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Estimating the non-market benefits of climate change adaptation of river ecosystem services: A choice experiment application in the Aoos basin, Greece

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ABSTRACT

Mountains are important global reservoirs of water resources. However they are highly vulnerable to climate change as limited alterations in temperature and precipitation may cause harmful effects to water systems. Southern Europe and especially Greece are expected to undergo a drought trend over the next decades, resulting in less recharge for the aquifers and water services reduction. Thus, climate change may distort both natural and socioeconomic characteristics of freshwater ecosystem services deteriorating the general social welfare related to them. This paper examines the economic impacts of climate change on river uses of the Aoos basin in Greece. In this regard, a choice experiment is conducted to estimate the value changes in different ecological and economic services in a mountain community. The econometric simulations using conditional logit, random parameters logit and latent class models reveal that despite existing preference heterogeneity, respondents on average derive positive and significant welfare effects from climate change adaptation measures. The findings of the survey may assist in adaptation planning for the Aoos River basin, with possible extensions to other river systems enduring similar climate change indications.

1. Introduction

Water resources are finite and their allocation varies spatially and temporally. Mountains, in particular, are considered as the water towers of the world since all major rivers have their headwaters in mountains and half of the humanity depends on the water that is gathered, purified and stored in mountainous areas (Gret-Regamey et al., 2012). Mountains, however, are highly vulnerable to climate change and any shift in precipitation, runoff and evapotranspiration rates may perturb the hydrological balance with subsequent negative

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impacts on water resources provision (Stournaras et al., 2011). In addition, if these shifts provoke water depletion, it is anticipated an increase in freshwater pollutants, while water ecosystems' biological and hydro-morphological characteristics will be severely disturbed (Feenstra et al., 1998). Furthermore, water resources provide goods and services and their management incorporates the socioeconomic dimension. For this reason, the impacts of climate change on water resources may affect a wide spectrum of activities and economic sectors with high importance for the society (Metroeconomica, 2004). Climate change expectations for Southern Europe and especially for the Mediterranean region indicate an annual precipitation decrease over the next decades (Bates et al., 2008; Philandras et al., 2011). Such trend has already been observed in Greece, where over the last five decades precipitation decreased by about 30–150 mm per decade, in turn leading to the reduction in rivers runoff between 5% and 10% during the last century (Milly et al., 2005). These forecasts associated with the present high demand for water resources will result in less water availability in the next future. The IPCC scenarios (e.g. A1B, A2, B2) for the future climate trends foresee that the precipitation in Greece will further drop by 3–7% and 14–22% for the periods 2021–2050 and 2071–2100, respectively. Consequently, a further decline is predicted for the total water potential from 7 to 20% to 30–50% for the respective time periods throughout the country (Stournaras et al., 2011). This study aims at investigating the economic dimensions of climate change impacts, in welfare terms, on the Aoos River basin (Epirus, Greece). The downscaled climate scenarios for this region indicate 10–15% precipitation reduction and 15–20% loss of the total water potential by 2100 (Giannakopoulos et al., 2011). As the future climate is predicted to reduce the Aoos River flow, the river ecosystem and a wide range of economic sectors in the adjacent mountain town of Konitsa will be affected. Thus, the main focus of this study is on Konitsa residents' willingness to pay for adaptation interventions to climate change impacts on the local water resources using a stated preference approach, namely Choice Experiment (CE).

2. Study area and methodology

The town of Konitsa (40°2′44″N 20°44′56″E) lies along the Northern Pindos mountain range, at an altitude of about 600 m a.s.l. The location of the town is at the southern exit of Vikos-Aoos national park, on the Aoos River banks. The river is 260 km long, 70 km of which lie within the Greek territory, and features an annual average flow of 52 $m^3 s^{-1}$. The drainage area of the basin is 2154 km^2 having a pronounced mountainous character. The mean annual precipitation height in the area is about 1150 mm leading to an annual runoff of 1630 hm^3 (Baltas, 2008). At present, the Aoos hydrological regime is not severely affected by anthropic pressures, even though a hydropower plant producing an average of 10^3 MWh of electric energy per year operates in the headwaters (Stournaras et al., 2011). Konitsa has a population of about 3500 residents, living in 750 households. The primary sector is the predominant activity of the local economy in as much the southern part of the town is an irrigated plain area. Recently, the local economy has also turned to the tourism development, as the national park and the Aoos River provide several hiking and rafting possibilities (Papageorgiou et al., 2005).

Today, the most characteristic direct and indirect uses of the Aoos River in Konitsa are: (a) irrigation of 1000 ha of the plain area; (b) rafting for 7 months per year; (c) hydroelectricity production upstream of the town of 10^3 MWh/year. Additionally, a fourth considerable non-use value is formulated by the 'good' ecological state of the Aoos River as imposed by the Water Framework Directive (WFD) 2000/60. Under the anticipated climate variations (i.e. 20% decrease in river runoff by 2100) and no adaptation measures, the above-mentioned services of the Aoos River are expected to significantly decline, and therefore adaptation measures should be embraced by the local society to mitigate the adverse impacts of the forecast trend.

To this aim, the understanding of people's preferences is crucial to develop welfare-improving public policy. Since market or actual data cannot reveal the public's willingness to participate in adapting to future climate change impacts, a stated preference technique is needed to simulate these distant (in time) markets (Layton and Brown, 2000). Many recent studies consider CEs as the most suitable technique for environmental valuation (Adamowicz et al., 1998; Alriksson and Oberg, 2008; Hoyos, 2010), because they have considerable merit in measuring use and non-use values and provide a richer description of the attributes trade-offs that individuals are willing to make (Adamowicz et al., 1998). Furthermore, CEs, as survey based methods enabling public involvement, are critical for the sustainable and long term climate change adaptation policy (Akter et al., 2012).

3. Theoretical background of CEs

The basis for most of the microeconomic models of consumer behaviour is the maximization of consumer's utility under a finite income. The CE is an application of Lancaster's theory of value, according to whom '*the consumers reap the utility of the good from its characteristics and not from the good itself*' (Lancaster, 1966), combined with the random utility theory. The utility that the consumer obtains from one good or service is equal to the sum of part-utilities deriving from the attributes of the good or service. Therefore, the individual has a utility function of the form:

$$U_{ij} = U(x_j, p_j, Z_i) \tag{1}$$

where the individual i receives utility U_{ij} when chooses the alternative j. His choice is influenced by the attributes of the good j, which are presented as vector $\mathbf{x}$, the price $\mathbf{p}$ of alternative j and the socioeconomic characteristics $\mathbf{Z}$ of the respondent. According to the utility maximization theory, the respondent weights the attributes of every alternative choice and opts for the one that offers the highest utility. In practice, individuals may make choices that do not maximize their utility due to lack of information, market failure, non-observable features or secondary characteristics of alternative choices that are not included (Louviere et al., 2002). These errors are incorporated in the utility function being based on the random utility approach (McFadden, 1974), which assumes that consumers besides behaving towards utility maximization (deterministic or observed aspect of behaviour) they may also act driven by unobserved or undefined motives (stochastic or unobserved aspect of behaviour). This can be expressed with the following equation:

$$U_{ij} = V_{ij} + \epsilon_{ij} = \beta x_{ij} + \epsilon_{ij} \tag{2}$$

where U_{ij} is the indirect utility function representing the satisfaction that individual i receives from alternative j, V_{ij} is the deterministic component assumed to be a linear index of the attributes of the j different alternatives and ε_{ij} is the non-observable component of individual choice, which is independent of the deterministic part and follows a predetermined distribution. The linearity assumption is considered almost exclusively in studies applying random utility models (Farsi, 2007) and enables the estimation of marginal utilities and marginal willingness to pay (WTP) values (Hanemann, 1989). The error term implies that welfare predictions cannot be made with certainty; x_{ij} is a combination of the levels of the river-specific attributes of the individual i for an alternative j and $\boldsymbol{\beta}$ the vector of preference parameters associated with x_{ij}. Therefore, according to the utility maximization theory, the probability the individual i to choose the alternative j from any other alternative k from a choice set C_i is given by:

$$\begin{aligned} &P_{(j|C_i)} = Prob(U_{ij} > U_{ik};\, j \neq k,\, \forall k \in C_i) \\ &\Rightarrow Prob(V_{ij} + \epsilon_{ij} > V_{ik} + \epsilon_{ik};\, j \neq k,\, \forall k \in C_i) \\ &\Rightarrow Prob(V_{ij} - V_{ik} > \epsilon_{ij} - \epsilon_{ik};\, j \neq k,\, \forall k \in C_i) \\ &\Rightarrow Prob(\epsilon_{ik} - \epsilon_{ij} < \beta x_{ij} - \beta x_{ik},;\, j \neq k,\, \forall k \in C_i) \end{aligned} \tag{3}$$

Assuming that the relationship between utility and attributes is linear in the parameters and variables function as mentioned, and that the error terms are identically and independently distributed (*IID*) with a Weibull distribution, the above model can be estimated with a conditional logit (CL) model (McFadden, 1974), as in Eq. (4):

$$P_{ij} = \frac{\exp(\beta x_{ij})}{\sum_{k \in C_i} \exp(\beta x_{ik})} \tag{4}$$

The CL is a specification of the general multinomial logit model and is defined such that it is a function of choice-specific characteristics only (Poirier and Fleuret, 2010). A basic assumption of the CL model is that the choice sets must comply with the 'Independence from Irrelevant Alternatives' (*IIA*) property (Hausman and McFadden, 1984). 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 (Bliem et al., 2012). This property derives from the random components of utility, which are supposed to be *IID*. In order to relax the *IIA* limitation of the CL model, a more complex model, i.e. the Random Parameters Logit (RPL) or 'mixed logit' model, is considered. This model derives by allowing the attributes' coefficients to be distributed. In the RPL model instead of assuming that $\boldsymbol{\beta}$ is fixed like in the CL model, $\boldsymbol{\beta}$ is assumed to vary among respondents. Most of the discrete choice analysts allow $\boldsymbol{\beta}$ coefficients to vary with a normal distribution. Then the functional form of the indirect utility function is such that:

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

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

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

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:

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

This probability is approximated through simulation for any given value of θ. To generate values from the normal distribution, the simulation technique of sequences is applied. As discussed by Train (2003), the Halton sequences provide better approximations to the integral. This procedure is repeated many times and is concluded by averaging the result.

Another approximation of choice preferences that the *IIA* is not applied is the latent class (LC) model. The LC model attempts to distinguish the sample population into subgroups of subjects who share similar responses. Thus, preference homogeneity is assumed within the same class, whilst preferences are allowed to vary across classes. If we assume the existence of S segments in a population and that individual i belongs to segment s ($s = 1, \ldots, S$), the utility function can be expressed:

$$U_{ij|s} = V_{ij} + \epsilon_{ij} = \beta_s x_{ij} + \epsilon_{ij|s} \tag{8}$$

In this expression, the utility parameters are now segment-specific and Eq. (4) becomes:

$$P_{i|s(j)} = \frac{\exp(\beta_s x_{ij})}{\sum_{k \in C_i} \exp(\beta_s x_{ik})} \tag{9}$$

where β_s are segment-specific utility parameters. The LC model includes, except for a choice probability function, another probability function for class membership, which follows the multinomial logit form. Attitudinal or/and socioeconomic characteristics influence segment membership and are used as classification variables. The probability of membership in segment S takes the form:

$$P_{is} = \frac{\exp(\lambda_s Z_i)}{\sum_{s=1}^{S} \exp(\lambda_s Z_i)} \tag{10}$$

where Z_i is a vector of attitudinal and socioeconomic characteristics and λ_s is a vector of parameters. The probability that an individual i chooses alternative j is the joint probability that individual i belongs to segment s and chooses alternative j:

$$P_{i(j)} = \sum_{s=1}^{S} \left[\frac{\exp(\lambda_s Z_i)}{\sum_{s=1}^{S} \exp(\lambda_s Z_i)} \right] \left[\frac{\exp(\beta_s x_{ij})}{\sum_{k=1}^{K} \exp(\beta_s x_{ik})} \right] \tag{11}$$

This model enables both choice-specific attributes and individual characteristics to explain choice behaviour.

4. Experimental design and data collection

The good to be valued, in terms of its attributes and their levels, is an adaptation policy scenario that will reduce climate change risk to the Aoos River. Significant adaptation policy attributes were defined such as to comprise the river services that are prevalent for the public, along with the levels of their provision that depend on the activation or not of adaptation plans. The local community derives direct and indirect benefits related to the river mainly from hydropower, irrigation and rafting. Besides the use-values, amenity values and intrinsic values are attached to the river system, even if there is little or no likelihood of the individual actually ever using them. These non-use values, according to Pearce et al. (1996), may constitute the major portion (30–80%) of the total value of river systems. The levels of the attributes used were defined by the ''amount'' of services provided prior and posterior the consideration of climate change impacts. The maximum levels of the attributes were set considering the current levels of river uses that can be achieved in the future with relevant adaptation schemes. As regards the 'status quo' alternative or 'neither adaptation scenario', in which no payment would be required, the expected changes were described, as follows: (a) irrigation land is reduced by 30%, i.e. to 700 ha; (b) rafting period will be 4 months per year (i.e. 3 months decrease); (c) hydroelectricity production is expected to decrease by 25%; and (d) ecological status will be classified as 'poor' (from 'good'), assuming that river flow is declined by 20%. Finally, a cost ('price') attribute was introduced in order to estimate the economic values for marginal substitution of each river service. The 'price' was defined in terms of a monthly voluntary contribution to a non-profit organization dedicated to designing and implementing adaptation measures to alleviate the expected impacts of climate change. The payment vehicle and the levels of the 'price' attribute were selected by means of a pilot survey in the study area. The attributes and the respective levels are presented in Table 1.

The so-called full factorial design consisting of all possible combinations of the levels of the attributes could give rise to 405 possible alternatives ($3^4 \times 5^1$). To delineate the number of different combinations, a fraction factorial design was created using the principles of orthogonality, balance and D-efficiency. For this purpose, the 'Complete Enumeration' experimental design developed by Sawtooth software was used, as in other CE surveys (e.g. Nordh et al., 2011; Olschewski et al., 2012). This routine considers all possible choice tasks and picks those that lead to nearly optimal design, by combining as different options as possible in every choice situation. 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. The design report indicated that this strategy was optimally balanced, nearly orthogonal and efficient (Orme, 2010). An example of a choice set is presented in Table 2.

The questionnaire of the study was structured into five parts. First, respondents confronted with broad questions about the local environmental status with special regard to the ecosystem of the Aoos River. Second, general questions were asked in order to reveal the way and the degree that people use the Aoos River. Third, perceptions about climate change issues in the global perspective and how this may affect water provision in the local watershed were investigated. Fourth, people encountered the choice tasks and were prompted to trade off on the main Aoos River services. In the last part, respondents' socio-demographic characteristics, which constitute significant components of extended or interacted forms of utility models, were collected. The survey was carried out between January and February 2013 in the Konitsa town. Candidates were selected randomly and were personally interviewed. In total, 303 questionnaires were completed. Approximately 15% of the respondents (i.e. 45) opted for the status quo scenario, 60% of whom were motivated by protest incentives. The protest bidders stated either that they already pay enough taxes for environmental purposes or that they would be willing to contribute in adaptation actions, in case of more reliable national and local strategic environmental planning.

Before applying the econometric models, the reference sample was defined on the basis of excluding or not the protest responses, even though their percentage is relatively low compared to the zero bids reported usually in stated preference studies (Meyerhoff and Liebe, 2008). Although it is a common practice to exclude protest responses from the sample (Morrison et al., 2000), there is still a controversy on their treatment. To further extend, it has been argued that censoring protest answers may be indefensible and stated preferences' practitioners should restrain this attitude (Jorgensen and Syme, 2000; Jorgensen et al., 1999). Even if protest behaviour seems to be less problematic for CEs than Contingent Valuation (Hasler et al., 2005), protest responses

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€

Table 2 – Sample choice set.

Which of the following adaptation scenarios do you favour? Each alternative provide different provision levels of the Aoos water uses under climate change impacts. The Alternatives 1 or 2 impose a cost to your household. You have always the possibility to pay nothing. In this case no adaptation measures are foreseen and all river uses will deteriorate as indicated in the Status Quo scenario.

	Status quo (i.e. 'no action')	Alternative 1	Alternative 2
Irrigated area	700 ha	900 ha	1000 ha
Rafting period	4 months	6 months	7 months
Hydroelectricity production	Decrease by 25%	Decrease by 10%	No decrease
Ecological state	Poor	Fair	Good
Price	0€	10€	20€

should be considered attentively, because their treatment can significantly influence the results of valuation studies (Meyerhoff and Liebe, 2008). Since there is no consensus on how to treat protest responses, we identified their impact on each of the models used. The inclusion of protesters within the sample resulted in a negative impact on the statistical fit of the CL and RPL models. On the other hand, the LC model behaved better when protesters were included. The dissent about protest responses treatment in the relevant literature together with the empirical estimates of fit statistics led us to include protest responses in the LC further analysis, unlike in the CL and RPL models. All models were estimated using the Nlogit 3.0. econometric software.

5. Sample summary and descriptive statistics

On average, respondents were 41 years old, and the average family size was about 3.5 persons. Regarding education, two large groups emerged: one of high-school graduates (25.1%) and one of university degrees holders (27.7%). The majority was employed (84.2%) and declared a total annual household income that did not exceed €17,800 on average. Looking at people's perception of their living environment, 75% of the respondents considered the local environmental conditions as "good" or "very good". The Aoos River was indicated by most of the respondents (86.8%) as an important ecosystem, while the opinions about the status of the river were equally split, since half of the respondents described it as "fair" or "low" and half as "good" or "very good". Furthermore, 59.1% of the participants noted that the general condition of the Aoos River has worsened in the last 10–15 years. Most of the respondents use the river for recreational purposes, whereas a small group (11.9%) uses the river water for irrigation. Regarding river uses priorities, respondents ranked first the good ecological status of the river (48.8%), followed by irrigation (42.6%), hydroelectricity production (5%), and rafting activities (3.4%). Almost 90% of the respondents were concerned about the river's future condition, while 21.8% identified the reduction in water flow as the most possible threat. About 77% of the respondents were aware about climate change issues. Moreover, around 70% were convinced that climate shifts will affect the river, and about half of them confirmed the reduced river flow as the main potential impact. About one-third of the respondents believe that the impacts of climate change on the Aoos River will arise in about 20–30 years. Almost all respondents recognized the need of adaptation measures against climate change at a local level. Basic descriptive statistics can be found in Table 3.

6. Econometric results

6.1. CL model

The CL model is basically used in all CE studies offering an overview of the average preferences and constitutes the benchmark for further analysis (Juutinen et al., 2011). The CL model operates under the simplistic assumption of homogenous preferences across respondents and all interviewee choices are pooled, generating a single attribute coefficient associated with all respondents. The observable component of the utility function (as given in Eq. (2)) follows a complete additive form, being expressed by the sum of the attributes' part-worth utilities of the respondents (Zander and Garnett, 2011). The utility function for an individual i selecting an alternative j at a choice situation t takes the form:

$$U_{ijt} = \beta^{ASC} ASC_j + \beta^{Ir} Irrigation\_Area_{ijt} + \beta^{Raft} Rafting\_Period_{ijt} + \beta^{El} Electricity\_Production_{ijt} + \beta^{Ec} Ecological\_State_{ijt} + \beta^{Pr} Price_{ijt} + \epsilon_{ijt} \quad (12)$$

where β^{ASC} denotes the coefficient of 'alternative specific constant' (ASC), which equals 1 for alternatives other than status quo, and β^{Ir}, β^{Raf}, β^{El}, β^{EC} represent the coefficients describing attributes associated with the different uses of the Aoos River. The term β^{Pr} stands for the coefficient of the price attribute, whereas ε_{ijt} displays the error component incorporated in random utility models. The results of the model are reported in Table 4. The coefficients are highly significant at the 1% level, indicating that the attributes used are significant factors in the choice of the adaptation scenarios, while their signs are as

Table 3 – Basic descriptive statistics.

Variable x_i	Mean x_i	Definitions and remarks
EnvStatus	1.99	The state of the environment in the area (1:v.good, 5:v.bad)
Aoos	87%	Piave consists of an important ecosystem (1:yes)
AoosStatus	2.53	The state of the Piave system (1:v.good, 5:v.bad)
ChangAoos	59%	Change of Aoos's state the last 15 years for the worse
RiverUse	54%	Respondents using the river for recreational purposes
FutureThreats	90%	Aoos confronts threats in the future
InfClimChan	77%	Information about climate change
ClimchPiave	70%	Climate change will affect the Piave river
LessWater	48.2%	The negative effect will be less river flow
Import1	48.8%	The good ecological state is the most important river service
AdaptMeasur	96.3%	Adaptation measures are important to be activated
Gender	0.28	Male: 0, female: 1, 28% women
Age	41.11	Average age of respondents
MemHous	3.5	Average household members
Educ	5.36	Level of education (1:no school – 8:postgrad)
Income	3.36	Level of annual income (1: below 9000€ – 8:more than 42,500€)

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

Variable	CL model	RPL model	Extended RPL model
Irrigation area	0.102*** (0.026)	0.144*** (0.048)	0.126*** (0.038)
Rafting period	0.063*** (0.026)	0.083* (0.047)	0.075** (0.037)
Hydroelectricity production	0.016*** (0.032)	0.025*** (0.007)	0.021*** (0.005)
Ecological state	0.567*** (0.042)	0.943*** (0.199)	0.529*** (0.139)
Price	−0.047*** (0.006)	−0.074*** (0.017)	−0.061*** (0.012)
ASC	0.720*** (0.126)	0.997*** (0.261)	2.581*** (0.661)
Additional variable interacted			
Aoos × ASC	–	–	−0.260*** (0.101)
Age × ASC	–	–	−0.031*** (0.008)
Educ × ASC	–	–	0.115** (0.061)
InfClimc × ASC	–	–	−0.535** (0.238)
Rivus × ASC	–	–	0.204** (0.103)
Inc × ECST	–	–	0.072** (0.030)
Standard deviations parameters			
σ (Irrigation area)	–	0.408* (0.266)	0.227 (0.255)
σ (Rafting period)	–	0.549** (0.265)	0.376** (0.186)
σ (Electr. production)	–	0.025 (0.053)	0.013 (0.063)
σ (Ecological state)	–	1.060*** (0.34)	0.712** (0.288)
Summary statistics			
Log-Likelihood	−1467.208	−1460.947	−1437.071
ρ^2	0.193	.197	0.210
AIC	2946.415	2933.894	2886.142
BIC	2985.48	2978.959	2976.271
Observations	4968	4968	4968
Sample size	276	276	276

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

expected. More explicitly, a positive attribute coefficient denotes that the probability of a respondent selecting adaptation options is higher if this attribute is provided at a greater level, while the contrary interpretation stands for a negative attribute coefficient. The positive sign of the *ASC* coefficient indicates that respondents prefer moving away from the status quo scenario for reasons other than of those explained by the choice attributes (the ASC captures general preferences for alternatives different from status quo). Scenarios with higher levels of irrigation, rafting period, hydroelectricity production and ecological state are preferred by the respondents. In line with expectations, the price attribute has a negative sign, implying a negative utility effect if scenarios with higher payment levels are chosen.

6.2. RPL model

The basic shortcomings of the CL model are that the choice sets must conform to the *IIA* property together with the assumption of preferences' homogeneity, which in most of the stated preference approaches for environmental goods is unlikely to be valid. Nevertheless, it is a commonplace to begin with more simple models, like the CL (Hasler et al., 2005) and after heterogeneity or/and *IIA* violation is detected to proceed with more rigorous specifications. To test whether the *IIA* is violated or not, the widely used Hausman and McFadden (1984) test was carried out. The test resulted in high and significant Hausman statistics, indicating that the *IIA* property is circumvented and, as a result, the application of the CL model could incur misleading results (Kountouri et al., 2011). To this end, the RPL model that does not undergo any *IIA* limitations allows choice parameters to vary, and consequently preferences for the river-specific attributes are considered heterogeneous. Hence, the policy is better guided since the RPL model enables to determine the possible sources of heterogeneity (De Valck et al., 2012) and consecutively to understand who is affected by policy alterations (Birol et al., 2006). The RPL model was estimated by allowing all the river-specific parameters to be normally distributed based on 1000 Halton draws. The price and the *ASC* variables were specified to remain constant and, hence, simple to interpret the welfare estimates subsequently. Moreover, no sample's share is predicted to have a positive coefficient on price, which is likely to occur by constraining the price attribute to have a normal distribution (Layton and Brown, 2000). The results of the RPL estimation are reported in the second column of Table 4. The four river-specific attributes have the expected positive signs and are statistically significant below the 1% level, except the rafting period attribute, which is statistically significant below the 10% level. The price attribute is represented, as expected, negative and significant at the 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 estimate increase in absolute value for the RPL model.

6.3. RPL model with interactions

The parameter estimates for the RPL model are determined at the level of the population preference's mean value, while difference in respondents' individual tastes is represented by the standard deviation of taste from the population average. The estimates of RPL coefficients revealed large and significant standard deviations (except for the "hydroelectricity production" attribute), providing an empirical way to prove that parameters' variation exists and the data indicate choice-specific unconditional, unobserved preference heterogeneity for these attributes. Although the simple RPL model incorporates unobserved heterogeneity, it fails to reveal its sources (Boxall and Adamowicz, 2002). To account for the heterogeneity's origin, variables in the form of respondent-specific characteristics (i.e. social, economic and attitudinal) interacted with choice specific attributes or the ASC are taken into account (Kjaer, 2005; Poirier and Fleuret, 2010). The third column of Table 4 provides the results of the extended RPL model including interactions of the ASC with education, age, perception about the Aoos River state, information about climate change issues, level of the river use and the ecological state interaction with the respondents' income.[1] All river-specific attributes have positive signs and are statistically significant, whereas the price attribute remains negative and significant, as expected. The interaction term *Aoos* × *ASC* shows that those who believe that the river is generally in a "good" or very "good" condition are more positive to support adaptation initiatives. The coefficient sign of *Age* × *ASC* indicates that younger people are more likely to move away from the status quo option, selecting policies that promote adaptation measures. A similar attitude is observed concerning respondents with higher education. The *InfClimc* × *ASC* variable indicates a higher probability to opt in for those who are generally unaware or not well-informed about climate change. The latter occurs probably due to the highly detrimental perceived risk, which leads to positive behavioural response to climate change adaptation. River users are more willing to opt-in for adaptation scenarios (*Rivus* × *ASC*), proving a 'distance decay' factor (Bateman et al., 2003) towards river uses preservation. In the context of the attributes' related interactions, solely respondents' income level interacts significantly and positively with the river ecological state (*Inc* × *ECST*), showing that willingness to opt for a higher ecological river state depends on household's income (the higher the respondent's income the more derived utility from choices with higher level of ecological state). The standard deviations are lower and only two of them are statistically significant, indicating that variation in willingness to opt for adaptation scenarios and preference heterogeneity are captured to a greater extent with the RPL including interactions.

6.4. LC model

An alternative way to analyze choice data sets is to determine preference heterogeneity on the segment instead of the individual level as assumed in the RPL specification (Kosenious, 2010). The segment classification in LC models is endogenously attained by identifying categorical latent class variables within the data (Nylund et al., 2008), which are related to general attitudes and perceptions as well as socioeconomic characteristics (Boxall and Adamowicz, 2002). As a guide to the selection of the optimal number of classes the use of information criteria (*AIC*, *BIC*) is recommended tempered by the interpretability of the produced results (Boxall and Adamowicz, 2002; Garrod et al., 2012; Nylund et al., 2008). The improvement of log-likelihood and $\rho 2$ statistics from the initial one-segment model, which is the baseline model for LC models, to the four-segment model implies the existence of heterogeneity and the presence of latent classes within the population. The improvement of model fit above the two-segment model is negligible though. In addition, the best *BIC* estimation was acquired for the two-segment LC model indicating that preference heterogeneity is better captured by considering two discrete groups of respondents. The two-segment LC model results are reported in Table 5.

Based on the highest probability of the individuals to be members in one of the two segments, it turned out that 84.5% of the respondents were members of the first segment and the remaining 15.5% of the second one. The segmentation membership coefficients of the second segment are used as a base (normalized to zero) and the other segment estimates are compared to that class. The first segment is characterized

Table 5 – Results of two-segment LC model.

	Segment 1 (84.5%)	Segment 2 (15.5%)
Irrigation	0.110*** (0.024)	−1.267** (0.562)
Rafting	0.075*** (0.025)	−1.211*** (0.402)
Hydroelectricity production	0.016*** (0.003)	0.056 (0.051)
Ecological state	0.583*** (0.039)	0.889 (0.626)
Price	−0.048*** (0.006)	−0.220** (0.101)
ASC	1.686*** (0.146)	−1.556 (2.289)
Segment function: respondent's social and economic characteristics		
Constant	5.575*** (1.282)	Fixed parameters
Age	−0.051*** (0.016)	
Education	−0.003 (0.116)	
River use	0.389** (0.195)	
Aoos state	−0.340* (0.185)	
Information clim. change	−1.278** (0.565)	
Income	−0.017 (0.099)	
Log-likelihood	−1310.074	
ρ^2	0.344	
Observations	5454	
Sample size	303	
Latent class probabilities	0.845	0.155

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

[1] The utility function takes the form: $U_{ijt} = \beta^{C}ASC_j + \beta^{Ir}Irrigation\_Area_{ijt} + \beta^{Raf}Rafting\_Period_{ijt} + \beta^{El}Electricity\_Production_{ijt} + \beta^{EC}Ecological\_Status_{ijt} + \beta^{Pr}Price_{ijt} + \beta^{A}Aoos \times ASC + \beta^{Ag}Age \times ASC + \beta^{Ed}Educ \times ASC + \beta^{Inf}Infclimc \times ASC + \beta^{R}RivusASC + \beta^{InEC}Inc \times ECST + \varepsilon_{ijt}$.

by having younger people, using in some way the Aoos River, having inadequate information about climate change phenomena and believing that the Aoos system is in good or a very good ecological status. However, no conclusions can be drawn for education and income variables because their coefficients are not statistically significant. Therefore, it is likely that attitudinal variables are more important factors to differentiate people in segments compared to socioeconomic ones. All the choice-specific coefficients are statistically significant at the 1% level in the first segment and with the expected sign. The ranking for the utility coefficients is in accordance to all previous estimated models. For the second segment, the utility coefficients of 'ecological state' and 'hydroelectricity production' are insignificant determinants of choice. The other two utility coefficients 'irrigation' and 'rafting' are significant at the 5% and 1% level, respectively; yet, they have a negative sign imposing a disutility towards payment for adaptation actions concerning irrigation and rafting activities for the second segment members. The price coefficient is negative and significant, whilst the ASC, which accounts for choices out of the status quo is negative. The percentage of being member in the second segment, which corresponds to the opt-out responses, and the negative sign of the ASC demonstrate that the second segment is mainly constituted by zero-bidding respondents (the majority of the zero-bidders are driven by protest reasons) who are unwilling to contribute monetarily for the implementation of river adaptation measures.

6.5. *Models comparison*

Since there is no *a priori* optimal econometric simulation for our CE dataset, different econometric models were applied and statistically cross-compared. For instance, the CL model is subjected to the *IIA* assumption, in contrast to the RPL and LC models. In addition, the presence of preference heterogeneity among choices is approached either on the individual (RPL) or on the segment level (LC) and no suspicion in favour of one or the other approach exists in advance. Overall, all models included in our analysis are widely used in the relevant literature (Kjaer, 2005). Except the fit statistics estimated for each model that provided useful indications about models performance, two different comparative tests were conducted in order to identify the best fitting model, namely the likelihood ratio test for nested models and the Akaike likelihood ratio test for non-nested models (e.g. Ben-Akiva and Swait, 1986; Birol et al., 2006; Colombo et al., 2009; Shen, 2009). The likelihood ratio points out that, at the 5% level, the RPL is better than the CL model and the Akaike likelihood ratio dictates that the LC model clearly outperforms the interacted RPL model. Therefore, the LC model describes better heterogeneity in the choice data, implying that individual characteristics affect choices through segment membership more evidently than affecting straightforward the utility function (Kontoleon, 2003).

7. Welfare analysis

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 (Hanley et al., 2002), as follows:

$$\mathrm{WTP} = -\frac{\beta_j}{\beta^{Pr}} \qquad (13)$$

All the implicit prices were obtained using the Wald procedure in Nlogit 3.0 and are presented in Table 6. The benefit estimates, according to the optimally fitting LC model, indicate that Konitsa's households are willing to contribute monthly 1.06€ for every 100 ha irrigated area preserved, 0.47€ for having an extra month sufficient flow for rafting activities, 0.28€ for 10% more hydroelectricity production and 10.31€ for improving the state of the river ecosystem at the next better level.

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 and alternative utility states divided by the marginal utility of income, which is represented by the coefficient of the 'price' attribute. Hence, in order to estimate WTP for adaptation plans, three distinct hypothesized scenarios (utility states) were defined, as follows:

- Scenario 0 represents the 'do-nothing' case, in which no adaptation actions are considered. As a result, river services will be under deterioration due to climate change with subsequent loss of utility. More explicitly, the irrigated land will be reduced from 1000 ha to 700 ha, the rafting period will be confined to 4 months per year, the hydroelectricity production will decrease by 25%, and the ecological state will experience a decline from 'good' to 'poor'.

Table 6 – Marginal WTP for the choice experiment attributes (€/month).

Attribute	CL model	RPL model	Extended RPL model	LC model		
				Latent class segment 1	Latent class segment 2	Weighted
Irrigation area	2.17 (0.58)	1.96 (0.61)	2.08 (0.60)	2.31 (0.54)	−5.75 (2.24)	1.06 (0.57)
Rafting period	1.34 (0.56)	1.13 (0.64)	1.24 (0.61)	1.57 (0.52)	−5.49 (2.46)	0.47 (0.58)
Hydroelectricity production	0.34 (0.08)	0.34 (0.08)	0.34 (0.08)	0.32 (0.07)	–	0.28 (0.06)
Ecological state	12.12 (1.61)	12.81 (1.68)	8.73 (2.02)	12.20 (1.50)	–	10.31 (1.27)

- Scenario 1 stands for a moderate adaptation policy. In this case, all river services are preserved to some extent from climate change-induced impacts. More specifically, the irrigated land will decrease by 10% (i.e. from 1000 to 900 ha), the rafting period will be shorten from 7 months per year to 6 months per year, and the hydroelectricity production will decrease by 10%. Finally, the Aoos River ecology will be characterized as 'moderate'.
- Scenario 2 foresees a strong adaptation policy that maintains the present river status in the future. To wit, irrigation land will remain the same as today (i.e. 1000 ha), river water level will support rafting activity for 7 months per year, hydroelectricity production will not decrease, and the present situation of the Aoos River ecology will be characterized as 'good', meeting the requirements of the WFD 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 obtained by using the CS formula described by Hanemann (1989), as in Eq. (14).

$$CS = -\frac{1}{\beta^{Pr}}(V^1 - V^0) \quad (14)$$

where β^{Pr} is the parameter estimate on the cost attribute, and V^0, V^1 represent indicative respondents' utilities before and after the change under consideration. The estimates of WTP for the alternative scenarios are given in Table 7.

As expected, the CS increases moving from the status quo situation to the adaptation scenarios considered. The welfare estimates can be used in the context of a cost–benefit analysis to assess whether the non-market benefits obtained by the CE exceed the costs of a proposed adaptation plan, as illustrated hereinafter. In the study area, adaptation measures have not yet been considered. Thus, it is assumed that the maximum cost of an adaptation plan would not exceed the economic damages induced by climate change on river services. To this end, economic damages attributed to a 20% decrease in river discharge, to farmers, rafting activity, electricity industry and the society (regarding the river ecological status) were estimated. According to the Greek Ministry of Finance (2013), the net income per ha of irrigated land is 178€$_{2013}$, whereby the total damage to farmers in the area of interest is estimated at 53,400 €$_{2013}$ per year for a loss of 300 ha of irrigated land. Furthermore, Konitsa receives 2000 rafting visitors per year and each of them spends on average 200€$_{2013}$ for a two-day visit (MoD, 2008). According to local rafting companies a 3-month reduction in rafting period would result in 20% less visitors. Based on these figures, rafting activity would experience a loss of nearly 80,000€$_{2013}$ per year.

Table 7 – Compensating surplus for each scenario (€/month).

Scenario	Extended RPL model	Weighted LC
Scenario 1	35	46
Scenario 2	50	61

Hydroelectricity is expected to decrease by 25%, i.e. about 250MWh/year. Given an average price of about 90€ per MWh for the period of the study, the economic damage to electricity generation is estimated to be 22,500€$_{2013}$ per annum. Finally, the cost of achieving "good ecological status" is estimated at approximately 210€ per household per year (MoEEaCC, 2013), i.e. 157,500€$_{2013}$ per year. In order to estimate the aggregated social benefits from practically preserving all human and ecosystem services of the Aoos River to current levels, the estimated annual CS for the "strong" adaptation scenario was used, i.e. 732€ per household per year or 549,000€$_{2013}$ per year, as obtained by the best fit weighted LC model. The above-mentioned figures imply that adaptation is worthwhile, since the social benefits clearly outweigh the adaptation costs, although the hypothetical base of WTP estimates requires considering the social benefits generated by the adaptation scenarios as upper bound values (Hanley et al., 2006). It should be also noted that these findings should be verified and validated by additional future studies dealing with the cost of adaptation of case and site-specific measures.

8. Policy implications and conclusive remarks

Climate change will constitute the main stressor on water resources the ongoing years and should be considered in the WFD 2000/60 (Kanakoudis and Tsitsifli, 2010). This study analyzed trade-offs of choices and estimated the welfare effects of expected climate change impacts on a Greek mountain river, relying on the public's WTP for adaptation measures. More specifically, the choices were linked to climate change by means of respondents' preferences to maintain the provision level of several river services after appropriate adaptation measures. In that respect, respondents were asked to choose scenarios that are composed of different river services provision levels, attributed to climate change impacts. The results indicate that positive and significant values (both use and non-use) are associated with different river services, highlighting that any deterioration of the river would lead to utility losses. More explicitly, respondents are willing to pay to move away from the 'do-nothing' situation towards adaptation strategies that could preserve the current status of the Aoos River in terms of services provision. An interesting aspect is that the respondents' income – usually proportional to the WTP – has no significant effect in this study, and it appears only as an interaction with the ecological state. Indeed, this has been already observed in other CE applications (Birol et al., 2006), but not particularly emphasized. Moreover, the observed influence of individual characteristics, as well as the heterogeneity in choice preferences, proved to be significant and should be considered during the preparation of any climate change adaptation plan. In particular, the latter could lead to a better deliberation process among the stakeholders, i.e. including both decision-makers and decision-affected subjects. Even though adaptation is not being discussed yet in detail at the political level, the understanding gained through this research on people's attitude towards river services may soon represent an important asset. In the context of this study, as adaptation of the Aoos River services to climate change is deemed the bundle of actions that will prevent river use depletion and hence utility losses. Nevertheless, these actions will likely lead to unavoidable utility abatement either directly (e.g. reducing inevitably the provision of river services such as future possible hydropower development), or indirectly by increasing the cost of adaptation strategies (e.g. modernization of irrigation system, subsidization of crop changes etc.). To this end, revealing the welfare effects of climate change impacts on river services provision is critical to perform cost-benefit analyses, and thus, to inform adaptation policies considering not only economic criteria but also social welfare and equity. Even though the costs of climate change impacts on use values of the river are calculable, the estimation of the economic benefits in terms of human well-being of these values remains challenging. Similarly for the ecological state and amenities, benefits are even harder to estimate due to the public nature of these values (Birol et al., 2008). This study shows that there are substantial additional non-market benefits to be expected besides the market-based benefits such as avoided damage costs (e.g. lower agricultural and hydropower outputs or costs of rehabilitation projects), as a proxy of the economic welfare implications of adaptation strategies. Therefore, river adaptive strategies – at least in the analyzed region – should be designed and implemented considering all use and non-use values. Adaptive responses could incorporate, for example, crop changes, more sustainable irrigation system to reduce consumption and distribution losses and replenishment with water from the riverhead dam in order to maintain the environmental flows together with the hydroelectricity production. Finally, the good ecological status of the river aggregates a considerable value in residents' welfare, and hence its continuous monitoring through biological and hydro-morphological indicators is also needed to endorse the effectiveness of future adaptation measures. Bearing in mind the above-mentioned remarks, it is evident that non-market valuation techniques are necessary to estimate the total economic benefits of adaptation. So far, however, data for non-market benefits about adaptation of water resources management to climate change are rather scarce (EEA, 2013). Yet, such approaches underlie several limitations associated with the nature of the methods used and the validity of parameter estimates, as well. For example, the contingent character of the CE method or the assumption of the additive and non-correlated utility form has been criticized (Sayadi et al., 2009). In addition, biases have been reported related to payment vehicles, strategic behaviour, interviewing, and difficulty to link choices to the real world (Louviere et al., 2000). As regards our research, even though these caveats were expected to be augmented by the uncertain nature of climate change issues, no additional biases were observed at least according to the follow-up answers given by the respondents. However, this study relies on survey data and therefore its results reflect only the characteristics of the spatial and temporal sample frame. Preference variations could be enhanced if the population living in areas downstream from those sampled was surveyed, i.e. considering the choice patterns across the whole catchment area. In addition, the focus of the study was on the general drought trend envisaged by present climate projections. Nevertheless, it is likely that climate change in the area (Giannakopoulos et al., 2011) will bring about also extreme events (i.e. more frequent and intense precipitations, floods, intensive drought), whose economic impacts are not captured by this experimental application. Thus, further surveys and analyses are required to improve our knowledge of the adaptation costs and benefits, leading to the reinforcement of the adaptive capacity with the concurrent attainment of WFD's goals in the long run for the European water bodies.

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