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

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Abstract

This paper examines local residents' preferences for adaptation to climate change on services provided from a specific river basin in Italy, using the Choice Experiment (CE) method, since climate change models project a considerable discharge loss for the Piave River the forthcoming decades. The study design accounted for preservation of current levels of different river services such as: irrigation, rafting, hydroelectricity power and ecological services. Our estimation strategy consisted in estimating a Conditional Logit (CL) model and a Random Parameters (RPL), together with their extended form with census and attitudinal interacted variables. Results for 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 towards explication of choice patterns. The policy implications of these results may assist to develop more robust adaptation practises to cope with the socioeconomic 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 (GHG) 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 runoff), which result in significant alterations in the hydrological system [1]. Nevertheless, there are large regional differences attributed to the seasonal-interannual variability of precipitation and runoff along with the level of water resources demands. For instance, in the Mediterranean area precipitation indicates a strong decline pattern, 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 center and in the south, where reductions in precipitation up to 20% have been reported during the last century. Furthermore, according to IPCC scenarios and especially under A2 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 a 10% to 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 socioeconomic 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, among others, shrink the economic and social disruptions. Nonetheless, after the Kyoto protocol ran out in 2012, no coalitions towards 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 the forthcoming decades on different uses of a major Italian river basin. The potential impacts of climate change on water provision of the examined river basin 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 local level, in order to avoid welfare losses due to 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 predicted climate change scenarios for the 21st century (A2 A1B, IPCC climate scenarios) to quantify the variations on the hydrological balance in the broader region of the study area indicate a reduction of about ~ 0.5 mm/day towards the end of the century. As a result, the simulation of climate change scenarios shows at least 10% of recharge reduction by the end of the century [2]. The reduction of the water flow will consecutively affect the provision of services deriving from the Piave River.

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, Covolo, which are settlements riparian to Piave system and the total population is 7500 inhabitants. The main river uses are irrigation as the major water consuming activity in the area; outdoor water activities, such as rafting, as a dynamic parameter for touristic development in proximity with river systems; generation of hydroelectric power as an important activity affecting the hydromorphology and water allocation of the surface water body and; the state of the ecosystem as an attribute supporting all the other services.

More explicitly, the Piave River system feeds the broader plain area of Pederobba with water for irrigation of approximately 1000 hectares of land. Along the river and within the municipality's borders, there is also a hydropower plant producing electricity of about $17*10^3$MWh per year, sufficient to cover the energy demand of 6500 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 7 moths per year. Finally, the present state of the ecosystem of the Piave River is considered to be 'good' according to the Water Framework Directive 2000/60/EC classification.

In order to investigate the economic impacts of climate change the forthcoming decades on the main uses of Piave River, local residents' preferences for adaptation were approached by a Choice Experiment (CE). 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 the present 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 pressures and no adaptation measures, the Piave River services will significantly decline. The anticipated changes are, as follows: (a) irrigated land will be reduced to 700 hectares; (b) rafting period will decrease to 4 months per year; (c) electricity production will decrease by 25%; and (d) ecological state will be worsen to 'poor'. However, moderate adaptation could alleviate the 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

Conditional Logit model

In CEs the utility of a good or service derives from its attributes and levels, a theory that first launched by Lancaster (1966) [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 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 of the following form:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \beta x_{ij} + \varepsilon_{ij} \quad (1)$$

where U is the indirect utility function, V 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 stem from a particular option j is higher than any other option k, i.e.:

$$P_{ij} = Prob(U_{ij} > U_{ik}) \Rightarrow Prob(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik})$$
$$\Rightarrow Prob(V_{ij} - V_{ik} > \varepsilon_{ij} - \varepsilon_{ik})$$
$$\Rightarrow Prob(\varepsilon_{ik} - \varepsilon_{ij} < \beta x_{ij} - \beta x_{ik}) \quad (2)$$

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 Equation 3:

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

Where μ is the scale parameter, which is 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:

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

where N is the number of respondents, and d_{ij} is a 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 comply with the 'Independence from Irrelevant Alternatives' (*IIA*) property. The *IIA* property implies that the relative probabilities of two alternatives being 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 components of utility, which are supposed to be independently and identically distributed. The latter implies that the error terms are independent of the different alternatives included in the choice sets. If the IIA property is not satisfied from the dataset then the CL is not the appropriate model to estimate unbiased coefficients.

Random Parameters Logit model
In order to relax the *IIA* limitation of CL model, a more complex model, i.e. RPL or 'mixed logit' model, is considered. This model derives by allowing the attributes' coefficients to be distributed according to a specific distribution. In RPL model instead of assuming that β is fixed like in CL model, β is assumed to vary among respondents. Most of the discrete choice analysts allow β coefficients to vary with a normal distribution. Then the functional form of the indirect utility function is such that:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \beta_h X_{ij} + \varepsilon_{ij} \quad (5)$$

Where $\beta_h = \beta_n + v_i \text{ and } v_i \sim N(0, \sum \beta n)$, 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 *iid* extreme value type 1, the probability for choosing alternative i thus becomes:

$$L_{ij} = \frac{\exp(\beta_h x_{ij})}{\Sigma_k \exp(\beta_h x_{ik})} \quad (6)$$

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:

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

The probability is approximated through simulation 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].

3. Experimental design and survey application

The survey design phase is the most important part of the design process, provided that it contains assumptions and decisions that affect and constrain the survey development. Applications of choice experiments 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 one environmental good or service in return of zero cost. The design that permits different combinations to be generated by the product of the attribute levels number is referred as full factorial. Based on the characteristics of the specific case, the attributes and the respective levels selected are presented in Table 1.

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

Attribute	Levels
Attr1: Irrigated Area (in hectares)	700, 900, 1000
Attr2: Rafting period (in months)	4, 6, 7
Attr3: Hydroelectricity production (% decrease)	0%, 10%, 25%
Attr4: Ecological state	poor, fair, good
Price: Monthly payment for 10 years	0, 2€, 5€, 10€, 15€, 20€

These attributes and levels could give rise to 405 possible sets (3^4*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 using the principles of orthogonality, balance and D-efficiency [13, 14], by means of the Sawtooth software CBC routine. Focusing only on main effects of the attributes, 96 different alternatives were produced, which were merged into pairs plus the status quo scenario. The generated 48 choice sets were blocked into 8 versions of 6 choice sets and each respondent was allocated one of each version randomly. A hold-out choice set was also included to introduce the respondents to all of the different attribute levels (the fixed set was drawn up by all the attribute levels) and make clear to them what the choice exercise pertained to. 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 set is part of a broader questionnaire, which attempts to reveal various aspects of the examined issue. Preferences elicitation is doable by asking different question types prior the choice exercises, whilst the choice tasks enable the procedure of trading-off on attributes. The attributes that the environmental good is composed of, have been selected to better represent the total utility of the environmental good. Respondents' socioeconomic profile is also of interest in order to acquire data on the individual-level basis. Perceptions about the examined issue and socioeconomic characteristics of the participants except for initial principles may constitute significant components of extended or interacted forms of utility models examined by using variables that stem from perceptions or/and respondent's socioeconomic profile.

The questionnaire deployed for this study was structured into five parts. First, respondents confronted with broad questions about the local environmental status with special regard to the ecosystem of 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.

The survey was carried out between November and December 2013 to the residents of the Pederobba municipality. Candidates were selected randomly and were personally interviewed. The outcome of the survey was 300 completed 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. (2006) [16] and entered into statistical packages for further analysis.

4. Econometric Results

Table 2 presents basic descriptive statistics in regard to perceptions concerning the Piave system and its state and the socioeconomic profile of the respondents. According to the answers given, the Piave River is designated as an important ecosystem for 93% of the respondents, worthy of preservation 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 phenomenon 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 of 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. The average family size was almost 3 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.

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)
Piave	67%	Piave consists of an important ecosystem (1:yes)
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 recognized as the main factor of worse state
ContrEcon	42%	Piave contributes in the local economy
ImportEcosys	93%	Piave comprises an important ecosystem for the area
ClimConf	66%	Piave configures 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
Futurethreats	64%	Piave confronts threats 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
Kindinflu	55%	Climate change will affect the Piave river negatively
LesswaterDr	30%	The negative effect will be less river flow
Import1	42%	The good ecological state is the most important river service
Adaptmeasur	95%	Adaptation measures are important to be activated
Sex	0.42	Male:0, Female:1, 42% women
Age	44.19	Average age of respondents
MemHous	2.96	Average household members of population
Educ	3.81	Level of education (1:no school-6:postgrad)
Income	4.26	Level of annual income (1:below 9000€ - 8:more than 42500€)

5. Econometric Results

Conditional Logit 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 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*:

$$U_{nit} = \beta_j^C ASC_j + \beta^{Ir} IrrigationArea_{nit} + \beta^{Raf} RaftingPeriod_{nit} + \beta^{El} ElectricityProduction_{nit} + \beta^{EC} EcologicalStatus_{nit} + \beta^P Price_{nit} + \varepsilon_{nit} \quad (8)$$

where $\beta_j^C ASC_j$ 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} , β^{P} represent the vector of coefficients describing attributes associated with the different uses of Piave River.

The results of the model are reported in Table 4. The log-likelihood value achieved (-1662) 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 *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 socioeconomic 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' beliefs and profile on the model simulation. The result of the model is also reported in Table 4. A model that includes interaction of the ASC with sex, age, perception about future threats for the river, information about climate change issues, level of the river use and the ecological state interaction 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 state depends on household's income.

To test whether the IIA is violated or not, the widely used Hausman and McFadden 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* assumption cannot be calculated for the status quo exclusion as displayed in the Table 3. It is possible by removing one or more alternatives, some attributes to remain constant in the remaining alternatives, which leads to singularities [27]. The exclusion of the two other alternatives induces the rejection of null hypothesis about IIA property, since Hausman test in both cases, reached high and significant statistics. Therefore, the IIA property is not satisfied and the application of the CL model could incur misleading results

Table 3: Test of independence of irrelevant alternatives

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

Random Parameters Logit Model

In the RPL model, the coefficients of the four river-specific attributes were allowed to have a normal distribution accounting simultaneously for heterogeneity 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) [28]. 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 towards these attributes. Although the simple RPL model incorporates unobserved heterogeneity, it fails to elaborate the sources of heterogeneity [29]. To account for the heterogeneity's origin, interactions with choice specific attributes or the ASC are again taken into account [17, 30-31].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, as expected. The interaction terms are similar to the ones of the extended CL specification, indicating mainly that willingness to opt for an adaptation scenario varies with 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 great extent with the RPL including interactions.

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)	0.18*** (0.0639)
Rafting period	-0.0631* (0.0254)	-0.0629** (0.0255)	-0.386** (0.1822)	-0.207*** (0.0796)
Hydroelectricity production	0.0231*** (0.0031)	0.023*** (0.0032)	0.0842** (0.0334)	0.0482*** (0.0128)
Ecological state	0.5789*** (0.0407)	0.4295*** (0.0888)	2.07*** (0.7907)	0.8799*** (0.2641)
Price	-0.0429*** (0.0056)	-0.0424*** (0.0056)	-0.1476*** (0.057)	-0.087*** (0.0221)
ASC	0.4476*** (0.1167)	0.5847** (0.2971)	1.5906** (0.6833)	1.4714** (0.6494)
	Additional variables interacted			
Age*ASC	-	-0.014*** (0.0042)	-	-0.024*** (0.0083)
Sex*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(Electr. Production)			0.0136 (0.0963)	0.0048 (0.0355)
σ(Ecological State)			2.4162** (1.1815)	1.2447*** (0.4553)
Summary statistics				
Log-Likelihood	-1662.481	-1625.498	-1646.863	-1616.799
R^2	0.1593	0.1780	0.1672	0.1824
AIC	3336.962	3274.996	3313.726	3265.568
BIC	1688.263	1677.063	1689.834	1682.552
Observations	5400	5400	5400	5400
Sample Size	300	300	300	300

Note: standard errors in parentheses *:p<0.1,**:p<0.05 and ***:p<0.01

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 CL, as the acquired value from the test statistic (31.24) is greater than the one of the chi-square for 4 degrees of freedom (9.49).

6. 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 accrues from the ratio of the coefficient of the attribute j and the 'Price' coefficient [32], as follows:

$$WTP = -\frac{\beta_j}{\beta^{Pr}} \quad (9)$$

All the implicit prices were obtained using the Wald procedure (Krinsky-Robb method) in Nlogit 5.0 and are presented in Table 5.

Table 5: Marginal WTP for the Choice Experiment attributes

Attribute	CL model	Extended CL model	RPL model	Extended RPL model
Irrigation area	2.53 (0.72)	2.65 (0.67)	1.95 (0.64)	2.07 (0.74)
Rafting period	-1.47 (0.69)	-1.48 (0.68)	-2.61 (0.71)	-2.38 (0.84)
Hydroelectricity production	0.54 (0.11)	0.54 (0.1)	0.57 (0.10)	0.55 (0.12)
Ecological state	13.51 (1.96)	10.14 (2.36)	14.02 (1.78)	10.11 (2.84)

Note: standard errors in parentheses

The abovementioned implicit prices do not provide estimates of compensating surplus (CS) for alternative adaptation scenarios. Welfare measures derive from the marginal rate of substitution between residual of the initial utility state and 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, as follows:

- Scenario 0 represents the 'do-nothing' case that is 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 hectares to 700 hectares, the rafting period will be confined to 4 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. 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 hectares), the rafting period will be shorten from 7 months per year to 6 months per year, and the electricity production will decrease by 10%. Finally, the Piave River ecology will be characterized as 'moderate'.

- Scenario 2 foresees s strong adaptation policy that maintains the present river status in the future. To wit, irrigation land will remain the same as today (i.e. 1,000 hectares), river water level will support rafting activity for 7 months per year, electricity 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 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 alternatives scenarios are estimated. Welfare changes are then obtained by using the compensating surplus formula described by Hanemann (1989) [33], as in Equation 10.

$$CV = -\frac{1}{\beta^{Pr}}(V^1 - V^0) \tag{10}$$

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

Table 6: Compensating surplus for each scenario (€/month)

Scenario	***RPL model***	***Extended RPL model***
Scenario 1	32	33
Scenario 2	51	50

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 33 € per month (i.e. 396 € 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.

7. Conclusions

This paper presents a CE that was conducted in order to analyze trade-offs of choices and to estimate the welfare effects of adaptation measures in Piave river basin. From the econometric simulation of acquired choices significant values derive for three different services, namely irrigated land, hydroelectric power production and state of 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 hectares irrigated area preserved, 0.55€ for every 10% more hydroelectric power production and 10.11€ for improving the state of the river ecosystem to 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 from 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, 32]. 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 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 the stakeholders.

Introducing monetary 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 water resources 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 relating to climate change impacts [3, 34-37]. 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.

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