructed from higher primes, and thus sequences used in higher dimensions. To ameliorate this, modified procedures such as scrambled and shuffled Halton draws have been used (see, for example, Bhat, 2003; Hess and Polak, 2003). Both these sequences have been found to outperform the standard Halton sequence. As a result shuffled Halton sequences, with 100 draws, are used in this paper to estimate the mixed logit models.

A key element of the mixed logit model is the assumption regarding the distribution of each of the random parameters. Random parameters can take a number of predefined functional forms, the most popular being normal, lognormal, uniform and triangular (Hensher, *et al.*, 2005a). In most applications, such as Layton and Brown (2000), Revelt and Train (1998), and Train (1998), the random parameters are specified as normal or lognormal. Greene *et al.* (2005), and Greene *et al.* (2006) have used uniform and triangular distributions. However it is well known that choices of some commonly employed mixing distribution implies behaviourally inconsistent WTP values, due to the range of taste values over which the distribution spans. Normal and log-normal distributions are particularly problematic (Train and Weeks, 2005). This is due to the presence of a share of respondents with the ‘wrong’ sign in the former, and the presence of fat tails in the latter. This is of particular importance in a study concerned with improvements from the status-quo, on which taste intensities are expected to be positive.¹ Following Hensher *et al.* (2005b), a bounded triangular distribution is used in this paper in which the location parameter is constrained to be equal to its scale. Such a constraint forces the distribution to be bounded over a given orthant, the sign of which is the same as the sign of the location parameter. In practice, for all random parameters associated with the various categories of rural landscape improvements it is assumed that $\beta \sim \tau(\theta)$, where θ is both the location and scale parameter of the triangular distribution $\tau(\cdot)$.² This included cost, which was bounded to the negative orthant.

When the status-quo option is included in the set of alternatives, such inclusion can cause respondents to regard the status-quo alternative in a systematically different manner from the designed alternatives involving changes from the status-quo. This is because the status-quo is actually experienced, while the experimentally designed options are hypothetical. As a result, the utility from experimentally designed hypothetical alternatives are more correlated amongst themselves than with the utility associated with the status-quo. This may be

¹ For a general discussion on bounding the range of variation in random utility models see Train and Sonnier (2005) who propose a Bayesian estimation approach, for an application of bounding directly to the expenditure function see Train and Weeks (2005).

² See Hensher *et al.* (2005a) for a description of the triangular distribution in this context.

captured by a specification with additional errors accounting for this difference in correlation across utilities. Correlation is a consequence of the fact that experimental alternatives share this extra error component, which instead is absent from the status-quo alternative. Previous studies have found theoretical reasons for status-quo bias (Samuelson and Zeckhauser, 1988; Haaijer *et al.*, 2001), and choice experiment applications in environmental economics (see, for example, Lehtonen *et al.*, 2003; Kontoleon and Yabe, 2003) found these effects to be significant. Status-quo effects are examined by including an alternative specific constant representing the No Action alternative is included in the mixed logit model specification. A positive sign would indicate that *ceteris paribus* the status-quo alternative is more desirable. A negative sign would mean it is less so.

Reported in Table 3 are the parameter estimates for two models. Model 1 pertains to the estimation of the discrete choice experiment without accounting for lexicographic decision-making rules. The estimates of Model 2 were obtained after accounting for such heuristics. Following Hensher *et al.* (2005b), to ensure unnecessary weight was not placed on attributes which were ignored, the mean and standard deviations estimates in Model 2 were specified as a function of a dummy variable representing whether or not the attribute was considered by the respondent. Parameter estimates in both models were generated using 100 shuffled Halton draws. In both models the random parameters were specified as random with constrained triangular distributions to ensure non-negative WTP for landscape improvements over the entire range of the distribution. The number of respondents and observations in both models was 564 and 4036 respectively. The log-likelihood function at convergence is -2686.782 for Model 1 and -2646.363 for Model 2, indicating a better model fit is achieved when lexicographic preferences are accounted for. Both models are found to be statistically significant with a χ^2 statistic of 3494.435 and 3575.272 for Model 1 and Model 2 respectively against a χ^2 critical value of 18.307 (with 10 degrees of freedom at alpha equal to 0.05).

Across both models estimated coefficients are all found to be statistically significant and of the expected sign. The relative dimensions of the parameter estimates for the landscape attributes conformed with theoretical expectations of decreasing marginal utility. While the level of significance of the parameter estimates for the landscape attributes did not vary substantially, the Cost attribute was estimated with a much higher level of significance which enabled WTP to be estimated more precisely. The status-quo alternative specific constant was found to be negative and significant in both models indicating that the respondents found the No Action is less desirable than the experimentally designed alternatives.

Table 3: Comparison of a model that assumes no lexicographic preferences with a model that accounts for lexicographic preferences

	Model 1				Model 2			
	Assuming no lexicographic preferences				Accounting for lexicographic preferences			
	Mean		Scale		Mean		Scale	
	Beta	<i>t</i> -ratio	Beta	<i>t</i> -ratio	Beta	<i>t</i> -ratio	Beta	<i>t</i> -ratio
WH_ALot	0.774	10.966	0.774	10.966	0.743	9.951	0.743	9.951
WH_Some	0.572	7.200	0.572	7.200	0.429	5.384	0.429	5.384
RL_ALot	1.786	20.334	1.786	20.334	1.874	21.116	1.874	21.116
RL_Some	1.069	13.067	1.069	13.067	0.987	13.091	0.987	13.091
H_ALot	0.494	7.027	0.494	7.027	0.497	6.370	0.497	6.370
H_Some	0.262	3.765	0.262	3.765	0.181	2.383	0.181	2.383
P_ALot	0.736	10.380	0.736	10.380	0.743	9.833	0.743	9.833
P_Some	0.706	9.023	0.706	9.023	0.685	8.465	0.685	8.465
Cost	-0.004	-4.008	0.004	4.008	-0.009	-7.235	0.009	7.235
SQ ASC	-0.864	-4.555	Non-random		-1.646	-12.155	Non-random	
Log-likelihood	-2686.782				-2646.363			
χ^2	3494.435				3575.272			
Pseudo- R^2	0.394				0.403			
BIC	5467.579				5386.743			

To highlight the effect of various forms of violations of the continuity axiom, median and mean individual-specific WTP estimates obtained from Model 1 and 2 in Table 3 are compared in Table 4. The estimates based on the analysis that did not account for lexicographic preferences are quite high, and their aggregate total exceeds what we expect an individual Irish citizen would be WTP for landscape improvements. This finding is probably due to fact that a large proportion of respondents ignored the Cost attribute and thus did not trade-off the landscape improvements with cost of improvement. Lexicographic preferences are not necessarily an indication of strong preferences for a subset of attributes. Indeed respondents may focus on a subset of attributes as a form of protest voting behaviour whereby they place an absolute value on the attribute and refuse to make tradeoffs between it and another attribute. The empirical results reported here, however, do not support this view. Higher WTP estimates were attached to those attributes which were concentrated on most in

Table 4: Comparison of the individual-specific WTP descriptive statistics derived from the model that assumes no lexicographic preferences with a model that accounts for lexicographic preferences

	Model 1		Model 2		Difference	
	Assuming no lexicographic preferences (Euro/year)		Accounting for lexicographic preferences (Euro/year)		Change between Model 1 and Model 2 (Percent)	
	Median	Mean	Median	Mean	Median	Mean
WH_ALot	243.55	258.99	100.73	91.82	-58.64	-64.55
WH_Some	175.88	186.46	59.01	51.63	-66.45	-72.31
RL_ALot	553.26	547.85	260.81	242.23	-52.86	-55.78
RL_Some	328.84	343.46	141.31	133.39	-57.03	-61.16
H_ALot	154.34	160.66	65.11	53.38	-57.82	-66.78
H_Some	80.71	85.06	23.86	19.86	-70.43	-76.65
P_ALot	234.29	251.44	101.18	89.58	-56.81	-64.37
P_Some	218.46	235.26	93.25	80.37	-57.31	-65.84

the choice experiment. In line with this finding, attaching unnecessary weight to the attributes led to an overestimation of the WTP estimates. Accounting for lexicographic preferences resulted in a lowering of the WTP and thus provided more plausible estimates. In fact accounting for lexicographic preferences resulted in a lowering of median and mean individual-specific WTP estimates by over 50 percent for all attributes. This result is robust to other ways of computing welfare measures (for example, using population moments). Notice also that while the implied monotonicity of the two levels of action is adequately reflected in the magnitude of individual-specific WTP estimates across both models in Table 4, the implied preference ordering varied across the models.

To highlight the features of the WTP distributions the box-plots for these distributions are reported in Figure 2. From the locations of the box-plots it is apparent that as one moves from the estimates obtained from assuming no lexicographic preference to those obtained when lexicographic preferences are taken into account the WTP distributions shift markedly to the left. Non-overlapping notches indicate rejection of the null of equal medians. A further finding illustrated by Figure 2, is that the spread and variability of WTP estimates for the Wildlife Habitats and Rivers And Lakes attributes is lower when lexicographic decision-making rules are accounted for. However this result was not found for the Hedgerows and

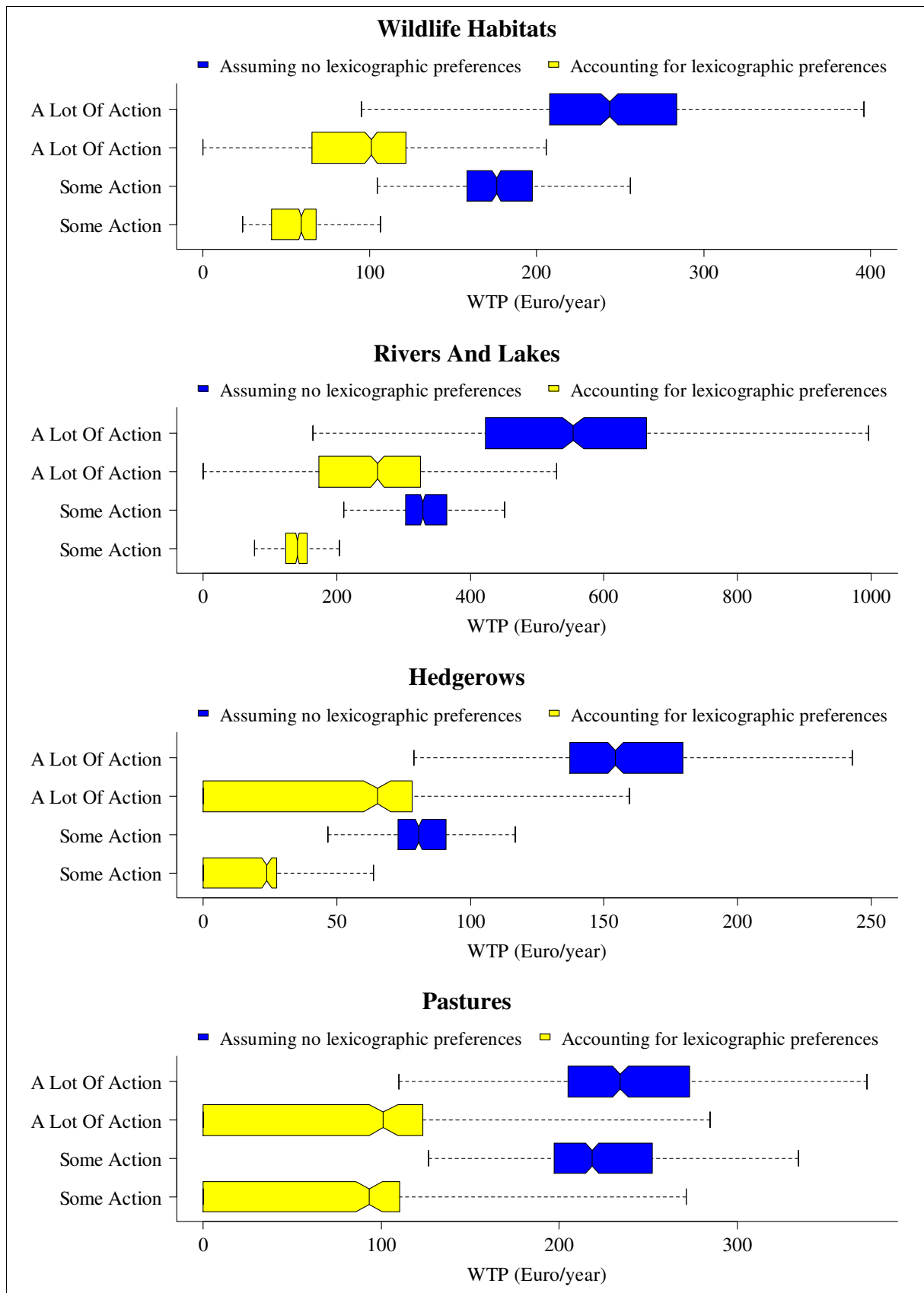


Figure 2: Box-Plots of distributions of individual-specific WTP estimates for the landscape attributes

Pastures attributes. This is because more than 25 percent of respondents ignored these attributes which meant their lower hinge was positioned at zero. Another robust result illustrated by Figure 2, is that the WTP distributions which accounted for lexicographic preferences are positively skewed to a greater extent, which is in keeping with prior expectations.

5.0 Conclusions and recommendations

A basic assumption within the discrete choice experiment framework is that of unlimited substitutability between the attributes within the choice set. Evidence reported in this paper revealed that many respondents use lexicographic decision-making rules when reaching their decisions in choice experiments. Lexicographic preferences constitute a violation of the continuity axiom in the neoclassical framework.

Reported in this paper are the results from an empirical study which investigated the implication on WTP of lexicographic decision-making rules. The analysis is conducted on the results from a discrete choice experiment that was conducted in Ireland designed to elicit WTP for a number of landscape attributes. The landscape attributes in question were Wildlife Habitats, Rivers And Lakes, Hedgerows and Pastures. Each of these landscape attributes were depicted with three levels, either A Lot Of Action, Some Action or No Action. Since valuation of landscape improvements can be very subjective, and verbal descriptions can be interpreted differently depending on individual experience, each level of improvement was qualified by means of digitally manipulated images of landscapes. This study also attempted to take stock of the main advances in the areas of multi-attribute stated preference techniques. In particular, a sequential experimental design with an informative Bayesian update, in addressing the heterogeneity of the estimation of the structural parameters of the random utility model the distributions of taste-parameters were bounded to account for the fact that landscape improvement takes the form of an improvement on the status-quo.

Several findings are reported. Almost one third of the respondents ignored the Cost attribute in reaching their decisions in the discrete choice experiment, which is an important finding in a study that was primarily concerned with the valuation of non-market goods. A further finding was that better model fit was achieved when lexicographic preferences were accounted for. In addition the Cost attribute was estimated with much higher precision. Lexicographic preferences were found to affect the weights assigned to each attributes in the analysis of discrete choice models, which in turn led to increased variability in the WTP

estimates. Moreover the distributions of individual WTP estimates conditional on observed choices were found to be sensitive to whether lexicographic decision-making rules were accounted for because markedly lower WTP estimates were obtained. In fact WTP estimates were less than half as high as those obtained when lexicographic decision-making were accounted for in the mixed logit model. This has clear implications when discrete choice experiments are used for policy appraisal and the valuation of non-market goods.

This paper explored the sensitivity of lexicographic preferences on individual-specific WTP estimates. Deciding whether or not to account for such preferences is a judgement that should not be based on statistical criteria alone. However lexicographic preferences do not satisfy the underlying continuity axiom and are a departure from the use of compensatory decision-making. The fact that a significant proportion of respondents employed these simple decision-making heuristics, combined with the reported effect that accounting for lexicographic preferences resulted in a substantial lowering of WTP estimates, suggests some caution when this issue is neglected in deriving non-market valuation estimates by means of the discrete choice experiment methodology. The evidence presented in this paper quite clearly suggests that choice experiment studies should incorporate procedures for identifying respondents who have lexicographic preferences and that the sensitivity of such preferences on WTP should be evaluated.

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(Ixxviii) This paper was presented at the Second International Conference on "Tourism and Sustainable Economic Development - Macro and Micro Economic Issues" jointly organised by CRENoS (Università di Cagliari and Sassari, Italy) and Fondazione Eni Enrico Mattei, Italy, and supported by the World Bank, Chia, Italy, 16-17 September 2005.

(Ixxix) This paper was presented at the International Workshop on "Economic Theory and Experimental Economics" jointly organised by SET (Center for advanced Studies in Economic Theory, University of Milano-Bicocca) and Fondazione Eni Enrico Mattei, Italy, Milan, 20-23 November 2005. The Workshop was co-sponsored by CISEPS (Center for Interdisciplinary Studies in Economics and Social Sciences, University of Milan-Bicocca).

(Ixxx) This paper was presented at the First EURODIV Conference "Understanding diversity: Mapping and measuring", held in Milan on 26-27 January 2006 and supported by the Marie Curie Series of Conferences "Cultural Diversity in Europe: a Series of Conferences.

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