The Economic and Social Review, Vol. 43, No. 3, Autumn, 2012, pp. 397–422

Estimating the Value of Achieving "Good Ecological Status" in the Boyne River Catchment in Ireland Using Choice Experiments

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Abstract: Following the implementation of the Water Framework Directive (WFD), integrated catchment management plans must be prepared for all river basins in order to achieve "Good Ecological Status" (GES) in all EU waters. This concept is a broader measure of water quality than the chemical and biological measures which were previously dominant in EU water policy. The directive also calls for a consideration of the economic costs and benefits of improvements to the water bodies" ecological status in catchment management plans, along with the introduction of full social cost pricing for water use. In this paper, the Choice Experiment (CE) method of valuation is used to estimate the value of improvements in a number of components of ecological status in the Boyne river catchment in Ireland. The study determines what value the targeted population of the catchment place on the non-market economic benefits of moves towards GES. In addition, the effect of various factors of observed individual heterogeneity on choice is explored.

Acknowledgements: This study was funded by Teagasc under the Walsh Fellowship programme, the Department of Agriculture, Fisheries and Food under the Research Stimulus Fund and the Environment Protection Agency under the Science, Technology, Research & Innovation for the Environment (STRIVE) Programme 2007-2013. We are grateful to Ray Earle – project co-ordinator of Eastern River Basin Project, John Lucy, Michael Neill and Catherine Bradley from the EPA and Sue Scott from the Economic and Social Research Institute for their expert advice. We would also like to thank the EPA for providing us with valuable GIS data that made mapping of the RBD according to the study's needs possible.
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I INTRODUCTION

The Water Framework Directive (WFD) (2000/60) was adopted in October 2000 and established a framework for European Community action in the field of water policy (CEC, 2000). The directive calls for integrated catchment management plans to be prepared in order to achieve Good Ecological Status (GES) in all EU waters by 2015. This concept is a broader measure of water quality than the chemical and biological measures which were dominant in European water policy prior to the WFD. According to Article 2 (18) of the Directive "Good surface water status" referred to the status achieved by a surface water body when both its ecological status and its chemical status meet certain agreed criteria for river health. As such, the directive aims, at a minimum, for "good" and "non-deteriorating" status for all European waters, and sets common approaches and goals for water management in all EU Member States (MS).

The main steps involved in the implementation of the WFD include the setting of ecological standards, the identification of anthropogenic pressures (i.e., human induced pressures such as point source and diffuse source pollution, water abstraction, morphological alterations, etc.) and the adoption of corrective measures. In implementing these steps MS are expected to take account of the principle of full recovery of costs of water services that will provide incentives for the efficient use of water by different users. Another important change in water management policy introduced in the directive is that the measures to achieve the WFD objectives will be co-ordinated at the level of River Basin District (RBD) that correspond to large catchment basins incorporating smaller Hydrometric Area (HA) units.[1] In Ireland's case there are eight such RBDs.

Another important element of the Directive from an economic perspective is that it calls for a consideration of the economic costs and benefits of improvements to ecological status in catchment management plans. Hence, benefits can play an important role in the assessment of the proportionality of costs in the implementation of the WFD. Article 4 Paragraph 3(b) of the Directive allows for the lower target of "Good Ecological Potential" for a heavily modified or an artificial water body (a water body resulted from physical alterations by human activity, which substantially change its hydrogeomorphological character). The ecological potential of a water body is the degree to which the quality of the water body's aquatic ecosystem

[1] Each Hydrometric Area is comprised of a single large river basin, or a group of smaller ones and if relevant neighbouring coastal areas (http://www.epa.ie/whatwedo/monitoring/water/hydrometrics/network/).

approaches the maximum it could achieve, given the heavily modified characteristics of the water body that are necessary for the use or for the protection of the wider environment (CEC, 2000). This represents a change in both the way the water body's status is classified and the objectives that apply. In these cases, if the costs of achieving Good Ecological Status (GES) are disproportionately expensive compared to the monetised benefits then the target of achieving "Good Ecological Potential" instead of GES needs to be met by 2015. Also, the WFD requires that charges for water services should adopt the principle of full cost recovery in accordance with the polluter pay principle, thus providing incentives for improved water use efficiency. At the same time common methods to estimate these costs are yet to be determined and it is expected to be quite challenging in a number of member states (MS) where water in the domestic and agricultural sectors is subsidised (Spain, Greece, Portugal) or where water pricing has been almost completely absent (Ireland).

In general, measuring the benefits associated with a healthy water body as defined by the WFD is an important but difficult task of the river basin authorities and will involve them having to consider and evaluate costs and benefits of implementing the policy – including non-market environmental benefit values. In this context, the objective of this paper is to elicit the value of achieving GES in an Irish river catchment through the exploration of the preferences that the Irish public holds for river improvements. In particular, the paper identifies how Irish citizens make trade-offs between potential benefits from water quality improvements such as recreation, river life, bank erosion and water appearance by employing a choice experiment.

At this point, it should be noted that while some valuation studies for water resource benefits have been undertaken in Ireland (Curtis, 2002, 2003; Hynes and Hanley, 2006; Hynes *et al.*, 2009) there is no comprehensive set of values. This study, has therefore, the potential to inform the policy debate on a number of levels by exploring the value for achieving GES under the WFD and assessing the implicit prices associated with a number of individual water characteristics including the ecological health and recreational usage. The determinants of choice with regard to individuals' preference heterogeneity are also explored.

The rest of the paper is organised as follows. In Section II an overview of the implementation of the Directive's economics elements in Ireland is presented as well as a literature review of the water related valuation studies that have taken place in the country. Section III introduces the study area while Section IV presents a short description of the choice experiment methodology. Decisions related to survey design and data are discussed in Section V, while Section VI reports the results from the analysis of the data. The final section comments on the results and offers some conclusions.

II IRELAND'S IMPLEMENTATION OF THE WATER FRAMEWORK DIRECTIVE

Currently, Ireland is up to date with the requirements of the WFD's implementation timetable. In particular, Ireland undertook a characterisation and analysis of all RBDs as required by Article 5 in 2004. The report (ERBD, 2005) also provided an economic analysis of water use in accordance with the requirements of Article 5 of the Directive. As referred to in its Executive Summary (page vi) the report served as a comprehensive assessment of all waters (groundwater, rivers, lakes, transition and coastal waters), established a baseline and identified priority actions for subsequent stages in the river basin planning cycle.

As part of the 2005 National Summary Report for Ireland (EPA, 2005), a baseline economic analysis has been completed with a preliminary assessment of the value and costs associated with water resources in Ireland. In this context key information gaps were identified along with a proposed strategy to address them. The results presented in the final report *Economic Analysis of Water Use in Ireland* (CDM, 2004), provided the foundation for the economic component of the summary National Characterisation report under Article 5 of the Directive. The methodology used for the estimation of water use benefits suggested an economic impact assessment of key water-using activities and valuations of abstractive and in-stream water resources in each RBD. In particular, for the in-stream valuations such as water based leisure activities, national estimates of expenditures related to recreational fisheries, navigable waters, beaches, and other marine amenities from the Economic and Social Research Institute Report (Williams and Ryan, 2004) were used.

Goodbody's (2008) report also investigated the possibility of making use of values derived in other countries, particularly the UK, in the absence of original studies in Ireland, in order to estimate the non-market value associated with Irish water bodies. They concluded that although "… the benefit values mandated in the UK are the most appropriate ... the incremental changes in status that underpin the guidance do not map directly onto water status levels, as defined in the WFD" (Goodbody, 2008, p. 26).

The number of studies that have applied stated preference techniques in the context of valuing economic benefits that derive from the WFD is increasing across Europe (see for example Kontogianni *et al.*, 2005; Baker *et al.*, 2007; Spash *et al.*, 2009). A considerable number of these studies have applied the Choice Experiments (CE) method (Álvarez-Farizo *et al.*, 2007; Hanley *et al.*, 2007; Hanley *et al.*, 2006a, 2006b; Lago and Glenk, 2008; Kataria 2009; Kataria *et al.*, 2009; Brouwer *et al.*, 2010; Poirier and Fleuret, 2010). Adamowicz *et al.* (1994) is the first study to apply CE to non-market valuation and in particular to sites of water based recreation.

The above CE studies vary in terms of the purpose of the study,[2] the geographic scale (local, regional, national) and hence the affected population. They also vary in terms of the good, the baseline, the change in ecological status, the payment vehicle, the survey mode and the validity of the results. That makes comparisons difficult but nevertheless they provide an indication of related values and demonstrate how the idea of valuing benefits within the WFD may be approached, since there is no specific guideline from the EU on how to proceed in this regard.

In the case of Ireland, valuation studies with a focus on river quality improvements are limited. Those studies which are available focus on valuing water-based leisure activities. Hynes and Hanley (2006) estimated through Travel Cost Method (TCM) the mean Willingness to Pay (WTP) of the average kayaker using the Roughty River in Co. Kerry, in order to shed light on the conflict between commercial interests and recreational pursuits on Irish rivers. In Hynes *et al.* (2009) the authors examined the welfare loss to recreationalists from a reduction (50 per cent) in the recreational rating of a river due to water diversion for agricultural use or the implementation of a hydro scheme. This study uses revealed preference data to estimate values for a range of river attributes relevant to kayaking. Another study by Curtis (2002) applied the TCM to estimate the demand for and economic value of salmon angling in Co. Donegal. In Curtis (2003) the demand for water-based leisure activity (sea angling, boating, swimming and other beach/sea/island day-trips) in Ireland was examined using data from a nationally representative telephone survey.

There are also a number of other economic studies in Ireland that involve some form of economic appraisal of water based activity that do not, however, measure water related benefits. For example, Lawlor *et al.* (2007) conducted an economic evaluation of selected water investment projects in Ireland. Elsewhere, Bullock *et al.* (2008) carried out an economic assessment of the value of biodiversity in Ireland and considered the economic and social benefits of biodiversity across a range of sectors, including water. However, the findings were indicative only and were not based on any primary valuation studies.

Despite the aforementioned studies that have explored aspects of water quality and valuation in Ireland, no major CE valuation exercise on water quality features has been conducted to date. Moreover, no studies have attempted to estimate the value of achieving good ecological status arising

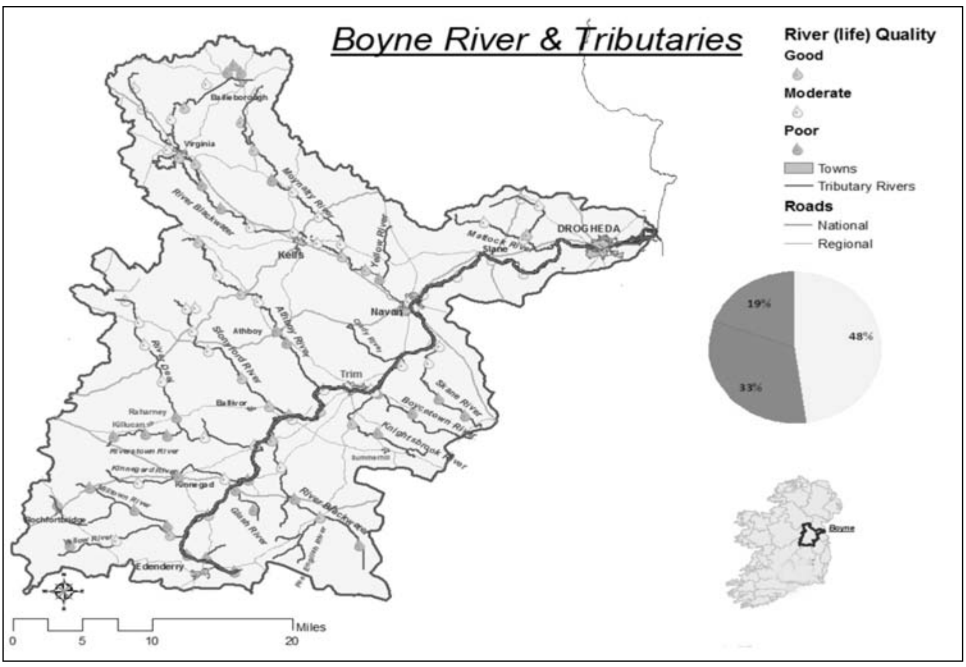
[2] The purpose of the studies may differ in the final use of the derived economic values. For example they may be used in a Cost-Benefit Analysis context, to assess the importance of an issue, to set priorities within a sector, to establish the basis for an environmental charge, etc. (EFTEC 2008).

from the WFD for any Irish water body. This research seeks to fill this gap in the literature and for a case study we focus on the catchment of the River Boyne.

III THE BOYNE CATCHEMENT

In Ireland there are eight RBDs, one of which lies wholly in Northern Ireland. The country is also divided into 40 HAs each of which comprises a single large river catchment or a group of smaller catchments. The River Boyne (Figure 1) belongs to the Eastern RBD. The Boyne system has a lowland catchment covering the fertile plains of Co. Meath, a significant area of Co. Westmeath and parts of Kildare, Offaly, Cavan and Louth. The river rises near Edenderry, Co. Offaly and flows in a north-easterly direction for 70 miles before entering the Irish Sea at Drogheda. The Boyne is one of Ireland's premier game fisheries and both the main channel and the tributaries offer a wide range of angling, from spring salmon and grilse to sea trout and extensive brown trout fishing.[3] Agriculture is the predominant land use within 91 per cent of the Boyne catchment, occupied by arable lands or pasture. The

Figure 1: *Boyne Hydrometric Area (HA)*



[3] http://www.IrishFisheries.com

agricultural sector (arable and pasture) is estimated to generate the greatest total phosphorus load in the Boyne catchment (MCOS, 2002). The rivers Boyne and Blackwater and the Boyne estuary[4] are registered Special Areas of Conservation (SAC) while the Boyne estuary is also a Special Protection Area (SPA). The catchment is also of historical significance as a result of the famous Battle of the Boyne in 1690.[5]

The Boyne River, along with the Suir and the Liffey, are regarded as "… valuable, national and regional resources having major importance in terms of natural and cultural heritage, tourism, recreation and water abstraction for public and industrial uses" (MCOS, 2002, p.9). In addition, following the "Three Rivers Project",[6] the Boyne was one of the rivers in which the national decline in water quality was deemed to be reflected. Therefore, the river can be considered as a representative water body of Ireland where moderate improvements in water quality are likely to be needed to meet GES. This is also reflected in Figure 1[7] which presents the map used in the survey to inform respondents about the geographical distribution of the river system and its current condition (the map also contains 2005 EPA Q-values for the catchment which is the Irish biological assessment index for water quality). From this map it is apparent that only a small percentage of the river system is classified as being of good quality (approximately 19 per cent).

IV METHODOLOGY

The methodology we use to estimate the value of improvements in river ecology is the choice experiment (CE) approach. The CE method is consistent with utility maximisation and demand theory (Bateman *et al.*, 2002). Within this framework environmental goods are valued by applying probabilistic models to choices between different bundles of the good's associated attributes. Individuals will choose to "consume" the bundle of attributes presented in a choice card that gives them the highest utility. Respondents are asked to provide answers to a sequence of such choice cards. The alternatives/bundles are constructed according to experimental design theory which makes it

[4] http://www.npws.ie/

[5] This was a historic battle between two rival monarchs, King James II and his son-in-law, William III which occurred on July 1690. At stake were the British throne, French dominance in Europe and religious power in Ireland.

[6] This Three River Project was a Government initiative, supported by the European Union Cohesion Fund, which started before WFD came into force and had as an objective the development of catchment-based water quality monitoring and management systems for the Boyne, Liffey and Suir river catchments (MCOS, 2002).

[7] Map was designed using GIS data kindly provided by EPA, Ireland.

possible to explore how an individual makes trades-offs in terms of a set of attributes whose levels differ across the choice options on the choice cards.

Choice Experiments have their roots in random utility theory (McFadden, 1974; Ben-Akiva and Lerman, 1985). The conditional logit (CL) is the most commonly used model for analysing choice data but is often rather restrictive in practice as it relies on the assumption of independence of irrelevant alternatives (IIA).[8] The mixed multinomial logit (MMNL) that is used in this study is a more flexible model that relaxes the IIA assumption and allows for preference heterogeneity. The standard indirect utility function underlying the MMNL (as detailed in McFadden and Train (2000)) is given by:

$$\boldsymbol{U}_{ij} = \boldsymbol{V}_{ij} + \boldsymbol{\varepsilon}_{ij} = \boldsymbol{\beta}_i \boldsymbol{X}_{ij} + \boldsymbol{\varepsilon}_{ij} \tag{1}$$

where $\boldsymbol{U}_{ij}$ is the utility held by individual i for alternative j. Utility has two components; one part that is measurable denoted by $\boldsymbol{V}_{ij}$, and a stochastic element, $\boldsymbol{\varepsilon}_{ij}$, that captures the unobserved influences and which is assumed as having an IID extreme value distribution. In the MMNL context the vector $\boldsymbol{\beta}$, which is made up of the coefficients for a number of observed choice attributes and possibly individual characteristics $\boldsymbol{X}_{ij}$, follows a mixing distribution with density $f\,(\boldsymbol{\beta})$. This has the advantage of facilitating preference heterogeneity among the sample of respondents. This density represents the mean and covariance of $\boldsymbol{\beta}$ in the sample population:

$$\boldsymbol{U}_{ij} = \boldsymbol{\beta X}_{ij} + f(\boldsymbol{\beta})\boldsymbol{X}_{ij} + \boldsymbol{\varepsilon}_{ij} \tag{2}$$

In this framework, we can express the representative component of utility as follows:

$$\boldsymbol{V}_{ij} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_m \boldsymbol{M}_{ij} + \boldsymbol{\beta}_p \boldsymbol{P}_{ij} + \boldsymbol{\beta}_s \boldsymbol{S}_{ij} \tag{3}$$

where $\boldsymbol{\beta}_0$ is the alternative specific constant,[9] $\boldsymbol{\beta}_m$ the vector of coefficients attached to the river quality attributes $\boldsymbol{M}$ that follows the normal distribution ($\boldsymbol{\beta}_m \sim N(\mu, \sigma^2)$), $\boldsymbol{\beta}_p$ the price vector, and $\boldsymbol{\beta}_s$ the vector of coefficients related to the individual's socio-economic characteristics $\boldsymbol{S}$. By including price, denoted $\boldsymbol{P}$, as one of the attributes, marginal utility estimated using probabilistic choice models can be converted into willingness-to-pay estimates for changes

[8] According to that property, the ratio of choice probabilities between two alternatives in a choice set remains unaffected by the introduction or removal of other 'irrelevant' alternatives.

[9] An alternative specific constant is a variable representing the *status quo* alternative or the designed choice alternatives which is generally included in the econometric analysis to capture unobservable influences beyond attributes present in the choice sets (Meyerhoff and Liebe, 2009).

in attribute levels (Hanley *et al.*, 2005). In particular, marginal WTP (MWTP) can be derived using the following formula (Adamowicz *et al.*, 1994):

$$MWTP_m = -\frac{\beta_m}{\beta_p} \tag{4}$$

Thus, the MWTP for a change in attribute *m* is the ratio between it and the price attribute. This ratio is often referred to in the literature as the implicit price of attribute *m*. The expected welfare gain (or loss) from alternative policy options which are associated with a change in a bundle of attributes can be estimated based on the Compensating Variation (CV) log-sum formula, described by Hanemann (1984):

$$CV = -\frac{1}{\beta_p}\left[\ln\left(\sum_{j=1}^{J}\exp(V_j^0)\right) - \ln\left(\sum_{j=1}^{J}\exp(V_j^1)\right)\right] \tag{5}$$

where $\boldsymbol{\beta_p}$ is once again the coefficient of the monetary attribute defined as the marginal utility of income, and $\boldsymbol{V_j^0}$ and $\boldsymbol{V_j^1}$ represent the deterministic part of the indirect utility function before and after the policy change.

Within the CE framework, the value of a good is derived by separately evaluating individuals' preferences for each of the attributes that characterise that good rather than eliciting the preferences for the good as a whole. In this framework it is possible to explore how households within a catchment, value different improvements related to the river's environmental condition that the WFD is supposed to deliver.

V SURVEY DESIGN AND DATA

The survey instrument employed in the study evolved through consecutive steps recommended for a CE (Hoyos, 2010). These steps include the selection of attributes, the definition of attribute levels, the choice of the experimental design, the construction of the choice sets and the measurement of preferences. Input from experts, focus groups, cognitive interviews and pilot testing contributed to the survey development. The input of the focus groups was necessary to identify the aspects of the river's ecological status that are important to residents living within the catchment, and to understand expert opinion on water quality issues in the Boyne. The first focus group was organised with experts, namely river managers and ecologists who are directly involved in the establishment of the RBD and the River Basin Management

Plans. These included the RBD Co-ordinator for the Boyne, the relevant consultancies that contribute to the development of the management plans, scientists from the EPA responsible for each HA and a Teagasc specialist on water matters.

The overall aim of the consultation with the experts was to help shape the agenda for later focus group discussions, identify a preliminary set of attributes and also to extract background information for the HA to be used in the valuation scenario of the questionnaire. The second focus group involved a sample from the local population. The suitability of visual tools (maps and show cards) and the capability of participants to answer the choice sets were examined. In particular, the appropriate level of choice task complexity was explored. Focus groups also served to derive values for the price attribute through the use of an open-ended elicitation question. Finally, a pilot survey tested the questionnaire's efficiency and derived the priors to be used in the next step of experimental design's construction.

According to the Directive, progress towards GES is monitored by a combination of biological and chemical indicators. As a result, one of the non-market benefits that were considered from the beginning for inclusion as an attribute in the choice experiment was the provision of improved ecosystems. The second attribute included was improved conditions for recreation in and around the water body. Finally, another feature that was considered was the aesthetic appearance of the water environment in terms of water clarity, plant growth and odour. Feedback from focus groups suggested that the condition of river banks was another important element of the river's environmental quality and therefore it was included in the final group of attributes. Show cards of illustrations were employed to explain attributes and levels to the respondents. Both focus groups suggested an increase in annual tax payments as a payment mode for the next 10 years since domestic water service charges at a national level were not implemented at the time of the survey (such charges have been used as a payment vehicle in equivalent UK studies). As a result, four environmental river related attributes and an annual cost attribute were employed. The river attributes of water appearance, recreational opportunities and river life were all specified using three levels. River Banks were specified with two and the annual Cost attribute was presented with six levels. Table 1 presents the five attributes and their associated levels.

Following the selection of attributes and levels, the experimental design of the choice cards was generated. A Bayesian efficient choice design was employed. The design was derived using the D_b-error criterion which takes the determinant of the Asymptotic Variance-Covariance matrix of the parameter estimates as its design criterion to be optimised. Hence, the lower the D_b-error

Table 1: *Attributes and Levels in Choice Experiments*

Attribute	*Description*	*Levels*
River Life: Fish, Insects, Plants	Composition and abundance of biological elements (fish, plants, invertebrates, mammals and birds)	*Three levels:* 1. Poor 2. Moderate 3. Good
Condition of River Banks	Level of erosion and presence of vegetation (scrubs, trees) and animals (mammals and birds)	*Two levels:* 1. Visible erosion that needs repairs 2. Natural looking banks
Water Appearance	Clarity, plant growth, visible pollution, noticeable smell	*Three levels:* 1. No improvement 2. Some improvement 3. A lot of improvement
Recreational Activities	Number of activities available	*Three levels:* 1. No fishing and swimming 2. No swimming 3. All available (walking, boating, fishing, swimming)
Cost	Annual household taxation for 10 years	*Six levels:* €0, €5, €10, €20, €40, €80

the higher the efficiency of the experimental design (Bliemer and Rose, 2006). In both the pilot and the main survey four choice cards were presented to each respondent. Prior estimates from the pilot survey were used to create the efficient design in the main survey instrument. In addition, restrictions were placed on certain attribute level combinations in order to take account of possibly incompatible attribute interactions (e.g. no improvement in Water Appearance and all the Recreational Activities are possible should not appear as levels on the same choice card).

The design, with four blocks of four choice cards, allowed for nonlinear effects in all attributes except the River Banks attribute, while socio-economic variables were considered by interacting them with the alternative specific constant representing the No Change *status quo* option (SQ). As Figure 2 shows, three options appeared on each choice card, two showing river improvements and a No Change (Zero Payment or *status quo)* alternative that was constant across all choice sets and was assigned a €0 cost. The questionnaire also included questions related to general attitudes towards environmental issues and participation in water activities as well as questions that solicited standard socio-economic information. A cheap talk script[10] was also included in the survey.

Figure 2: *Example of a Choice Card Concerning the Boyne River*

	No Change	*Option A*	*Option B*
River Life: Fish, insects, plants	Poor	Moderate	Good
Water Appearance	No improvement	Some improvement	A lot of improvement
Recreational Activities	Walking Boating	Walking Boating Fishing	Walking Boating Fishing Swimming
Condition of River Banks	Visible erosion that needs repairs	Natural looking banks	Visible erosion that needs repairs
Increase in annual tax payments by household for next 10 years	€0	€5	€80
Which do you like best?	☐	☐	☐

A total of 252 households were interviewed face to face during the autumn of 2010. A multi-staged quota controlled probability sampling procedure with randomly selected starting points was employed. The response rate was approximately 60 per cent. The Boyne catchment's respondents' profile revealed that 61 per cent belonged to the lower middle and skilled working class, 11 per cent belonged to the upper middle and middle class, 17 per cent to the category "other" working class while 10 per cent were farmers.

[10] A cheap talk script, initially suggested by Cummings and Taylor (1999), attempts to reduce the hypothetical bias that stems from the hypothetical nature of the experiments describing and discussing the propensity of respondents to exaggerate stated WTP (Carlsson *et al.*, 2005). In particular, the cheap talk treatment contained the following text: "Finally, we would like to mention that some people say they are willing to pay more in surveys for these types of improvements in rivers quality than that they actually would pay if the situation were real. This is because when people actually have to part with their money, they take into account that there are other things they may want to spend their money on."

Furthermore, 52 per cent were male, 61 per cent were 35 years old and over, 39 per cent had education higher than secondary and 50 per cent were full time employed. Other interesting characteristics of the sample were that 78 per cent of respondents stated that they were concerned about the environment, 16 per cent were aware about a specific water related policy in the catchment and 37 per cent found the general environmental quality (water and surroundings) of the Boyne river system unsatisfactory. Mean distance of households to the closest accessible tributary was about 2 kilometers. Finally, 13 per cent of the respondents were identified as protesters, 9 per cent as true zero bidders and 77 per cent as positive bidders.

VI RESULTS

Violation of the IIA property based on the Hausman-McFadden test[11] (Hausman and McFadden, 1984) suggested that estimating the model as a CL could generate misleading results. After considering different model diagnostics[12] (Log-Likelihood (LL) function, ρ^2, BIC and percentage of cases correctly predicted) and the Likelihood Ratio (LR) tests of different models, the MMNL was revealed to be more flexible and superior compared to other models tested (CL and Nested MNL).[13] In addition, the combination of

[11] A violation of the assumption occurs whenever the Hausman-McFadden IIA test value is strictly higher than the critical value for the χ^2 statistic which in our case was 16.92. Hence, acceptance of IIA was firmly rejected with the Hausman statistic being large and statistically significant at the 5 per cent level.

[12] The ρ^2 is defined as: $1 - (LL(\hat{\beta})\ /\ LL(0))$ where $LL(\hat{\beta})$ and $LL(0)$ are the log-likelihoods for the estimated model and the model in which all parameters are set to zero respectively. The Bayesian information criterion (BIC) can be used to discriminate between un-nested models by also placing a penalty on the number of parameters. The BIC is defined as follows: $BIC = -LL(\hat{\beta}) + (P/2) \times ln(N)$, where P is the number of parameters and N is the number of respondents in the sample.

[13] In particular, an overall observation was that inspection of the χ^2 statistics suggested that the MMNL models (base and extended) were superior to their CL and NMNL model equivalents, thereby providing evidence of preference heterogeneity across respondents for the river attributes. The predominance of the MMNL model was also deduced by comparing the model diagnostics of the MMNL models against those of the CL and the NMNL models for both base and extended models. These findings are in accordance with the improvements observed in the ρ^2, BIC statistic and percentage of cases correctly predicted statistics. Hence, although there were additional parameters to be estimated, as measured by the peudo-R^2s, there appeared to be improvement in fit in the MMNL models compared to their simpler CL and NMNL counterparts. Moreover, the BIC statistics indicated that this improvement remained even after penalising for the loss of parsimony for the extended model. This implies the presence of considerable preference heterogeneity and vindicated the move away from the base CL model and the simpler NMNL specifications. Regarding the latter model it is noted that its flexibility lies in the possibility of the variance of the unobserved component of utility being different across groups of alternatives in the choice set (Hensher and Greene, 2002).

including observed individual-specific characteristics (in order to capture observed heterogeneity) as well as unobserved sources of preference heterogeneity led to overall improvements in model fit. The LR-test statistic of 105.72 for the extended MMNL model with individual-specific interactions was higher than the χ^2 critical value of 18.31 (with 10 degrees of freedom[14] at α= 0.05) and as a result the extended model produced a significantly higher LL function than the model with only river attributes variables and the alternative specific constant that represents the *status quo* option.[15]

The observed individual characteristics included different groups of variables such as socio-economic (gender, if full-time employed, if belonging to middle class) and psychometric (if respondent chose by only following her instinct, by thinking what family and friends would expect her to choose and perceived degree of cognitive burden related to the choice tasks). Other variables were location (calculated distance from closest tributary) and knowledge and belief related (if respondent believed that the river's general environmental quality was unsatisfactory, if was not sure whether concerned about the environment and if respondent was aware about any water policy in Ireland).

The non-cost attributes (River Life, Appearance, Recreation and River Banks) were specified as random with normal distributions. The normal distribution allows for the possibility that respondents may have a negative or positive preference for each of these attributes. For example, for the river banks attribute some respondents may like riverbanks without vegetation that makes them more accessible, while other respondents may find natural looking banks more aesthetically appealing. Furthermore, we follow the relatively common practice in the literature and hold the cost coefficient fixed. This makes it convenient to interpret the model results as the WTP for each attribute is distributed in the same way as the attribute's coefficient. Revelt and Train (1998) also point out that fixing at least one coefficient in a random parameter logit model is recommended for reasons of identification and stability. Parameter estimates were generated using 500 Halton draws (Greene, 2002). It should also be noted that the panel dimension of the data was considered in the estimation process.

Results from both the base and extended models are reported in Table 3. The first model includes only the river and cost attributes along with *status quo* alternative specific constant. It should be noted that in the models the SQ takes the value 1 for the alternative describing the SQ/No Change option and indicates a preference for the *status quo* while zero indicates a preference for

[14] There are 10 degrees of freedom because of the inclusion of 10 individual-specific characteristics in the extended MMNL model.
[15] The statistical package NLOGIT (Version 4) was used to estimate the models (Greene, 2002)

Table 2: *Definition of Variables Included in Discrete Choice Model*

Variable Name	*Description*
River Life _G	River Life (fish, insects, plants): Good relative to Poor
River Life _M	River Life (fish, insects, plants): Moderate relative to Poor
Appearance _A	Water Appearance: A lot of improvement
Appearance _S	Water Appearance: Some improvement
Recreation _A	Recreational Activities: Walking, Boating, Fishing, Swimming
Recreation _S	Recreational Activities: Walking, Boating, Fishing
River Banks	Condition of River Banks: Natural looking banks relative to Visible erosion that needs repairs Cost Household's annual tax payments for the next 10 years (€/year) SQ *Status quo* (No Change alternative) Gender 1 if respondent is male, 0 if female Fullempl 1 if respondent is full-time employed, 0 otherwise Middlecl 1 if chief income earner belongs to the upper middle or middle class, 0 otherwise
Waterpolicy	1 if respondent is aware of any specific water related policy taking place in Ireland at the moment or in the past, 0 otherwise
Nsconcerned	1 if respondent is not sure thinking of him/herself as being concerned about the environment, 0 otherwise
Unsatisfqual	1 if respondent describes river's general environmental quality (water & surroundings) unsatisfactory, 0 otherwise
Instinct	1 if respondent chose by only following her instinct, 0 otherwise
Socialcon	1 if respondent chose according to what family/friends would expect/like her to chose, 0 otherwise
Cognitive	Total score of cognitive ability, measured on a 1 to 7 likert scale, according to perceived degree of difficulty concentrating on the task, remembering the necessary information, thinking clearly and logically and choosing the best option. The smaller the score the higher the degree of difficulty.
Distance	Continuous variable of distance in kilometer from respondent's townland to the closest tributary

one of the other positively priced alternatives. The second model includes these same variables as the base model but also incorporates aspects of observed heterogeneity by enriching the specification with respondents' various characteristics (socio-demographic, belief, psychometric and other variables) which are necessarily interacted with the SQ variable.[16] Results show that in the extended model all river attributes apart from Recreation_S were positive and statistically significant. Cost was negative and significant while the SQ parameter is insignificant. As far as unobserved heterogeneity is

[16] Since attributes of the individual remain the same across all alternatives the effect of individual characteristics are not identifiable in the probability of choosing specific alternatives and thus, cannot enter directly into the model on their own, as they would drop out from the estimation.

concerned, standard deviations of all river attributes were statistically significant at conventional levels, indicating statistically different preferences for these attributes across respondents. Overall the model was statistically significant with a χ^2 value of 617.64, against a χ^2 critical value of 38.85 (with 26 degrees of freedom at $\alpha = 0.05$).

Table 3: *Model Results*

	Model 1-Base		*Model 2-Extended "Best fit"*	
	Estimated	*t-ratio*	*Estimated*	*t-ratio*
River Life _G	1.911	(2.651)***	1.532	(2.745)***
River Life _M	2.995	(4.562)***	2.134	(4.107)***
Appearance _A	3.053	(3.863)***	1.881	(3.481)***
Appearance _S	0.675	(1.017)	0.832	(1.751)*
Recreation _A	1.982	(2.414)**	1.220	(2.099)**
Recreation _S	0.589	(1.052)	0.302	(0.756)
River Banks	2.952	(3.821)***	1.638	(3.076)***
Cost	–0.075	(–4.493)***	–0.056	(–4.311)***
SQ	–0.510	(-0.611)	2.288	(1.611)
GenderSQ			–1.893	(–2.439)**
FullemplSQ			–2.075	(–3.108)***
MiddleclSQ			2.472	(2.383)**
DistanceSQ			0.256	(3.137)***
WaterpolicySQ			–2.373	(–2.260)**
NsconcernedSQ			5.779	(3.255)***
UnsatisfqualSQ			–1.883	(–2.523)**
InstinctSQ			1.746	(2.368)**
SocialconSQ			1.343	(2.121)**
CognitiveSQ			–0.121	(–2.062)**
St. Dev. of parameters				
River Life _G	3.529	(3.987)***	2.658	(2.254)**
River Life _M	2.726	(3.725)***	1.967	(2.690)***
Appearance _A	3.462	(4.376)***	2.302	(3.233)***
Appearance _S	5.399	(4.469)***	3.195	(4.511)***
Recreation _A	3.802	(3.783)***	2.391	(2.184)**
Recreation _S	3.199	(4.281)***	1.767	(3.179)***
River Banks	5.821	(4.148)***	3.695	(4.575)***
LL	–671.270		–618.409	
χ^2	564.649		617.637	
ρ^2	0.30		0.33	
BIC	714.30		687.98	
Correctly predicted	47%		50%	
Observations	868		844	
# of respondents	217		211	

(*) indicates significant at 10 per cent; (**) indicates significant at 5 per cent; (***) indicates significant at 1 per cent.

It is interesting to note that the River Life attribute seems to be an anomaly as the coefficient of the Good level is lower than the coefficient of the Moderate level. However, performing a Wald test for possible linear restrictions indicates that the null hypothesis of equal coefficients for the River Life attribute cannot be rejected[17] (at the 95 per cent confidence level). This result would suggest that preferences between the River Life levels Poor and Moderate and between Poor and Good are linearly related. It is possible that the ecological conditions variable could have been coded using just two levels (Poor *versus* High or Moderate).

Various socio-economic, psychometric and attitudinal interaction regressors were found to be significant determinants of choice. In line with a priori expectations, respondents who were full-time employed, who had knowledge of previous or current water policy in Ireland, who were unsatisfied about the environmental conditions of the local river and who lived closer to the river or one of it's tributaries were significantly less likely to select the No Change alternative on the choice cards. In addition, respondents who experienced less cognitive difficulty and were male were also significantly less likely to choose the No Change alternative. In contrast, respondents who belonged to the upper/middle class and who were not sure if they were concerned about the environment, who trusted their instinct in making-up their minds and who were concerned about what their circle of friends or relatives expected them to choose, were significantly more likely to choose the No Change alternative. The extended model also highlights the significant role of psychometric variables which is often ignored in a choice modelling context and provides evidence on deviation from a behavior according to which people only choose by fully consulting their own preferences in a rational manner. Although these behavioural issues are not expanded upon in the current paper they are an interesting avenue for further investigation.

Table 4 reports the implicit prices (mean marginal WTP estimates) of the river attributes along with their 95 per cent confidence intervals estimated using the Krinsky and Robb (1986)[18] procedure using 1,000 draws. Most of these marginal WTP are statistically significant showing that the public is

[17] Testing H_0: River Life _G = River Life _M, Wald Statistic was 3.196 and probability from χ^2 with 1 degree of freedom 0.0737. Regarding H_0: Appearance _A= Appearance _S, Wald Statistic was 10.697 and probability from χ^2 with 1 degree of freedom 0.001.

[18] Krinsky-Robb procedure estimates the empirical distribution based on *N* random drawings from the multivariate normal distribution defined by the coefficients and covariance matrix estimated from the logit model (Krinsky and Robb, 1986). This technique is used more often than the traditional bootstrap technique in estimating WTP confidence intervals because of its relative efficiency. The delta method could also be used but since it depends on the assumption that WTP is symmetrically distributed, it yields symmetric confidence intervals. This is considered inappropriate as it will not reflect the skewness of the distribution of the marginal WTP.

supportive of improvements related to surface river water. Having said that, the lower bounds on the confidence intervals in Table 4 suggest that the implicit price for moderate improvements in water quality and moderate levels of recreational activities may be zero. This observation would suggest that residents of the catchment are willing to pay positive amounts to achieve larger improvements in the river attributes assessed but may be less likely to pay for only moderate changes. It is also worth noting that the confidence intervals reported for the implicit prices are relatively wide. This is a common finding in the literature where calculated implicit prices for the random parameters in a mixed logit model will generally have larger confidence intervals compared to the basic conditional logit model (Wang *et al.*, 2007). This is due to the fact that the mixed logit models are accounting for the variations in people's preferences for these attributes; variations that can be often represented by very wide distributions. The wide confidence intervals reported may also be partly due to the relatively small sample size used in this study.

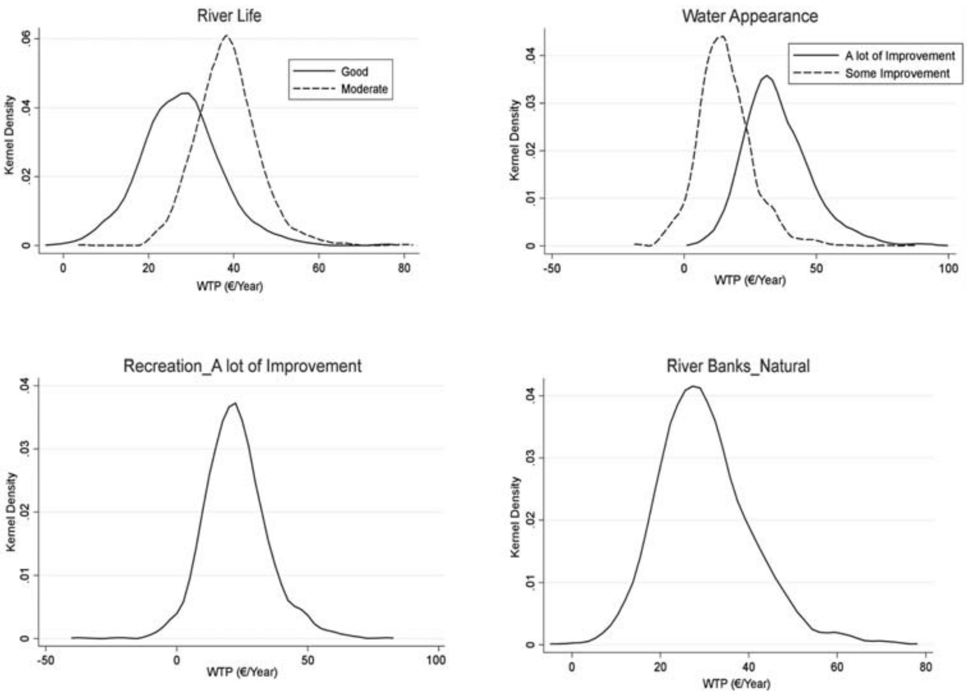
Table 4: *Implicit Prices and Confidence Intervals for Boyne River**

River Life _G	27.60
	(9.47, 47.95)
River Life _M	38.47
	(25.04, 54.68)
Appearance _A	35.44
	(14.60, 66.40)
Appearance _S	15.62
	(–2.95, 38.75)
Recreation _A	22.67
	(0.63, 49.33)
Recreation _S	6.15
	(–8.41, 23.03)
River Banks	30.10
	(12.40, 53.37)

* Model 2- Extended. 95 per cent confidence interval in brackets.

The results of this analysis are also presented using plots for the conditional marginal WTP distributions as shown in Figure 3. The kernel-smoothed distributions of the individual-specific marginal WTP estimates conditional on observed choices (Hensher and Greene, 2003) illustrate that for the river attribute Appearance, theoretical expectation of decreasing marginal utility is reflected in the magnitude of individual-specific WTP estimates.

Figure 3: *WTP Distributions for the Attributes of River Improvements (Extended Model)*



Compensating Surplus (CS) estimates for the catchment were calculated according to formula (5). However, for the MMNL model it was required to account for the heterogeneity, meaning that the expected measure of CS had to be integrated over the distributions of taste in the population. Hence, the integral of the estimated distributions for the taste is also approximated by simulation from 1,000 draws, following the Krinsky and Robb (1986) procedure. CS estimates based on the extended model for four different policy scenarios were estimated as presented in Table 5.

The CS estimates represent respondents' average WTP to move from the state of the world given in the baseline (*no change* in ecological status of the catchment) to the state of the world that results from the change in a number of the river attributes under four alternative scenarios. The levels of each attribute under each of the alternative scenarios are also presented in Table 5. In calculating the utility associated with the baseline *no change* in ecological status of the catchment' (V_j^0) in Equation (5), we took account of the

Table 5: *Scenario Descriptions and Associated CS Values (€/household/year)*

	Scenario 1 High Impact Management	*Scenario 2 Medium Impact Management*	*Scenario 3 Medium Impact Management*	*Scenario 4 Medium Impact Management*
River Life: Fish, insects, plants	Good	Moderate	Moderate	Good
Water Appearance	A lot of improvement	A lot of improvement	Some improvement	Some improvement
Recreational Activities	Walking Boating Fishing Swimming	Walking Boating Fishing Swimming	Walking Boating Fishing Swimming	Walking Boating Fishing Swimming
Condition of River Banks	Natural looking banks	Natural looking banks	Visible erosion that needs repairs	Natural looking banks
Compensating Surplus (mean)*	65.68 (18.49,134.46)	75.56 (21.98,145.35)	26.02 (–5.70, 68.96)	23.32 (–9.01,68.95)

* Model 2- Extended. 95 per cent confidence interval in brackets.

proportion of the Boyne catchment classified as being of poor, moderate or good status as defined by the EPA (2005) and shown in Figure 1.[19]

The results indicate that the CS for the change from the *no change* to the different scenarios increased as greater improvements in river conditions in the catchment were considered resulting in positive utility. The greatest mean CS was achieved under Scenario 2 the medium impact management scenario that ensures moderate levels of river life along with the highest levels for all the other river attributes. Only Scenarios 2 and 1 ensure a statistically significant positive welfare impact. In any other medium impact management scenario where even one of the other attributes are not at the highest level, the associated CS estimates are not statistically significantly different from zero.

[19] In calculating the utility associated with the '*no change* in ecological status of the catchment' 19 per cent of the catchment was assumed to be of good ecological status, 48 per cent moderate ecological status and 33 per cent of poor ecological status. Within our log sum calculation (Equation (5)) V_j^0 assumed the good ecological status to be associated with good levels of river life, a lot of improvement in water appearance, all recreational activities possible and natural looking river banks; Moderate ecological status was associated with moderate levels of river life, some improvement in water appearance, some recreational activities possible and natural looking river banks while poor ecological status was associated with poor levels of river life, no improvement in water appearance, few recreational activities possible and visibly eroded river banks.

VII DISCUSSION AND CONCLUSION

In this study, we applied a choice experiment to determine what values the public places on improvements to a water body in Ireland as envisaged under the WFD. Four attributes were selected to represent improvements under the Directive. These were river ecology, aesthetics, potential for recreation and condition of river banks. Respondents living in different parts of the river basin were asked to value the characteristics simultaneously and make trade-offs in terms of the levels of each characteristic.

We found significant marginal WTP values attached to improvements in the river ecology. From a policy perspective, both the estimated implicit prices of the attributes and the CS estimates demonstrated that the households in the Boyne do not just have preferences for quality improvements to acceptable levels but they also prioritise these improvements. As a caveat, it should be noted that until recently, households in Ireland have not been familiar with paying for drinking water services or environmental improvements and the lack of a relevant well established mechanism for water payment may have had an impact on the reported WTP estimates. On the other hand, it should be borne in mind that successive government campaigns have made domestic residents more aware of both the supply and environmental costs of using water domestically and of the impacts that other human interactions with water bodies can have. It is also important to keep in mind the environmental condition of the river as well as the general economic and political situation at that point of time that the study was conducted in the Boyne catchment when assessing the reported WTP values.

The welfare impact scenario results, calculated using the log-sum formulae, also demonstrated that improvements in characteristics other than just the ecological status of the river contribute to high CS estimates. In this context, it is important for river managers to realise the public's preferences, when setting catchment policy for a specific river and for decision making to be more targeted towards these preferences. In addition, the scenarios analysed provide evidence of the magnitude of benefits derived by the Boyne catchment households that could inform decisions related to the implementation of "polluter pays" and cost recovery principles. Having said that, given the wide confidence intervals associated with the reported estimates in Table 5 we would caution catchment managers in making any water policy decisions based solely on the presented welfare estimates. Nevertheless, these values could be included in a Cost-Benefit context in order to broadly indicate any potential "derogations" in the case of the Boyne. With regard to this concept, Article 4 of WFD states that exemptions are possible if the cost of reaching the GES is disproportionate.

Model results also indicated that accounting for both observed and unobserved individual heterogeneity produced a better fitting model. In particular, awareness of water related policies, perception of degradation of the river's environment and full-time employed respondents are more likely to agree to improvements taking place in the Boyne catchment rather than preserving the current situation. As expected, households located in close proximity to the river are also less likely to opt for the No Change scenario. In addition, from a methodological point of view there is evidence that less (perceived) cognitive burden involved in the CE task results in a higher probability of respondents choosing a non-*status quo* option. Overall, CEs do seem promising in providing estimates for the value of achieving ecology related improvements under the WFD, especially for non-marketed characteristics. In particular, the main advantage of CEs is that they can incorporate variations in both environmental quality and socio-economic characteristics across sites, which would seem a priori to be the biggest drivers of differences in value.

As pointed out by Birol *et al.* (2006), in order to achieve maximum economic efficiency (where marginal social benefits are equal to marginal social costs) or at the very least to try and move towards achieving it for water resources, it is necessary to establish the full value of achieving GES of these water resources, and to incorporate this into private and public decision making processes While we have attempted to do this for one river catchment body in this paper further research is needed in order to examine the value of achieving GES across all water bodies in Ireland.

Regarding the limitations of the current study, the households surveyed were all local (based within the Boyne catchment) which ignores the potential value placed on improving the environmental quality of the Boyne for others outside of the catchment and especially for specific interest groups such as fishermen that travel from further afield. Estimating the value of achieving GES for these non-catchment residents is an area for further research. Finally, another interesting avenue for future research would be to use the study's results to inform benefit transfer technique in an attempt to place a value of achieving GES in a series of alternative water bodies in Ireland based on a classification of their attributes and the socio-economic characteristics of their catchment populations. Also, benefit transfers from (or towards) other catchments in Europe, that have similar characteristics in terms of attributes and population could also be used to inform policymakers on the value of these other water bodies achieving GES and the results presented in this paper could be used to test for the magnitude of transfer errors in such a benefit transfer approach.

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