Waiting or acting now? The effects on willingness-to-pay of delivering inherent uncertainty information in choice experiments

Cati Torres, Michela Faccioli, Antoni Riera

Abstract

With a focus on expected climate change (CC) risks, this paper analyzes the effects of inherent uncertainty on the willingness-to-pay for a preservation policy. To do this, it relates outcome uncertainty to the probability of occurrence of an expected CC impact within a given time horizon. Thus, unlike the existing studies, this paper links outcome uncertainty to the uncontrollable component of environmental uncertainty derived from the stochastic nature of ecosystems' behavior. Results show the support for the preservation policy is stronger in the presence of inherent uncertainty, this indicating risk aversion. In contrast, findings are not conclusive with respect to individuals' sensitivity to the probability of impact occurrence. These results are policy relevant since they can serve to stimulate rather than discourage environmental action when it comes to contexts characterized by many uncertainties.

Keywords: preference analysis, inherent uncertainty, choice experiment, adaptation, climate change.

1. Introduction

Risk and uncertainty are becoming central in environmental cost-benefit analysis (ECBA). In this sense, it has been recognized that ECBA of public policies cannot be undertaken under the assumption that the expected policy outcomes are certain. In a risky world, the analyst has an incomplete understanding of the complex environmental, social, institutional and economic processes that interact jointly to produce policy results (Glenk and Colombo, 2011). So, assuming outcome certainty rather than uncertainty could lead to wrong conclusions about the *true* policy benefits, and hence the *true* policy's social return if events are not as expected, this leading to poorly inform policy makers. Consequently, it could lead to consider as optimal environmental policies being less effective in terms of results, intensity or implementation timing (Pindyck, 2007).

Outcome uncertainty has been argued to depend on many factors such as policy's technical performance, social, political and economic contexts, and environmental uncertainty (Wielgus et al., 2009; Bartczak and Meyerhoff, 2013; Lundhede et al., 2015; Rolfe and Windle, 2015). In this sense, it has been considered that improving training and education as well as increasing scientific knowledge about ecosystems' functioning can lead to reduce outcome uncertainty (Langsdale, 2008). Implicitly, this means that many of the factors influencing outcome uncertainty can be controllable to some extent. However, outcome uncertainty also depends on an uncontrollable factor which is derived from the stochastic nature of ecosystems' behavior: inherent uncertainty. Inherent uncertainty is the component of environmental uncertainty which derives from the ordinary variability of natural systems resulting from interactions among physical, chemical, ecological and human factors (Thom et al. 2004; Ascough II et al., 2008). As it is associated with the non-linear, chaotic behavior patterns of ecosystems, increasingly recognized to be inherently unpredictable (Berkes, 2007), the presence of inherent uncertainty makes it difficult to predict the occurrence of many environmental phenomena. Accordingly, this type of uncertainty cannot be controlled by any action and hence it is difficult to be reduced.

This paper analyzes the effects on the willingness-to-pay (WTP) for environmental policies of delivering information about inherent uncertainty. To our knowledge, no paper has focused on the difficulty to know with certainty the policy result due to the influence of the uncontrollable component of environmental uncertainty. Indeed, environmental uncertainty has been treated as scientific uncertainty, that is, the level of knowledge about the natural systems in terms of gaps in the model's structure or in the data required to support the model. Thus, it has been assumed to be reducible through further scientific research (Cameron, 2005; Viscusi and Zeckhauser, 2006; Akter and Bennett, 2012). The assumption scientific uncertainty can be reduced through increasing knowledge about models' structure or data has been at the core of the existing papers focusing on outcome uncertainty. In fact, these works try to gain some understanding about the WTP to reduce uncertainty in order to give information to policy makers about the desirability of measures aimed at reducing scientific uncertainty. Glenk and Colombo (2011) state that 'significant WTP to reduce uncertainty can be a signal for policy-makers to invest more into scientific research which has the potential to reduce delivery uncertainty'. Likewise, Koundouri et al. (2014) conclude that 'scientific research that reduces environmental uncertainty should be encouraged and promoted'. In contrast, when it comes to inherent uncertainty, no amount of research will generate absolute predictions about the probability of occurrence of many environmental phenomena (Langsdale, 2008). While increasing scientific knowledge in terms of ecosystems' responses to critical loads and carrying capacities could contribute to shed some light on this, knowing how close a natural system is to a critical threshold is still highly difficult to predict in many contexts. As the probability of occurrence of a given environmental phenomenon is unknown to the analyst, outcome uncertainty could still emerge even if it is assumed that the remaining (controllable) factors influencing outcome uncertainty don't affect the policy result.

The difficulties to control (and reduce) inherent uncertainty by means of further scientific research helps to explain the low attention valuation researchers have paid to the issue. This is reasonable in a context in which policy makers usually consider scientific certainty as a prerequisite for environmental decision-making (Mitchell, 2002; Sethi et al., 2005). In this setting, researchers put emphasis on the importance of reducing uncertainty through increasing scientific knowledge in an attempt to stimulate environmental action. However, even if inherent uncertainty is difficult to be controlled and hence reducible through further research, the analysis of its effects on WTP is also relevant for environmental decision-making. Informing individuals that outcome uncertainty can emerge due to the difficulty of knowing if an environmental phenomenon will occur or not could also affect their WTP for measures pursuing to counteract the expected derived impacts. Would individuals be willing to pay for these measures in a framework in which these impacts might not occur? Gaining understanding of voting public in this context could have interesting implications for policy-making. Viscusi and Zeckhauser (2006) state that, in settings characterized by many inherent uncertainties, "those who wish to "go slow" point to the level of scientific uncertainty; they propose that we wait to learn more, and possibly learn that the risk was greatly overstated". Preference analysis in the presence of inherent uncertainty could offer an insight into this. It could contribute to stimulate rather than discourage environmental action aimed at addressing (inherently) uncertain expected impacts.

This paper examines, through a choice experiment (CE), the effects on WTP of delivering information about inherent uncertainty over the occurrence of a climate change (CC) impact on wetland's biodiversity. Difficulties to predict climate system's alterations due to unforeseen variations and trends both in the drivers of change and the associated system's responses indicate CC is beset with lots of uncertainties (Heal and Millner, 2014). The structure of the paper is as follows. Next section reviews the stated preference (SP) literature concerned with the analysis of risk preferences to show that examining the effects on WTP of inherent uncertainty has been an overlooked issue to date. Section 3 describes the data source and the methodology employed for the analysis. Results are reported in section 4, followed by a discussion and conclusions section that ends the paper.

2. Analysis of risk preferences in the stated preference literature: a review

The growing concern among researchers about how to handle risk and uncertainty in economic valuation has resulted in an extensive SP literature on risk preference analysis. Three broad approaches can be distinguished. The first one is followed by papers which estimate the WTP for policies aimed at reducing health or environmental risks to examine individuals' preferences for changes in risk exposure. Concerning risk factors to health, most of papers focus on valuation of mortality risks induced by air pollution problems, which has been mainly undertaken through a contingent valuation (CV). Examples are Krupnick et al. (1999), Alberini et al. (2006), Hammitt and Zhou (2006), Wang and Mullahy (2006) and Alberini and Chiabai (2007). In contrast, Fu et al. (1999) and Bateman et al. (2005) value, also through a CV, the risk of cancer. Valuation of health risks has also been undertaken in papers which measure, through a CE, the WTP for policies aimed at reducing a specific environmental risk: the risk of flooding. These papers value, together with flood risks, the health risks induced by flooding episodes. This is the case of Zhai (2006), Reynaud and Nguyen (2013) and Veronesi et al. (2014). In fact, valuation of flooding risks through a CE has been another topic of interest within this approach. It has been central in Birol et al. (2009), Dekker and Brouwer (2010) and Brouwer and Shaafsma (2013). Other risks that have also captured the attention of researchers are those related to endangered species (Mitani et al., 2008; Lew et al., 2010; Bartczak and Meyerhoff, 2013) and algae bloom episodes (Roberts et al., 2008), which have been valued through a CE, and wildfires (Fried et al., 1999), valued through a CV. All these papers consider individuals can exert some control over risks through specific measures. Particular cases are Cameron (2005) and Viscusi and Zeckhauser (2006) which, with a focus on the influence of subjective perceptions about future CC risks, assume that the policy can totally eliminate these risks. Their main findings show a positive WTP for risk reduction, this indicating risk aversion.

The second approach is followed by studies measuring the WTP for policies with uncertain environmental outcomes in an attempt to analyze the effects on policy's benefits of delivering information about outcome uncertainty. These papers state that outcome uncertainty depends on different factors such as management changes, social, political and economic contexts, and environmental uncertainty. The first works within this approach apply a CV and hence deliver information about outcome uncertainty through the scenario description. Examples are Johansson (1989), which is the first study concerned with the estimation of money measures in an uncertain environmental setting, and Macmillan et al. (1996). Both papers focus on the analysis of individuals' attitudes towards risk. They present outcome uncertainty through two possible policy results each associated with a given probability.

However, delivering information about outcome uncertainty through an attribute representing policy effectiveness has become common practice among researchers due to the increasing use of CEs. In this sense, most of studies published in the last years focus on estimating preferences for policy effectiveness. The majority assume the evaluation of the stated uncertainty measures is not affected by subjective perceptions. Examples are Ivanova et al. (2010), Glenk and Colombo (2011), Wibbenmeyer et al. (2013) and Koundouri et al. (2014). In this context, some authors put emphasis on analyzing the effect on WTP of different ways of delivering information about uncertainty around policy effectiveness (Wielgus, 2009), while others focus on analyzing the impact of alternative ways to model choice behavior (Rigby et al., 2010; Glenk and Colombo, 2013; Rolfe and Windle, 2015). In recent years the analysis of the effects on WTP of subjective perceptions about policy effectiveness's uncertainty has also captured the attention of researchers applying CEs. Examples are Akter et al. (2012), Cerroni et al. (2013) and Lundhede et al. (2015).

The papers following this second approach put emphasis on the fact that outcome uncertainty can be reduced through improving training and education as well as increasing scientific knowledge. Indeed, they consider that many of the factors influencing outcome uncertainty can be controllable to some extent. This is especially true in the papers applying a CE which explicitly value a policy effectiveness attribute. The interest in knowing preferences for policy effectiveness is motivated by the assumption that some control can be exerted over the final policy results. Their main findings are consistent with predictions of the economic theory which state that individuals are risk-averse.

The third approach is followed by papers focusing on preference uncertainty, which refers to how confident individuals have felt while stating their preferences and is normally assessed through a follow up question to the valuation exercise (Akter et al., 2008; Martínez and Lyssenko, 2012). Preference uncertainty tends to be high either when the utility difference between the chosen option and the best alternative to it is small (Balcombe and Fraser, 2011; Olsen et al., 2011) or when an offered referendum bid is not clearly different from the mean value of one's valuation distribution (Wang et al., 1997). The effect of stated preference uncertainty on WTP has received considerable attention by CV practitioners and, most recently, also by researchers applying CEs. Mixed results have emerged concerning this effect. Some studies find that WTP tends to increase when respondents' uncertainty is accounted for (Ready et al., 1995; Alberini et al., 2003), while others show the opposite (Li and Mattson, 1995). In addition, some evidence also exists that WTP may increase or decrease with preference uncertainty depending on the approach employed to classify respondents as certain or uncertain basing on their stated degree of uncertainty (Loomis and Ekstrand, 1998; Shaikh et al., 2007; Lundhede et al., 2009; Ready et al., 2010).

This literature review shows that inherent uncertainty has been an overlooked issue in the SP literature to date. In specific, the analysis of the effects on WTP of delivering information about this type of uncertainty has not captured the attention of researchers dealing with outcome uncertainty. This paper will show that a focus on the uncontrollable factor of outcome uncertainty is also of great relevance for environmental policy-making.

3. Data source and methodology

3.1 Data source

The data used to test for the effects on WTP of delivering information about inherent uncertainty come from Faccioli et al. (2015), who undertook a CE study in S'Albufera wetland between April the 15th and June the 30th, 2013. The humid land, which is located in Mallorca, is outstandingly vulnerable to CC risks related to both the increase in temperature and the decrease in precipitation rates expected for the Mediterranean region. The CE focuses on the analysis of visitors' preferences for adaptation policies aimed at counteracting expected CC impacts on bird species. On the one hand, it centers on the effects of the above-mentioned CC risks on 'specialist' bird species, which mostly rely on S'Albufera habitat. Indeed, CC might lead to declines in freshwater volumes which might intensify salinization problems currently suffered by the wetland. This could lead to a loss in the number of 'specialist' bird species, this generating a qualitative loss in the site's biological diversity. On the other hand, it also considers the CC effects on 'generalist' migratory bird species, which suit a wider habitat range and move to this humid land for resting and breeding. In specific, it is assumed that the projected rises in temperature at their origin places might stimulate their advanced departure, such that they might arrive earlier to S'Albufera. In this case, if nesting and breeding conditions were not optimal, either they could pass by without stopping or they could die if they stopped this leading to a loss in their number. As a result, the number of both 'specialist' bird species and 'generalist' migratory ones might decline.

In this context, Faccioli et al. (2015) estimate the social benefits of two different adaptation policies. First, an adaptation policy aimed at preserving species' diversity and, hence, the original wetland heterogeneity, by avoiding a quantitative loss of 'specialist' bird species. This measure pursues to counteract a potential increase in water salinization by strengthening efforts on current water management practices. Second, an adaptation strategy oriented to recovering species' abundance, regardless of the species' type, by avoiding a quantitative loss of bird species. This strategy aims to advance work on creating optimal nesting conditions for 'generalist' migratory bird species. Management efforts are assumed to be either moderate or high for both adaptation policies.

Table I reports the attributes employed in the CE to generate the experimental design, which is a D-efficient Bayesian:[1]

[INSERT TABLE I]

3.2 Linking outcome uncertainty to inherent uncertainty

The present analysis wants to identify the effect on WTP of inherent uncertainty. So it relates the impossibility of knowing with certainty the policy result to the difficulty of knowing if an environmental phenomenon will occur or not. In other words, the analysis links outcome uncertainty only to inherent uncertainty. To do this, it assumes that the remaining

[1] See Faccioli et al. (2015) for a detailed description of the case study and the experimental design.

(controllable) factors influencing outcome uncertainty don’t affect the policy result derived from each type of management effort. In specific, the analysis associates outcome uncertainty with the probability of occurrence p_1 of a specific decline in freshwater volumes in S’Albufera within a given time horizon. This decline would lead to an increase in water salinization and hence a decrease in the number of ‘specialist’ bird species. Thus, following Faccioli et al. (2015), it is assumed a loss of 10 species with a probability p_1 in a 10 years’ time if CC finally leads to a decline in freshwater volumes and no adaptation policy is undertaken today (BAU). Consequently, it is considered that, under a moderate management effort, a policy outcome representing a 0 increase in the number of species will be achieved with a probability p_1. Put another way, a moderate management effort will lead to keep the current levels of species with a probability p_1. Likewise, a policy outcome representing an increase by 5 is considered to be achieved under a high management effort with a probability p_1.[2]

To give a better picture of the stochastic nature of inherent uncertainty, and hence better identify the effects on WTP of this type of uncertainty, respondents are also provided with information about what is going to happen in case the impact does not occur in a 10 years’ time. In this sense, they are informed about the probability of impact non-occurrence p_2, where $p_2=1-p_1$, together with the associated change in the number of species. In specific, it is assumed that if CC does not finally lead to a decline in freshwater volumes, which will happen with a probability p_2, the number of ‘specialist’ bird species will not change if no adaptation policy is undertaken today (BAU). Accordingly, it is considered the possibility of achieving another policy outcome with a probability p_2 under each management effort. In

[2] The CC impact on the number of ‘generalist’ migratory bird species is considered to occur with certainty and hence outcome uncertainty is not assumed for the adaptation policy aimed at counteracting this impact. As S’Albufera wetland already suffers water salinization problems, respondents considered reasonable to strengthen efforts on current water management practices to reduce these problems in the presence of inherent uncertainty. Indeed, they believed the policy oriented to preserve species’ diversity could lead to recover some ‘specialist’ bird species in case the decline of freshwater volumes didn’t finally occur. So they perceived as credible the policy outcomes representing an increase in the number of these species by both 5 and 10 in a non-occurrence scenario. In contrast, focus groups showed that they didn’t believe in additional increases in the number of ‘generalist’ migratory bird species in a context in which they didn’t arrive earlier to the humid land due to an advancement in their departure (non-occurrence).

particular, increases by both 5 and 10 in the number of species are assumed to be achieved under a moderate and high management effort, respectively.

Note that under both types of management efforts, policy results always represent a number of ‘specialist’ bird species which is either equal to or higher than the present one. This is reasonable since adaptation both ensures at least to keep constant the current levels of species if the impact occurs and leads to higher numbers in the absence of the impact. Table II shows the levels of the ‘specialist’ bird species attribute considered for each scenario:

[INSERT TABLE II]

To facilitate choice, information about p_1 and p_2 together with the associated attribute values is given through text and visual information. In this sense, each alternative in each choice card depicts the same values for p_1 and p_2. This allows linking outcome uncertainty (present in the improving alternatives) to inherent uncertainty around the expected loss in the number of ‘specialist’ bird species (present in the BAU scenario). Besides, to make clearer the uncontrollable nature of the probability of impact occurrence, information about p_1 is also included in the CE design through a framing statement, as shown below. A framing statement is useful in valuation contexts where the likelihoods of outcomes cannot be influenced (Glenk and Colombo, 2011).

The evolution of the number of ‘specialist’ bird species in 10 years’ time is uncertain. To make a comparison, it is like in a lottery, results are subject to a probability. In this sense, experts think that if park managers’ efforts on current management practices are not strengthened, the decrease in the number of ‘specialist’ bird species will occur with a probability equal to p_1. Of course, the changes in the number of ‘specialist’ bird species resulting from strengthening efforts will also be uncertain.

To investigate whether the inclusion of inherent uncertainty has some effects on the WTP, three scenarios are considered. On the one hand, a scenario of no inherent uncertainty (*No_Inherent*) where respondents are informed that the probability p_1 of a loss of 10 'specialist' bird species in a 10 years' time is equal to 100%. In this case, the policy leads with certainty both to keep the current levels of species under a moderate management effort and to increase their number by 5 under a high management effort. Thus, only one policy outcome is presented to respondents under each effort. Information about p_1=100% is only given through the framing statement.[3] On the other one, two inherent uncertainty scenarios where p_1 (and hence p_2) takes two different values: a value of 80% (20% for p_2) to represent a scenario of low inherent uncertainty (*Inherent_80*) and a value of 60% (40% for p_2) to depict a scenario of high inherent uncertainty (*Inherent_60*). According to the classic distinction made by Knight (1921), uncertainty is applied to situations where probabilities are unknown to the analyst. However, it is worth noting the probability values used in this analysis are applied to the same expected impact in a random fashion. Assigning probabilities randomly to a given outcome implicitly indicates no knowledge of the probability distribution that this outcome will be achieved (Glenk and Colombo, 2011). In this sense, while p_1 cannot be predicted with certainty, it is assumed that scientific knowledge of ecosystems' responses to critical loads and carrying capacities could contribute to shed some light on it. Thus, by using objective probabilities, it is assumed that further research will lead to provide some empirical knowledge allowing assigning probabilities and hence providing information about how near extinction the species might be.

Table III depicts the attribute levels considered for each scenario together with the probabilities of both impact occurrence (p_1) and non-occurrence (p_2):

[INSERT TABLE III]

[3] This is the valuation scenario used in Faccioli et al. (2015).

Figure 1 depicts a sample card for a probability of occurrence p_1 equal to 60%:

[INSERT FIGURE 1]

SP studies dealing with outcome uncertainty have usually showed that individuals' WTP decreases with uncertainty. Indeed, outcome uncertainty has been usually related to policy effectiveness in such a way that higher uncertainty implies a lower probability of policy success (Lundhede et al., 2015) or a higher risk of failure (Glenk and Colombo, 2011), which makes the policy less desirable when the scenario becomes more uncertain. However, in this analysis, the WTP for the adaptation policy is expected to be higher in the presence of inherent uncertainty. This is because increasing this type of uncertainty leads to a lower risk of species' loss and, as predicted by the EU theory, low risk increases WTP (Wielgus et al., 2009).

Besides, the way outcome uncertainty is illustrated in the present analysis shows a policy which, under a moderate management effort, leads at least to keep the current number of 'specialist' bird species with probability p_1 while it increases this number with probability p_2. If the management effort is high, the two potential increases in the number of species are even higher (+5 with p_1 and +10 with p_2). Given the policy leads to the same two policy outcomes under each management effort in the three considered scenarios (as the values of p_1 and p_2 are the only difference between *No_Inherent*, *Inherent_80* and *Inherent_60*), it leads to higher expected outcomes with inherent uncertainty (as p_1 diminishes while p_2 increases), thus becoming more desirable under the uncertain scenarios. Wielgus et al. (2009) state that individuals should be willing to pay more in contexts with a higher probability of occurrence of the environmental improvement as it leads to a higher expected outcome. Bartczack and Meyerhoff (2013) also show that the WTP increases with the probability of survival of a given species.

According to this, this paper tests these two null hypotheses:

1. *Delivering information about inherent uncertainty does not affect the WTP for the adaptation policy.*
2. *WTP does not increase with the probability of impact occurrence.*

To test for these hypotheses, a split sample approach was used to reduce the burden of respondents. In particular, three versions of the CE questionnaire were considered, only differing in terms of the value of p_1 and p_2. Data were collected by means of on-site interviews. Sample sizes, which ranged from 310 to 322, were obtained by considering a confidence interval of 95% and a sample error of 5.5%.

3.3 Modelling approach

Preference analysis through CEs is carried out on the basis of the random utility maximization (RUM) theory. In this sense, individual choices are modelled by assuming respondent *n* chooses the alternative *j* providing him with the highest utility level from among a set of options. As shown in Equation 1, utility is defined as the sum of two components. First, a deterministic part $V_{nj}(\cdot)$ consisting of the alternative's non-monetary (X_{nj}) and monetary ($X_{COST_{nj}}$) attributes, as well as a set of parameters (β) to be estimated. Second, a stochastic part ε_{nj} capturing all the unobserved factors affecting choice and indicating the analyst's incomplete knowledge about the individual decision process:

$$U_{nj} = V_{nj}(X_{nj}, X_{COST_{nj}}, \beta) + \varepsilon_{nj} \tag{1}$$

A common way to analyze decisions involving risk and uncertainty is to draw on the expected utility (EU) theory (von Neumann and Morgenstern, 1944) or the subjective expected utility (SEU) theory (Savage, 1954). Both approaches are linear in the probabilities that characterize risks and assume individuals have preferences over outcomes only and not over probabilities. In recent years, alternative treatments of risk have emerged which suggest that treatment of risks may be non-linear or that people may emphasize risks of extreme events (Rolfe and Windle, 2015). Another recent approach assumes the effect of risk on utility can be partially or fully separable from the utility effect of the good affected by risk (Gneezy et al., 2006). In this context, recent studies focusing on comparing different representations of choice under risk show that findings are mixed, this suggesting further research is still needed to draw conclusions about which specification is better. For instance, Rolfe and Windle (2015) don't find significant non-linear effects. Besides, they find mixed evidence for increased certainty to be valued independently from the environmental good of interest. In contrast, Glenk and Colombo (2013) find that a direct utility specification shows the greatest model fit to data (although they don't believe individuals don't conduct any probability weighting of outcomes in the choice process). Thus, they cautiously advocate the use of a non-linear EU model over models that consider probability-weighted outcomes and in combination with direct utility from risk. Interestingly, both papers find significant support for different types of EU models.

According to this, this paper assumes respondents process information on risk within the choice task according to the EU framework. Besides, it is a common theoretical assumption in the SP literature which appears well suited to the present application. In particular, it is considered a non-linear EU for the risky attribute whose outcomes are weighted by their objective probability of both occurrence (p_1) and non-occurrence (p_2).

Following Faccioli et al. (2015), parameter estimation is carried out through a random parameter logit (RPL) model due to its many advantages over the conditional logit model (McFadden and Train, 2000; Train, 2009). RPL model considers individual-specific preferences by assuming parameters are random and follow a distribution. Thus, the coefficients result from the sum of a population mean parameter and an individual-specific deviation over this mean. Based on Faccioli et al. (2015), only the cost parameter is considered to be random with a lognormal distribution to constrain it to have the same sign over all individuals. While limited evidence of heterogeneity was found in the remaining attributes, it was clear the presence of heterogeneity in the cost coefficient. Thus, as Torres et al. (2011) show that making a wrong assumption about the heterogeneity of the cost parameter can have severe implications for the analysis of welfare measures, only the cost parameter is considered random, as found elsewhere (Carlsson et al., 2005).

Equation 2 shows the utility specification considered for estimation purposes which has been adapted from Faccioli et al. (2015):

$$U_{nj} = \beta_1[(p_1 \cdot X_{SPEC1_{nj}} + p_2 \cdot X_{SPEC2_{nj}})] + \beta_2 X_{GEN_{nj}} + \beta_3 X_{TIME(less)_{nj}} + \beta_4 X_{BENCHES(double)_{nj}} + \beta_5 X_{BENCHES(triple)_{nj}} + + \beta_6[(p_1 \cdot X^2{}_{SPEC1_{nj}} + p_2 \cdot X^2{}_{SPEC2_{nj}})] + \beta_7 X^2{}_{GEN_{nj}} + \beta_8 X_{GEN_{nj}} \cdot [(p_1 \cdot X_{SPEC1_{nj}} + p_2 \cdot X_{SPEC2_{nj}})] + + \beta_9 X_{TIME(less)_{nj}} \cdot [(p_1 \cdot X_{SPEC1_{nj}} + p_2 \cdot X_{SPEC2_{nj}})] + \beta_{10n} X_{COST_{nj}} + \varepsilon_{nj} \quad (2)$$

for respondent n and alternative j, $X_{SPEC1_{nj}}$ is the level of the 'specialist' bird species attribute under a probability of impact occurrence equal to p_1, and $X_{SPEC2_{nj}}$ is the attribute level when the probability of impact non-occurrence is p_2; $X_{GEN_{nj}}$ is the level of the 'generalist' migratory bird species attribute; $X_{TIME(less)_{nj}}$ is a dummy variable taking value 1 for less than 15 minutes waiting time for a seat in an observation cabin and 0 otherwise; $X_{BENCHES(double)_{nj}}$ and $X_{BENCHES(triple)_{nj}}$ are two dummy variables taking value 1 when the number of benches throughout the park is double and triple with respect to the current one, respectively, and 0 otherwise; and β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8 and β_9 are the fixed attribute coefficients and β_{10n} is the individual-specific parameter for $X_{COST_{nj}}$.

The monetary value individuals assign to each attribute has been calculated by using the Hanemann (1984)'s formula for compensating variation. Based on Equation 3, the WTP for a unit increase in the expected number of 'specialist' bird species attribute is shown in Equation 4:

$$WTP_{X_{SPECnj}} = -\frac{1}{\beta_{10n}}\Big[\beta_1 \cdot \Big(p_1 \cdot \big({X_{SPEC1_{nj}}}^1 - {X_{SPEC1_{nj}}}^0\big) + p_2 \cdot \big({X_{SPEC2_{nj}}}^1 - {X_{SPEC2_{nj}}}^0\big)\Big) + \beta_6 \cdot (p_1 \cdot ({X^2_{SPEC1_{nj}}}^1 - {X^2_{SPEC1_{nj}}}^0\big) + p_2 \cdot ({X^2_{SPEC2_{nj}}}^1 - {X^2_{SPEC2_{nj}}}^0)) + \beta_8 \cdot {X_{GEN_{nj}}}^0 \cdot \Big(p_1 \cdot \big({X_{SPEC1_{nj}}}^1 - {X_{SPEC1_{nj}}}^0\big) + p_2 \cdot \big({X_{SPEC2_{nj}}}^1 - {X_{SPEC2_{nj}}}^0\big)\Big) + \beta_9 \cdot {X_{TIME(less)_{nj}}}^0 \cdot (p_1 \cdot \big({X_{SPEC1_{nj}}}^1 - {X_{SPEC1_{nj}}}^0\big) + p_2 \cdot \big({X_{SPEC2_{nj}}}^1 - {X_{SPEC2_{nj}}}^0\big))\Big] \quad (4)$$

where superscripts ^{1} and ^{0} respectively indicate the level of the attribute after and before the change, respectively.

4. Results

After having eliminated the invalid and protest questionnaires[4] and taking into account each respondent faces 6 choice sets, the RPL models for the three scenarios depicted in Table III have been estimated. Table IV reports models' results:

[INSERT TABLE IV]

As shown in the Table IV for *No_inherent*, when the policy leads with certainty to one outcome under each management effort (0 and +5 under a moderate effort and a high effort, respectively), respondents value a policy which leads to a higher number of both 'specialist'

[4] Surveys are considered to be invalid when missing responses are detected in the section concerning the choice of the alternatives. Protests refer to questionnaires where the choice of the BAU option is motivated by one of the following reasons: *"I don't perceive any problem to justify extra efforts on current practices"*, *"I consider I am already paying for these services"*, *"Others should pay"* and *"I don't trust the local authorities"*.

bird species and 'generalist' migratory ones, allows for less waiting time for a seat in an observation cabin, and doubles the number of benches throughout the park. However, the interaction effects indicate that the utility they get depends on the level of 'specialist' and 'generalist' migratory bird species, and the waiting time. In this sense, it can be observed that the utility they get from both $E(X_{SPEC})$ (where $E(X_{SPEC})=p_1 \cdot X_{SPEC1}+p_2 \cdot X_{SPEC2}$, that is, the expected increase in the number of 'specialist' bird species) and X_{GEN} increases at a decreasing rate with the number of both types of species. Additionally, they seem to perceive 'specialist' bird species as substitutes of 'generalist' migratory ones. A substitution pattern can also be observed between $E(X_{SPEC})$ and $X_{TIME(less)}$, which suggests that individuals value less the 'specialist' bird species when congestion in the wetland is low ($X_{TIME(less)}=1$) as a lower waiting time can be related to a lower number of visitors. In other words, they value more this type of species when congestion is high. This could be explained by the fact that, under high congestion, they would have less chances of viewing all types of bird species from an observation cabin, which could lead them to prioritize viewing 'specialist' bird species over other types of species. As expected, the cost coefficient is random, thus indicating the marginal utility of income is heterogeneous.

When respondents make choices in the face of inherent uncertainty around the expected loss of 'specialist' bird species, the magnitudes of attribute coefficients vary although their sign and significance don't change in most of cases. According to the Swait and Louviere (1993) test, the differences in parameters are not explained by changes in scale, which suggests individuals' preferences could be impacted when inherent uncertainty information is included in the CE design.[5] To test for this, differences in the mean marginal value of the risky attribute ($E(X_{SPEC})$) under *No_Inherent*, *Inherent_80* and *Inherent_60* have been examined through the Poe et al. (2005)'s test. Marginal values have been calculated following Equation

[5] The null hypothesis of scale parameters' equality across the models cannot be rejected at 1% level.

4, which is referred to a unit increase in the expected number of ‘specialist’ bird species from the BAU situation, and considering the BAU levels for the interacting attributes (X_{GEN}=-10 and $X_{TIME(less)}$=0).[6] Table V reports the mean marginal values under each scenario together with the confidence intervals resulting from Poe et al. (2005)’s test:

[INSERT TABLE V]

As shown in Table V, the mean marginal value under *No_Inherent* is significantly lower than those obtained under *Inherent_80* and *Inherent_60* (1.31<2.43<2.75). This suggests visitors are willing to pay more for a unit increase in the expected number of ‘specialist’ bird species when inherent uncertainty is present. In other words, they show a stronger support for a policy aimed at preserving species’ diversity when they don’t know with certainty if the expected loss of ‘specialist’ bird species will occur. Thus, the null hypothesis that delivering information about inherent uncertainty does not affect the WTP for the adaptation policy, is rejected. As expected, individuals find more desirable the adaptation policy in the presence of inherent uncertainty. This is reasonable since this type of uncertainty implies a lower risk of species’ loss (p_1 diminishes) and hence the possibility of achieving a better policy outcome under each management effort with a probability p_2>0. In specific, if the expected impact finally occurs, undertaking the policy will allow at least keeping the current level of species with a probability p_1 under a moderate management effort, while leading to a higher number of species if the impact does not occur. In addition, it will lead to better environmental improvements under a high management effort with both p_1 and p_2 (see Table III). Consequently, the policy leads to higher expected outcomes with uncertainty, thus becoming more desirable to respondents.

[6] The Poe et al. (2005)’s test has relied on simulated vectors of mean marginal values, obtained through bootstrapping, for all the scenarios (Hole et al., 2007). Models have been replicated 1,000 times, this leading to three vectors consisting of 1,000 mean marginal values for *No_Inherent*, *Inherent_80*, *Inherent_60*. For each pair of vectors, differences between all vector elements have been calculated to obtain a new vector for which a confidence interval has been computed. An entirely positive or negative confidence interval indicates significant differences in the mean marginal values.

Interestingly, the Poe et al. (2005)'s test also indicates that there is no significant difference between the marginal values under both *Inherent_80* and *Inherent_60* (2.43 and 2.75, respectively), this indicating the WTP does not increase with the probability of impact occurrence. In other words, it seems individuals are insensitive to the magnitude of uncertainty while expressing their preferences. This would suggest that the second null hypothesis should not be rejected.

To better test for the robustness of these conclusions, differences in the marginal value of $E(X_{SPEC})$ under *No_Inherent*, *Inherent_80* and *Inherent_60* have been examined by considering also the remaining levels of X_{GEN} and $X_{TIME(less)}$ (0 and +5 for X_{GEN} and 1 for $X_{TIME(less)}$). Table VI depicts the value for a unit increase in the expected number of 'specialist' bird species for all the levels of waiting time and 'generalist' migratory bird species. It also provides information about whether the difference between the mean marginal values is statistically significant or not:[7]

[INSERT TABLE VI]

As seen, when congestion is high ($X_{TIME(less)}$=0), the marginal value of $E(X_{SPEC})$ when inherent uncertainty is present is significantly higher than that obtained in a context of certain future losses, regardless of the number of 'generalist' migratory bird species. Similarly, when congestion is low ($X_{TIME(less)}$=1), the marginal values under inherent uncertainty tend to be, in most of cases, significantly higher than those estimated under *No_Inherent*. Therefore, regardless of the levels of X_{GEN} and $X_{TIME(less)}$, visitors generally value more the preservation policy in the presence of inherent uncertainty. This confirms that the null hypothesis that delivering information about inherent uncertainty does not affect welfare measures, can be rejected.

[7] The confidence intervals resulting from the Poe et al. (2005)'s tests are available from the authors upon request.

A different story concerns the sensitiveness of WTP to information about the probability of impact occurrence. Individuals seem to be insensitive to this information when congestion is high regardless of the level of X_{GEN} as all differences in values under *Inherent_80* and *Inherent_60* are not significant. In contrast, when congestion is low, they seem to become more sensitive to this information as the marginal values under *Inherent_60* are always significantly higher than those obtained under *Inherent_80*. In specific, the values under *Inherent_80* diminish in such a way that, on the one hand, they become significantly lower than those under *Inherent_60*, which don't change when passing from a higher to a lower congestion scenario[8]. On the other one, they become, in most of cases, not significantly different from those under *No_Inherent*, which diminish in a lower proportion.

According to these findings, it is difficult to draw conclusions about the sensitivity of WTP to the probability of impact occurrence. Indeed, the substitution patterns between $E(X_{SPEC})$ and both X_{GEN} and especially $X_{TIME(less)}$ identified under each scenario seems to be strong determinants of how individuals react to information about impact probabilities. In this specific context, it seems that probabilities of impact occurrence around 80% might represent switching points in respondents' behavior.

5. Discussion and conclusion

With a focus on expected CC risks, this paper analyzes the effects of inherent uncertainty on the WTP for an adaptation policy aimed at preserving species' diversity in S'Albufera wetland. To do this, it links outcome uncertainty to the probability of occurrence of a loss in the number of 'specialist' bird species in a 10 years' time. Thus, unlike the existing studies, this paper links outcome uncertainty to inherent uncertainty, that is, to the uncontrollable

[8] Note that the values under *Inherent_60* don't change with respect to the scenario where $X_{TIME(less)}=0$ because the time attribute is not significant under this uncertain setting (see Table V).

component of environmental uncertainty derived from the stochastic nature of ecosystems' behavior.

Results show individuals are willing to pay more for the policy in the presence of inherent uncertainty. So, the null hypothesis that delivering information about inherent uncertainty does not have any impact on the WTP, is rejected. The stronger support for the preservation policy under an inherently uncertain scenario is consistent with predictions of EU theory which states that WTP increases with low risk for risk-averse individuals. Indeed, results are reasonable since the inherent uncertainty scenarios depict a lower risk of species' loss and higher expected policy outcomes compared to a no inherent uncertainty scenario. This is because i) inherent uncertainty is illustrated through a probability of impact occurrence p_1 which is lower than 100%, this implying the existence of a positive probability of impact non-occurrence p_2, and ii) p_1 and p_2 are associated with positive increases (with respect to the current level) in the number of 'specialist' bird species.

Findings also show that the substitution patterns found between 'specialist' bird species and both 'generalist' migratory bird species and waiting time for a seat in an observation cabin seem to be strong determinants of how individuals' react to information about impact probabilities. In this sense, they seem to be insensitive to this information when congestion in the wetland is high. In other words, their WTP in a scenario where the degree of inherent uncertainty is high (p_1=60%) is not significantly different from their WTP in a context in which uncertainty is lower (p_1=80%) regardless of the level of 'generalist' migratory bird species. However, when congestion is low, they seem to become more sensitive to information about the probability of impact occurrence as their WTP under p_1=60% is significantly higher than that under p_1=80%. It seems that probabilities values of p_1 around 80% might represent switching points in respondents' behavior. However, these results don't allow us to draw robust conclusions about the sensitivity of WTP to different degrees of uncertainty, so further research is recommendable to gain more insights into this issue.

The analysis has been undertaken by considering the EU framework which assumes utility of outcomes are linearly weighted by their probabilities. However, in the light of the results, respondents might also have treated risk in a non-linear manner, thus overweighing the probability of impact non-occurrence (Shaw and Woodward, 2008). Thus it would be interesting to further explore alternative treatments of risk when inherent uncertainty is present. In specific, further research could examine whether individuals treat risks in a non-linear way or whether they emphasize risks of extreme events. The analysis could then be replicated by treating risk according to prospect theory (Kahneman and Tversky, 1979), the rank-dependent utility theory proposed by Quiggin (1982) and/or prospective reference theory (Viscusi, 1989). After all, this paper is the first one analyzing the effects of inherent uncertainty on the WTP and hence many questions still remained unanswered.

Additionally, it would also be of interest to study whether and how different ways of delivering inherent uncertainty information can influence choice strategies and consequently can impact on the WTP for the policy. It has been argued that specific elicitation formats might drive respondents' attention during the choice (Lipkus, 2007; Spiegelhalter et al., 2011). In this paper, information about p_1 and p_2 has been depicted through a mix of visual and text information to facilitate understanding. However, this way of delivering uncertainty information could have led respondents to focus more on the policy outcome associated with impact non-occurrence. Also, information about p_2 and the associated outcomes has been provided to respondents to emphasize the stochastic nature of inherent uncertainty. As earlier discussed, consideration of additional policy outcomes associated with p_2 help to explain the results. Thus it would be interesting to test whether the effects of inherent uncertainty on WTP remain the same if only p_1 is considered in the analysis.

One of the limitations of this paper has to do with the low sample sizes used for each split sample. In fact, the representative sub-samples were drawn from a population of 23,172 visitors. However, given the way inherent uncertainty is illustrated in this analysis, a split sample approach was considered more appropriate to reduce respondents' burden and hence facilitate choice. Indeed, inherent uncertainty is presented to respondents through two possible levels for the 'specialist' bird species attribute in each alterative in each choice card, where the levels are linked to p_1 and p_2. Besides, a mix of visual and text information is employed. Focus groups showed that presenting individuals different choice cards each linked to different probability values substantially increased respondents' burden. Despite this, it is undeniable that the use of low sample sizes could imply some or all the results may be due to random factors and hence further research is of course recommendable.

Nevertheless, findings are still suggestive and indicate inherent uncertainty potentially impacts on the benefits of a policy aimed at preserving species' diversity. In this sense, it is worth noting the policy relevance of illustrating inherent uncertainty through the probability of occurrence of a specific impact within a given time horizon. While it is true that inherent uncertainty information could have also been depicted by considering different uncontrollable impact magnitudes, a focus on the probability of occurrence makes the analysis more policy relevant. Indeed, it allows drawing more straightforward conclusions for policy making. Note that the analysis revolves around a relevant question: Would individuals be willing to pay for measures aimed to counteract expected environmental impacts in a context in which these impacts might not occur? Results can be viewed as a vote for environmental action when it comes to contexts of many inherent uncertainties. Viscusi and Zeckhauser (2006) find that, if respondents are risk-averse, they 'predominantly view the current scientific uncertainty as a rationale for greater support of policy interventions rather than for a wait-and-see approach'. Thus, people seem to advocate for the adoption of a precautionary approach in contrast to the opinion of those who wish ‘to go slow’ to avoid assuming the costs of action. Findings suggest people view action today as something desirable as it will allow avoiding future losses in case of impact occurrence while leading to higher environmental quality levels in the absence of impacts.

Results should also be viewed as a signal to stimulate action to increase knowledge about the natural system. Despite inherent uncertainty makes difficult to predict with certainty the probability of occurrence of a given environmental phenomenon, knowledge on ecosystems’ responses to critical loads and carrying capacities can provide some insight on how close a natural system is to a critical threshold. This knowledge is crucial for policy making as it leads to increase system reliability and hence design more effective measures aimed at reducing environmental risks. Langsdale (2008) states that ‘once inherent uncertainties dominate, then the focus should shift away from reducing uncertainties and move on to clarifying and communicating what is known about the system and determining effective and robust responses.

Thus, an approach to outcome uncertainty which focuses on the effects of inherent uncertainty on WTP for preservation measures can play a role in environmental decision-making when thresholds are threatened. Indeed, it can stimulate action oriented to guarantee an effective intergenerational allocation of natural endowments on the basis of welfare maximization issues. Therefore, it is undoubtedly a relevant issue for further research.

References

Akter S, Bennett J (2012). *Valuing climate change mitigation: applying stated preferences in the presence of uncertainty*. Cheltenham (UK), Northampton (USA): Edward Elgar.

Akter, S., Bennett, J., Akhter, S. (2008). Preference uncertainty in contingent valuation. *Ecol. Econ.* 67(3): 345-351.

Akter, S., Bennett, J., Ward, M.B. (2012). Climate change scepticism and public support for mitigation: evidence from an Australian choice experiment. *Glob. Environ. Chang.* 22(3): 736-745.

Alberini, A., Boyle, K., Welsh, M. (2003). Analysis of contingent valuation data with multiple bids and response options allowing respondents to express uncertainty. *J. Environ. Econ. Manag*. 45(1): 40-62.

Alberini, A., Chiabai A. (2007). Urban environmental health and sensitive populations: how much are the Italians willing to pay to reduce their risks? *Reg. Sci. Urban Econ.* 37(2): 239-258.

Alberini, A., Hunt, A., Markandya, A. (2006). Willingness to pay to reduce mortality risks: evidence from a three-country contingent valuation study. *Environ. Resour. Econ.* 33(2): 251-264.

Ascough II, J.C., Maier, H.R., Ravalico, J.K., Strudley, M.W. (2008). Future research challenges for incorporation of uncertainty in environmental and ecological decision-making.

Ecol. Model. 219 (3-4): 383-399.

Balcombe, K., Fraser, I. (2011). A general treatment of 'don't know' responses from choice experiments. *Eur. Rev. Agric. Econ.* 38(2): 171-191.

Bartczak, A., Meyerhoff, J. (2013). Valuing the chances of survival of two distinct Eurasian lynx populations in Poland – Do people want to keep the doors open? *J. Environ. Manage.* 129: 73-80.

Bateman, I.J., Brouwer, R., Georgiou, S., Hanley, N. Machado, F., Mourato, S., Saunders, C. (2005). A 'natural experiment' approach to contingent valuation of private and public UV health risk reduction strategies in low and high risk countries. *Environ. Resour. Econ.* 31(1): 47-72.

Berkes, F. (2007). Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. *Nat. Hazards* 41(2): 283–295.

Birol, E., Koundouri, P., Kountouris, Y. (2009). Using the choice experiment method to inform river management in Poland: flood risk reduction versus habitat conservation in the Upper Silesia region. In: Birol, E., Koundouri, P. (Eds.), *Choice experiments informing environmental policy. A European perspective*. Cheltenham (UK) and Northampton (USA): Edward Elgar Publishing.

Brouwer, R., Schaafsma, M. (2013). Modelling risk adaptation and mitigation behaviour under different climate change scenarios. *Clim. Chang.* 117(1-2): 11-29.

Cameron, T.A. (2005). Individual option prices for climate change mitigation. *J. Public Econ.* 89: 283-301.

Carlsson, F., Frykblom, P., Lagerkvist, C.J. (2005). Using cheap talk as a test of validity in choice experiments. *Econ. Lett.* 89(2): 147-152.

Cerroni, S., Notaro, S., Raffaelli, R., Shaw, W.D. (2013). The incorporation of subjective risks into choice experiments to test scenario adjustment. Paper presented at the 2nd AIEAA Conference "Between Crisis and Development: which Role for the Bio-Economy", Parma (Italy), 6-7 June 2013.

Dekker, T., Brouwer, R. (2010). Trading off alternatives and attributes: accounting for preference uncertainty in choice experiments. Paper presented at the 4th World Congress of Environmental and Resource Economists, Montreal (Canada), 28 June - 2 July 2010.

Faccioli, M., Riera, A., Torres, C.M. (2015). Valuing the recreational benefits of wetland adaptation to climate change: a trade-off between species' abundance and diversity. *Environ. Manage.* 55(3): 550-563.

Fried, J.S., Winter, G.J., Gilless, J.K. (1999). Assessing the benefits of reducing fire risk in the wildland-urban interface: a contingent valuation approach. *Int. J. Wildland Fire* 9(1): 9-20.

Fu, T.-T., Liu, J.-T., Hammitt, J.K. (1999). Consumer willingness to pay for low-pesticide fresh produce in Taiwan. *J. Agr. Econ.* 50(2): 220-233.

Glenk, K., Colombo, S. (2011). How Sure Can You Be? A Framework for Considering Delivery Uncertainty in Benefit Assessments Based on Stated Preference Methods. *J. Agr. Econ.* 62(1): 25–46.

Glenk, K., Colombo, S. (2013). Modelling out come-related risk in choice experiments. *Aust. J. Agr. Resour. Ec.* 57: 559-578.

Gneezy, U., List, J.A., Wu, G. (2006). The uncertainty effect: when a risky prospect is valued less than its worst possible outcomes. *Q. J. Econ.* 121, 1283– 1309.

Hammitt, J.K., Zhou, Y. (2006). The economic value of air-pollution-related health risks in China: a contingent valuation study. *Environ. Resour. Econ.* 33: 399–423.

Hanemann, W.M. (1984). Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses. *Am. J. Agr. Econ.* 66 (3): 332-341.

Heal, G., Millner, A. (2014). Uncertainty and Decision-Making in Climate Change Economics. *Rev. Environ. Econ. Policy* 8(1): 120–137.

Hole, A.R. (2007). A comparison of approaches for estimating confidence intervals for willingness to pay measures. *Health Econ.* 16: 827-840.

Ivanova, G., Rolfe, J., Tucker, G. (2010). Using Choice Modelling to assess the willingness to pay of Queensland households to reduce greenhouse emissions. Environmental Economics

Research Hub Research Reports - Research Report no. 67. Canberra (Australia): the Crawford School of Economics and Government, Australian National University.

Johansson, P.-O. (1989). Valuing public goods in a risky world: an experiment. In: Folmer, H., van Ierland, E. (Eds.), *Valuation Methods and Policy Making in Environmental Economics*. Amsterdam (Netherlands): Elsevier Science Publisher.

Kahneman, D., Tversky, A. (1979). Prospect theory: an analysis of decision under risk. *Econometrica* 47(2): 263-292.

Knight, F.H. (1921). *Risk, Uncertainty and Profit*. Boston (USA): Houghton Mifflin Company.

Koundouri P, Stithou M, Kougea E et al. (2014). The contribution of non-use values to inform the management of groundwater systems: the Rokua esker, Northern Finland. In: Nunes, P.A.L.D., Kumar, P., Dedeurwaerdere, T. (Eds.), *Handbook on the Economics of Ecosystem Services and Biodiversity*. Cheltenham (UK) and Northampton (USA): Edward Elgar Publishing.

Krupnick, A., Alberini, A., Cropper, M., Simon, N. (1999). Mortality Risk Valuation for Environmental Policy. Discussion Paper 99-47. Washington (USA): Resources for the Future.

Langsdale, S. (2008). Communication of climate change uncertainty to stakeholders using scenario approach. *Journal of Contemporary Water Research and Education* 140(1): 24-29.

Lew, D.K., Layton, D.F., Rowe, R.D. (2010). Valuing Enhancements to Endangered Species Protection under Alternative Baseline Futures: The Case of the Steller Sea Lion. *Marine Resource Econ.* 25: 133-154.

Li, C.-Z., Mattson, L. (1995). Discrete choice under preference uncertainty: An Improved structural Model for Contingent Valuation. *J. Environ. Econ. Manag*. 28(2): 256-269.

Lipkus, I. (2007). Numeric, verbal, and visual formats of conveying health risks: suggested best practices and future recommendations. *Med. Decis. Making* 27: 696-713.

Loomis, J., Ekstrand, E. (1998). Alternative approaches for incorporating respondent uncertainty when estimating willingness to pay: the case of the Mexican spotted owl. *Ecol. Econ.* 27(1): 29-41.

Lundhede, T. H., Olsen, S.B., Jacobsen, J. B., Thorsen, B. J. (2009). Handling respondent uncertainty in Choice Experiments: Evaluating recoding approaches against explicit modelling of uncertainty. *Journal of Choice Modelling* 2(2): 118-147.

Lundhede, T.H., Jacobsen, J.B., Hanley, N., Strange, N., Thorsen, B.J. (2015). Incorporating outcome uncertainty and prior outcome beliefs in stated preferences. *Land Econ*. 91(2): 296-316.

Macmillan, D., Hanley, N., Buckland, S. (1996). A contingent valuation study of uncertain environmental gains. *Scot. J. Polit. Econ*. 43: 519-533.

Martínez, R., Lyssenko, N. (2012). Alternative approaches to dealing with respondent uncertainty in contingent valuation: A comparative analysis. *J. Environ. Manage.* 93(1): 130-139.

McFadden, D., Train, K. (2000). Mixed MNL models of discrete response. *J. Appl. Econom.* 15(5): 447–470.

Mitani, Y., Shoji, Y., Kuriyama, K. (2008). Estimating economic values of vegetation restoration with choice experiments: a case study of an endangered species in Lake Kasumigaura, Japan. *Landscape Ecol. Eng.* 4(2): 103-113.

Mitchell, B. (2002). Resource and environmental management. London (UK) and New York (USA): Routledge.

Olsen, S.B., Lundhede, T. H., Jacobsen, J. B., Thorsen, B. J. (2011). Tough and easy choices: testing the influence of utility difference on stated certainty-in-choice in choice experiments. *Environ. Resource Econ.* 49: 491-510.

Pindyck, R.S. (2007). Uncertainty in Environmental Economics. *Rev. Environ. Econ. Policy* 1(1): 45-65.

Poe, G.L., Giraud, K.L., Loomis, G.B. (2005). Computational methods for measuring the difference of empirical distributions. *Amer. J. Agr. Econ.* 87(2): 353–365.

Quiggin, J. (1982). A theory of anticipate utility. *J. Econ. Behav. Organ.* 3(4): 323-343.

Ready, R.C., Champ, P.A., Lawton, J.L. (2010). Using Respondent Uncertainty to Mitigate Hypothetical Bias in a Stated Choice Experiment. *Land Econ.* 86(2): 363-381.

Ready, R.C., Whitehead, J.C., Blomquist, G.C. (1995). Contingent valuation when respondents are ambivalent. *J. Environ. Econ. Manag.* 29: 181-196.

Reynaud, A., Nguyen, M.-H. (2013). Valuing Flood Risk Reduction. Working paper Vietman Center of Research in Economics, Management and Environment (VCREME) WP-01-2013

Rigby, D., Alcon, F., Burton, M. (2010). Supply uncertainty and the economic value of irrigation water. *Eur. Rev. Agric. Econ.* 37(1): 97–117.

Roberts, D.C., Boyer, T.A., Lusk, J.L. (2008). Preferences for environmental quality under uncertainty. *Ecol. Econ.* 66(4): 584-593.

Rolfe, J. Windle, J. (2015). Do Respondents Adjust Their Expected Utility in the Presence of an Outcome Certainty Attribute in a Choice Experiment? *Environ. Resour. Econ.* 60(1): 125-142.

Savage, L.J. (1954). *The foundations of statistics*. New York (USA): Wiley.

Sethi, G., Costello, C., Fisher, A.C., Hanemann, W.M., Karp, L.S.. (2005). Fishery management under multiple uncertainty. *J. Environ. Econ. Manag.* 50(2): 300-318.

Shaikh, S.L., Sun, L., van Kooten, G.C. (2007). Treating respondent uncertainty in contingent valuation: A comparison of empirical treatments. *Ecol. Econ.* 62: 115-125.

Shaw, W.D., Woodward, R.T. (2008). Why environmental and resource economists should care about non-expected utility models. *Resour. Energy Econ.* 30(1): 66-89.

Spiegelhalter, D., Pearson, M., Short, I. (2011). Visualizing uncertainty about the future. *Science* 333: 1393-1400.

Swait, J., Louviere, J. (1993). The role of the scale parameter in the estimation and comparison of multinomial logit models. *J. Mark. Res.* 30(3): 305-14.

Thom, R.M., Diefenderfer, H.L., Hofseth, K.D. (2004). A framework for risk analysis in ecological restoration projects. Report 04-R-02 prepared for the U.S. Department of Energy under Contract DE-AC06-76RL01830. Alexandria (USA): U.S. Army Engineers Institute for Water Resources.

Torres, C., Hanley, N., Riera, A. (2011). How wrong can you be? Implications of incorrect utility function specification for welfare measurement in choice experiments. *J. Environ. Econ. Manag.* 62: 111-121.

Train, K. (2009). *Discrete Choice Models with simulation*. Cambridge (UK): Cambridge University Press.

Veronesi, M., Chawla, F., Maurer, M., Lienert, J. (2014). Climate change and the willingness to pay to reduce ecological and health risks from wastewater flooding in urban centers and the environment. *Ecol. Econ.* 98: 1-10.

Viscusi, W.K. (1989). Prospective reference theory: toward an explanation of the paradoxes. *J. Risk Uncertainty* 2(3): 253-263.

Viscusi, W.K., Zeckhauser, R.J. (2006). The perception and valuation of the risks of climate change: a rational and behavioral blend. *Clim. Chang.* 77: 151-177.

von Neumann, J., Morgenstern, O. (1944). *Theory of games and economic behaviour*. Princeton (USA): Princeton University Press.

Wang, H. (1997). Treatment of ‘‘Don’t-Know’’ Responses in Contingent Valuation Surveys: A Random Valuation Model. *J. Environ. Econ. Manag.* 32: 219-232.

Wang, H., Mullahy, J. (2006). Willingness to pay for reducing fatal risk by improving air quality: a contingent valuation study in Chongqing, China. *Sci. Total Environ.* 367(1): 50-57.

Wibbenmeyer, M.J., Hand, M.S., Calkin, D.E., Venn, T.J., Thompson, M.P. (2013). Risk preferences in strategic wildfire decision making: a choice experiment with U.S. wildfire managers. *Risk Anal.* 33(6): 1021-1037.

Wielgus, J., Gerber, L.R., Sala, E. (2009). Including risk in stated-preference economic valuations: experiments on choices for marine recreation. *J. Environ. Manage.* 90: 3401-

3409.

Zhai, G. (2006). Public Preference and Willingness to Pay for Flood Risk Reduction. In: Ikeda, S., Fukuzono, T., Sato, T. (Eds.), *A better integrated management of disaster risks: Toward resilient society to emerging disaster risks in mega-cities*. Tokyo (Japan): Terra Scientific Publishing Company and National Research Institute for Earth Science and Disaster Prevention.

Table I. Attributes' description and their levels

Attribute	Description	Levels
'Specialist' bird species	Change in the number of species[a]	+5, 0, -10[c]
'Generalist' migratory bird species	Change in the number of species[a]	+5, 0, -10[c]
Waiting time	Minutes waited for an observation cabin's seat	About 3, About 7, About 15[c]
Rest-stop benches	Number of benches throughout the park[b]	Triple, Double, Equal[c]
Entrance fee	Entrance fee per adult visitor and trip (in euros)	4, 8, 12, 16, 20, 24

[a] Changes with respect to the current number of 'specialist' bird species and 'generalist' migratory bird species.

[b] Number measured with respect to the current level of rest-stop benches.

[c] Business-as-usual (BAU) levels, being €0 for the Entrance fee attribute.

Table II. Levels of the 'specialist' bird species attribute[a]

	Probabilities of impact occurrence and non-occurrence in a 10 years' time	
	p_1	**p_2**
BAU	-10	0
Adaptation	0[b]/+5[c]	+5[b]/+10[c]

[a]Changes in the number of 'specialist' bird species with respect to current levels.

[b]Changes in the number of 'specialist' bird species under a moderate management effort.

[c]Changes in the number of 'specialist' bird species under a high management effort.

Table III. Levels of the 'specialist' bird species attribute under each scenario[a]

	Inherent uncertainty				
	No_Inherent	Inherent_80		Inherent_60	
		p_1=80%	p_2=20%	p_1=60%	p_2=40%
BAU	-10	-10	0	-10	0
Adaptation	0/+5	0[b]/+5[c]	+5[b]/+10[c]	0[b]/+5[c]	+5[b]/+10[c]

[a]Changes with respect to current levels.

[b]Changes in the number of 'specialist' bird species under a moderate management effort.

[c]Changes in the number of 'specialist' bird species under a high management effort

Table IV. Results from RPL models under No_Inherent, Inherent_80 and Inherent_60 scenarios[a]

Variables	No_Inherent		Inherent_80		Inherent_60	
	Coeff.	*Std. error*	Coeff.	*Std. error*	Coeff.	*Std. error*
Fixed parameters						
$p_1 \cdot X_{SPEC1}+p_2 \cdot X_{SPEC2}$	2.113^{***}	*0.286*	1.956^{***}	*0.181*	1.613^{***}	*0.180*
X_{GEN}	1.245^{***}	*0.236*	0.568^{***}	*0.177*	1.729^{***}	*0.188*
$X_{TIME(less)}$	0.455^{***}	*0.139*	1.118^{***}	*0.118*	0.150	*0.109*
$X_{BENCHES(double)}$	0.584^{***}	*0.150*	0.116	*0.109*	0.600^{***}	*0.125*
$X_{BENCHES(triple)}$	0.276	*0.173*	0.838^{***}	*0.140*	0.274^{*}	*0.140*
$p_1 \cdot X^2_{SPEC1}+p_2 \cdot X^2_{SPEC2}$	-0.780^{***}	*0.274*	-1.567^{***}	*0.236*	-1.841^{***}	*0.249*
X^2_{GEN}	-0.758^{***}	*0.255*	-0.968^{***}	*0.256*	0.685^{***}	*0.226*
$(p_1 \cdot X_{SPEC1}+p_2 \cdot X_{SPEC2}) \cdot X_{GEN}$	-0.290^{*}	*0.165*	-0.998^{***}	*0.151*	-1.097^{***}	*0.165*
$(p_1 \cdot X_{SPEC1}+p_2 \cdot X_{SPEC2}) \cdot X_{TIME(less)}$	-0.684^{***}	*0.167*	-1.901^{***}	*0.173*	-0.075	*0.215*
Random parameters[b]						
X_{COST}_mean	1.371^{***}	*0.065*	1.087^{***}	*0.073*	0.996^{***}	*0.076*
X_{COST}_std. deviation	0.718^{***}	*0.043*	0.861^{***}	*0.053*	0.966^{***}	*0.061*
Log-likelihood	-1,050.601		-1,061.169		-1,183.264	
Observations	1,788		1,734		1,746	
N	298		289		291	

[a] ***Significant at 1% level; ** Significant at 5% level; * Significant at 10% level.

[b] Coefficients of the normal distribution associated with the lognormal one.

Table V. Mean marginal value of E(X_{SPEC}) under No_Inherent, Inherent_80 and Inherent_60 scenarios[a]

	Test 1		Test 2		Test 3	
E(X_{SPEC})	**No_Inherent**	**Inherent_80**	**Inherent_80**	**Inherent_60**	**No_Inherent**	**Inherent_60**
Mean marginal value	1.31	2.43	2.43	2.75	1.31	2.75
Standard deviation	(1.12)	(2.21)	(2.21)	(3.29)	(1.12)	(3.29)
Interval	[0.54;2.37]***		[-1.03;1.41]		[0.65;2.61]***	

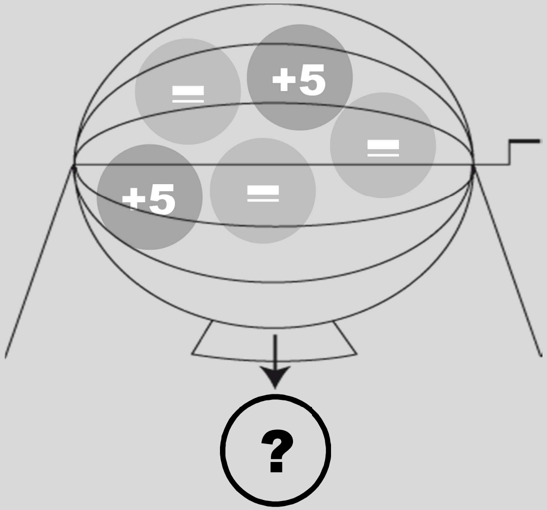
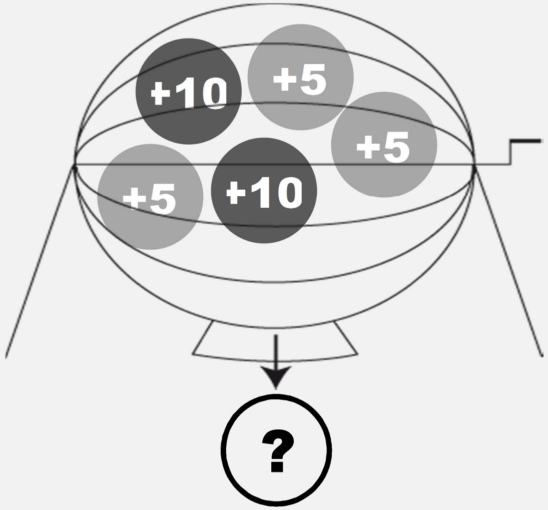
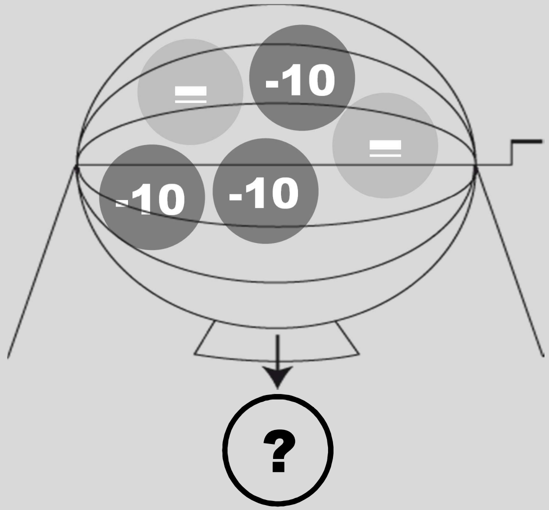
[a]The mean marginal value of E(X_{SPEC}) has been calculated by computing the mean of the individual-specific marginal values, which follow a lognormal distribution due to the random cost parameter. ***Significant difference between values at the 1% level.

Table VI. Mean marginal value of $E(X_{SPEC})$ for different levels of $X_{TIME(less)}$ and X_{GEN}[a]

	$X_{TIME(less)}=0$					$X_{TIME(less)}=1$				
X_{GEN}	No_Inherent		Inherent_80		Inherent_60	No_Inherent		Inherent_80		Inherent_60
-10	1.31	≠	2.43	=	2.75	1.08	≠	1.56	≠	2.75
0	1.21	≠	1.97	=	2.11	0.98	=	1.10	≠	2.11
+5	1.16	≠	1.74	=	1.79	0.93	=	0.87	≠	1.79

[a] For each value of $X_{TIME(less)}$, '=' means the values are not significantly different from each other, while '≠' means they are significantly different from each other.

FIGURE 1

ATTRIBUTES	POLICY A	POLICY B	NO POLICY INTERVENTION (C)
‘SPECIALIST’ BIRD SPECIES	 **60% chance**, keep the current number **40% chance**, increase the current number by 5	 **60% chance**, increase the current number by 5 **40% chance**, increase the current number by 10	 **60% chance**, decrease the current number by 10 **40% chance**, keep the current number
‘GENERALIST’ MIGRATORY BIRD SPECIES	= Keep the current number	-10 Decrease the current number by 10	-10 Decrease the current number by 10
WAITING TIME	≃15' Wait about 15 minutes for a seat in observation cabins	≃7’ Wait about 7 minutes for a seat in observation cabins	≃15' Wait about 15 minutes for a seat in observation cabins
REST-STOP BENCHES	x3 Triple the current number throughout the park	x2 Double the current number throughout the park	= Keep the current number
ENTRANCE FEE	**€16**	**€24**	**€0**