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Assessment of renaturation measures for improvements in ecosystem services and flood risk mitigation

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Abstract

The present paper offers a contribution to the research on social acceptance of interventions aimed at water ecosystem improvement and flood risk mitigation through renaturation measures. A CE study has been implemented to assess trade-offs between attributes of alternative projects, including social costs deriving from proposed actions of renaturation of river flows. The aim of our approach is to investigate the role of attitudinal factors in the valuation of costs and benefits generated by renaturation measures. A Hybrid Latent Class (HLC) model is applied to the data, revealing the existence of two distinct groups, characterised by different valuations of the attributes of the project. It is found that class membership depends on latent attitudes toward environmental protection and risk perception. Our study confirms the fruitfulness of the HLC modelling approach in stated preference studies regarding ecosystems valuation, as it provides a richer understanding of public preferences and allows more finely targeted policy indications.

Keywords

Renaturation Measures, Water Ecosystems, Flood Mitigation, Choice Experiments, Hybrid Latent Class Choice Model

1. Introduction

Overexploitation and pollution of water resources is an urgent problem in many countries, and dealing with these issues is crucial for pursuing sustainable development (Wang et al., 2020). Since the early 2000s, the European Union has set ambitious goals for the management of aquatic ecosystems: the Water Framework Directive (WFD) 2000(60) has been developed with the purpose of establishing a framework for the protection of all waters (inland, coastal, transitional and groundwater), and to promote sustainable water use (EC, 2000). More recently, the hazard posed by catastrophic flood events to human lives, the economy and the environment, due to climate change and increased urbanisation (Wang et al., 2021) has called attention for considering risk mitigation objectives within the scope of sustainable water management plans. The Flood Directive (FD) 2007/60/EC has been delivered with the aim "to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity" (EC, 2007). The Member States are required to establish appropriate management plans in flood-prone areas, in order to reduce the likelihood of floods and limit their impacts through actions of risk assessment and mitigation. It is explicitly indicated that the Flood Directive "shall be carried out in coordination with the Water Framework Directive", and that flood risk management plans and river basin management plans should be coordinated. In fact, all Water Directives (which also include the Environmental Quality Standards Directive, EQSD (2008/105/EC), and the Groundwater Directive, GWD (2006/118/EC) should be seen as components of a single policy scheme (EC, 2006, 2008). This systemic approach is particularly relevant if we consider the impact on the quality and quantity of waters, or on the biodiversity of ecosystems, produced by conventional practices for flood control. For example, structures which change the river flow, or are designed to contain the water in the river-bed, may negatively affect the quality of the ecosystem, because of soil sealing and land transformation. Besides, such strategies may even increase the risk of catastrophic flood events in the downstream areas, especially if rivers are straightened and canalised. An alternative approach, advocated by EU Water Directives, is to protect and manage water resources using natural means and processes. Natural Water Retention Measures (NWRM) (EU, 2020) have the potential to provide multiple benefits, including flood risk reduction, water quality improvement, groundwater recharge and habitat improvement. For example, interventions that favour the natural course of rivers, expanding the storage capacities of rivers during floods, may be more effective in protecting against catastrophic events, while providing further benefits through improved ecosystem services, in compliance with both the WFD and the FD. Admittedly, the cost of such measures can be substantial, including direct, indirect and opportunity costs stemming from the relinquishment of flood-prone areas which are currently, or could be in the future, used for economic purposes. And yet, their implementation would be justified if the net benefits accruing to society were positive.

A report issued by the European Commission in 2014 remarked that "…despite growing evidence, the lack of knowledge and awareness of the potential costs and benefits associated with NWRM remains one of the strongest impediments to their widespread implementation" (EC, 2014). The current state of the art has not changed much since then. The dearth of valuation studies dealing with natural measures for flood mitigation is quite surprising, especially if confronted with the attention dedicated to the WFD (Hanley et al., 2006; Alvarez-Farizo et al., 2007; Brouwer, 2008; Bliem et al., 2012; García-Llorente et al., 2012; Kataria et al., 2012; Metcalfe et al., 2012; Doherty et al., 2014 are just a sample of the many valuation studies in this context). In contrast, as far as we know, only few applications regard the European Flood Directive, or more in general renaturation measures to mitigate flood risks: for example, Zagonari, 2013; Ryffel et al., 2014; Brouwer et al., 2016; Rulleau et al., 2017.

The aim of the current paper is to contribute to filling this gap, providing an economic assessment, and estimating trade-offs of improvements in ecosystem services and mitigation of flood risk, in a multiple function project perspective, as the NWRM approach suggests. A Choice Experiment (CE) has been designed to evaluate social costs and benefits associated with measures aimed at improving water quality and ecosystem services, and at mitigating flood risk by means of rivers renaturation measures. The application regards an Italian insular region (Sardinia), characterised by a Mediterranean climate, with recurrent problems of droughts, eutrophication of freshwaters and increasing flood risk. Since social acceptance of public projects is influenced by attitudinal factors (e.g. Spash et al., 2009; Liu et al., 2018) particular attention is given to estimating the influence of respondents' beliefs on their stated preferences. The data has been modelled through a Hybrid Choice model structure (Ben-Akiva et al., 1999, 2002), which allows joint estimation of both latent psychological and observed socio-demographic factors in the analysis of choice. More specifically, we applied a Hybrid Latent Class (HLC) model, where the latent class membership is modelled conditional on latent constructs, which are identified through measurement indicators. This modelling approach, first proposed by Hess et al. (2013) in a transportation context, has seldom been used in environmental economics applications (notable exceptions are Hoyos et al., 2015; Mariel et al., 2015; Bartczak et al., 2016; Grilli et al., 2018; Owusu-Sekyere et al., 2019) and, to the best of our knowledge, it has never been implemented to assess public projects in compliance with the European Water Directives, nor projects involving NWRM.

The paper is structured as follows: the following paragraph contains an analysis of socio-psychological determinants of individual preference for ecosystem services and a review of previous stated preference studies (including those applying a hybrid choice model) on valuation of water improvements; the third paragraph exposes the methods applied in this paper; the fourth section focuses on the description of the case study and survey administration; the results of the statistical analysis and the willingness to pay (WTP) estimates are reported in section 5; the last section contains conclusions and policy suggestions.

2. Behavioural models

The influence of attitudes and beliefs on the intention to perform environmentally significant behaviours, such as stating willingness to pay for a certain policy, is a matter that has been analysed in various social psychological models, and especially in the Value-Belief-Norm theory proposed by Stern et al. (1999). According to this theory, specific beliefs, activated by personal values, are major drivers of the decision process: in particular, Awareness of Consequences[1] (AC) and Ascription of Responsibility[2] (AR) are triggers of a sense of obligation to act (moral norm). Personal capabilities (education, means, knowledge and skills) and contextual factors (information, social norms, regulation) are also important in influencing the decision process either indirectly, through attitudinal factors, and/or directly, facilitating or hindering the outcome realisation. The latter aspect has been explicitly taken into account by the Theory of Planned Behaviour (Ajzen, 1985), by adding the component of perceived control to the behavioural model. From an economic theory perspective, control can be interpreted in terms of budgetary and technical constraints in a utility maximising process: this framework is perfectly compatible with the assumption of a rational decision-making process. However, as emphasised by Stern (2000), only the attitudinal part of a behavioural model can provide deeper insights on the motivation behind a certain behaviour. As suggested by Halkos and Matsiori (2014), such understanding can be especially important in water ecosystems valuation studies, to provide useful indications for optimal water resource management.

[1] The belief that certain current conditions have an impact on valued objects.
[2] The belief that a person's own behaviour can reduce threats on valued objects.

The importance of pro-environmental and altruistic attitudes, perceived personal responsibility and awareness of consequences has been examined in previous studies concerning water ecosystems valuation. Cooper et al. (2004) find a significant positive effect of pro-environmental values and AR beliefs on WTP for water quality improvements in East Anglia, UK. In a CE study regarding the valuation of a wetland in Greece, Birol et al. (2006) construct an Environmental Consciousness Index (ECI), finding that higher environmental consciousness is associated with pro-environmental behaviour and stated WTP for conservation. A similar index has been adopted by García-Llorente et al. (2012) to model preferences toward alternative scenarios regarding land use in a water district in Spain: the authors confirm the result that higher ECI scores are associated with higher WTP for environmental improvement. Buckley et al. (2016) analysed the effect of two psychological constructs describing "Ecocentric" (pro-environmental) and "Environmental Apathy" (egoistic) orientations on WTP for water-saving measures. Both factors resulted significant, with opposite effects (positive for the former, negative for the latter). In a choice experiment study aimed at assessing preferences for wetland conservation in Malaysia, Hassan (2017) finds that people characterised by higher AC of environmental damage were willing to pay more for environmental protection. This result is confirmed by Martin-Ortega et al. (2011), who find that AC of water scarcity in an area is positively correlated with willingness to pay for solving the problem.

Pro-environmental attitudes and risk perception are often associated with personal characteristics, such as education (Liere and Dunlap, 1980; Botzen et al., 2009; Casaló and Escario, 2018); or contextual factors, such as experience (Corral-Verdugo and Pinheiro, 2006; Kellens et al., 2013). The effect of previous experience of problems on WTP is unclear: on one hand, people who have experienced problems related to the state of water ecosystems should be more aware, and therefore more likely to accept improvements scenarios, and more willing to pay for them; but this experience may also induce a lack of confidence in the efficacy of policy actions (this is the "risk perception paradox" suggested by Wachinger et al., 2013). For example, Brouwer et al. (2015) find mixed evidence on the effect of past experience of restrictions in the water service on WTP for improving the service; while Abbas et al., (2015) and Brouwer et al. (2016) do not find significant effects of previous experience of floods on WTP to mitigate flood risk, or hedge against flood damages. A possible explanation is provided by the hypothesis that experience influences the perception of risk: if, based on experience, people think that they can cope with the risk, then they would be less motivated to act; whereas the experience of catastrophic events, which cannot be controlled by the individual, may be powerful in activating hedging behaviour (see Slovic, 1987; Botzen et al., 2009).

3. Methodology

The Random Utility Model (RUM) is an econometric model of choice proposed by McFadden (1974), based on Luce's (1958) probabilistic utility theory. Individuals are assumed to choose the option that maximises their utility, which is a function known to the individual but unknown to the researcher. From a modeller point of view, the utility that the decision maker *n* derives from alternative *i* in the choice situation *t* could be expressed as:

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

The term V_{int} is a function of explanatory variables x_{int} and preference parameters β. The covariates are attributes of the object of choice (in our case, a project) and, possibly, individual (observed) characteristics. The preference parameters often include alternative specific constants (ASC) to capture preferences for a specific alternative which do not depend on the level of the attributes.

The utility parameters are estimated based on assumptions regarding the distribution of the error term ε_{int}. The multinomial logit model (MNL) is the "workhorse" model employed in CE studies.

It assumes that errors are independently and identically distributed (IID) as a Type I GEV (or Gumbel) distribution. Under the MNL model, the probability that individual n chooses y_i in the choice situation *t* is:

$$Prob(y_{int}|x_{nt}) = P_{nt} = \frac{\exp{(\beta' x_{int})}}{\sum_{j=1}^{J} \exp{(\beta' x_{jnt})}} \tag{2}$$

and the probability of a sequence of choices is the product of these probabilities:

$$P_n = \prod_{t=1}^{T} P_{nt} = \prod_{t=1}^{T} \frac{\exp{(\beta' x_{int})}}{\sum_{j=1}^{J} \exp{(\beta' x_{jnt})}} \tag{3}$$

In the MNL model, the preference parameters are invariant across individuals (some heterogeneity may be allowed by interacting the parameters with socioeconomic covariates). More sophisticated models have been proposed to account for heterogeneity of preferences: in particular, the Latent Class model (LC) (Greene and Hensher, 2003) relaxes the assumption of homogeneity of tastes by assuming that individuals can be grouped into classes according to their preferences toward the attributes of the project or the specific alternatives. The preference parameters are the same within a class, while differ across classes. Actual membership to a class is not observed: it is a latent variable depending on the probability of observing a given choice, conditional on the utility of the alternatives faced by the respondent. The probability of a sequence of choices conditional on class *c* membership is

$$P_{n|c} = \prod_{t=1}^{T} \frac{\exp{(\beta_c' x_{int})}}{\sum_{j=1}^{J} \exp{(\beta_c' x_{jnt})}} \tag{4}$$

The class membership is usually modelled as a logit, which may be dependent on covariates *z*:

$$Prob(c|z_n) = q_{n,c} = \frac{\exp{(\delta_0 + \delta' z_n)}}{\sum_{c=1}^{C} \exp{(\delta_0 + \delta' z_n)}} \tag{5}$$

hence, the unconditional probability of a choice is

$$Prob(y_{int}|x_n, z_n) = P_{n,c} = \sum_{c=1}^{C} q_{n,c} \times P_{n|c} \tag{6}$$

i.e. the expectation of the probability of the sequence of choices over the probability distribution of the class membership.

The LC model may include covariates in the class membership equation, with the aim of explaining the individual preference profile: in the standard model, such covariates are usually socioeconomic, demographic, or other observed characteristics of the individuals. However, as discussed in the previous section, unobserved characteristics, such as underlying attitudes, perceptions and beliefs, may play a relevant role in shaping individuals' preferences. Hybrid Choice models incorporate attitudinal indicators and structural equations to account for the influence of psychological factors in the decision process. In particular, the Hybrid Latent Class (HLC) model has been proposed by Hess et al. (2013) to estimate class membership probabilities conditional on latent constructs: the latter are based on attitudinal indicators, functionally related to socio-demographic characteristics of the individual and jointly estimated with the utility function parameters (Mariel and Meyerhoff, 2016).

Attitudinal characteristics are usually elicited through Likert scales, and modelled by means of measurement equations. The measurement is represented by a variable I_n, functionally related to the attitudinal Latent Variable LV as follows:

$$I_n = \zeta' LV_n + \nu_n \tag{7}$$

The variable I_n is not observed: we observe the indicators $i_1, i_2, .. i_M$ selected by the respondents on the proposed Likert scale, where $i_1 < i_2 < .. i_M$, and it is assumed that

$$i = \begin{cases} i_1 \; if & -\infty < I_n \leq \tau_1 \\ i_2 \; if & \tau_1 < I_n \leq \tau_2 \\ & \vdots \\ i_M \; if & \tau_{M-1} < I_n < +\infty \end{cases} \tag{8}$$

where the thresholds $\tau_1, \tau_2 \ldots, \tau_{M-1}$ are parameters to be estimated through an ordered probabilistic model. The probability of observing the specific answer i_m in a Likert scale is expressed as:

$$L_{I_n} = Prob(i_m) = Prob(\tau_{m-1} < I_n < \tau_m) = Prob(\tau_{m-1} < \zeta' LV_n + \nu_n < \tau_m) =$$

$$Prob(\tau_{m-1} - \zeta' LV_n < \nu_n < \tau_m - \zeta L' V_n) = F(\tau_m - \zeta' LV_n) - F(\tau_{m-1} - \zeta' LV_n) \quad (9)$$

where F is the distribution function (e.g. logistic, if an ordered logit structure is assumed). The probability of a sequence of answers from a series of items k is calculated as:

$$PL_{I_n} = \prod_{k=1}^{K} L_{I_n^k} \quad (10)$$

The attitudinal latent variable is usually specified as a random variable characterised by a linear structural equation:

$$LV_n = \gamma' z_n + \eta_n \quad (11)$$

where γ is a vector of parameters capturing the effect of socio-economic characteristics, namely the vector z_n, on the latent variable LV_n, whereas η_n is a random component usually assumed to follow a standard Normal distribution, i.e. $\eta_n \sim N(0,1)$.

A particular realisation of LV (i.e. a specific attitudinal characterisation) will influence the probability of class membership, and, through the preference parameters, the choice of a specific alternative: so, the expectation of the choices over the probability distribution of class membership (6) must be integrated over the density of the probability function η_n of LV. Summing up, a HLC specification will have four model components: the structural equation model, the measurement equations, the class membership model and the choice model. The joint log-likelihood is expressed as follows:

$$\sum_{n=1}^{N} ln \int_{\eta} \left(\sum_{c=1}^{C} q_{n,c} \times P_{n|c} \times PL_{I_n} \right) \times \mathrm{g}(\eta) d\eta \quad (12)$$

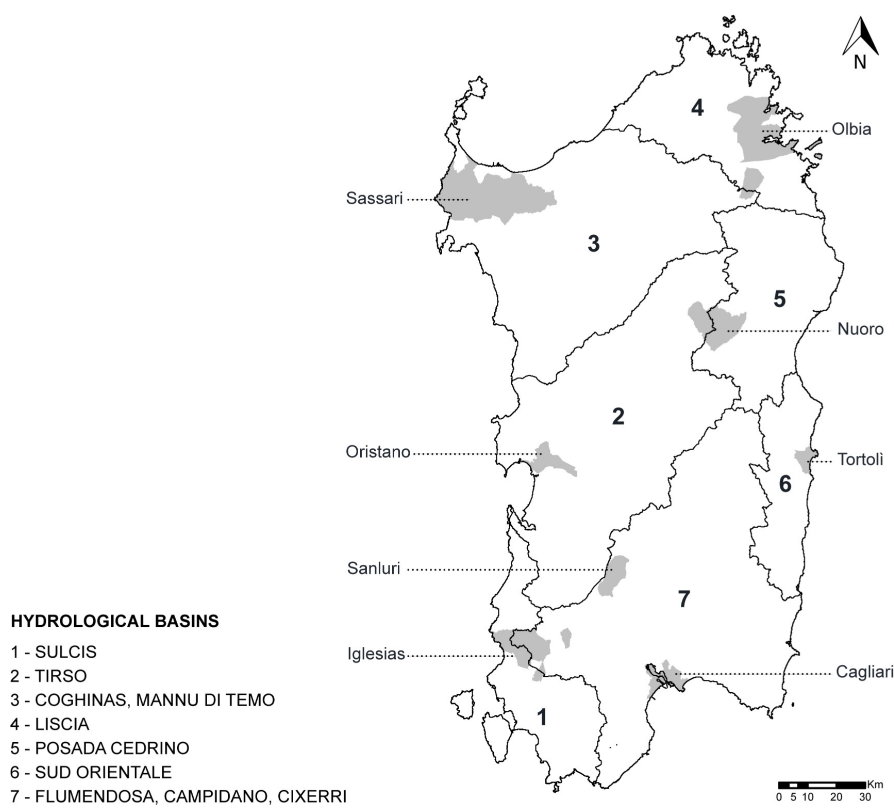
which is a function of parameters γ (measuring the impact of socioeconomic covariates in the LV structural equation), ζ (of LV in the measurement equations), τ (threshold parameters), δ (constant and latent variable coefficients of the class membership probability function), and β (capturing preferences for the attributes of alternatives, and for specific alternatives). Since this integral does not take a closed form, its computation requires approximation through simulation. The inclusion of multiple latent constructs in the model requires integration over multiple density functions, and a more complex computation.

4. Case study

Sardinia, the second largest island in the Mediterranean, is characterised by a hydrological system typical of Mediterranean regions, with highly irregular seasonal flow patterns observed in nearly all rivers. Although the regional territory includes several hydrological basins (see Figure 1), a single River Basin District has been established.

This political decision is grounded on the fact that in the last 50 years a complex infrastructure system has been created, to connect dams and reservoirs located in different regional areas.

Figure 1 Hydrological basins in the Sardinia River Basin District



About 34 large reservoirs (artificial lakes) store and provide raw water for residential, agricultural and industrial uses. This system makes possible, up to a certain extent, to redistribute water from well-endowed to lacking areas. However, quantity and quality issues still affect hydrological ecosystems and water provision. High temperatures and lack of rainfalls affect the quantity of water stored in the reservoirs, so that water restrictions are applied in drought periods. These conditions have also an effect on water quality, due to eutrophication and anoxia processes. On the other hand, the frequency of extreme rain events ("water bombs") has risen with climate change: this, especially after prolonged periods of drought, aggravates the risk of catastrophic floods. The province of Olbia is especially fragile in this respect, with 65% of its towns comprising areas classified "at very severe risk", i.e. risk of possible loss of human lives (RAS, 2004). The catastrophic flood induced by Cyclone "Cleopatra" in 2013 caused 16 deaths, 13 of which in the province of Olbia. The province of Cagliari ranks second, with 44% of municipalities with areas affected by very severe hydraulic risk, while the last in this risk scale is the province of Oristano (16%).

4.1 The research

The research has been carried out through three phases. The first step entailed a desk analysis of the Hydrographic District Management Plan (RAS, 2015) for data regarding the quality status of water bodies and the causes of pollution and of the Hydrogeological Management Plan (RAS, 2004) for data regarding flood risk in the region; a local press review over the preceding 5 years, which focused on floods, pollution, water service and related water issues; and a review of the literature dealing with valuation of water ecosystem services and/or flood risk. This information was used to develop the second phase of the research, which consisted of a qualitative analysis of in-depth interviews with various stakeholders and experts, and of focus groups with citizens. This in turn informed the third phase of the research, which entailed the administration of a survey, with choice experiments, to a representative sample of the Sardinian population.

4.1.1 Focus groups

Four focus groups were organised, engaging a total of 44 subjects aged between 34 and 64 years and residing in different locations in Sardinia, in order to obtain different social and territorial perspectives. The qualitative study aimed to highlight recurring themes, opinions and perceptions about water resources. The issues discussed in the focus groups can be grouped in five main areas:

(1) Knowledge, attitudes and values associated with water ecosystem services.

(2) Water service issues and opinions toward entities (institutions, companies, agencies) managing water bodies.

(3) Risk perception regarding quantity and quality of water bodies, and floods.

(4) Potential drawbacks of NWRM for improving the quality of water bodies and mitigating flood risks.

(5) Recreational value of water bodies.

Below are summarised the key insights that guided the definition of attributes and levels of the choice experiment:

(1) All participants expressed interest in the conservation of water resources, although they had scarce acquaintance with inner water ecosystems in the region and scarce awareness of their ecological conditions.

(2) The provision of tap water appears unevenly distributed in the region, with areas experiencing shortages and other disservices (Sassari, Olbia) and areas enjoying a regular service (Cagliari, Sanluri, Oristano). Inefficiencies were in part ascribed to presumed faults

of the water agency, and in part to structural reasons (droughts, excessive demand, insufficient storage capacity).

(3) Great concern was expressed for hydrological risks, especially by people who had a direct experience of flood events.

(4) The focus groups raised issues of potential conflicts between risk mitigation, through renaturation measures, and economic interests of farmers, firms and residents operating and living in proximity of river belts.

(5) Another theme proposed in the discussions was the indirect use value associated with recreational activities. In our focus groups, recreational uses received uneven levels of attention, probably because only a few participants engaged in recreational activities in inland aquatic ecosystems of Sardinia.

4.1.2 Choice Experiments Design

Based on the previous research steps, the following project elements were considered in the CE exercise: ecosystem quality, flood risk, water service, recreational services, economic losses due to renaturation measures; finally, a monetary cost for the individual was included to allow measurement of WTP.

The ecosystem quality attribute is expressed in terms of reduction of the percentage of rivers and lakes in Sardinia with poor ecological status (as seen in Hanley et al., 2006; Alvarez-Farizo et al., 2007; Brouwer, 2008; Martin-Ortega and Berbel, 2010; Martin-Ortega et al., 2011; García-Llorente et al., 2012; Kataria et al., 2012; Tait et al., 2012; Doherty et al., 2014; Brouwer et al., 2015, 2016). Good ecological status, and absence of specific pollutants, is essential to consider a river basin or a lake of good quality. Poor ecological status means that there is little biodiversity of aquatic species (plants, insects, fish) in the environment of rivers and lakes. Currently, about 30% of the regional rivers and lakes are estimated to have a poor ecological status.

Flood risk refers to the percentage of municipalities in Sardinia with areas classified as zones at "very high" flood risk by the Regional Water Authority. In these areas, floods could seriously harm people and the built environment, and human casualties are possible. Based on the Hydrogeological Management Plan (RAS, 2015) data, it can be estimated that, at present, 30% of Sardinian municipalities have part of their territory classified as areas at very high risk. The proposed measures would reduce this percentage through renaturation of riverbanks and creation of buffer areas along the riverbanks.

Potential conflicts between risk mitigation and economic interests of farmers, firms and residents operating and living in proximity of river belts, may arise. It is important that this aspect is taken into account in the valuation study, since the perception of social costs may influence the social acceptance of the proposed measures. Previous studies on ecosystem valuation dealing with this issue include Hanley et al. (2006), Hensher et al. (2006), Alvarez-Farizo et al. (2007), García-Llorente et al. (2012), Kataria et al. (2012), Stithou et al. (2012), Doherty et al. (2014), Ryffel et al. (2014), Brouwer et al. (2016). In our study, the concept of social costs was conveyed in terms of loss of jobs, as in Latinopoulos (2014) and Marsh and Phillips (2015).

Water service is a fundamental use value associated with aquatic ecosystems: the qualitative and quantitative condition of aquatic ecosystems has an obvious effect on the quality and quantity of tap water. This element has been considered in several CE studies dealing with valuation of aquatic ecosystems services, e.g. Alvarez-Farizo et al. (2007), Latinopoulos (2014), Rungie et al. (2014), Brouwer et al. (2015), Czajkowski et al. (2015), Dauda et al. (2015). In our case, the Water Service Restrictions project attribute is expressed as a decrease in the percentage of Sardinian municipalities that had experienced *severe* problems in the use of tap water in the five years preceding the survey: either quality problems (the water could not be used for drinking or cooking) or quantity restrictions (the water was supplied only for a limited time in a day). While the experience of milder restrictions is quite pervasive in the region, the percentage of Sardinian municipalities that, over the selected period, have been affected by *serious* water service problems[3] is about 10%.

The recreational attribute has been included to assess potential interest in this ecosystem service. Previous literature showed that the recreational use of inner waters directly influences the perception and the valuation of quality (Martin-Ortega and Berbel, 2010; Bliem et al., 2012; Kataria et al., 2012; Stithou et al., 2012; Buckley et al., 2016). Also, users are more willing to pay to support policies directly affecting the attributes related to their particular use of water bodies, such as renaturation of riparian areas for walkers and day-trippers, or water quality improvements for swimmers and fishermen (García-Llorente et al., 2012; Doherty et al., 2014). Nowadays, tourist, recreational or sporting activities – i.e. boat trips, canoeing, triathlon, sport fishing, etc. – are possible only in few rivers and lakes of Sardinia, also due to their environmental quality status. The proposed scenario regarded an extension of this possibility to the most of the water basins.

Finally, the private cost attribute is formulated as the possible increase in local taxes required by the Regional Government to carry out the investments necessary to improve the quality of the water of rivers and lakes, to improve water service and recreational uses, and to mitigate flood risk.

The Choice Experiment was based on an MNL-d efficient design, consisting of a set of 36 combinations with 6 blocks. Each respondent faced 6 cards and each card showed three scenarios:

[3] We define restrictions as serious if they are recurrent (a problem that occurred more than twice in the period 2010-2016 in a discontinuous manner) or chronic (a problem lasting several consecutive days in a year and that occurs in several consecutive years, hence affecting the most part of the period considered).

one representing the status quo and two intervention scenarios. An example of choice exercise is reported in Table 1.

Table 1 Choice exercise

	Scenario A	Scenario B	Status Quo
% of rivers and lakes classified as "SCARCE quality" ecosystems	0%	15%	30%
% of municipalities with serious water service problems	10%	0%	10%
Jobs lost as a result of the renaturation of river belts	400	180	0
% of municipalities with areas at "highest flood risk"	30%	10%	30%
Recreational uses in rivers and lakes	Possible only in a few	Possible in most	Possible only in a few
Annual increase in Local Taxes	40 €	90 €	0 €

Summarising, the attributes and levels are presented in Table 2 (in *italic*, status quo levels):

Before the CE exercise, an informative card was handled to the respondents, which explained the project scenarios compared with the status quo and the proposed project improvements, with associated social and private costs. The questionnaire was handed out to 804 residents in the administrative centres of the Sardinian provinces in the period of the survey (Cagliari, Iglesias, Sanluri, Oristano, Sassari, Olbia, Nuoro, Tortolì), with quota sampling on the adult resident population in each province. Descriptive statistics about the sub-samples and their population counterparts can be found in the Supplementary Materials.

The questionnaire included items on demographic and socio-economic characteristics, acquaintance with regional water ecosystems, and experience of water service issues and floods. Likert scales were employed to elicit beliefs and attitudes, drawing from the literature on pro-environmental behaviour, and including statements from the Awareness of Consequences (AC) and the Ascription of Responsibility (AR) scales (Schwartz, 1968a, 1968b); as well as items eliciting respondents' knowledge of water resources issues (causes of poor water quality, water scarcity and floods), and perceived probability of critical events related to water service or floods, and awareness of their impacts, as in Zagonari (2013), drawing from Fischhoff et al. (1978) and Slovic (1987).

Table 2 Attributes and levels

Attribute	Levels
Water ecosystem improvement	*30%* of water resources classified as "scarce quality"
	15%
	0%
Water service improvement	*10%* of municipalities with water service problems
	0%
Jobs lost as a result of the renaturation of river belts	*0*
	180
	400
Mitigation of hydrological risk	*30%* of municipalities with areas classified as areas at highest hydrological risk
	10%
Improvement of recreational activities	*recreational activities only in few rivers and lakes*
	recreational activities in most rivers and lakes
Increase in local taxes	*No tax increase*
	+40 €/year
	+90 €/year
	+150 €/year

5. Results

5.1 Model estimates

Model estimation has been carried out using the Apollo software for choice model estimation (Hess and Palma, 2019a, 2019b). Starting from the "workhorse" MNL, several LC specifications have been estimated. To define the appropriate number of classes, we estimated several specifications, and selected a model with two segments on the basis of AIC and BIC, and significance of coefficients.

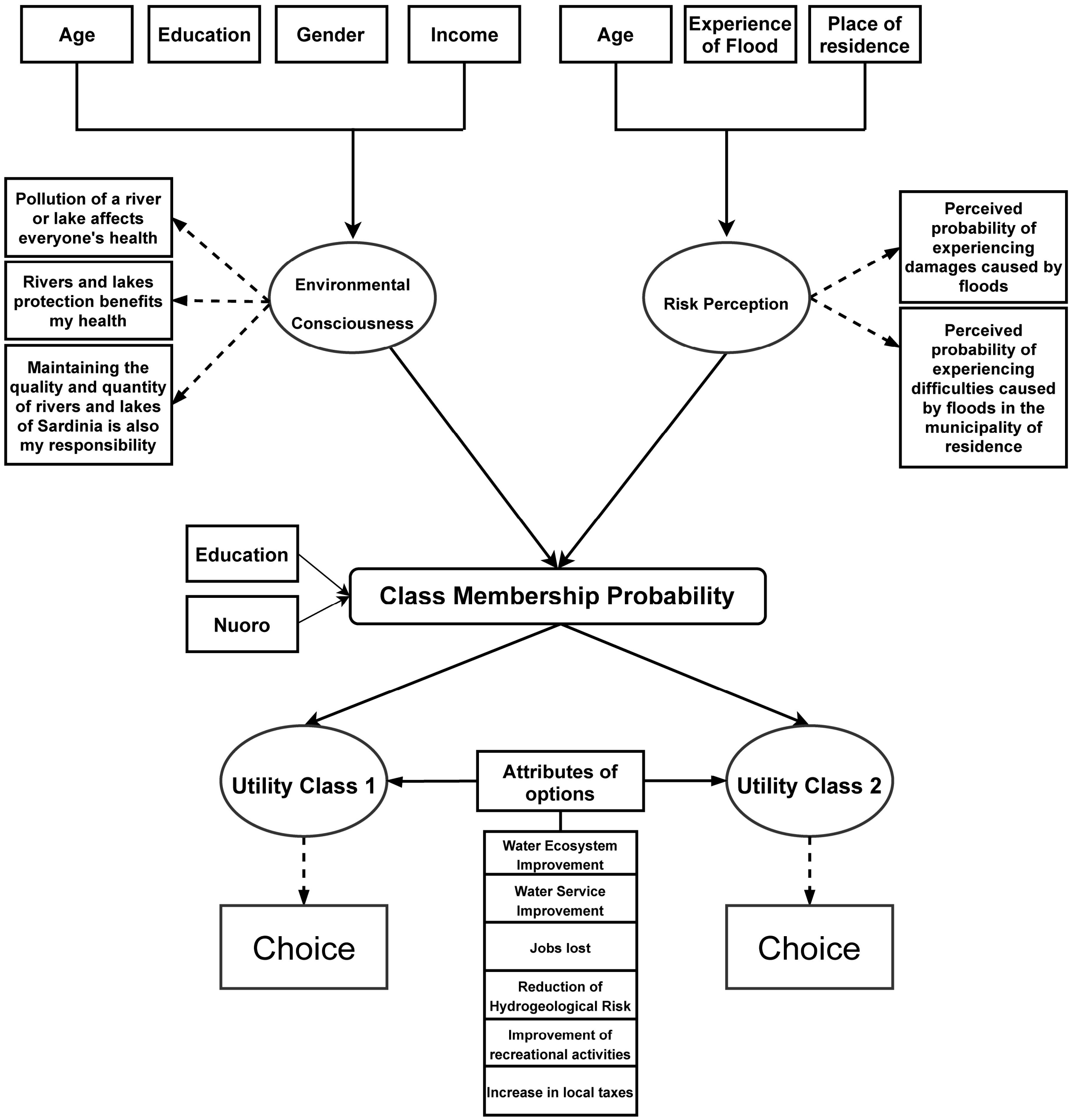


Figure 2 Hybrid Framework to model preferences for water ecosystem services improvement

Results for the MNL and LC model specifications, estimated first without and then with observed covariates, are provided in the Supplementary Materials.

Table 3 HLC Choice Model estimates

	Class A		**Class B**	
Utility functions	*Means*	*(St.err.)*	*Means*	*(St.err.)*
$\beta_{Ecosystem}$	0.389***	(0.043)	0.327***	(0.059)
$\beta_{\text{Water service}}$	0.175***	(0.053)	0.168*	(0.086)
β_{Jobs}	-0.235***	(0.022)	-0.588***	(0.035)
$\beta_{\text{Flood Risk mitigation}}$	0.661***	(0.056)	0.377***	(0.093)
$\beta_{\text{Recreational activities}}$	0.318***	(0.050)	0.113	(0.086)
β_{Tax}	-0.039***	(0.008)	-0.123***	(0.012)
$\beta_{\text{Status Quo}}$	-1.342***	(0.119)	-0.089	(0.115)
Class Allocation Probabilities	*Means*		*(St.err.)*	
δ_{A}	-0.412***		(0.181)	
δ_{LV1}	0.406***		(0.113)	
δ_{LV2}	0.148**		(0.070)	
$\delta_{HighEdu}$	0.7083***		(0.212)	
δ_{NU}	0.8867***		(0.345)	
Structural equation: Environmental Consciousness				
$\gamma_{HighEdu\_LV1}$	0.410***		(0.113)	
γ_{Female_LV1}	0.233**		(0.093)	
$\gamma_{Under30\_LV1}$	-0.486***		(0.121)	
Structural equation: Risk Perception				
$\gamma_{Under30\_LV2}$	0.450***		(0.113)	
$\gamma_{ExperDam\_Flood\_LV2}$	0.724***		(0.148)	
$\gamma_{ExperInc\_Flood\_LV2}$	0.796***		(0.101)	
γ_{CA_LV2}	1.516***		(0.196)	
γ_{IG_LV2}	1.096***		(0.246)	
γ_{SL_LV2}	0.974***		(0.261)	
γ_{SS_LV2}	0.959***		(0.192)	
γ_{OL_LV2}	1.969***		(0.225)	
γ_{NU_LV2}	1.533***		(0.235)	
γ_{TO_LV2}	1.775***		(0.268)	
Goodness of fit measures				
Average Class Probabilities	0.53		0.47	
N. of obs.		4824		
Estimated parameters		57		
Log likelihood (whole model)		-8435		
Log likelihood (Choice)		-4501		
AIC		16983		
BIC		17353		

*Notes: '***' p<0.01; '**' p<0.05; '*' p<0.10*

Afterwards, to enrich the interpretation of the results, we used a HLC structure to model the class membership allocation. To help identification of the latent constructs we first carried out an exploratory analysis through a Principal Components Analysis (PCA) on psychometric responses.

A simultaneous routine has been employed to estimate the HLC model, so as to minimise bias and maximise efficiency (Vij and Walker, 2016). A graphical representation of the estimated model is provided in Figure 2, whereas the estimation results are presented in Table 3. Results for the measurement equations are provided in the Supplementary Materials.

5.1.1 Choice model

The vector of parameters β contains the preference coefficients, all with the expected sign, and all significant at 1% level in class A; conversely, in class B the coefficient of Water Service is only significant at 10% level, and the coefficients of Recreational activities and the Status Quo alternative are not significant.

Compared to class A, individuals in class B are characterised by lower interest in actions leading to improvement of ecosystem quality and water-related recreational activities, and in flood risk mitigation, whereas they show greater attention to both social and private costs: for example, they perceive higher disutility from the loss of jobs caused by the renaturation of river banks and from the increase in local taxes. Individuals in Class A are characterised by a significant negative coefficient of the Status Quo alternative: this indicates that, on average, respondents perceive a loss of utility if the current situation is maintained, and that they generally prefer the project scenarios presented. The corresponding coefficient is not significant for individuals in Class B, suggesting that on average individuals in this class are indifferent between the Status Quo and the project options. The 58 respondents (7% of the sample) who always selected the status quo option in the CE exercises are (stochastically) allocated within this class. These individuals had been prompted with a follow-up question, asking the motivation behind their choice: the typical answer was that they did not trust the relevant authorities to make effective investments, and would not accept higher taxes.

5.1.2 Class membership

We identified two latent constructs, henceforth labelled *Environmental Consciousness* and *Risk Perception*, as the most relevant factors in determining class membership. Results of the Principal Component Analysis and the Cronbach's Alpha test are provided in the Supplementary Materials. The first LV is associated with three statements, eliciting the respondent's awareness of consequences deriving from water pollution for public and personal health, and ascription of responsibility in preserving water quality and quantity. Even though the alpha score (α=0.6) indicates moderate internal consistency, possibly because two different beliefs are merged in one construct, it proves very relevant for power fit; furthermore, exploratory PCA reveals high correlation of these three items with the corresponding latent factor. The second construct, *Risk Perception,* is associated with two statements, measuring the respondents' perceived probability that, in the next five years, they would have experienced: a) damages to the house, car or belongings due to a flood (private cost); b) difficulties caused by a flood in the municipality in which the respondent used to live (social cost). In this case, the alpha score (α=0.8) indicates high internal consistency of the construct. The δ coefficients of the two attitudinal constructs in the membership allocation model are both significant (1% and 5% significance level) and positive, suggesting that individuals characterised by higher *Environmental Consciousness* and higher *Risk Perception* are more likely to belong to Class A. This is clearly consistent with the interpretation of preference coefficients in the choice model: individuals in Class A perceive higher benefits from the proposed measures that increase environmental quality and mitigate the risk of floods; whereas individuals in Class B are more worried of the private and social costs associated with such measures. As suggested by Vij and Walker (2016), we estimated both the indirect (through the latent variables) and the direct effects of the observed variables on the class membership probability function. The only direct effects (residual with respect to the indirect effects) that are found significant are given by education (more educated people are more likely to be in Class A, beyond the effect of education on *Environmental Consciousness*); and by the NU spatial dummy (clear of the effect on *Risk Perception*, citizens living in Nuoro are more likely to belong to Class A).

5.1.3 Structural equations

The structural equations models provide useful information for social profiling. To identify the appropriate set of explanatory variables in the structural equations we tested several specifications and selected the best model based on Information Criteria. The γ coefficients of the structural equations reported in Table 3 are all significant and with the expected sign. The positive sign of coefficients for Female and High Education is consistent with previous research investigating socio-economic determinants of a pro-environmental attitude. For example, Weaver (2002), Hirsh (2010) and Farizo et al. (2016) found that women are more likely to support pro-environmental beliefs; Dunlap et al. (2000), Markowitz et al. (2012), Casaló and Escario (2018) and Melo et al. (2018) found a significant positive relationship between higher levels of education and both pro-environmental attitudes and behaviours. Then, we find that younger people are less concerned about the impacts of low quality in freshwater bodies, which is somehow in contrast with previous literature: as observed by Grønhøj and Thøgersen (2009), most studies identify a negative relationship between age and pro-environmental beliefs (e.g. Liere and Dunlap, 1980; Dunlap et al., 2000; Weaver, 2002). Our result can be explained considering that the factor *Environmental Consciousness* is associated with awareness of consequences on health: previous research has shown that older people tend to be more risk adverse in the health domain (Bonem et al., 2015; Dohmen et al., 2011).

As regards the latent construct *Risk Perception*, we find that age, residential location and experience of problems caused by a flood are significant explanatory variables in the structural model. Previous literature found that education was an important predictor of Risk perception (Botzen et al., 2009), but this relationship was not significant in our application. The territorial dummies (coefficients γ_{CA}, γ_{IG}, γ_{SL}, γ_{SS}, γ_{OL}, γ_{NU} and γ_{TO}) measure the effect of residing in other areas compared to the baseline Oristano, i.e. the safer province in terms of flood risk (see section 4). The positive sign of the coefficients implies that residents in Oristano are characterised by the lowest *Risk Perception* with respect to the other Sardinian citizens. In contrast, residents in Olbia, followed by those in Cagliari and Tortolì, are those with the highest perception of risk: this result is in line with our expectations since these territories are characterised by higher flood risk (see Section 4). The results also indicate that younger respondents show a higher perception of flood risk. In this respect, the literature is not univocal: some authors found that older individuals have a lower risk perception (Miceli et al., 2008; Botzen et al., 2009); other studies underline a positive relationship between age and risk perception (Peacock et al., 2005; Grothmann and Reusswig, 2006). In the last decade, flood events have increased in frequency and intensity at the global level, and this is true also in the case of Sardinia. Our interpretation is that younger individuals have a higher perception of flood risk because they have experienced such events relatively more frequently, whereas older respondents have a more diluted lifespan experience. In fact, previous research (Grothmann and Reusswig, 2006; Miceli et al., 2008; Whitmarsh, 2008; Bradford et al., 2012) has found evidence of a positive relationship between risk perception and previous experiences of damages or inconveniences due to a flood. Also in our case the personal experience of losses caused by flood events proves to be an important factor in shaping respondents' *Risk Perception*, as can be seen from the positive and significant coefficients of the latent constructs "Experience of Damages" and "Experience of Inconveniences" caused by floods.

5.2 WTP estimates

Table 4 presents the estimates of willingness to pay for the five attributes of water quality improvement measures[4].

Table 4 Estimated WTP value for the Hybrid Latent Class model

Variables	Class A Mean WTP *Robust St.err.* *(C.I.)[a]*	Class B Mean WTP *Robust St.err.* *(C.I.)*
Ecosystem	**98.99** *23.04* *(53.84 144.14)*	**26.51** *4.68* *(17.34 35.69)*
Water service	**44.50** *12.90* *(19.23 69.78)*	**13.66** *6.31* *(1.28 26.03)*
Jobs	**-59.67** *11.87* *(-82.93 -36.41)*	**-47.75** *5.47* *(-58.48 -37.02)*
Flood Risk mitigation	**168.18** *41.94* *(85.97 250.39)*	**30.59** *7.81* *(15.28 45.89)*
Recreational activities	**80.87** *24.93* *(32.02 129.73)*	**-**

a: standard errors and Confidence Intervals calculated using Delta method

The confidence intervals are obtained by applying the delta method. On average, the WTP values show that citizens are willing to support measures of improvement of water ecosystems in Sardinia, accepting an increase in local taxes. In particular, people belonging to Class A are willing to pay an extra €99 per year to reduce the percentage of water bodies with low ecological status; whereas respondents of Class B are willing to pay approximately €26.5 per year. Our results are within the range of values obtained in other Stated Preference studies. Using Contingent Valuation, Brouwer

[4] To compute the individual WTP values, the *tax* coefficient is multiplied by 10, since, in order to ease computations in the model estimation, the corresponding variable was downscaled by 10.

(2008) estimates the WTP for improving water quality, through the implementation of the Water Framework Directory. He finds an average value of €90 - €105 per household, but underlines significant differences related to the income level: respondents with low income are willing to pay approximately €45per year; whereas those with higher income are willing to pay €165 per year. Using a Discrete Choice Experiment, Metcalfe et al. (2012) find that the average WTP for improving local water bodies quality in England and Wales is approximately equal to €97; in Ireland, Doherty et al. (2014) find that the WTP for good ecological status (considering both ecosystem health and water clarity and smell) is €71.

The value associated with a reduction of water service problems is €44.5 for Class A and €13.7 for Class B. Other studies consider a similar attribute: in Latinopoulos (2014) the WTP for a reduced frequency of water supply interruptions is approximately €17; Italian respondents in the study of Brouwer et al. (2015) are willing to pay about €60 to reduce the frequency of water use restrictions. The Flood risk mitigation is valued €168.2 by respondents in Class A and €30.6 by those belonging to Class B. The latter value is much lower than the range estimated by Ryffel et al. (2014) from €110 to €304 for renaturation interventions aimed at reducing flood risk.

The estimated WTP for improving recreational opportunities is about €81 for Class A. The value for Class B is not significant. The value for Class A is higher than the range of values found in other studies: Doherty et al. (2014) found a WTP of €14 and Stithou et al. (2012) of €22.67. As regards the social costs caused by environmental interventions of renaturation of river banks, which could impact on agriculture and other activities located close to the riparian area, respondents in Class A and Class B would respectively accept, for the loss of 100 jobs, a compensation of about €60 and €48 (i.e. €0.60 and €0.48 per job). These values are reasonably close to the findings of Marsh and Phillips (2015), who estimate a WTA of about €0.88 per job lost.

6. Conclusions

The present paper offers a contribution to the research on social acceptance of measures aimed at improving water ecosystems and flood risk mitigation through NWRM. The analysis of the data gives evidence of the existence of two main groups: preferences differ across groups over most of the proposed ecosystem improvement scenarios. Only for the *Water Service* attribute the individuals' willingness to pay appears substantially homogeneous across the sample. Two latent constructs have been found to significantly influence the class allocation: the first, which we dubbed *Environmental Consciousness,* is associated with beliefs regarding awareness of consequences on health of bad quality of freshwaters, and acknowledgment of personal responsibility in their control, and is explained by socioeconomic characteristics such as high education income, and older age. The second construct, *Risk Perception*, is associated with beliefs regarding the probability of adverse consequences from floods, and is explained by individual characteristics such as younger age, previous experience of floods and location in areas at higher flood risk. Individuals showing higher *Environmental Consciousness* and *Risk Perception* perceive higher benefits from interventions aimed at mitigating the risk of floods, and improving the quality of water ecosystems and their recreational uses. On the other hand, also the social costs that such measures may entail are important to the citizens: in particular, this is true for people characterised by lower *Environmental Consciousness* and lower *Risk Perception*, so that in some situations the perceived costs may offset the perceived benefits, especially if use values (e.g. agricultural uses of river buffer areas) generate high (perceived) opportunity costs.

The WTP values obtained in this study reflect the wide range of use and non-use values related to water ecosystems, and can be used to assess the social value of measures related to the Water Directives before their implementation.

In addition, the findings of this research can be useful to inform decision-making about communication campaigns and actions to promote support of the adoption of the measures required to achieve the Water Directives objectives. In this application, awareness of impacts caused by polluted water on health, and ascription of responsibility are seen as important drivers of preference for environmental attributes and choice of intervention options. People characterised by lower levels of environmental conscience are more attentive to the costs associated with the proposed measures. Hence, the suggestion for communication campaigns is, on one side, to increase general environmental awareness; on the other side, more information should be conveyed on the economic costs brought by lack of intervention: cost of damage related to flood events, impacts on tourism and the economy due to scarce quality of water, higher bills due to water treatment etc. The other important driver of choice seen in our study is risk perception: in this case, past experience of floods events plays a fundamental role, and information campaigns should show, through examples, the increased risk of floods and the efficacy of renaturation measures in mitigating the risk of catastrophes associated with floods.

Moreover, communication could be customised on the basis of the structural relations uncovered, through the HLC model, between socio-psychological and socio-economic and demographic characteristics of the citizens. For example, as regards our case study, information campaigns could be targeted to younger individuals, who resulted to be less conscious of the impacts on health of bad quality of water, to increase their awareness; and it could be tailored to reach less educated people, and especially to the male segment of the audience. Specific information campaigns could be targeted to more mature citizens to increase their perception of risk, and awareness of consequences, in flood-prone areas; and to broader audiences in areas that have not experienced recent catastrophic flood events. Such implications apply to the regional context under analysis, but the approach adopted in this study could be fruitfully applied at country level: first, to determine the cost and benefits of renaturation measures, in order to guide national decision-making processes concerning water resources; and second, to understand whether beliefs and perceptions driving WTP for improving water quality and mitigating flood risk are consistent across regions and countries, with the purpose of providing suggestions for tailored communication campaigns.

Despite these rich insights, this study only included beliefs on specific environment-related topics and further research is required to gain a deeper and comprehensive understanding of the association between stated choices and values, beliefs and norms. Future work might explore these more complex causal relationships underlying the process of human decision-making.

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