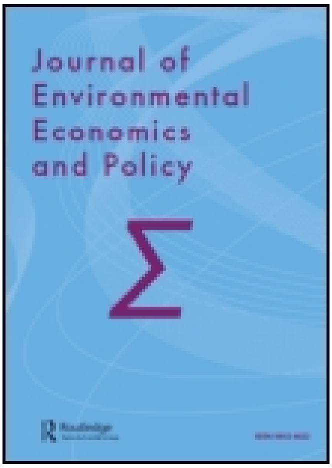

Journal of Environmental Economics and Policy
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/teep20

The value of scientific information on climate change: a choice experiment on Rokua esker, Finland

Phoebe Koundouri [a] , Eva Kougea [a] , Mavra Stithou [a] , Pertti Ala-aho [b] , Riku Eskelinen [b] , Timo P. Karjalainen [c] , Bjorn Klove [b] , Manuel Pulido-Velazquez [d] , Kalle Reinikainen [e] & Pekka Matias Rossi [b]

[a] Department of International and European Economic Studies , Athens University of Economics and Business , Athens , Greece

[b] Department of Process and Environmental Engineering , Water Resources and Environmental Engineering Laboratory, University of Oulu , P.O. Box 4300, Oulu , 90014 , Finland

[c] Thule Institute, University of Oulu , P.O. Box 7300, Oulu , 90014 , Finland

[d] Research Institute of Water and Environmental Engineering (IIAMA) , Universitat Politècnica de València , Camino de Vera s/n, 46022 , Valencia , Spain

[e] Poyry Finland Oy , Tutkijantie 2 A-D, 90590 , Oulu , Finland

Published online: 05 Jan 2012.

Journal of Environmental Economics and Policy
Vol. 1, No. 1, March 2012, 85–102

The value of scientific information on climate change: a choice experiment on Rokua esker, Finland

Phoebe Koundouri[a]*, Eva Kougea[a], Mavra Stithou[a], Pertti Ala-aho[b], Riku Eskelinen[b], Timo P. Karjalainen[c], Bjorn Klove[b], Manuel Pulido-Velazquez[d], Kalle Reinikainen[e] and Pekka Matias Rossi[b]

[a]*Department of International and European Economic Studies, Athens University of Economics and Business, Athens, Greece;* [b]*Department of Process and Environmental Engineering, Water Resources and Environmental Engineering Laboratory, University of Oulu, P.O. Box 4300, Oulu 90014, Finland;* [c]*Thule Institute, University of Oulu, P.O. Box 7300, Oulu 90014, Finland;* [d]*Research Institute of Water and Environmental Engineering (IIAMA), Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain;* [e]*Poyry Finland Oy, Tutkijantie 2 A-D, 90590 Oulu, Finland*

(*Received 3 October 2011; final version received 25 November 2011*)

This article presents an application of the choice experiment method in order to provide estimates of economic values generated by water quantity improvements in the environment. More importantly, this is the first choice experiment study valuing scientific information and in particular scientific information on climate change. The case study of interest is Rokua in Northern Finland, a groundwater dependent ecosystem very sensitive to climate change and natural variability. The study deals with the uncertainty about the actual dynamics of the system and the effect of future climate change by exploring whether the public values sustained provision of resources for scientific research to better understand long-term environmental changes in Rokua. Data are analysed using a nested multinomial logit and an error component model. Evidence from this study suggests that individuals are willing to pay in order to assure scientific research so as to better understand long-term environmental changes. As a result, policy should consider investing in and supporting related research. Other aspects of water management policy valued by the public are water quantity, recreation, and total land income.

Keywords: choice experiment method; nested logit model; error component model; willingness to pay; improved scientific information; water management practices

1. Introduction

Groundwater resources are declining due to land use and consumption pressures and there is evidence of dramatic changes in aquifer resources in Europe (Kløve *et al.* 2011a). The complexity of the relationships among groundwater and surface water and the failure to understand the consequences of land use and water management result in an information breakdown (Schuyt and Brabder 2004) which can be said to be the root cause of groundwater-dependent ecosystems degradation.

*Corresponding author. Email: pkoundouri@aueb.gr

ISSN 2160-6544 print/ISSN 2160-6552 online

http://dx.doi.org/10.1080/21606544.2011.647450
http://www.tandfonline.com

Climate change introduces an additional element of uncertainty in water resource management in which the future effect of climate change is dependent on trends in both climatic and non-climatic factors (IPCC 2007). But scientific uncertainty is not inherited to the ecosystem and water dynamics. An increase in the epistemic understanding may reduce the overall level of unpredictability in terms of better determining the impact of climate change on water resources and on ecosystems. In the climate change literature, many studies can be found that have concluded that new information may lead to changes in our assessment of uncertainty, for example with respect to carbon cycle (Melnikov and O'Neill 2006) or climate sensitivity (Schlesinger and Andronova 2003). In terms of scientific information and economic aspects of the climate change issue, most of the work has focused on the role of various forms of learning by doing models of endogenous technological change and exploring its influence on lowering future mitigation costs (O'Neill *et al*. 2006). For example, Nordhaus and Popp (1997) estimated the value of early information using the PRICE model, an extension of economics of global warming model.

This article presents a Choice Experiment (CE) initiated as a result of a water quantity problem in Rokua region (Northern Finland), involving an interconnected system of aquifer, lakes and springs. The disturbance of the water dynamics of the system by human activity (mainly caused by peat land drainage by the forest industry) is causing the loss of ecosystem goods and services, affecting recreation and other associated activities. The situation is expected to be exacerbated in the scenarios depicted by climate change projections. The current study considers uncertainty about the actual dynamics of the system and the effect of future climate change by eliciting the value of the reduction of this uncertainty by improved scientific information. According to the authors, this is the first attempt to estimate the value of scientific information using a non-market valuation technique. Furthermore, this is the first attempt that elicits the value of scientific information in relation to climate change. In particular, it is explored whether and how the wider public values scientific knowledge that would increase the understanding of the extent and the nature of the problems related to groundwater-dependent ecosystems' management. In a more general framework, the CE employed here aimed to show how respondents' preferences are shaped under different sustainable water management scenarios and estimate the benefits generated by water management practices and improved scientific information. The contribution of the latter is considered important for the reduction of the risk of a future deterioration and for allowing the accomplishment of the targets of the relevant European environmental legislation, such as Water Framework Directive (WFD) (2000/60/EC) and Groundwater Directive (2006/118/EC). Benefits from achieving good water status are related, apart from the availability of healthy ecosystems, to recreational values and potential tourism opportunities, increase in jobs, scientific value on climate change, etc. Regarding the nature of benefits, the contribution of valuation methods is deemed considerable for the benefits that are more difficult to quantify, for which no value measures can be derived from observing individual choices through markets. This is mainly due to the public good aspect of groundwater quantity, the nature of values we are interested in capturing and the fact that the policy change examined is potential rather than actual.

CEs are one example of the stated preference approach to environmental valuation, since they involve eliciting responses from individuals in constructed, hypothetical markets, rather than the study of actual behaviour. In this framework, respondents are required to trade-off changes in the levels of different attributes that describe the good against the cost of these changes. CEs may capture all of people's preferences for the complementary non-market good (Hanemann 2006). Some of people's motives for valuing the natural environment may differ from those for valuing a market good. People may value the natural environment out of considerations unrelated to their own immediate and direct use of it, or non-use values (Young 2005, Hanemann 2006). CEs have been widely applied for the valuation of environmental goods and services such as wetlands' management (Morrison *et al.* 1999, Carlsson *et al.* 2003, Othman *et al.* 2004, Birol *et al.* 2006, Birol and Cox 2007), groundwater quality and quantity (Hasler *et al.* 2007) and water quality improvements in surface water bodies (Hanley *et al.* 2006, Del Saz-Salazar *et al.* 2009, Brouwer *et al.* 2010, Bateman *et al.* 2011) using modifications of the well-known water quality ladder proposed originally by Mitchell and Carson (1989).

The contribution of this article to the literature is threefold. First, it contributes to water resources, climate change and uncertainty literature by providing one of the first estimates of the value of scientific information by employing CE method. Second, it contributes to the limited but growing application of choice models to water resources in the context of the WFD. Last, it contributes to the economic valuation studies which have estimated values generated from the management of water resources in terms of improvements in water quantity status.

The rest of the article unfolds as follow. Section 2 offers on overview of the CE method and the decision modeling approaches used in this article. Section 3 presents the study site, while Section 4 presents CE application and survey design. The results of the econometric models are reported in Section 5, and Section 6 discusses and concludes with the role of valuation results in policy design.

2. Methodology

CEs 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*. Hence, in a model for economic choice the individual chooses the alternative yielding the greatest realisation of utility (McFadden 2001). However, the fact that it is difficult to describe everything in terms of its attributes or that is possible to make errors in measuring attributes, gave place to the second strong link of CE with economic theory, that of random utility theory (Luce 1959, McFadden 1974). According to the random utility theory, the utility of a choice is comprised of a deterministic component (V) and an error component (ε), which is independent of the deterministic part and follows a predetermined distribution:

$$U_{ij} = V(z_{ij}, s_i) + \varepsilon(z_{ij}, s_i), \tag{1}$$

where, for any individual i, a given level of utility will be associated with any alternative j. The researcher observes some attributes of the alternatives as faced by the individual, labelled $z_{ij}\forall j$, and some attributes of the individual, labelled s_i, and can then specify a function that relates these observed factors to the individual's utility.

Choices made between alternatives will be a function of the probability that the utility associated with a particular alternative j is higher than another alternative h given the set of alternatives A:

$$\begin{aligned} P_{ij} &= \text{Prob}(U_{ij} > U_{ih}\ \forall j \neq h \in A) \\ &= \text{Prob}(V(z_{ij}, s_i) + \varepsilon(z_{ij}, s_i) > V(z_{ih}, s_i) + \varepsilon(z_{ih}, s_i)\ \forall j \neq h \in A). \end{aligned} \tag{2}$$

Assuming that the relationship between utility and attributes is linear in the parameters and variables function and that the error terms are identically and independently distributed (IID) with a Weibull distribution, the probability of any particular alternative j being chosen can be expressed in terms of a logistic distribution (McFadden 1974). This specification is known as the multinomial logit model (MNL). In this model, the choice probabilities have a closed form (Ben-Akiva and Lerman 1985, Swait and Louviere 1993):

$$P_{ij} = \frac{\exp\left(V(z_{ij}, s_i)\right)}{\sum_{h \in A} \exp\left(V(z_{ih}, s_i)\right)} \tag{3}$$

The assumptions about the distribution of error terms implicit in the use of the MNL impose the condition of the independence of irrelevant alternatives (IIA) property.[1] Another limitation of the MNL is the IID assumption of the error terms that implies that cross-substitutions between pairs of alternatives are equal and unaffected by the presence or absence of other alternatives. If the IIA property is violated, then MNL results will be biased; hence, a discrete choice model that does not require the IIA property should be used. Hausman and McFadden (1984) test is employed to examine whether the IIA property is rejected, and therefore use another model which relaxes the IIA assumption. In this article, we use the nested MNL (NMNL) (McFadden 1981) in order to capture substitution patterns in a sense that respondents first choose between Change and No Change and then given that they have chosen Change, they select either Option A or B. Hence, alternatives are grouped according to similarity of the unobserved error terms of the indirect utility. It is noted that although more elaborated models, such as mixed MNL, were considered no evidence for their applicability (preference heterogeneity across respondents for the included attributes) was provided. Among the models that could circumvent the IIA violation, only the error components logit model (ECM) provided a further insight on preference heterogeneity.

This model is estimated similar to NMNL in a sense that Options A and B are in the same nest, while No Change in a second test. According to this model's specification, the random part of utility is decomposed to an individual unobserved effect and other variables that influence choice ($\varepsilon_{ij} = \alpha_i + k_{ij}$) and the possibility for error components in the combined Change nest and the No Change nest is examined.

In the NMNL, the random error terms (in Equation (1)) are assumed to have an extreme value distribution correlated within each nest but not with that of the *status quo*/No Change alternative.

The overall probability of choosing Option A is the product of choosing Change and the probability of choosing Option A among the two options offered ($Prob\ (Option\ A) = Prob\ (A|Change) \times Prob\ (Change)$):

$$P(A/Change) = \frac{e^{V_{A|}\tau}}{e^{V_{A|}\tau} + e^{V_{B|}\tau}} \tag{4}$$

$$P(Change) = \frac{e^{\tau IV}}{e^{\tau IV} + e^{V_{SQ}}} \quad (5)$$

where Change is the Change branch, A and B are the two alternative options, SQ is the *status quo*, IV is the inclusive value on the Change nest, and τ is the coefficient of the IV.

$$IV = \ln(e^{V_{A|\tau}} + e^{V_{B|\tau}}) \quad (6)$$

Utility maximization requires the IV coefficient τ to be in the $0-1$ interval. Values of τ closer to 0 indicate a higher correlation. If τ is 1, then the correlation is 0, which is the case of the MNL; that is, the random components of the alternatives are not similar. Finally, the probability of choosing the SQ/No Change option is as follows:

$$P(\text{No Change}) = \frac{e^{V_{SQ}}}{e^{\tau IV} + e^{V_{SQ}}} \quad (7)$$

3. Case study description

The case study in this article is Rokua esker located in Northern Finland. Eskers are the main aquifers in Finland and many other areas covered by the last glaciation. The Rokua esker area forms part of a long esker ridge stretching inland from the North Ostrobothnian coast (Aartolahti 1973). Rokua is situated 100 km inland from the coast, has an area of 90 km^2 and rises at its highest point about 80 m above the surrounding peat lands making it clearly visible in an otherwise flat landscape. The esker material consists mainly of sand with layers varying in thickness from 30 m to more than 100 m above the bedrock. A deposit of gravel has also been found. Rokua has a rolling terrain because of kettle hole, wave action and aolian dunes (Aartolahti 1973). The eskers were formed during the last deglaciation some 9000–12,000 years ago (Tikkanen 2002). The surrounding peat lands started to form some 8000 years ago between the sand deposits and in some kettle holes (Pajunen 1995). These peat layers have grown to be in some locations more than 5 m thick and have a low permeability. Rokua is a very popular recreation area. There can be found a number of important crystal-clear lakes which are valuable for tourists and summer house owners. Rokua is also an internationally recognized natural reserve and part of the esker is included in the Natura 2000, while the site is the first Geopark in Finland.

However, during the last few decades, a significant reduction in the water level of small lakes has been observed. Rokua is a groundwater-dependent ecosystem and as such, the water level of most of the lakes is a function of the level of the groundwater table of the esker which is naturally recharged. This decline in water quantity has been due to many reasons such as climate change, land use and drainage. Almost all peat lands have been drained for forestry which is a main threat to the esker groundwater and its groundwater-dependent ecosystems (Kløve *et al.* 2011b). However, there is yet a degree of uncertainty as scientific knowledge is lacking on this complex ecosystem. The impacts of drainage and also the natural variability or impact of climate change on groundwater dynamics are not very clear yet. At present, scientific understanding of long-term environmental change is incomplete.

Therefore, uncertainty is surrounding both the ultimate damage likely to be sustained if no action is taken and the extent of the possible environmental gains after the revision of the management.

Finally, in Rokua different socio-economic activities take place and four different stakeholders groups have been identified, namely local residents, second house owners, forestry – peat land industry and visitors, who are hypothesized to derive economic benefits, mainly use values and options values, from peat lands' ecosystem goods and services. The driving forces of water demand in Rokua are strongly linked to local economic policies, mostly related to land use issues, while additional pressures on water shortages are due to natural variability and climate change.

4. Choice experiment survey design and application

4.1. Choice experiment design

It is regarded that the output of this CE will contribute to the revision of management practices in order to achieve and maintain "*good water status*" which ensures sufficient water of good quality for humans and the environment for today and the future. In this framework, designations and actions are ought to be implemented in order to maintain good water quantity in lakes, spring and aquifer and to sustain as many ecological and landscape functions as possible. A package of measures includes the following: (i) restrict peat land drainage in the groundwater area, (ii) expand the conservation area and compensation when legally required and (iii) restore (technical solutions) of peat lands, groundwater and lakes level.

Policy under consideration is characterized by five different management-related attributes. The attributes and their possible levels, in the mid-term horizon (5–10 years from now) depending on whether a policy is implemented or not can be seen in Table 1.

Implementation of a revised water management policy is anticipated to contribute positively to water quantity, as proposed policy options will help lakes to restore their water levels and avoid future possible deteriorations. Environmental improvements are also expected to result to an increase in recreational values as wider public derives a range of benefits other than environmental from the services that wetland provides (Portney 1994). Many CE studies can be found in the literature that have included social and economic attributes into their analysis in order to examine the benefits that people derive from such factors (Morrison *et al.* 1999, Bennett *et al.* 2004, Othman *et al.* 2004, Birol *et al.* 2006). Following findings from the literature, the impact of an economic factor to the process of environmental decisions is being examined through a total land income attribute. Respondents were informed that in the absence of revised management, environmental degradation may result in a decline in the popularity of and the number of visitors to Rokua area, so income from tourist activities will tend to decline. As a result land income (total income opportunities) is expected to become restricted. On the other hand, implementation of proposed scheme will moderately restrict activities associated with logging and peat harvesting but at the same time might render this area an attractive (geo-tourism and/or eco-tourism) tourism location in Finland.

To capture the value of scientific information, an attribute called investment on research, referring to the scientific research to better understand long-term environmental changes in Rokua is included in the analysis. At the moment, scientific understanding of long-term environmental change is incomplete and

Table 1. Water management attributes and levels used in the CE.

Attribute	Definition	Management Level
Water quantity	This attribute refers to the total quantity of water available in groundwater aquifer, lakes and spring	**Increased**: most of the lakes have restored their water level **Same as now**: some lakes have water quantity problems. Current state of water is sustained. **Limited**: water quantity has been considerably declined. The last alternative reflects what is expected to happen in the absence of revised management in the future *(Status quo level)*.
Recreation	This attribute refers to the sum of all values (direct and indirect) derived from recreational activities	**Increased:** environmental improvements result in an increase in recreational values. **Same as now:** current levels of recreational values are sustained. **Low**: This is the case where no measures are taken. As a result of environmental degradation in the absence of the revised management, recreational values are going to decline *(Status quo level)*.
Total Land Income	This attribute refers to the total income opportunities for the local people emerging from economic activities of logging, peat harvesting and tourism industry based in Rokua area	**Same as now:** Total income will remain unchanged. **Restricted**: Total income opportunities will get restricted *(Status quo level)*.
Investment on Research	This attribute refers to the scientific research to better understand long-term environmental changes in Rokua	**High**: More Resources **Medium**: Current Resources *(Status quo level)*. **Low**: Stop current research
Price	One-off payment	0€,10€, 20€, 50€, 100€

uncertainty is surrounding both the ultimate damage likely to be occurred if no action is taken and the extent of the possible environmental gains after a revision of the existing water management. Individuals were informed that currently scientific understanding of complex hydrological functions and interrelationships between different users and their potential impact on water dynamics is limited. Improved scientific knowledge could reduce the overall level of uncertainty regarding future environmental gains for the revision of the management.

Finally, a monetary attribute in the form of a one-off payment per household to a fund for the implementation of the proposed policy options is included to capture

Assuming that the following three water management scenarios were the only choices you had, which one would you prefer?			
Attributes	Scenario A	Scenario B	Scenario C:
			Status quo
Water Quantity	Increased	Same as now	Limited
Recreation	Same as now	Increased	Low
Total Land Income	Restricted	Restricted	Restricted
Investment on Research	High	Low	Medium
One-off Payment	100	50	None
I prefer (Please tick as appropriate)	Option A	Option B	Option C

Figure 1. Sample choice set.

the trade-offs among variables in willingness to pay (WTP) terms and to attach an implicit price on each attribute (Perman *et al.* 2003). Levels of the price attribute were determined during discussions with experts and pre-testing of the questionnaires.

A large number of unique water management scenarios can be constructed from this number of attributes and levels. Experimental design techniques were employed in SPSS to obtain an orthogonal design (Louviere *et al.* 2000, Hensher *et al.* 2005). In this case, orthogonal design consisted of 32 pair-wise comparisons of alternative water management scenarios, which were randomly blocked to four different versions of eight choice sets. An example of a choice card is presented in Figure 1.

Each set contained two different management scenarios and an option to select neither scenario. Inclusion of the "opt out" option in the choice sets is instrumental for achieving welfare measures (Bateman *et al.* 2003). Scenarios A and B are characterized by a change in attributes with respect to the *status quo* alternative. *Status quo* situation reflects what is expected to happen in the absence of revised management in the future, and no payment is required because no management is implemented.

4.2. Survey implementation

The development of CE survey instrument took place over a period of one year and involved initially focus group discussions, face-to-face interviews with local stakeholders, literature review, extensive discussions with experts and pre-testing. The first stage focused on the development of a pilot survey instrument which was carried out in July and August 2010. Pilot questionnaires were targeted at different stakeholders in the area including experts, farmers, land owners, second house owners and organisations or companies working in the implementation area. Discussions with local stakeholders revealed people's understanding of the issues related to the management of water resources and services in Rokua. Respondents' awareness of WFD and the changes it will cause to water management were also a part of the pre-questionnaire. During these discussions with experts, the valuation problem was defined along with the exact attributes to be valued and the level to which these attributes can be increased through the implementation of a policy option. The aim of this first questionnaire was to get an idea of how well the local residents and stakeholders know water quantity and quality problems in Rokua and how concerned they were about the situation. In this questionnaire respondents could freely express their opinions related to water quantity and quality problems in Rokua.

Pre-testing questionnaires were delivered to the respondents in person or by mail after a brief telephone discussion, giving the possibility to clarify the questionnaires' purpose. Overall 38 responses to questionnaires were collected. The main purpose of this pilot survey was to test the readability of the questionnaire and the ability of individuals to complete the choice modelling sections. Pre-testing verified that the questionnaire was appropriate and ensured that the information given to the respondents was comprehensive, easy to understand and presented in such a way that the respondents' cognitive abilities were not strained (Fischhoff and Furby 1988). After the preliminary questionnaire, a seminar was held at the end of September 2010. During the seminar, stakeholders were interviewed about their opinions and thoughts in order to clarify further the CE questionnaire. Making use of the results of preliminary questionnaire and interviews, the survey was re-adjusted and then administered through face-to-face interviews from April to August 2011.

The beginning of the questionnaire introduced the study area and the issue in question. Individuals were provided with an accurate and clear description of attributes and their associate levels. Scientific facts (i.e. the link between local biotopes and groundwater level), possible causes of groundwater level decline, and visual aids (i.e. colour photographs and simplified graphs from previous research results from the area showing the declining trend in groundwater level) were employed to help respondents understand the situation in Rokua and the characteristics of the choice scenarios they have been asked to value. In order to obtain more information for the purpose of the analysis, complementary to the choice modelling section the questionnaire contained debriefing questions and questions that aimed to reveal the environmental consciousness of the respondents. Finally, socio-economic questions were asked. All these questions intend to provide additional information that could affect each respondent's choice on the level of WTP.

The total amount of collected questionnaires was low, mainly due to the low population density in the target area. Total population living in this vast area is 15,000. A random sample of 168 respondents was collected from Oulu and around the municipalities of Utajärvi and Vaala where Rokua area is situated. Interviewed persons in municipalities were either local inhabitants of the area or recreational users of Rokua. It is estimated that Rokua recreational area accommodates about 65,000 guests yearly. Table 2 presents the socio-economic and attitudinal characteristics of the final usable sample, showing that a few deviations of social and economic characteristics between the sample and Finish population are observed with respect to age, household size, and income.

5. Results

5.1. Nested logit and error component models

Violation of the IIA property based on the Hausman-McFadden test[2] (Hausman and McFadden 1984) suggested that estimating the model as a MNL could generate misleading results. A basic NMNL and ECM were initially specified according to which the probability of choosing a particular option was a function of the attributes and the SQ alternative constant. Results are presented in Appendix 1. The models were estimated with LIMDEP 9.0 NLOGIT 4.0 and the full data set of 1328 observations from 166 respondents. In order to account for observed heterogeneity, individual specific characteristics were also included, in extended models as presented in Table 4, interacted with the SQ. Table 3 presents a description of the included individual specific variables and the employed coding.

As the particular focus of this study is on the research variable, its inclusion in the model was considered in different ways. Exploring the possibility of non-linear effects, it was found that the coefficients for moderate and high levels of research, although positive and significant, were not statistically different (Wald Statistic = 2.032, Prob. from χ^2(1 d.f.) = 0.154.) As a result, it was decided to merge those levels

Table 2. Socio-economic and attitudinal characteristics of the respondents.

Variable	Sample average (SD)	Finnish average[a,b]
Gender (% female)	39 (0.489)	51
Age	41.58 (17.47)	41,5
Pensioners (% in 2009)	17.46 (0.379)	27
Students (% in 2009)	22.8 (0.42)	6
Employment (% with full time employment)	40 (0.49)	70,6
Household size	2,14 (1.26)	2,07
Children (% with children)	43 (0.495)	75,6
Number of dependent children in the household	0,51 (1.05)	1,83
Education (% with university degree and above)	35 (0.47)	27,3
Tenure (% own property)	59.63 (0.49)	70
Income (gross in €/month)	2764 (1349.9)	2930
Visited Rokua (% visited)	78 (0.414)	–
Sample size, N	166	5,326,314

Note: [a]Source: Official Statistics of Finland (OSF): http://www.stat.fi; [b]Source: The Social Insurance Institution (KELA).

Table 3. Summary of socio-economic variables.

Variable	Definition
Age	Age of a person (in years)
Gender	Dummy variable equals to 1 if female, 0 if male
Children	Dummy variable equals to 1 if respondents have a children, 0 otherwise
Degree	Dummy variable equals to 1 if the respondents have education with university degree and above, 0 otherwise
Visited Rokua	Individuals who have visited Rokua in the past = 1, 0 otherwise
Income	Income brackets of annual gross household income

Table 4. NMNL and ECM (extended) results.

	NMNL		ECM	
	est.	*t*-ratio	est.	*t*-ratio
Water Quantity	0.344***	3.447	0.400***	4.052
Recreation	0.172*	1.956	0.171**	2.110
Research	0.543***	5.892	0.583***	7.182
Total Land Income	0.122	1.316	0.174**	2.183
Cost	−0.014***	−6.526	−0.017***	−9.939
SQ	−1.986***	−5.397	−8.778**	−2.385
Age × SQ	0.0184***	2.870	0.070	1.205
Gender × SQ	−1.274***	−6.759	−4.437**	−2.517
Children × SQ	−1.210***	−5.360	−4.359**	−2.084
Degree × SQ	−1.013***	−5.360	−3.835**	−2.083
Visit × SQ	1.104***	4.646	4.958**	2.158
Income × SQ	0.033	0.740	0.342	0.655
IV parameters/SD of latent random effects				
No change	Fixed	Fixed	0.877	0.234
Change	0.4601***	2.929	7.214***	5.031
LL	−1158.860	−865.2540		
χ^2	687.7660	923.7392		
Pseudo-R^2	0.23	0.35		
BIC	1.99501	1.51479		
Observations	1208	1208		
No. of respondents	151	151		

Note: *indicates significant at 10%; **indicates significant at 5%; ***indicates significant at 1%.

into one. It is therefore reminded for the analysis that follows that the research variable included in the model is relative to low level.

Considering first the results reported in Appendix 1, overall the models are statistically significant and water, recreation, research and cost attributes are significant determinants of choice in NMNL, while total land income is also significant in ECM. This result shows that after accounting for the panel dimension of the data, the true impact of income on choice is revealed. The cost price is negative, indicating that an alternative is less likely to be chosen if the cost is higher, while other attributes' coefficients conform to theoretical expectation of increasing marginal utility. Considering our variable of interest research, we can see that respondents are more likely to choose an option of high/moderate level compared to low level. The same result holds for recreation and water quantity. Overall, for both models NMNL and ECM (basic and extended) respondents prefer water management practices which provide higher water quantity, recreation and research potential, while total land income attribute has an effect on their choice only under ECM specification. Furthermore, the models also demonstrate a negative and significant coefficient for the *status quo* indicating that *ceteris paribus*, the *status quo* alternative is less desirable than the other options maintained also in both basic and extended specifications.

Regarding the NMNL both basic and extended, the IV estimate is in the (0, 1) interval and hence is consistent with utility maximization. IV value is related to the inverse of the scale parameter capturing correlations among unobserved components of alternatives in the partition. The IV parameter for the No Change branch has been normalized to 1 making possible to inspect the IV parameter and hence if Options A and B are similar or dissimilar for unobserved reasons. The value of the parameter shows a considerable correlation in unobserved factors within the nest. In addition, it is significantly different from zero showing that there exist two totally independent choice models for the two branches and there is evidence for the partition used in these models. In order to test whether the upper bound of (0, 1) has been exceeded, a Wald test is needed. The Wald test is measured as (IV parameter-1)/standard error, which in the case of the basic model yields $(0.381-1)/0.140 = -4.421$ for the Change branch. Comparing the test statistic of -4.421 to the critical value of ± 1.96 we cannot accept the hypothesis that the Change IV parameter is statistically equal to one. The value of the parameter is also significantly different to zero and one in the extended model, showing a moderate correlation in unobserved factors within the nest and warranting the partition. This finding implies that the two branches should not collapse into a single branch and the NMNL model would be preferable.

Regarding the ECM, it is noted that with 500 Halton draws, the error component for the combined alternatives A and B was statistically significant, for both basic and extended models, revealing alternative specific variance heterogeneity (heteroscedasticity) in the unobserved effects of these alternatives. Furthermore, all attributes were significant and of the expected sign.

In addition, the statistically significant extended NMNL and ECM models reported in Table 4 capture observed heterogeneity by incorporating interaction regressors specific to individual respondents accounting for differences between individuals. In particular, interaction coefficients show that respondents who are older and have visited Rokua in the past are more likely to choose the *status quo* than Option A or B, showing that familiarity with the site does not necessarily encourage Change. An opposite effect is observed for male respondents, with children and a higher than secondary education. It is also noted that income has no effect on choice which could be explained by the reluctance of participants to reveal their real income.

Finally, LL function, pseudo-R^2 and BIC diagnostics show that further improvement in the NMNL and ECM specifications was achieved with the inclusion of individual specific interaction regressors. In addition, the LR-test statistic for the extended NMNL model of 420.296 was higher than the χ^2 critical value of 12.6 (with 6 d.f. at $\alpha = 0.05$) and as a result the extended model produced significantly higher LL function than the model with only water management attributes and *status quo* effects. Then, observing the model diagnostics and performing an LR-test (test statistic of 587.212 against a χ^2 critical value of 3.84) between extended ECM and NMNL models, the first seems superior to the latter.

5.2. Estimation of willingness to pay

The CE method is consistent with utility maximization and demand theory (Hanemann 1984); therefore the marginal value of change in water management program attribute can be calculated as:

$$\mathrm{MWTP} = -\frac{\beta_{\mathrm{attribute}}}{\beta_{\mathrm{cost}}} \tag{8}$$

This part-worth (or implicit price) formula represents the marginal rate of substitution between one-off payment and the water management program attribute in question.

Table 5. Implicit prices (per household, one-off payment) for water management attributes from NMNL and ECM and 95% confidence intervals.

Attributes	NMNL	ECM	$IP_{NMNL} = IP_{ECM}$
Water quantity	23.53 (10.95, 35.46)	22.54 (13.44, 32.18)	0.448
Recreation	11.95 (−0.06, 24.11)	9.71 (0.57, 18.88)	0.388
Research	36.92 (24.78, 51.05)	33.50 (24.12, 43.34)	0.351
Total land income	0.00[a]	9.76 (1.50, 17.78)	NA

Note: [a]WTP estimate was not found to be significantly different to zero and is expressed as zero.

Using the Krinsky and Robb (1986) procedure with 1000 draws in LIMDEP 9.0 NLOGIT 4.0., respondents' valuation of water management program attributes and 95% confidence intervals were calculated for the extended NMNL and ECM models and reported in Table 5. Values from basic models are also reported in Appendix 2.

The estimated WTP values for both models indicate that an average household values the improvement in research the most, as it is willing to pay €37 (NMNL) and €33 (ECM) to ensure that the scientific research to better understand long-term environmental changes will not stop. It is also noteworthy that the comparative higher WTP demonstrates the importance of the research in the prospect of reducing uncertainty in the face of climate change. The households also derive positive values from improving water quantity and lastly from increasing recreational values but of less magnitude than research. This may be a result of the high expectations that the public holds for research regardless of (the certainty of) the outcome and of the other benefits that arise from improved knowledge (cultural heritage, research opportunities, visits by scientists, public awareness, etc.). Therefore, implicit prices clearly demonstrate the importance of scientific research for the respondents. The ECM model also provides WTP for land income which is, however, of less magnitude compared to research and water quantity.

The last column shows the approximate significance levels resulting from the Poe *et al.*'s (1994) test of equality of means. Although, the NMNL seemed to provide slightly higher implicit prices, results do not reveal any statistically significant difference at the 5% level between the two models. Finally, it should be also noted that the same test did not reveal any statistically significant different implicit prices between basic and extended models for both NMNL and ECM.

6. Policy implications and conclusions

Water resources provide significant commodity and environmental benefits to society. As a result, the management of water has relevant economic, political, and social implications, as well as ecological consequences. Decision makers often have to face trade-offs between competing uses and conflicting objectives, while attempting to balance economic development and ecosystems' protection. The price signals, that often guide investments and resource allocation in the private sector, are usually absent or distorted for water, not reflecting its real value to society, thus complicating public decision making regarding water management policies (Young 2005). Economic valuation contributes to improved water management decisions by informing decision makers about the full social cost of water use and full benefits of the goods and services that water provides. This information is considered very important in order to comply with targets of relevant European legislation such as these of the WFD. In particular, results can contribute to assess the recovery of costs of water services and effectiveness of water pricing policies and also the existence of "disproportionate costs" compared to the benefits obtained from improvements. Overall, the WFD integrates economics into water management and policy making, contributing decisively to the development of the programme of measures of the new river basin management plans (Heinz *et al.* 2007, Moran and Dann 2008).

In this context, as the WFD is expected to generate substantial non-market values (Bateman *et al.* 2006, Brouwer 2008), the assessment of the economic benefits due to improvements requires necessarily the application of non-market economic valuation techniques, such as the one applied in this study. In particular, the study provides implicit prices for improvements in water quantity, recreation and scientific knowledge in the case of Rokua esker. As we are particularly interested in exploring what values people place on improvements to scientific research, that opts to reduce uncertainty about the effects of future climate changes on groundwater dependent ecosystem, we have included a relevant attribute amongst the chosen attributes that describe alternative water management practices.

The aspect of the value of scientific information is largely not considered in the literature. Yet the level of scientific information on climate change and its provision to all relevant stakeholders and management authorities ease the design of sustainable water management practices as it enables policy makers to adjust management regimes to be more resilient to climate change and natural variability and at the same time achieve public awareness.

The benefit estimates reported in this study reveal that scientific research followed by water quantity status and recreation is not only a significant factor in the choice of a management scenario but is also valued higher compared to other improvements. Particularly, an average household would be willing to pay €33 to €37 to ensure that the scientific research to better understand long-term environmental changes in Rokua will not stop. *Ceteris paribus*, high levels of these attributes increase the probability that a management scenario other than the *status quo* is selected. This study revealed that public's willingness to pay for research exists regardless of the certainty of the outcome. Respondents did not differentiate between moderate and high levels of research but were willing to pay to avoid less research.

Furthermore, individual specific interactions accounting for differences between individuals were incorporated to capture observed heterogeneity. Male respondents, respondents with children and with a higher than secondary education were more likely to prefer a move from the *status quo*, while those who have visited Rokua in the past and older people were more likely to choose the *status quo* option.

Introducing monetary valuation into public decision making contributes to public debate and awareness concerning specific (environmental) problems, while supporting decisions (*ex ante* and *ex post*) taken by policy agencies (Bonniex and Rainelli 1999, Pearce and Ozdemiroglu 2002). The results of this study provide an insight into the return value of the foreseen investment programs in water quantity improvements and help to prioritize limited budgets for WFD implementation or shape future land use and ecosystem protection policies.

Scientific research which reduces the uncertainty on climate change should be encouraged and supported, since results clearly demonstrate the importance of this attribute as well as its relative value compared to other management-related improvements. Findings are expected to guide policy making by providing an estimate of the value that public places on investments in research towards a better scientific understanding that reduces the uncertainty that dominates water resources management, groundwater-dependent ecosystems and climate change.

Acknowledgements

We gratefully acknowledge the financial support from the European Union via the 7th Framework Program GENESIS: Groundwater and dependent ecosystems: New Scientific basis on climate change and land-use impact for the update of the EU Groundwater Directive; WP-6 Groundwater systems management: scenarios, risk assessment, cost-efficient measures and legal aspects. We finally thank two anonymous referees for constructive and insightful comments.

Notes

1. 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.
2. 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 16.87. Hence, acceptance of IIA was firmly rejected with the Hausman statistic being large and statistically significant at the 5% level.

References

Aartolahti, T., 1973. Morphology, vegetation and development of Rokuanvaara, an esker and dune complex in Finland. *Fennia*, 127, 1–53.

Bateman, I.J., *et al.*, 2011. Making benefit transfers work: deriving and testing principles for value transfers for similar and dissimilar sites using a case study of the non-market benefits of water quality improvements across Europe. *Environmental and Resource Economics*, 50 (3), 365–387.

Bateman, I.J., *et al.*, 2006. Analyzing the agricultural costs and non-market benefits of implementing the Water Framework Directive. *Journal of Agricultural Economics*, 57 (2), 221–237.

Bateman, I.J., *et al.*, 2003. *Guidelines for the use of stated preferences techniques for the valuation of preferences for non market goods*. Cheltenham: Edward Elgar Publishing.

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

Bennett, J., Van Bueren, M., and Whitten, S.M., 2004. Estimating society's willingness to pay to maintain viable rural communities. *Australian Journal of Agricultural and Environmental Economics* 48 (3), 487–512.

Birol, E. and Cox, V., 2007. Using choice experiments to design wetland management programmes: the case of Severn Estuary Wetland, UK. *Journal of Environmental Planning and Management*, 50 (3), 363–380.

Birol E., Karousakis K., and Koundouri, P., 2006. Using a choice experiment to account for preference heterogeneity in wetland attributes: the case of Cheimaditida wetland in Greece. *Ecological Economics*, 60 (1), 145–156.

Bonniex, F. and Rainelli, P., 1999. Contingent valuation methodology and the EU institutional framework. In: I.J. Bateman and K.G. Willis, eds. *Valuing environmental preferences, theory and practice of the contingent valuation method in the US, EU and developing countries*. New York: Oxford University Press, 585–612.

Brouwer, R., 2008. The role of stated preference methods in the Water Framework Directive to assess disproportionate costs. *Journal of Environmental Planning and Management*, 51 (5), 597–614.

Brouwer, R., Martin-Ortega, J., and Berbel, J., 2010. Spatial preference heterogeneity: a choice experiment. *Land Economics*, 86, 552–568.

Carlsson, F., Frykblom, P., and Liljenstolpe, C., 2003. Valuing wetland attributes: an application of choice experiments. *Ecological Economics*, 47, 95–103.

Del Saz-Salazar, S., Hernández-Sancho, F., and Sala-Garrido, R., 2009. The social benefits of restoring water quality in the context of the Water Framework Directive: a comparison of willingness to pay and willingness to accept. *Science of the Total Environment*, 407 (16), 4574–4483.

Fischhoff, B. and Furby, L., 1988. Measuring values: a conceptual framework for interpreting transactions. *Journal of Risk and Uncertainty*, 1, 147–184.

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

Hanemann, W.M., 2006. The economic conception of water. In: P.P. Rogers, M.R. Llamas and L. Martinez-Cortina, eds. *Water crisis: myth or reality?* London: Taylor & Francis plc.

Hanley, N., Wright, R.E., and Alvarez-Farizo B., 2006. Estimating the economic value of improvements in river ecology using choice experiments: an application to the water framework directive. *Journal of Environmental Management*, 78, 183–193.

Hasler, B., Lundhede, T., and Martinsen, L., 2007. Protection versus purification - assessing the benefits of drinking water quality. *Hydrology Research*, 38 (4–5), 373–386.

Hausman, J. and McFadden, D.L., 1984. Specification tests for the multinomial logit model. *Econometrica*, 52, 1219–1240.

Heinz, I., *et al*., 2007. Hydro-economic modeling in river basin management: implications and applications for the European water framework directive. *Water Resources Management*, 21 (7), 1103–1125.

Hensher, D., Rose, J., and Green, W., 2005. *Applied choice analysis: a primer*. Cambridge: Cambridge University Press.

IPCC, 2007. Climate change 2007: impacts, adaptation, and vulnerability. *In*: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, eds. *Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge, UK: Cambridge University Press, 1000 pp.

Kløve B., 2011a. Groundwater dependent ecosystems. Part II. Ecosystems services and management in Europe under risk of climate change and land use intensification. *Environmental Science and Policy*, in press.

Kløve, B., *et al*., 2011b. Possible effects of climate change on hydrogeological systems: results from research on Esker aquifers in northern Finland. In: H. Treidel, J.L. Martin-Bordes, and J.J. Gurdak, eds. *Climate change effects on groundwater resources: a global synthesis of findings and recommendations*. London, UK: CRC press.

Krinsky, I. and Robb, R., 1986. On approximating the statistical properties of elasticities. *Review of Economics and Statistics*, 68, 715–719.

Lancaster, K., 1966. A new approach to consumer theory. *Journal of political economy*, 74, 132–157.

Louviere, J., *et al*., 2000. *Stated choice methods: analysis and application*. Cambridge: Cambridge University Press.

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

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

McFadden, D.L., 1981. Econometric models of probabilistic choice. In: C.F. Manski, and D.L. McFadden, eds. *Structural analysis of discrete data with econometric applications*. Cambridge: MIT Press.

McFadden, D.L., 2001. Economic choices. *The American Economic Review*, 91, 351–378.

Melnikov, N.B. and O'Neill, B.C., 2006. Learning about the carbon cycle from global budget data. *Geophysical Research Letters*, 33, L02705.

Mitchell, R.C. and Carson, R.T., 1989. *Using surveys to value public goods: the contingent valuation method*. Baltimore, MD: Johns Hopkins.

Moran, D. and Dann, S., 2008. The economic value of water use: implications for implementing the Water Framework Directive in Scotland. *Journal of Environmental Management*, 7 (3), 484–496.

Morrison, M., Bennett, J., and Blamey, R., 1999. Valuing improved wetland quality using choice modeling. *Water Resources Research*, 35 (9), 2805–2814.

Nordhaus, D.W. and Popp, D., 1997. What is the value of scientific knowledge? An application to global warming using the PRICE model. *Energy Journal*, 18 (1), 1–45.

O'Neill, B.C., *et al.*, 2006. Learning and climate change. *Climate Policy* [Commentary]. Submitted.

Othman, J., Bennett, J., and Blamey, R., 2004. Environmental values and resource management option: a choice modelling experience in Malaysia. *Environmental and Development Economics*, 9, 803–824.

Pajunen, H., 1995. Holocene accumulation of peat in the area of an esker and dune complex, Rokuanvaara, central Finland. *Geological Survey of Finland* [Special paper], 20, 125–133.

Pearce, D.W. and Ozdemiroglu, E., 2002. *Economic valuation with stated preference techniques. Summary Guide*. London: Department for Transport, Local Government and the Regions.

Perman, R.J., *et al.*, 2003. *Natural resource and environmental economics*. 3rd ed. Essex, UK: Pearson Education Limited.

Poe, G.L., Severance-Lossin, E.K., and Welsh, M.P., 1994. Measuring the difference of simulated distributions: a convolutions approach. *American Journal of Agricultural Economics*, 76, 904–915.

Portney, P.R., 1994. The contingent valuation debate: why economists should care. *Journal of Economic Perspectives*, 8, 3–17.

Schlesinger, M.E. and Andronova, N.G., 2003. Climate sensitivity: uncertainties and learning. In: Y. Izrael, *et al.*, ed. *Proceedings of world climate change conference*, Moscow, 168–175.

Swait, J. and Louviere, J.J., 1993. The role of the scale parameter in the estimation and comparison of multinomial logit models. *Journal of Marketing Research*, 30, 305–314.

Tikkanen, M., 2002. The changing landforms of Finland. *Fennia*, 180 (1–2), 21–30.

Schuyt, K. and Brabder, L., 2004. *The economic values of the world's wetlands*. Prepared with support from the Swiss Agency for the Environment, Forests and Landscape. Washington DC: WWF.

Young, R.A., 2005. *Determining the economic value of water: concepts and methods*. Washington, DC: Resources for the Future.

Appendix 1. NMNL and ECM (basic) results.

	NMNL		ECM	
	est.	*t*-ratio	est.	*t*-ratio
Water quantity	0.384***	3.998	0.435***	4.699
Recreation	0.214**	2.531	0.209 ***	2.761
Research	0.514***	5.790	0.551***	7.096
Total land income	0.110	1.237	0.158**	2.072
Cost	−0.014***	−6.508	−0.016***	−9.846
SQ	−1.358***	−6.342	−5.899***	−3.979
IV parameters/SD of latent random effects				
No change	Fixed		3.388	0.994
Change	0.381***	2.714	7.802***	3.275
LL	−1369.008	−964.8493		
χ^2	559.9778	988.2157		
Pseudo-R^2	0.17	0.34		
BIC	2.0996	1.49641		
Observations	1328	1328		
No. of respondents	166	166		

Note: *indicates significant at 10%; **indicates significant at 5%; ***indicates significant at 1%.

Appendix 2. Implicit prices (per household, one-off payment) for water management attributes from NMNL and ECM (basic models) and 95% confidence intervals.

Attributes	NMNL	ECM	$IP_{NMNL} = IP_{ECM}$
Water quantity	27.43 (16.24–39.27)	25.75 (15.93, 35.73)	0.411
Recreation	15.29 (3.75–29.67)	12.46 (3.63, 22.15)	0.347
Research	36.72 (25.07–53.08)	33.05 (24.22, 43.02)	0.338
Total land income	0.00[a]	9.33 (0.67, 17.51)	NA

Note: [a]WTP estimate was not found to be significantly different to zero and is expressed as zero.