# Lough Melvin Nutrient Reduction Programme

## Strand 3: Technical Report

***"Economic value of fish species"***

**Dr Danny Campbell and Professor George Hutchinson**

**Gibson Institute for Land, Food and Environment**

**Queen's University Belfast**

**David Keir Building**

**Stranmillis Road**

**Belfast**

**BT9 5AG**

**November 2007**

# 1 Economic analysis

***Abstract***

*The objective of this component is to provide information on the relative economic values that the general public (in NI and RoI) attach to a number of fish species within the Lough Melvin Catchment. The fish species focused on in the study are: the Arctic char, Salvelinus alpinus (L.); the Atlantic salmon, Salmo salar (L.); the ferox,* Salmo ferox (L.)*; the gillaroo, Salmo stomachicus (L.); and, the sonaghan, Salmo nigripinnis (L.). This was achieved using the discrete choice experiments methodology—which involved face-to-face interviews with a representative sample of 1,186 members from the NI and RoI general public. Results in this section show that the public places high values on preserving the rare and endangered fish species within the Lough Melvin Catchment. Highest values are found for preserving Atlantic salmon (€138 million per year), lowest for preserving ferox (€55 million per year), with preserving sonaghan (€167 million per year), gillaroo (€74 million per year) and Artic char (€59 million per year) ranking in between. To preserve all fish species the total value is found to be €167 million per year.*

## 1.1 Economic value of fish species

Environmental resources and services, such as clean air and water, and healthy fish and wildlife populations, are typically not traded in conventional markets. Therefore, their economic value is not revealed by market prices. The only option for assigning monetary values to them is to rely on non-market valuation methods. The rationale for attempting to estimate individuals' preferences for non-market goods and services in monetary terms is to enable environmental impacts generated by human activities to be accounted for in decision making. Valuing changes in the quantity and quality of environmental assets brought about by economic activity allows environmental costs and benefits to be made commensurate with, and placed in the same political dialogue as, conventional economic costs and benefits.

While many people benefit directly from preservation of fish species though angling, there may also be a sizable proportion of the population who derive little or no use benefit but possess strong existence values because they believe in the preservation for the current or future generations. Non-use or existence benefits to the public must not be omitted as this would understate the total resource value of the fish species, and may lead to under provision or less support for provision than is socially warranted. A non-market valuation technique known as discrete choice experiments is used as it captures both use and non-use values. The method is used reliably to provide estimates, in monetary terms, of the value to the public of preserving a number of rare and endangered fish species within the Lough Melvin Catchment.

Methods are discussed in Section 1.1.2 and the results are presented in Section 1.1.3. For a more detailed discussion on the discrete choice experiment methodology refer to Annex A and references cited therein.

### 1.1.1 Detail

The overall objective of this component is to provide information on the relative economic values that the general public (in NI and RoI) attach to a number of fish species within the Lough Melvin Catchment. The fish species focused on in the study are: the Arctic char, *Salvelinus alpinus* (L.); the Atlantic salmon, *Salmo salar* (L.); the ferox, *Salmo ferox* (L.); the gillaroo, *Salmo stomachicus* (L.); and, the sonaghan, *Salmo nigripinnis* (L.). Discrete choice experiments are the non-market valuation approach used.

### 1.1.2 Methods

In discrete choice experiments, respondents are asked to choose their preferred alternative among several hypothetical alternatives in a choice set. The alternatives are defined in terms of a number of attributes and each attribute is denoted with two or more levels. By asking respondents to complete a sequence of choice sets, it is possible to infer their willingness to give up some amount of one attribute in order to achieve more of another attribute. Discrete choice experiments are based on the idea that individuals derive benefits—defined here as 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 (such as price) can cause a respondent to switch their decision from one alternative to another that provides a superior combination of attributes. Thus, respondents choose the alternative that provides them with the highest utility. Based on this, the probability of choosing a specific alternative is a function that the utility associated with that alternative is greater than the utility associated with the remaining alternatives. Discrete choice experiments are the preferred approach for valuing complex and muti-dimensional scenarios, especially to:

- capture both use and non-use values;
- identify the attributes the general public value;
- determine the implicit ranking of these attributes; and
- estimate the value of changing more than one of the attributes at once.

In this application, the basic idea behind the discrete choice experiment technique is to quantify a respondent's willingness to pay (WTP) in order to conserve rare and endangered fish species within the Lough Melvin Catchment. The fish species—or attributes—focused on here are: the Arctic char; the Atlantic salmon; the ferox; the gillaroo; and, the sonaghan.

As part of the discrete choice experiment respondents were firstly informed that the above fish species are under threat and will become extinct if there is no intervention. Images of the fish species were shown to respondents and a brief description of each species—in terms of their uniqueness and angling potential—was read to respondents. Respondents were then made aware that a number of options are available to respond to the threats to the fish species. Subsequently, respondents were shown examples of the outcomes that could be achieved. An example of a typical set of outcomes—or choice set—which was presented to respondents in the course of the interview is presented in Figure 1, below.

| | Option A | Option B | Do Nothing |
|---|---|---|---|
| **Arctic Char**<br>▪ Not found in other catchments in NI but found in other catchments in RoI.<br>▪ Has no angling potential. | Conserved | Extinct | Extinct |
| **Atlantic Salmon**<br>▪ Found in other catchments in NI and RoI.<br>▪ Has angling potential. | Extinct | Conserved | Extinct |
| **Ferox**<br>▪ Found in other catchments in NI and RoI.<br>▪ Has angling potential. | Conserved | Extinct | Extinct |
| **Gillaroo**<br>▪ Found in other catchments in NI and RoI.<br>▪ Has angling potential. | Extinct | Conserved | Extinct |
| **Sonaghan**<br>▪ Only found in the Lough Melvin Catchment.<br>▪ Has angling potential. | Extinct | Conserved | Extinct |
| **Cost of the outcome to you** | €6 | €24 | €0 |

**Figure 1: Example choice set presented to respondents**

Each choice set outlined three possible outcomes. The first two outcomes—labelled as *Option A* and *Option B*—described the conservation status of each of the fish species after the implementation of two different conservation schemes. At the end of these policies, the fish species would either be: *conserved*; or, *extinct*. While a particular policy described under either *Option A* or *Option B* may have been unable to prevent some of the fish species from becoming extinct, they both ensured that all fish species would not become extinct. The final outcome—labelled as *Do Nothing*—showed the outcome if nothing was done to protect the fish species. In this case, the respondents were informed that all of the fish species would become extinct. When choosing their preferred outcome—either *Option A*, *Option B* or *Do Nothing*—respondents were explicitly asked to bear in mind the value that they personally would have to pay per year—through a one-off increase in their Income Tax and/or Value Added Tax contributions. As part of the interview, respondents were asked to identify their preferred outcome from 16 such choice sets.

The population of interest was the adult population of NI and RoI. A stratified random sample of 1,186 respondents was selected for this study to reflect the geographic distribution of the adult population; the approximate rural/urban spilt; the approximate socio-economic status of the regional population; and the approximate gender and age profile of the regional population.

### 1.1.3 Results

Overall, the survey was administered by experienced interviewers to a stratified random sample of 1,186 respondents drawn from the adult population in NI and RoI. Of these, 754 respondents agreed to participate. Thus, the overall response rate was 64 percent. In NI a response rate of 55 percent was achieved, which was somewhat lower to the response rate of 71 percent achieved in RoI.

As may be seen from the breakdown of respondents who participated in the survey according to gender and age in Table 1, below, the samples in NI and RoI are fairly representative of the population.

**Table 1: Profile of survey sample and population (percent)**

| | **Northern Ireland** | | **Republic of Ireland** | | **Total** | |
|---|---|---|---|---|---|---|
| | Sample (N=303) | Population[a] (N=1,369,334) | Sample (N=451) | Population[b] (N=3,375,399) | Sample (N=754) | Population[c] (N=4,744,733) |
| Male | 50.83 | 48.35 | 50.78 | 49.72 | 50.80 | 49.32 |
| Female | 49.17 | 51.65 | 49.22 | 50.28 | 49.20 | 50.68 |
| Aged between 15 and 24 years | 14.85 | 18.49 | 18.85 | 18.75 | 17.24 | 18.67 |
| Aged between 25 and 34 years | 16.17 | 16.66 | 20.62 | 21.40 | 18.83 | 20.04 |
| Aged between 35 and 44 years | 15.84 | 18.80 | 19.51 | 18.47 | 18.04 | 18.56 |
| Aged between 45 and 54 years | 17.82 | 15.63 | 16.63 | 15.46 | 17.11 | 15.51 |
| Aged between 55 and 64 years | 15.18 | 13.17 | 13.08 | 12.06 | 13.93 | 12.38 |
| Aged between 65 years and over | 20.13 | 17.25 | 11.31 | 13.86 | 14.85 | 14.84 |

[a] NI population includes only persons aged 15 years and over. Obtained from the Northern Ireland Statistics and Research Agency (NISRA). See www.nisra.gov.uk.

[b] RoI population includes only persons aged 15 years and over. Obtained from the Central Statistics Office (CSO). See www.cso.ie.

[c] Total population obtained by aggregating NI population and RoI population.

Using the choices made by respondents in the choice experiment, it is possible to estimate how much money respondents are willing to sacrifice—or, in other words, willing to pay—in order to prevent any, or all, of the fish species from becoming extinct. The main results of this are summarised in Table 2, below. Median WTP estimates per person per year are reported for preserving each of the fish species (i.e. the *ceteris paribus* values) and preserving all fish species. The implicit rankings of the fish species are also reported.

**Table 2: Median willingness to pay (WTP) to avoid the fish species becoming extinct from the Lough Melvin Catchment (€/year)**

| | **Northern Ireland** | | **Republic of Ireland** | | **Total** | |
|---|---|---|---|---|---|---|
| | WTP[a] | Rank | WTP[a] | Rank | WTP[a] | Rank |
| Artic char | 15.62 (12.39–18.56) | 4 | 10.36 (8.18–11.86) | 5 | 12.49 (10.89–14.04) | 4 |
| Atlantic salmon | 28.80 (21.10–32.80) | 1 | 28.96 (23.11–31.73) | 1 | 29.12 (24.44–34.80) | 1 |
| Ferox | 10.87 (8.12–12.31) | 5 | 12.45 (10.37–14.72) | 4 | 11.52 (10.43–12.64) | 5 |
| Gillaroo | 20.34 (17.10–23.50) | 3 | 13.26 (11.75–15.99) | 3 | 15.51 (14.00–17.08) | 3 |
| Sonaghan | 27.47 (22.49–31.07) | 2 | 21.98 (18.28–25.34) | 2 | 26.28 (23.15–28.51) | 2 |
| All fish | 34.58 (29.93–38.93) | – | 33.13 (28.29–37.64) | – | 35.13 (30.61–40.29) | – |

[a] 95 percent confidence interval in parenthesis.

As may be seen the public place highest value on preserving Atlantic salmon. Subsequently, sonaghan and gillaroo respectively are found to be the next highly valued fish species. Whereas ferox is found to be the least valued fish species in NI, in RoI it is found to be Artic char. As indicated by the non-overlapping confidence intervals, the public in NI have statistically significantly higher WTP for Artic char and gillaroo. For the other fish species, WTP estimates are found to be statistically equivalent for the two jurisdictions. For both jurisdictions, the median WTP per year for preserving Atlantic salmon and sonaghan is estimated to be €29.12 and €26.28 respectively. The equivalent figures for gillaroo, Artic char and ferox are €15.51, €12.49 and €11.52 respectively.

To preserve all five species of fish, the median WTP per year is estimated to be €34.58 and €33.13 for NI and RoI respectively.

In Table 3, below, the WTP estimates are generalised, or aggregated, to the NI and RoI populations as a whole to indicate the median total economic value for preserving each of the fish species (i.e. the *ceteris paribus* values) and preserving all fish species.

**Table 3: Aggregate median willingness to pay (WTP) to avoid the fish species becoming extinct from the Lough Melvin Catchment (million €/year)**

| | **Northern Ireland**[a,d] | **Republic of Ireland**[b,d] | **Total**[c,d] |
|---|---|---|---|
| Artic char | 21.384<br>(16.965–25.413) | 34.984<br>(27.601–40.025) | 59.253<br>(51.675–66.621) |
| Atlantic salmon | 39.434<br>(28.896–44.918) | 97.748<br>(78.019–107.105) | 138.176<br>(115.957–165.117) |
| Ferox | 14.884<br>(11.122–16.852) | 42.026<br>(34.989–49.699) | 54.664<br>(49.478–59.964) |
| Gillaroo | 27.858<br>(23.409–32.178) | 44.767<br>(39.644–53.963) | 73.602<br>(66.436–81.035) |
| Sonaghan | 37.622<br>(30.795–42.548) | 74.194<br>(61.706–85.519) | 124.686<br>(109.841–135.258) |
| All fish | 47.346<br>(40.980–53.304) | 111.837<br>(95.504–127.047) | 166.682<br>(145.246–191.156) |

[a] Aggregation based on population of 1,369,334 (see Note a in Table 1).

[b] Aggregation based on population of 3,375,399 (see Note b in Table 1).

[c] Aggregation based on population of 4,744,733 (see Note c in Table 1).

[d] 95 percent confidence interval in parenthesis.

Inspection of the aggregated median WTP estimates, shows that the total economic value of the fish species is estimated to be almost €50 million in NI and over €110 million in RoI.

### 1.1.4 Actions

The results in this section show that the public places high values on preserving the rare and endangered fish species within the Lough Melvin Catchment. Highest aggregate median WTP values are found for preserving Atlantic salmon (€138 million per year), lowest for preserving ferox (€55 million per year), with preserving sonaghan (€167 million per year), gillaroo (€74 million per year) and Artic char (€59 million per year) ranking in between. To preserve all fish species the total aggregate median WTP is found to be €167 million.

There are clear uses of the value estimates. The results signal the general public's high demand for policy instruments which ensure the preservation of rare and endangered fish species within the Lough Melvin Catchment. The results should also be used to inform decisions concerning the prioritisation of resources within such policy instruments.

# A Discrete choice experiments

## A.1 Background

Discrete choice experiments have been of interest to researchers in a variety of academic disciplines for a number of years. They are found in the literature under a variety of guises, and confusion arises from the different terms that are used to describe the various techniques that fall into this category (Garrod & Willis, 1999a). Discrete choice experiments have been used by psychologists since the 1960s (for example, Anderson, 1962; Luce & Turkey, 1964) and in the early 1970s were introduced to the marketing literature (for example, Green & Roa, 1971; Green *et al*., 1972). In the marketing field, the techniques became known as conjoint analysis.

Contemporary to the development and application of conjoint analysis, the economic literature—especially in the transportation field—reported new ways of modelling discrete choice and the theoretical foundations for modelling were developed using the random utility theory (Ben-Akiva & Lerman, 1985). The development of random utility theory became the benchmark for the use of choice techniques in the economic literature as it provided the necessary link between observed consumer behaviour and economic theory. Random utility theory provides a comprehensive way to conceptualise and model market behaviour. Discrete choice experiments are closely related to the dichotomous choice contingent valuation method, as both methods involve consumers making mutually exclusive choices from a set of substitutable goods. The methods also share the same economic foundation in the random utility theory (Luce, 1959; McFadden, 1974). The discrete choice experiment approach, as it is known today, was initially developed in the early 1980s by Louviere *et al*. (1981), Louviere & Hensher (1982), Louviere (1983) and Louviere & Woodworth (1983).

Although discrete choice experiments originated in the fields of marketing and transportation, they are increasingly applied to non-market valuation. Louviere & Timmermans (1990) and Adamowicz *et al*. (1994) were the first to apply the method in an environmental valuation setting. Since then there has been a growing number of non-market valuation studies using discrete choice experiments (see Campbell *et al*. (2007; 2008), Boxall *et al*. (1996), Adamowicz *et al*. (1998), and Hanley *et al*. (1998a) for applications within environmental economics, and Hall *et al*. (2004b), Ryan (2004) and McIntosh & Ryan (2002) for applications within health economics).

Aside from discrete choice experiments, there are three other main choice techniques that reflect differences with respect to theoretical assumptions, methods of analysis and experimental procedures. These are contingent ranking, contingent rating and paired comparisons. While the techniques have much in common with discrete choice experiments, they differ in the quality of information they generate, in their degree of complexity and also in their ability to produce willingness to pay (WTP) estimates that are consistent with economic theory (Hanley *et al*., 2001). In discrete choice experiments respondents choose one alternative out of a given number of alternatives. In contrast, in a contingent ranking exercise respondents are required to rank all the alternatives. Respondents in a contingent rating exercise are required to rate a series of individual alternatives on a semantic or numeric scale. Semantic or numeric scales are also used in a paired comparison exercise, but respondents choose their preferred alternative out of a set of two choices and indicate the strength of their preference. For a review of the contingent ranking, contingent rating and paired comparisons techniques, see Hanley *et al*. (2001).

Discrete choice experiments are the simplest of the multiple choice techniques and thus place the least cognitive demands on respondents. Since only the information regarding the preferred alternative is obtained from discrete choice experiments, a complete ordering of the alternatives cannot be determined, and thus the data is weakly ordered. However, complete ordering can be achieved by either (i) obtaining more discrete responses from each respondent and/or (ii) obtaining responses from more individuals under a wider range of attributes (Louviere *et al*., 2003).

The term 'discrete choice' arose from the distinction between discrete and continuous choices. Following Hanemann (1984a), a consumer's decisions can generally be partitioned into two parts: (i) which good to choose (that is, a discrete choice) and (ii) how much to consume of the chosen good (that is, a continuous choice). The optimal discrete choice depends partly on the outcome of the continuous choice, and *vice versa*. Both stages of the decision making process are, therefore, crucial to the analysis and should be modelled in a consistent manner (*ibid*.). However, in discrete choice experiments the decision context is constructed to assume a specific continuous dimension, which is a given part of the framework in which the discrete choice takes place. In so doing, the discrete dimension of the choice situation is isolated, therefore allowing the individual to make a purely discrete choice (Hanemann, 1999). To fit within a discrete choice framework, the set of alternatives, known as the choice set, must exhibit three characteristics (Train, 2003):

- the alternatives must be mutually exclusive;
- the choice set must be exhaustive; and
- the number of alternatives must be finite.

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; Hanley *et al*., 1998b). Discrete choice experiments can thus be used to examine the response of an individual to changes in each of the attributes. In other words, it is possible to infer people's willingness to give up some amount of an attribute in order to achieve more of another—that is, their marginal rate of substitution between the attributes. Including a monetary attribute provides discrete choice experiments with an elicitation procedure for obtaining WTP estimates for the non-monetary attributes. This implies that benefits are estimated in monetary terms and are consistent with welfare economics (that is, the potential Pareto improvement condition). Inclusion of a monetary attribute enables the respondent's WTP to be indirectly obtained for either an alternative in its entirety or for a non-monetary attribute, that is, marginal WTP (also termed partworth or implicit price) (Bennett & Adamowicz, 2001). This method is indirect in the sense that individuals are not directly asked their WTP, but instead to trade the monetary attribute against the non-monetary attributes.

### A.1.1 Theoretical background

The theoretical foundation of discrete choice experiments is rather complex as it combines several different theories. 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 (such as price) can cause a discrete switch from one good to another that will provide a superior combination of attributes. Based on the characteristics theory of value proposed by Lancaster, the probability of choosing a specific alternative (that is, a good) is a function of the utility associated with that same alternative. Moreover, the utility derived from each alternative is assumed to be determined by the preferences over the levels of the characteristics provided by that alternative. Lancaster's approach is thus very suitable for dealing with discrete choice experiments.

Discrete choice models are usually derived under the assumption that an individual behaves in a utility-maximising manner. The origin of probabilistic discrete choice modelling goes back to the work of Thurstone (1927), who developed the concepts in terms of psychological stimuli. Thurstone proposed the modelling of individual choice as the outcome of a process in which a random variable is associated with each alternative, and the alternative with the highest realisation is the one selected. When the perceived stimuli are interpreted as levels of satisfaction, or utility, this can be interpreted as a model for economic choice in which the individual chooses the alternative yielding the greatest realisation of utility (McFadden, 2001). Marschak (1960) introduced Thurstone's work into economics, by exploring the theoretical implications of choice probabilities for the maximisation of utilities that contained random elements (named random utility models). This idea was later taken up and further developed by McFadden (1974) and Manski (1977).

Random utility models are derived as follows. An individual, labelled *n*, faces a choice among *A* alternatives and obtains a certain level of utility from each alternative. The utility that individual *n* obtains from alternative *i* is $U_{ni}$, $i = 1, \ldots, A$. Neoclassical economic theory suggests that the individual has perfect discriminatory power and unlimited information-processing capacity, allowing the individual to rank the alternatives in a well-defined and consistent manner. The individual can thus determine their best choice and will repeat this choice under identical circumstances. The behavioural model is therefore: choose alternative *i* over alternative *j*, given the set of alternatives *A*, if and only if (iff)

$$U_{ni} > U_{nj} \;\; \forall i \neq j \in A \,. \tag{A.1}$$

The link with probabilistic choice theory arises from the researcher's lack of information about the individual's true utility function. The researcher observes some attributes of the alternatives as faced by the individual, labelled $x_{ni}\ \forall i$, and some attributes of the individual, labelled $s_n$, and can specify a function that relates these observed factors to the individual's utility. This function, $V_{ni}$, is denoted as

$$V_{ni} = V\left(x_{ni}, s_n\right) \;\; \forall i \,, \tag{A.2}$$

and is the representative component of utility. Since there are aspects of utility that are unknown to the researcher, $V_{ni} \neq U_{ni}$. Utility is, therefore, decomposed as

$$U_{ni} = V\left(x_{ni}, s_n\right) + \varepsilon\left(x_{ni}, s_n\right) \ \forall i , \tag{A.3}$$

where $U_{ni}$ is the true, but unobservable—that is, latent—utility individual *n* has for alternative *i*, *V*(·) is non-stochastic and reflects the observable component of utility and *ε*(·) is stochastic and is the unobservable factor of utility and is treated as a random component. This decomposition is fully general, since *ε*(·) is defined as simply the difference between true utility $U_{ni}$ and the part of utility that the researcher captures in *V*(·) (Train, 2003). Random utility theory assumes that an individual acts rationally and chooses the alternative that maximises their utility. Given its definition, the characteristics of *ε*(·), such as its distribution, depend critically on the researcher's specification of *V*(·). In particular, *ε*(·) is not defined for a choice situation *per se*. Rather, it is defined relative to a researcher's representation of that choice situation. From Equations (A.1) and (A.3), alternative *i* is chosen over alternative *j*, given the set of alternatives *A*, iff

$$V\left(x_{ni}, s_n\right) + \varepsilon\left(x_{ni}, s_n\right) > V\left(x_{nj}, s_n\right) + \varepsilon\left(x_{nj}, s_n\right) \ \forall i \neq j \in A . \tag{A.4}$$

Rearranging to place the observables and unobservables together yields:

$$V\left(x_{ni}, s_n\right) - V\left(x_{nj}, s_n\right) > \varepsilon\left(x_{nj}, s_n\right) - \varepsilon\left(x_{ni}, s_n\right) \ \forall i \neq j \in A . \tag{A.5}$$

Due to the presence of the random components, the researcher cannot observe the individuals true utility. It is only possible to make statements about choice outcomes up to a probability of occurrence. Thus, the probability that individual *n* will choose alternative *i* over alternative *j*, given the set of alternatives *A*, is represented by:

$$\begin{aligned} P_{ni} &= \text{Prob}\left(U_{ni} > U_{nj} \ \forall i \neq j \in A\right) \\ &= \text{Prob}\left(V\left(x_{ni}, s_n\right) + \varepsilon\left(x_{ni}, s_n\right) > V\left(x_{nj}, s_n\right) + \varepsilon\left(x_{nj}, s_n\right) \ \forall i \neq j \in A\right) \\ &= \text{Prob}\left(V\left(x_{ni}, s_n\right) - V\left(x_{nj}, s_n\right) > \varepsilon\left(x_{nj}, s_n\right) - \varepsilon\left(x_{ni}, s_n\right) \ \forall i \neq j \in A\right). \end{aligned} \tag{A.6}$$

In words, the probability of individual *n* choosing alternative *i* is equal to the probability that the difference in the observed sources of utility associated with alternative i compared to alternative j is greater than the difference in the unobserved sources of utility of alternative *j* compared to *i* after evaluating each and every alternative in the choice set *A*.

Using the joint density of the random vector, $f(\varepsilon_n)$, this cumulative probability is represented as

$$= \int_{\varepsilon} I\left(V\left(x_{ni}, s_n\right) - V\left(x_{nj}, s_n\right) > \varepsilon\left(x_{nj}, s_n\right) - \varepsilon\left(x_{ni}, s_n\right) \ \forall i \neq j \in A\right) f\left(\varepsilon_n\right) \, d\varepsilon_n \tag{A.7}$$

where *I*(·) is the indicator function, equalling 1 when the expression in parentheses is true and 0 otherwise. By integrating all the possible values of $\varepsilon_n$, the total probability of choosing alternative *i* is given. Different discrete choice models are obtained from different specifications of this density, that is, from different assumptions about the distribution of the unobserved portion of utility (Train, 2003). The integral can take a closed form, partially closed form or open form depending on the specification of *f*(·). In cases where the integral does not have a closed form it is evaluated numerically through simulation (see Stern, 1997).

### A.1.2 Properties

Many different discrete choice models can be derived by making different assumptions about the distribution of the random components. For example, a bivariate normal distribution yields the binary probit model (Thurstone, 1927), which has its multivariate generalisation in the multinomial probit (MNP) discrete model; an independent and identical distribution (*iid*) with extreme value gives rise to the conditional or multinomial logit model (McFadden, 1974); a generalised extreme value distribution gives rise to models such as the nested logit (McFadden, 1981) and the ordered generalised extreme value (Small, 1987); and a mixed logit is based on a distribution that follows any distribution specified by the researcher plus a part that is independently and identically distributed (*iid*) extreme value (McFadden & Train, 2000).

The specification of discrete choice experiments implies that only differences in utility matter. If a constant is added to the utility of all alternatives, the alternative with the highest utility does not change. The choice probability, which is given by Equation (A.6), depends only on the difference in utility, not its absolute level. Just as adding a constant to all utilities does not affect the individual's choice, neither does multiplying each alternative's utility by a constant. The alternative with the highest utility is the same no matter how utility is scaled.

Specifying the observed part of utility to be linear in parameters with a constant yields:

$$V_{ni} = V\left(x_{ni}, s_n\right) + k_i \;\; \forall i \,, \qquad \text{(A.8)}$$

where $k_i$ is a constant that is specific to alternative $i$, and remaining terms are as previously defined. The alternative specific constant (ASC), $k_i$, captures the average effect on utility of all factors that are not included in the model. Including ASCs can thus be used to examine alternative specific descriptor (Blamey *et al*., 2000) and status-quo (Haaijer *et al*., 2001; Scarpa *et al*., 2007) effects. Since only differences in utility matter, one of the ASCs is normalised to zero. It is irrelevant which ASC is normalised to zero: the other ASCs are interpreted as being relative to whichever one is set to zero.

While attributes of the good under evaluation generally vary across alternatives, attributes of the individual remain the same across all alternatives and thus cannot enter directly into the model on their own, as they would drop out from the estimation. In an econometric sense this means that the effect of individual characteristics are not identifiable in the probability of choosing specific alternatives, with the result that model parameters (that is, the indirect utility function) are the same for each sampled individual (Adamowicz & Boxall, 2001). They can only enter the model if they are specified such that they create differences in utility over alternatives. Socio-demographic variables must, therefore, be interacted either with the choice specific attributes or with the ASCs (Campbell, 2007). The inclusion of person-specific variables makes it possible to account for some heterogeneity in preferences between individuals, which can yield important information, and to perform sub-group analysis.

## A.2 Economic welfare measurement

As noted by Bennett & Adamowicz (2001), the basic idea behind any stated preference technique for estimating non-market environmental values is to quantify a person's willingness to bear a financial impost in order to achieve some potential (non-financial) environmental improvement or to avoid some potential environmental harm. One of the advantages of discrete choice experiments is their ability to reveal the value of attributes as well as the value of more complex changes in several attributes (Adamowicz *et al.*, 1999). Since discrete choice experiments are based on random utility theory, welfare economic principles—developed by Small & Rosen (1981) and Hanemann (1984b)—for random utility models can be employed.

A number of welfare measures can be obtained from the estimated model. If one of the attributes used to describe the alternatives in a discrete choice experiment is a cost attribute, then a change in one of the attributes from one level to another can be valued in terms of Hicksian income variations, like compensating variation (CV) (Kriström & Laitila, 2003; Roe *et al.*, 1996) or consumer surplus (McConnell, 1995). To examine the economic welfare impact of a quality change in an attribute it is necessary to compare situations before and after the change:

$$V_{ni}^{0} = \beta\left(x_{ni}^{0}\right) + \gamma\left(P\right) = \beta\left(x_{ni}^{1}\right) + \gamma\left(P + \mathrm{CV}\right) = V_{ni}^{1}, \qquad \text{(A.9)}$$

where $V_{ni}^{0}$ denotes the representative component of utility before the change, $V_{ni}^{1}$ denotes the representative component of utility after a change in attribute x from level $x_{ni}^{0}$ to $x_{ni}^{1}$ and $\gamma$ is the coefficient for the price attribute, *P*, and is interpreted as the marginal utility of money (or reverse marginal disutility of cost). From Equation (A.9) the economic welfare impact of the change from $x_{ni}^{0}$ to $x_{ni}^{1}$ is the CV (that is, the price increase) in the changed situation that makes individual *n* as well off in the original situation as in the situation after the quality change. Assuming a linear income effect, the estimation for a change in welfare is the ratio of the attribute coefficient and the marginal utility of income (Hanemann, 1984b):

$$\Delta \mathrm{CV} = \frac{\left(\partial V_{ni} / \partial x_{ni}\right)\Delta x_i}{\partial V_{ni} / \partial P} = \frac{\left(V_{ni}^{1} - V_{ni}^{0}\right)}{\gamma} = \frac{\Delta \beta x_{ni}}{\gamma} \qquad \text{(A.10)}$$

and thus the marginal WTP for a certain attribute is given by:

$$\mathrm{WTP} = -\frac{\beta}{\gamma}, \qquad \text{(A.11)}$$

where $\beta$ is the coefficient for the non-price attribute and $\gamma$ is the coefficient for the price attribute.

While Equations (A.10) and (A.11) provide a measure of economic welfare (that is, WTP) for a quality change in one alternative, it does not address situations involving many alternatives. In the multiple alternatives approach (Bennett & Adamowicz, 2001), the welfare measure incorporates the expected value (or utility for each alternative times the probability of choosing each alternative) of utility arising from the multiple alternatives. This is equivalent to the concept of expected utility in which the utility of being in several states of the world is weighted by the probability that each occurs, and the weighted utility sum equals the expected utility (Louviere *et al.*, 2003).

The general equation for a change in welfare measure in a discrete modelling framework is:

$$E(\text{CV}) = \frac{1}{\gamma}\int \text{Prob}\left(V_{ni}^{0}, V_{ni}^{1}\right)\, dV_{ni} \, . \tag{A.12}$$

Applying this formula, it is assumed that marginal utility of income is approximately independent of the price and quality of the alternative, and that the income effect is negligible (that is, the compensated (Hicksian) demand curve and the Marshallian demand curve approximate each other (Small & Rosen, 1981)). The multiple alternatives approach takes the random component of utility into account and hence the distributional assumptions of the error terms affect the estimation of the welfare change. Assuming that the random component of utility is *iid* extreme value distributed implies that the integral takes a closed form. The expectation becomes

$$E(\text{CV}) = \frac{1}{\gamma}\ln\left[\sum_{i\in A}\exp(V_{ni})\right] + C \, , \tag{A.13}$$

where $C$ is an unknown constant and represents the fact that the absolute level of utility cannot be measured. The change in consumer surplus that results from a change in alternatives and/or choice set is calculated from Equation (A.13). For a difference in welfare, $E$(CV) is calculated twice: first under the conditions before the change, and again under the conditions after the change (Train, 2003):

$$\Delta E(\text{CV}) = \frac{1}{\gamma}\ln\left[\sum_{i\in A}\exp\left(V_{ni}^{0}\right) - \sum_{i\in A}\exp\left(V_{ni}^{1}\right)\right]. \tag{A.14}$$

This expression is known as the log sum formula (Louviere *et al*., 2003). Since the unknown constant $C$ enters expected utility both before and after the change, it drops out of the equation and can be ignored. Besides, this constant is irrelevant from a policy perspective as only differences in utility matter (Train, 2003).

# References


Adamowicz, W.L. and Boxall, P.C. (2001) Future directions of stated choice methods for environment valuation. *Choice experiments: a new approach to environmental valuation conference*, London.

Adamowicz, W.L., Boxall, P.C., Louviere, J.J., Swait, J. and Williams, M. (1999) Stated-preference methods for valuing environmental amenities. In Bateman, I.J. and Willis, K.G. (eds.), *Valuing environmental preferences*. Oxford University Press, Oxford.

Adamowicz, W.L., Louviere, J.J. and Williams, M. (1994) Combining revealed and stated preference methods for valuing environmental amenities. *Journal of Environmental Economics and Management*, **26**, 271-292.

Adamowicz, W.L., Boxall, P.C., Williams, M. and Louviere, J.J. (1998) Stated preference approaches for measuring passive use values: choice experiments and contingent valuation. *American Journal of Agricultural Economics*, **80**, 64-75.

Alpízar, F., Carlsson, F. and Martinsson, P. (2001) Using choice experiments for non-market valuation. *Economic Issues*, **8**, 83-110.

Anderson, N.H. (1962) Application of an additive model to impression formation. *Science*, **138**, 817-818.

Ben-Akiva, M. and Lerman, S.R. (1985) *Discrete choice analysis: theory and application to travel demand*. MIT Press, Cambridge.

Bennett, J. and Adamowicz, W.L. (2001) Some fundamentals of environmental choice modelling. In Bennett, J. and Blamey, R. (eds.), *The choice modelling approach to environmental valuation*. Edward Elgar, Cheltenham.

Blamey, R., Bennett, J., Louviere, J.J., Morrison, M.D. and Rolfe, J. (2000) A test of policy labels in environmental choice modelling studies. *Ecological Economics*, **32**, 269-286.

Boxall, P.C., Adamowicz, W.L., Swait, J., Williams, M. and Louviere, J.J. (1996) A comparison of stated preference methods for environmental valuation. *Ecological Economics*, **18**, 243-253.

Campbell, D. (2007) Willingness to pay for rural landscape improvements: combining mixed logit and random effects models. *Journal of Agricultural Economic*, **58**, 467-483.

Campbell, D., Hutchinson, W.G. and Scarpa, R. (2007) Quantifying the landscape benefits arising from the Rural Environment Protection Scheme: results from a public survey. *Tearmann: Irish Journal of Agri-Environmental Research*, **5**, 1-12.

Campbell, D., Hutchinson, W.G. and Scarpa, R. (2008) Using mixed logit models to derive individual-specific WTP estimates for landscape improvements under agri-environmental schemes: evidence from the Rural Environment Protection Scheme in Ireland. In Koundouri, P. and Birol, E. (eds.), *Choice Experiments Informing European Environmental Policy*, Edward Elgar, Cheltenham.

Garrod, G.D. and Willis, K.G. (1999a) *Economic valuation of the environment: methods and case studies*. Edward Elgar, Cheltenham.

Green, P.E., Carmone, F.J., and Wind, Y. (1972) Subjective evaluation models and conjoint measurement. *Behavioral Science*, **17**, 288-299.

Green, P.E. and Rao, V.R. (1971) Conjoint measurement for quantifying judgmental data. *Journal of Marketing Research*, **8**, 355-363.

Haaijer, R., Kamakura, W. and Wedel, M. (2001) The 'no-choice' alternative in conjoint choice experiments. *International Journal of Market Research*, **43**, 93-106.

Hanemann, W.M. (1984a) Discrete/continuous models of consumer demand. *Econometrica*, **52**, 541-562.

Hanemann, W.M. (1984b) Welfare evaluations in contingent valuation experiments with discrete responses. *American Journal of Agricultural Economics*, **66**, 332-341.

Hanemann, W.M. (1999) Welfare analysis with discrete choice models. In Herriges, J.A. and Kling, C.L. (eds.), *Valuing recreation and the environment*. *Applications of simulation methods in environmental and resource economics*. Edward Elgar, Cheltenham.

Hanley, N., MacMillan, D., Wright, R.E., Bullock, C., Simpson, I., Parsisson, D. and Crabtree, B. (1998a) Contingent valuation versus choice experiments: estimating the benefits of Environmentally Sensitive Areas in Scotland. *Journal of Agricultural Economics*, **49**, 1-15.

Hanley, N., Mourato, S. and Wright, R.E. (2001) Choice modelling approaches: a superior alternative for environmental valuation? *Journal of Economic Surveys*, **15**, 435-462.

Hanley, N., Wright, R.E. and Adamowicz, W.L. (1998b) Using choice experiments to value the environment: design issues, current experience and future prospects. *Environmental and Resource Economics*, **11**, 413-428.

Hall, J., Viney, R., Haas, M. and Louviere, J.J. (2004b) Using stated preference discrete choice modeling to evaluate health care programmes. *Journal of Business Research*, **57**, 1026-1032.

Kriström, B. and Laitila, T. (2003) Stated preference methods for environmental valuation: a critical look. In Folmer, H. and Tietenberg, T. (eds.), *International yearbook of environmental and resource economics*. Edward Elgar, Cheltenham.

Lancaster, K.J. (1966) A new approach to consumer theory. *The Journal of Political Economy*, **74**, 132-157.

Louviere, J.J. (1983) Integrating conjoint and functional measurement with discrete choice theory: an experimental design approach. *Advances in Consumer Research*, **10**, 151-159.

Louviere, J.J. (2001) Choice experiments: an overview of concepts and issues. In Bennett, J. and Blamey, R. (eds.), *The choice modelling approach to environmental valuation*. Edward Elgar, Cheltenham.

Louviere, J.J., Henley, D.H., Woodworth, G., Meyer, R.J., Levin, I.P., Stoner, J.W., Curry, D. and Anderson, D.A. (1981) Laboratory-simulation versus revealed-preference methods for estimating travel demand models. *Transportation Research Record*, **794**, 45-51.

Louviere, J.J. and Hensher, D.A. (1982) Design and analysis of simulated choice or allocation experiments in travel choice modeling. *Transportation Research Record*, **890**, 11-17.

Louviere, J.J., Hensher, D.A. and Swait, J. (2003) *Stated choice methods: analysis and application*. Cambridge University Press, Cambridge.

Louviere, J.J. and Timmermans, H. (1990) Stated preference and choice models applied to recreation research: a review. *Leisure Sciences*, **12**, 9-32.

Louviere, J.J. and Woodworth, G. (1983) Design and analysis of simulated consumer choice or allocation experiments: an approach based on aggregate data. *Journal of Marketing Research*, **20**, 350-367.

Luce, R.D. (1959) *Individual choice behavior: a theoretical analysis*. Wiley, New York.

Luce, R.D. and Tukey, J.W. (1964) Simultaneous conjoint measurement: a new type of fundamental measurement. *Journal of Mathematical Psychology*, **1**, 1-27.

Manski, C.F. (1977) The structure of random utility models. *Theory and Decision*, **8**, 229-254.

Marschak, J. (1960) Binary choice constraints and random utility indicators. In Arrow, K.J., Karlin, S. and Suppes, P. (eds.), *Mathematical methods in social sciences*. Stanford University Press, Stanford.

McConnell, K.E. (1995) Consumer surplus from discrete choice models. *Journal of Environmental Economics and Management*, **29**, 263-270.

McFadden, D.L. (1974) Conditional logit analysis of qualitative choice behavior. In Zaremka, P. (ed.), *Frontiers in econometrics*. Academic Press, New York.

McFadden, D.L. (1981) Econometric models of probabilistic choice. In Manski, C.F. and

McFadden, D.L. (eds.), *Structural analysis of discrete data with econometric applications*. MIT Press, Cambridge.

McFadden, D.L. (2001) Economic choices. *The American Economic Review*, **91**, 351-378.

McFadden, D.L. and Train, K.E. (2000) Mixed MNL models for discrete response. *Journal of Applied Econometrics*, **15**, 447-470.

McIntosh, E. and Ryan, M. (2002) Using discrete choice experiments to derive welfare estimates for the provision of elective surgery: implications of discontinuous preferences. *Journal of Economic Psychology*, **23**, 367-382.

Ryan, M. (2004) Discrete choice experiments in health care. *British Medical Journal*, **328,** 360-361.

Scarpa, R., Campbell, D. and Hutchinson, W.G. (2007) Benefit estimates for landscape improvements: sequential Bayesian design and respondents' rationality in a choice experiment study. *Land Economics*, **83**, 617-634.

Small, K.A. (1987) A discrete choice model for ordered alternatives. *Econometrica*, **55**, 409-424.

Small, K.A. and Rosen, H.S. (1981) Applied welfare economics with discrete choice models. *Econometrica*, **49**, 105-130.

Stern, S. (1997) Simulation-based estimation. *Journal of Economic Literature*, **35**, 2006-2039.

Thurstone, L.L. (1927) A law of comparative judgment. *Psychological Review*, **34**, 273-286.

Train, K.E. (2003) *Discrete choice methods with simulation*. Cambridge University Press, Cambridge.