Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2014.984928

57 (2016) 2268–2278
January

Taylor & Francis
Taylor & Francis Group

Monetizing the impacts of climate change on river uses towards effective adaptation strategies

D. Andreopoulos[a,*], D. Damigos[b], F. Comiti[a], C. Fischer[a]

[a]*Faculty of Science and Technology, Free University of Bozen/Bolzano, Piazza Universita 5, Bolzano, Italy, Tel. +39 3315893408; email: dimitrios.andreopoulos@natec.unibz.it (D. Andreopoulos)*
[b]*School of Mining and Metallurgical Engineering, National Technical University of Athens, 9 Iroon Polytechneiou str., Zografou, 157 80 Athens, Greece*

Received 8 June 2014; Accepted 1 October 2014

ABSTRACT

This paper examines public preferences for adaptation to climate change of ecosystem services provided by the Piave River in Italy, using the choice experiment method. Climate change projections indicate a considerable precipitation decrease in the broader basin area leading to river discharge loss the forthcoming decades. The study design accounted for preservation of current levels of different river services such as: irrigation, rafting activities, hydroelectricity power and ecological services. Our estimation strategy consisted in estimating a conditional logit model and a random parameters logit, together with their extended forms with census and attitudinal interacted variables. Results from all models present a tendency towards the selection of adaptation alternatives, showing that people are willing to pay for all river services except for rafting activities. Preferences' heterogeneity proves to be present and determinant, illustrating the choice patterns. The policy implications of these results may assist in developing more robust adaptation practises to cope with the socio-economic impacts of climate change on water resources.

Keywords: Climate change; River uses; Choice experiment

1. Introduction

Climate is characterized by natural variability. Nevertheless, anthropogenic factors like greenhouse gas emissions intensify and expedite the appearance of extreme climatic events. In regard to water resources, climate change over the last decades is associated with changes in a number of constituents of the hydrological cycle (e.g. changes in precipitation patterns, intensity and extremes, melting of snow and ice, changes in run-off) resulting in significant alterations of the hydrological system [1]. In addition, there are large regional differences attributed to the seasonal–interannual variability of precipitation and run-off along with the level of water resources demand. For instance, in the Mediterranean region, precipitation indicates a strong decline trend enhancing the frequency of drought events. In particular, in Italy a 14% decrease in precipitation, between 1951 and 1996 has been reported throughout the country and most significantly in the centre and in the south, where

*Corresponding author.

Presented at AdaptToClimate Conference, 27–28 March 2014, Nicosia, Cyprus

reductions in precipitation up to 20% have been reported during the last century. Furthermore, according to IPCC (Intergovernmental Panel on Climate Change) scenarios and especially under A2 global emission scenario, a drop in precipitation seems to be the dominant feature of the precipitation regime in the near future (2031–2060). More specifically, an approximate 10% decrease in precipitation is anticipated for the northern part and 10–20% decrease in the southern part, respectively [2].

The relationship between climate change and freshwater resources has implications for all living species and thus, it has also strong environmental and socio-economic interconnections. Therefore, climate change holds a prominent position in the global policy agenda. Immediate action towards mitigation of climate change perturbations on natural systems has been emphasized by various reports [1,3] in order to *inter alia*, shrink the economic and social disruptions. Nonetheless, after the Kyoto protocol having ran out in 2012, no coalitions for an effective follow-up protocol have been deployed worldwide. The lack of consensus for climate change mitigation which is exacerbated by the long-term and uncertain nature of the phenomenon, promotes, as never before, the necessity to develop adaptation strategies to climate change at the local level.

Bearing in mind the above remarks, the present study aims at investigating the economic impacts of climate change in the forthcoming decades on different uses of an important river basin in Italy. The potential impacts of climate change on water provision of the examined river could significantly affect a wide range of economic sectors in the neighbouring mountainous communities. To this end, the main focus of the study relies on residents' willingness to pay for adaptation interventions to climate change at the local level, in order to avoid welfare losses due to the possible complications on river water uses.

2. Study area and methodology

The Piave River basin consists of a very dense hydrographic network with many tributaries and streams. The future climate change projections (according to A2, A1B emission scenarios) reveal a high variation on the hydrological balance in the broader study area, indicating a reduction in precipitation of about ~0.5 mm/d, until the end of the century. Additionally, the simulation of climate change scenarios shows, in turn, at least 10% reduction in the river flow in the next decades [2]. As a result, the decrease in the river water will affect the provision of services deriving from the Piave system.

The study site is located at the Southern Foothills of the eastern Dolomiti's region at the province of Treviso (Pederobba municipality) being in close proximity with the Piave River basin. Pederobba municipality consists of three different fractions, Pederobba, Onigo and Covolo, which are settlements within the riparian zone of the Piave system having a total population of 7,500 inhabitants. The main ecosystem services of the river are irrigation, considered as the major water consuming activity in the area; rafting activities that enhance the local touristic development; generation of hydroelectric power, which comprises an important economic activity that affects the hydromorphology and water allocation of the aquifer; and the ecological state of the Piave ecosystem, which constitutes the main non-use value of the river.

More explicitly, the Piave River system feeds the broader plain area of Pederobba, which covers approximately 1,000 ha, with irrigation water. Along the river and within the municipality's boundaries there is a hydropower plant producing electricity of about 17×10^3 MWh per year, sufficient to cover the energy demand of 6,500 households. Rafting is an off-site river service for Pederobba's residents, since the activity takes place in the upper stream part. The total duration of rafting activities under sufficient flow conditions is seven months per year. Finally, the present ecological state of the Piave River is "good" as imposed by the Water Framework Directive 2000/60/EC classification.

Non-market benefits of the Piave River uses' adaptation to climate change were approached through local residents' preferences by applying a choice experiment (CE) method. CEs allow respondents to value a good or a situational change described by means of its attributes and levels, under a certain hypothetical cost. CEs have been widely applied for the valuation of environmental goods and services being considered as the most advanced among the stated preferences techniques [4–6]. In a CE, respondents are presented with a series of alternative options and are asked to choose their most preferred one. In this study, the Piave River uses are assigned as the attributes of the CE, while the levels are defined by the "amount" of services provided prior and posterior the consideration of climate change effects. In particular, under climate change effect and no adaptation measures, the Piave River services will significantly decline. The anticipated changes are defined as follows: (a) irrigated land will be reduced to 700 ha; (b) rafting period will decrease to four months per year; (c) hydroelectricity production will decrease by 25% and (d) ecological state will be worse off, characterized as "poor". Nevertheless, moderate adaptation could alleviate climate change impacts on the Piave River, while more intense adaptation could maintain the present river status in the future.

3. Theoretical background of estimation models

3.1. Conditional logit (CL) model

In CEs, the utility of a good or service derives from its attributes and levels, a theory that first launched by Lancaster [7]. Furthermore, CEs comply with the random utility theory, which is the basis for the econometric simulation of any choice [8,9]. For illustration of the basic model behind any CE, consider a resident's choice for a Piave River adaptation scenario, and assume that utility depends on choices made from a set C, i.e. a choice set, which includes all the possible Piave services options. The respondent is assumed to have a utility function in the following form:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \beta x_{ij} + \varepsilon_{ij} \tag{1}$$

where U is the indirect utility function, V is the deterministic component and e is the non-observable component of individual choice, which is independent of the deterministic part and follows a predetermined distribution. This error term implies that predictions cannot be made with certainty.

Consumers attempt to maximize their utility *ceteris paribus* from a good or service under a price constrain. Therefore, choices made between alternatives are based on the probability that the utility from a particular option j is higher than any other option k, i.e.:

$$\begin{aligned} P_{ij} &= \text{Prob}\left(U_{ij} > U_{ik}\right) \Rightarrow \text{Prob}\left(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik}\right) \\ &\Rightarrow \text{Prob}(V_{ij} - V_{ik} > \varepsilon_{ij} - \varepsilon_{ik}) \\ &\Rightarrow \text{Prob}(\varepsilon_{ik} - \varepsilon_{ij} < \beta x_{ij} - \beta x_{ik}) \end{aligned} \tag{2}$$

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 with a Weibull distribution, the above model can be estimated with a CL model [9], as in Eq. (3):

$$P_{ij} = \frac{\exp(\mu\beta x_{ij})}{\sum_{k\in C_i}\exp(\mu\beta x_{ik})} \tag{3}$$

where μ is the scale parameter typically assumed to equal one in any single sample, implying constant error variance [10]. The log-likelihood function for the maximum likelihood estimates is as follows:

$$\ln L = \sum_{i=1}^{N}\sum_{j\in C} d_{ij}\ln P_{ij} \tag{4}$$

where N is the number of respondents and d_{ij} is the dummy variable that equals one when respondent i chooses alternative j, and zero otherwise.

A basic assumption of CL model is that the choice sets must conform to the "Independence of Irrelevant Alternatives" (IIA) property. The IIA property implies that the relative probabilities of two alternatives chosen from a choice set are unaffected by the introduction, or removal, of other alternatives in that choice set [11]. This property derives from the random component of utility, which is supposed to be independently and identically distributed (IID). The latter implies that the error term is independent of the different alternatives included in the choice sets. If the IIA property is not satisfied from the data-set then the CL is not the appropriate model to estimate unbiased coefficients.

3.2. Random parameters logit (RPL) model

In order to relax the IIA limitation of the CL model, a more complex model, i.e. RPL or "mixed logit" model, is considered. This model derives by allowing the attributes' coefficients to vary according to any specified distribution, and thus, instead of assuming that βs are fixed like in CL model, βs are assumed to range among respondents. Most of the discrete choice analysts allow β coefficients to vary with a normal distribution [11]. Then, the functional form of the indirect utility function is such that:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \beta_h X_{ij} + \varepsilon_{ij} \tag{5}$$

where $\beta_h = \beta_n + v_i$ and $v_i \sim N(0, \sum \beta n)$, β_n is the population mean and v_i is the stochastic deviation, which represents the individual's preference relative to the average preferences in the population. Assuming that ε_{ij} is the IID extreme value type I, the probability for choosing alternative i thus becomes:

$$L_{ij} = \frac{\exp(\beta_h x_{ij})}{\Sigma_{k\in C_i}\exp(\beta_h x_{ik})} \tag{6}$$

The maximum likelihood estimation for the RPL model requires that the unconditional choice probability should be integrated over all the possible values of β_h:

$$P_{ij} = \int L_{ij} f(\beta) d\beta = \int \left(\frac{e^{\beta_h x_{ij}}}{\sum_k e^{\beta_h x_{ik}}} \right) f(\beta) d\beta \tag{7}$$

The probability is approximated through simulations for any given value of the normal distribution's parameters. This procedure is repeated many times being based mainly on Halton draws and concluded by averaging the result [12].

4. Experimental design and survey application

The design phase is the most important part of the survey preparation, provided that it contains assumptions and decisions that affect and constrain the survey development. Applications of CEs to environmental goods or services mostly encompass three different alternatives. Each of the two first alternatives consists of different attribute levels combinations, while the third is defined standardly, as the situation that induces no action, change or improvement of an environmental good or service in return of zero cost. The design that permits all different combinations to be generated by the attribute levels is referred as full factorial design. Based on the characteristics of the specific case, the attributes and the respective levels selected are presented in Table 1.

These attributes and levels could give rise to 405 possible sets ($3^4 \times 5^1$). This number is far from respondents' evaluation abilities and requires large cognitive and time sources. To delineate the number of different combinations, a fraction factorial design was created considering the principles of orthogonality, balance and D-efficiency [13,14]. For the experimental design, we used the "Complete Enumeration" strategy developed by the Sawtooth software. Focusing only on main effects of the attributes, 96 different alternatives were produced, which were merged into pairs plus the status quo scenario (pay nothing get nothing). The generated 48 choice sets were blocked into eight versions of six choice sets and each respondent was allocated one of each version randomly. A hold out choice set was also included in order to introduce the respondents to all the different attribute levels (the hold out set was drawn up by the total number of attribute levels) and explain the choice exercise. Dominant choice tasks were reconsidered or slightly altered in order to be consistent and utility balanced. The design report indicated that this strategy was optimally balanced, nearly orthogonal and efficient [15].

The choice tasks are part of a broader questionnaire, which attempts to reveal various aspects of the examined issue. Eliciting preferences is doable by asking different question types prior the choice exercises, while the choice tasks enable the procedure of trading-off on river attributes. The attributes of the alternative scenarios have been selected to better represent the total utility of the river use. Respondents' socio-economic profile is also of interest in order to acquire data on the individual-level basis. Perceptions about the examined issue and socio-economic characteristics except for the initial identification of participants profile may constitute significant components of extended forms of econometric models generated by including these characteristics as interacted variables in the utility functions.

The questionnaire deployed for this study was structured into five parts. First, the survey focused on general matters about the local environmental status with special regard to the ecosystem of the Piave River. Second, more specific questions were asked in order to know how and how much people use the Piave River. Third, participants were required to provide their opinions about climate change issues in the global perspective and how this may affect water provision in the local watershed. Fourth, people encountered the choice tasks and were allowed to trade-off on the main Piave River uses. Fifth, survey questions were included concerning socio-demographic characteristics and follow-up control questions.

Table 1
Attributes and levels for various scenarios included into the CE survey

Attribute	Levels
Attr1: Irrigated area (in ha)	700, 900 and 1,000
Attr2: Rafting period (in months)	4, 6 and 7
Attr3: Hydroelectricity production (% decrease)	0, 10 and 25
Attr4: Ecological state	Poor, fair and good
Price: Monthly payment for 10 years	0, 2€, 5€, 10€, 15€ and 20€

The survey was carried out between November and December 2013 to the residents of Pederobba municipality. Candidates were selected randomly and were personally face-to-face interviewed. The response rate was relatively high (70%) and the outcome of the survey was 300 complete questionnaires. Approximately 12% of the respondents (i.e. 35) opted standardly the status quo scenario, mainly for protest reasons. Collected data were codified following the suggestions of Johnson et al. [16] and entered into statistical packages for further analysis.

5. Descriptive statistics

Table 2 presents basic descriptive statistics about perceptions concerning the Piave system and its state, plus the socio-economic profile of the respondents. According to the given answers, the Piave River was designated as an important ecosystem for 93% of the respondents, worthy of protection for all the respondents (i.e. 99%). The ecological state of the river was prioritized as the most important derived river service. About 78% of the respondents were aware about climate change issues, while global warming was the most mentioned impact regarding climate change by the respondents (i.e. 39%). At the local level, the majority of the respondents recognize that the river incurs damages over time, some of which are associated with climate change. More explicitly, 55% of the respondents stated that the Piave River will be negatively affected. Further, the reduction in the river water flow has been considered as the main potential impact by 30% of the participants. In general, a percentage of 64 believe that the river is under threat for various reasons in the near future. The necessity of adaptation measures for river services brought about consensus among the respondents (95% of the interviewees strongly supported adaptation measures).

Respondents were 44 years old on average (a range from 18 to 85 years old) and the average family size was almost three persons. Regarding education, half of the respondents were high school graduates and 18% hold a university degree. The majority was employed (82%) and declared a total annual household income that did not exceed €21,200 on average.

6. Econometric results

6.1. CL model

The CL model is a basic specification for econometric simulation, connecting choices made by the respondents to the choice alternatives' parameters. The CL model is defined such that it is a function of choice-specific characteristics only [17]. It is basically used in the majority of CE studies, offering an overview of the

Table 2
Basic descriptive statistics

Variable x_i	Mean x_i	Definitions and remarks
EnvStatus	2.82	The state of the environment in the area (1:v.good, 5:v.bad)
PiaveStatus	3.08	The state of the Piave system (1:v.good, 5:v.bad)
ChangPiave	63%	Change of Piave's state the last 15 years for the worse
Pollution	46%	Pollution is the main factor for the worse off state
ContrEcon	42%	The Piave contributes to the local economy
ImportEcosys	93%	The Piave comprises an important ecosystem for the area
ClimConf	66%	The Piave regulates the local climate conditions
FuturGener	99%	It is important to preserve the Piave for the future generations
RiverUse	54%	Respondents using the river for recreational purposes
Futurerisks	64%	The Piave faces risks in the future
Infclimchan	78%	Information about climate change
TemperIncr	39%	Global warming as an example of climate change information
ClimchPiave	71%	Climate change will affect the Piave river
LesswaterDr	30%	The negative effect will be less river flow
Import1	42%	The good ecological state is the most important river service
Adaptmeasur	95%	It is important to implement adaptation measures
Sex	0.42	Male:0, Female:1, 42% women
Age	44.19	Average age of respondents
MemHous	2.96	Average household members of population of the sampled population
Educ	3.81	Level of education (1:no school,6:postgrad)
Income	4.26	Level of annual income (1:below 9,000€,8:more than 42,500€)

average preferences, and it constitutes the benchmark for further analysis [18]. The observable component of the utility function follows a standard additive form, reflecting the sum of the attributes' part-worth utilities of the respondents [19]. The following model depicts the utility function that an individual *i* gets from alternative *n* at choice situation *t*:

$$U_{nit} = \beta_j^C ASC_j + \beta^{Ir}\text{Irrigation Area}_{nit} + \beta^{Raf}\text{Rafting Period}_{nit} + \beta^{El}\text{Electricity Production}_{nit} + \beta^{EC}\text{Ecological Status}_{nit} + \beta^{P} Price_{nit} + \varepsilon_{nit} \quad (8)$$

where $\beta_j^C \mathrm{ASC}_j$ denotes the "alternative specific constant" (ASC) and is equal to 1 for alternatives other than status quo [20] and β^{Ir}, β^{Raf}, β^{El}, β^{EC} and β^{P} represent the vector of coefficients describing attributes associated with the different uses of the Piave River.

The results of the model are reported in Table 4. The log-likelihood value achieved (−1,662) and R^2 (~0.15) are comparable with those reported by other studies [18,21,22] and are interpreted as a good fit for the model [23]. The coefficients are highly significant at 1% level except for rafting activity which is marginally significant (*p*-value below 10%). More explicitly, the positive sign of the ASC coefficient indicates that respondents prefer moving away from the status quo scenario (i.e. tendency towards choosing adaptation scenarios). In addition, higher levels of "Irrigation area", "Hydroelectricity production" and "Ecological state" increase the probability that an adaptation scenario is selected. The negative sign of "Rafting period" imposes a disutility to the respondents for higher levels of this attribute. In line with expectations, the price attribute has a negative sign. Thus, it poses a negative utility effect in case that scenarios with higher payment levels are chosen.

An extended form of the CL model was also estimated attempting to include interaction effects of opinions and socio-demographic variables. These variables were created by multiplying opinion or socio-economic variables to choice-specific attributes or the ASC. The extended form of CL model permits unbiased estimation of the conditional coefficients [24,25], since it takes into account the relative impact of respondents' profile and beliefs on the model simulation. The results of the model are also reported in Table 4. A model that includes interaction of the ASC with gender, age, perception about future threats for the river, information about climate change issues, level of the river use and the ecological state interacted with the respondents' income were found to fit the data reasonably well. The log-likelihood and R^2 values were improved, indicating a better model fit with the extended CL model. Female respondents and young people are more likely to move away from the status quo option, selecting alterative schemes, i.e. policies that promote adaptation measures. River users are more willing to opt-in for adaptation scenarios (Rivus × ASC), proving a distance "decay factor" [26] towards river uses preservation. The positive Inf × ASC variable indicates a higher probability to opt-in for those who are generally aware or well-informed about climate change. As per interaction term Future × ASC, paradoxically, the negative sign indicates that people who initially expressed no concern about future threats for the river are consecutively more willing to adopt attitudes towards river adaptation. In the context of the related interactions of the attributes, only respondents' income level interacts significantly and positively with the river ecological state (Inc × ECST), showing that willingness to opt for a better ecological river condition depends on household's income.

To test whether the IIA is violated or not, the widely used Hausman and McFadden [27] test was employed. This test relies on the notion that the parameters obtained through estimates of CL models without one of the three alternatives each time are compared with the initial estimates of the CL model consisted of all the alternatives. The results of the test are shown in Table 3. The IIA test statistic cannot be calculated for the status quo exclusion as displayed in Table 3. It is possible by removing one or more alternatives some attributes to be constant in the remaining alternatives, which leads to singularities [28]. The exclusion of any of the two other alternatives induces the rejection of null hypothesis about IIA property, since the Hausman test in both cases reached high and significant values. Therefore, the IIA property is not satisfied and the application of the CL model could incur misleading results.

6.2. RPL model

In the RPL model, the coefficients of the four river-specific attributes were allowed to have a normal distribution accounting simultaneously for heterogeneity

Table 3
Test of IIA

Excluded alternative	χ^2	Significance level
Alternative A	59.9458	0.0000
Alternative B	73.9382	0.0000

among preferences. The "Price" attribute coefficient remained constant since no sample's share is expected to have a positive "Price" coefficient (it may occur with a normal distribution for the Price attribute) [29]. The ASC was treated similarly (i.e. remained constant) in order to be easily interpretable [24]. The results of the RPL estimation are reported in the third column of Table 4. The four river-specific attributes have the signs as accrue from the CL model and are statistically significant below 1% level, except the "Rafting period" attribute, which is statistically significant below 5% level. The "Price" attribute is represented as expected, negative and significant at 1% level. The parameter estimates of CL and RPL models indicate that both estimators produce similar results in terms of attributes' ranking and valuation, although all parameters estimates increase in absolute value for the RPL model.

The estimates of RPL coefficients revealed large and significant (except for the "Hydroelectricity production" attribute) standard deviations, implying that variation of parameters exists and the data indicate choice-specific unconditional, unobserved preferences' heterogeneity for these attributes. Although the simple RPL model incorporates unobserved heterogeneity, it fails to elaborate the sources of heterogeneity [30]. To account for the heterogeneity's origin, interactions with choice-specific attributes or the ASC are again taken into account [17,31,32]. The fourth column of Table 4 depicts the obtained estimates for the choice-related attributes plus interacted respondent-related terms. All river-specific attributes have positive signs except the "Rafting period" and are statistically significant, whereas the "Price" attribute remains negative and significant. The interaction terms are similar to the ones of the extended CL specification, implying

Table 4
Results of CL, RPL and extended CL, RPL models

Variable	CL Model	Extended CL model	RPL Model	Extended RPL model
Irrigation area	0.1085*** (0.0254)	0.1124*** (0.0255)	0.2874** (0.1416)	0.1800*** (0.0639)
Rafting period	−0.0631* (0.0254)	−0.0629** (0.0255)	−0.3860** (0.1822)	−0.2070*** (0.0796)
Hydroelectricity production	0.0231*** (0.0031)	0.0230*** (0.0032)	0.0842** (0.0334)	0.0482*** (0.0128)
Ecological state	0.5789*** (0.0407)	0.4295*** (0.0888)	2.0700*** (0.7907)	0.8799*** (0.2641)
Price	−0.0429*** (0.0056)	−0.0424*** (0.0056)	−0.1476*** (0.057)	−0.0870*** (0.0221)
ASC	0.4476*** (0.1167)	0.5847** (0.2971)	1.5906** (0.6833)	1.4714** (0.6494)
Additional variables interacted				
Age × ASC	–	−0.0140*** (0.0042)	–	−0.0240*** (0.0083)
Gender × ASC	–	0.7537*** (0.1484)	–	1.1707*** (0.3037)
River × ASC	–	0.1749** (0.072)	–	0.2429 × 0.1242
Inf × ASC	–	0.6677*** (0.1491)	–	1.0415*** 0.3013
Futur × ASC	–	−0.3379*** (0.1128)	–	−0.6046*** (0.2245)
Inc × ECST	–	0.0352* (0.0188)	–	0.0788* (0.0422)
Standard deviations parameters				
σ (Irrigation)			1.7244** (0.7067)	0.9146*** (0.2879)
σ (Rafting period)			1.7836** (0.7278)	0.9255*** (0.2999)
σ (Hydroelectricity production)			0.0136 (0.0963)	0.0048 (0.0355)
σ (Ecological state)			2.4162** (1.1815)	1.2447*** (0.4553)
Summary statistics				
Log-Likelihood	−1,662.481	−1,625.498	−1,646.863	−1,616.799
R^2	0.1593	0.1780	0.1672	0.1824
AIC	3,336.962	3,274.996	3,313.726	3,265.568
BIC	1,688.263	1,677.063	1,689.834	1,682.552
Observations	5,400	5,400	5,400	5,400
Sample size	300	300	300	300

Note: standard errors in parentheses.
*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.

that willingness to opt for an adaptation scenario varies in relation to the social and attitudinal characteristics. The standard deviations are lower and only two of them are statistically significant. Therefore, variation in willingness to opt for adaptation scenarios and preference heterogeneity are captured to a greater extent with the RPL including interactions.

Except the fit statistics of each model that provide useful indications about model performance on the current data-set, the likelihood ratio test for nested models points out that, at 5% level, the RPL model is better than the CL. The likelihood ratio can be computed as:

$$D = -2 * (\ln(\text{likelihood for CL model}) - \ln(\text{likelihood for RPL model})) \quad (9)$$

The ratio under the null model (CL) is distributed as a chi-square distribution with the degrees of freedom equalling the number of constraints. The acquired value from the test statistic (31.24) is greater than the one of the chi-square for four degrees of freedom (9.49). The degrees of freedom are defined as the number of constraints that the more complex RPL model can be transformed into the simpler CL model.

7. Welfare analysis

Once the parameter estimates have been obtained, the WTP values for the marginal change in an attribute (known as "implicit price") are estimated by dividing the estimated coefficient on the attribute of interest by the negative coefficient on the monetary variable. In other words, the value of a marginal change in any of the attributes in terms of welfare measurements derives from the ratio of the coefficient of the attribute j and the "Price" coefficient [33], as follows:

$$\text{WTP} = -\frac{\beta_j}{\beta^{Pr}} \quad (10)$$

All the implicit prices were obtained using the Krinsky–Robb method in Nlogit 5.0 and are presented in Table 5.

The above-mentioned implicit prices do not provide estimates of compensating surplus (CS) for alternative adaptation scenarios. Welfare measures derive from the marginal rate of substitution between the residual of the initial utility state and an alternative utility state divided by the marginal utility of income, which is represented by the coefficient of the "Price" attribute. Thus, in order to estimate WTP for adaptation to climate change, three distinct hypothesized scenarios were defined.

Scenario 0 represents the "do-nothing" case in which no adaptation actions are considered. As a result, river water uses deteriorate due to climate change with subsequent loss of utility. More explicitly, the irrigated land will be reduced from 1,000 to 700 ha, the rafting period will be confined to four months per year, the electricity production will decrease by 25%, and the ecological state will experience a decline from "good" to "poor".

Scenario 1 stands for a moderate adaptation policy. Under this policy option, soft adaptation measures are established to restrain complications on river services attributed to climate change. Institutional, educational, management rectifications and generally low-cost actions are activated to prevent further deterioration of the aquifer and to achieve as much recovery of services provision as possible. In this case, all river water uses are preserved to some extent from climate change-induced impacts. More specifically, the irrigated land will decrease by 10% (i.e. from 1,000 to 900 ha), the rafting period will be shorten from seven months per year to six months per year and the electricity production will decrease by 10%. Finally, the Piave River ecology will be characterized as "moderate".

Scenario 2 foresees strong adaptation policy that maintains the present river status in the future. In this policy design, both hard and soft adaptation measures are deployed with all subsequent follow-up treatments. Technical interventions and where necessary

Table 5
Marginal WTP for the CE attributes (€/month)

Attribute	CL model	Extended CL model	RPL model	Extended RPL model
Irrigation area	2.53 (1.24, 3.82)	2.65 (1.32, 3.98)	1.95 (0.68, 3.21)	2.07 (0.61, 3.52)
Rafting period	−1.47 (−2.75, −0.20)	−1.48 (−2.75, −0.22)	−2.61 (−4.02, −1.21)	−2.38 (−4.02, −0.74)
Hydroelectricity production	0.54 (0.34, 0.73)	0.54 (0.34, 0.74)	0.57 (0.37, 0.77)	0.55 (0.31, 0.79)
Ecological state	13.51 (9.59, 17.42)	10.14 (5.32, 14.95)	14.02 (10.53, 17.52)	10.11 (4.54, 15.68)

Note: 95% confidence intervals in parentheses.

Table 6
CS for each scenario (€/month)

Scenario	CL model	Extended CL model	RPL model	Extended RPL model
Scenario 1	34.14 (27.06, 41.51)	34.41 (20.14, 48.68)	32.02 (20.45, 43.60)	34.69 (20.37, 49.02)
Scenario 2	54.08 (41.82, 66.35)	51.14 (33.85, 68.42)	51.08 (26.78, 75.39)	50.03 (29.85, 70.21)

Note: 95% confidence intervals in parentheses.

heavy infrastructure projects along with all the relevant legislative, administrative reforms and back-up capital availability to maintain robust intertemporal river health are considered towards an “all inclusive” solution. Therefore, any depletion of river services will be totally hindered and in particular irrigation land will remain the same as today (i.e. 1,000 ha), river water level will support rafting activity for seven months per year, hydroelectricity production will not decrease, and the present situation of the Piave River ecology will be characterized as “good”, meeting the requirements of the European Water Framework Directive 2000/60.

To find the CS associated with each of the above-described scenarios, the difference between the welfare measures under the status quo and the alternative scenarios are estimated. Welfare changes are then obtained by using the CS formula described by Hanemann [34], as in Eq. (11).

$$CV = -\frac{1}{\beta^{Pr}}(V^1 - V^0) \quad (11)$$

where β^{pr} is the parameter estimate of cost, and V^0 and V^1 depict representative respondent’s utility before and after the change under consideration. The estimates of WTP for the alternative scenarios are given in Table 6.

As expected, the CS increases moving from the status quo situation to the adaptation scenarios considered. For the best-fit extended RPL model, the results indicate that households are willing to pay 35€ per month (i.e. 420€ per year) for moderate adaptation. The voluntary contribution increases to 50€ per month (i.e. about 600€ per year) for an all-inclusive solution for adaptation, which will preserve all human and ecosystem services of the Piave River to current levels.

8. Conclusions

This paper presents a CE that was conducted in order to analyse trade-offs of choices and to estimate the welfare effects of adaptation measures in the Piave River basin. From the econometric simulation of the acquired choices, significant economic values derive from three different services, namely irrigated land, hydroelectric power production and ecological state of the river ecosystem. The benefit estimates for these attributes indicate that Pederobba’s residents are willing to contribute monthly per household 2.07€ for every 100 ha irrigated area preserved, 0.55€ for every 10% more hydroelectric power production and 10.11€ for improving the state of the river ecosystem at the next better level. The negative sign of “Rafting period” attribute and the fact that it is less statistically significant implies that this specific river service was disregarded by the respondents. Pederobba’s residents did not impose an economic value for using the Piave River for recreation motives, even if recreation has been designated in other similar studies as an indirect use having a considerable latent economic value [18,33]. This may occur due to the off-site location of the activity (it takes place in the upstream part) or/and to the fact that people give priority to other direct uses of the Piave River. As regards adaptation, positive and high economic values emerged for both moderate and absolute adaptation scenarios. The observed influence of the individual-related characteristics and the heterogeneity on choice preferences proved to be significant. This outcome should be considered during the preparation of any climate change adaptation plan, as it could lead to a better deliberation process among different stakeholder groups.

Introducing non-market valuation into public decision-making contributes to public debate and awareness concerning specific environmental problems, especially for those having a strong uncertain nature like climate change. The economic analysis performed in this study for river services affected by climate change has been evidently encouraged and promoted both by the existing legal framework for water resources (i.e. WFD 2000/60) and several technical reports related to climate change impacts [3,35–38]. However, further research is needed to increase the empirical data in regard to economic valuation of river services and expand the economic implications of water resources management under climate change risks.

References

[1] B.C. Bates, W.Z. Kundzewicz, S. Wu, J.P. Palutikof, Climate change and water, Technical Paper VI of the IPCC, IPCC Secreteriat, Geneva, Switzerland, 2008.

[2] TRUST, Tool for regional scale assessment of groundwater storage improvement in adaptation to climate change, Technical report. Authority of Isonzo, Tagliamento, Livenza, Piave, Brenta-Bacchiglione river basins, EU, 2011.

[3] N. Stern, The Economics of Climate Change, The Stern Review, Cambridge University Press, Cambridge and New York, 2006.

[4] W. Adamowicz, P. Boxall, M. Williams, J. Louviere, Stated preference approaches for measuring passive use values: Choice experiments and contingent valuation, Am. J. Agr. Econ. 80 (1998) 64–75.

[5] S. Alriksson, T. Öberg, Conjoint analysis for environmental evaluation, Environ. Sci. Pollut. Res. 15 (2008) 244–257.

[6] D. Hoyos, The state of the art of environmental valuation with discrete choice experiments, Ecol. Econ. 69 (2010) 1595–1603.

[7] K.J. Lancaster, A new approach to consumer theory, J. Polit. Econ. 74 (1966) 132–157.

[8] R.D. Luce, Individual Choice Behaviour: A Theoretical Analysis, Wiley, New York, NY, 1959.

[9] D.L. McFadden, Conditional logit analysis of qualitative choice behavior, in: P. Zaremka (Ed.), Frontiers in Econometrics, Academic Press, New York, NY, 1974, pp. 105–142.

[10] M.E. Ben-Akiva, S.R. Lerman, Discrete Choice Analysis: Theory and Application to Travel Demand, MIT Press, Cambridge, 1985.

[11] K. Train, Discrete Choice Methods with Simulation, first ed., Cambridge University Press, Cambridge, 2003.

[12] M. Bliem, M. Getzner, P. Rodiga-Laßnig, Temporal stability of individual preferences for river restoration in Austria using a choice experiment, J. Environ. Manage. 103 (2012) 65–73.

[13] H. Nordh, C. Alalouch, T. Hartig, Assessing restorative components of small urban parks using conjoint methodology, Urban For. Urban Greening 10 (2011) 95–103.

[14] R. Olschewski, P. Bebi, M. Teich, U.W. Hayek, A. Grêt-Regamey, Avalanche protection by forests – A choice experiment in the Swiss Alps, Forest Policy Econ. 15 (2012) 108–113.

[15] B.K. Orme, Getting Started with Conjoint Analysis, in: Strategies for Product Design and Pricing Research, Research Publishers, Madison, WI, 2010.

[16] F.R. Johnson, B. Kanninen, M. Bingham, S. Ozdemir, Experimental design for stated choice studies, in: B.J. Kanninen (Ed.), Valuing Environmental Amenities Using Stated Choice Studies, Springer, Paris, 2006, pp. 159–202.

[17] J. Poirier, A. Fleuret, Using the choice experiment method for valuing improvements in water quality: A simultaneous application to four recreation sites of a river basin, 59th conference of association francaise de science economique, nanterreuniversite, Paris, 2010.

[18] A. Juutinen, Y. Mitani, E. Mäntymaa, Y. Shoji, P. Siikamäki, R. Svento, Combining ecological and recreational aspects in national park management: A choice experiment application, Ecol. Econ. 70 (2011) 1231–1239.

[19] K.K. Zander, S.T. Garnett, The economic value of environmental services on indigenous-held lands in Australia, Plos One 6 (2011) 23–54.

[20] J.J. Louviere, D.A. Hensher, J.D. Swait, Stated Choice Methods: Analysis and Applications, Cambridge University Press, Cambridge, 2003.

[21] P. Tait, R. Baskaran, R. Cullen, K. Bicknell, Nonmarket valuation of water quality: Addressing spatially heterogeneous preferences using GIS and a random parameter logit model, Ecol. Econ. 75 (2012) 15–21.

[22] M. Goibov, P.M. Schmitz, S. Bauer, M.N. Ahmed, Application of a choice experiment to estimate farmers preferences for different land use options in northern Tajikistan, J. Sust. Develop. 5 (2012) 1–16.

[23] D.A. Hensher, L.W. Johnson, Applied Discrete Choice Modelling, Wiley, New York, NY, 1981.

[24] J. De Valck, P. Vlaeminck, I. Liekens, J. Aertsens, W. Chen, L. Vranken, Valuing landscape preferences for nature restoration: Drongengoed case study (Belgium), 129 EAAE Seminar, Castelldefels, Barcelona, 2012.

[25] E. Birol, K. Karousakis, P. Koundouri, Using a choice experiment to account for preference heterogeneity in wetland attributes: The case of Cheimaditida wetland in Greece, Ecol. Econ. 60 (2006) 145–156.

[26] I.J. Bateman, I.H. Langford, A. Graham, A Survey of Non-users' Willingness to Pay to Prevent Saline Flooding in the Norfolk Broads, CSERGE Working Paper GEC 95-11, Center for Social and Economic Research on the Global Environment, School of Environmental Sciences, University of East Anglia, Norwich, 1995.

[27] J. Hausman, D. McFadden, Specification tests for the multinomial logit model, Econometrica 52 (1984) 1219–1240.

[28] D.A. Hensher, J.M. Rose, W.H. Greene, Applied Choice Analysis: A Primer, first ed., Cambridge University Press, New York, NY, 2005.

[29] D. Layton, G. Brown, Heterogeneous preferences regarding global climate change, Rev. Econ. Stat. 82 (2000) 616–624.

[30] P. Boxall, W. Adamowicz, Understanding heterogeneous preferences in random utility models: A latent class approach, Environ. Resour. Econ. 23 (2002) 421–446.

[31] E. Birol, E.R. Villalba, Using a choice experiment to estimate Mexican farmers' valuation of milpa diversity and genetically modified maize: A latent class approach, in: Proceedings of the Third World Congress of Environmental and Resource Economists, Kyoto, Japan, 2006.

[32] T. Kjaer, A review of the discrete choice experiment—With emphasis on its application in health care, Health Economics Papers, Proceedings of the University of Southern Denmark, 2005.

[33] N. Hanley, R. Wright, G. Koop, Modelling recreation demand using choice experiments: Climbing in Scotland, Environ. Resour. Econ. 22 (2002) 449–466.

[34] W. Hanemann, Welfare evaluations in contingent valuation experiments with discrete response data: Reply, Am. J. Agr. Econ. 71 (1989) 1057–1061.

[35] G. Stournaras, M. Skourtos, A. Kontogianni, G. Yoxas, A. Machleras, P. Nastos, Climatic changes and impacts on Greece's water systems, The environmental, economic and social impacts of climate change in Greece, National Report, Bank of Greece Printing Works, Athens, 2012, pp. 127–152.
[36] J.F. Feenstra, I. Burton, J.B. Smith, R.S.J. Tol, Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies, second ed., UNEP and Institute for Environmental Studies/Vrije Universiteit, Nairobi and Amsterdam, 1998.
[37] Metroeconomica, Costing the impacts of climate change in the UK: Overview of guidelines, UK Climate Impacts Programme (UKCIP), UKCIP Implementation Technical Report, Oxford, UK, 2004.
[38] R.S.J. Tol, The Economic Impact of Climate Change, ESRI working paper (No. 255), Dublin, Ireland, 2008.