Understanding the distribution of economic benefits from improving coastal and marine ecosystems

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Abstract

The ecological status of coastal and marine waterbodies world-wide is threatened by multiple stressors, including nutrient inputs from various sources and increasing occurrences of invasive alien species. These stressors impact the environmental quality of the Baltic Sea. Each Baltic Sea country contributes to the stressors and, at the same time, is affected by their negative impacts on water quality. Understanding who benefits from improvements in coastal and marine waters is key to assessing public support for policies aimed at achieving such changes. We propose a new approach to account for variability in benefits related to differences in socio-demographics of respondents, by using a structural model of discrete choice. Our method (1) provides a convenient way of incorporating a wide range of socio-demographics as explanatory variables in conditional multinomial logit models without the risk of collinearity, and (2) is more statistically efficient than the alternative, typically used approaches. The new technique is applied in a study which examines the preferences of Latvian citizens towards improvements of the coastal and marine environment quality that could help the Baltic Sea waters of Latvia reach Good Environmental Status as required by the European Union's Marine Strategy Framework Directive. Applying the discrete choice experiment method, we find that overall, Latvians are willing to pay for reducing losses of biodiversity, for improving water quality for recreation by reduced eutrophication, and for reducing new occurrences of invasive alien species. A significant group within the sample seems not to value environmental improvements in the Baltic Sea, and, thus, is unwilling to support costly measures for achieving such improvements. The structural model of discrete choice reveals substantial heterogeneity among Latvians towards changes in the quality of coastal and marine waters of Latvia.

Keywords:

good environmental status; coastal and marine water quality; biodiversity; invasive alien species; eutrophication; discrete choice experiment; observed preference heterogeneity; socio-demographic characteristics; hybrid choice model

JEL:

C35, D12, H41, Q25, Q26, Q51, Q53, Q57, R50

Acknowledgements:

The study was carried out within the project "Good environmental status through regional coordination and capacity building" (GES-REG) funded by the Central Baltic INTERREG IV A Programme 2007-2013. MC gratefully acknowledges the support of the National Science Centre of Poland (project 2015/19/D/HS4/01972), Polish Ministry of Science and Higher Education and the Foundation for Polish Science. SS thanks the project "Development of the ships' ballast water management system to reduce biological invasions" (BALMAN, 2015-2017) for funding her work. NH thanks MASTS (www.masts.ac.uk) for funding a part of his work.

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1. Introduction

Across the world, coastal and marine water bodies are adversely impacted by a range of stressors resulting from human activities (Halpern *et al.*, 2008; Crain *et al.*, 2009; Korpinen *et al.*, 2012; Solan and Whiteley, 2015). These stressors include nutrient inputs from farmland due to fertilizer applications and livestock wastes, industrial sources, and sewage inputs (Hunter *et al.*, 2012). Introductions of new invasive alien species, which are often brought in ships' ballast waters, constitute another stressor threatening marine ecosystems (Occhipinti-Ambrogi and Savini, 2003). For one major regional waterbody – the Baltic Sea – excessive nutrient inputs, invasive alien species and loss of biodiversity have been identified as factors that substantially undermine its environmental quality and prevent the nine countries which border the Baltic Sea from achieving Good Environmental Status (GES) for the coastal and marine waters under their jurisdictions (Leppäkoski *et al.*, 2002; Leppäkoski, Olenin and Gollasch, 2002; Paavola, Olenin and Leppäkoski, 2005; HELCOM, 2009; 2010).

The environmental quality of the Baltic Sea is particularly endangered by human activities because of an interaction of two effects. First, the sea is surrounded by nine countries whose population density is particularly concentrated in coastal areas and which extensively (and often unsustainably) use marine waters. Second, water exchange is substantially limited due to the very narrow and shallow oceanic connection. The semi-enclosed character of the Baltic Sea basin fosters the accumulation of nutrients, and hazardous substances. The adverse impacts of these factors on this marine ecosystem has been acknowledged for many years, and the Baltic Sea has been identified as one of the most threatened marine environments in the world (WWF, 2011). All nine Baltic Sea countries would derive economic benefits from improvements to water quality (for instance, in terms of enhanced recreation opportunities). Improving the quality of the Baltic Sea is thus an important regional environmental management problem, but one which requires coordinated actions by many nations.

In 2008, the European Commission (2008) issued the Marine Strategy Framework Directive (MSFD), providing a regulatory framework aimed at effective protection of the European Union (EU) marine waters. The major objective of the MSFD is the attainment of Good Environmental Status (GES)[1] in marine waters of EU member states by 2020. What constitutes GES is determined by member states according to the qualitative descriptors provided in the MSFD. When divergence between the actual condition of the marine environment and GES is expected, appropriate measures need to be undertaken. Every member state must have developed a program of measures for achieving GES by the end of 2015 and update it every 6 years. In order to support the selection of the appropriate measures, the MSFD requires countries to undertake impact assessments, which may include the use of cost-benefit analysis (European Commission, 2008; CIS, 2014).

The aim of this paper is to understand and quantify how the economic benefits from improving the environmental status of the Baltic Sea vary across people within a country, since this will partly determine political support for costly measures to improve water quality. We take the example of Latvia and examine the preferences of Latvian citizens towards the improvements of coastal and marine waters. While the fundamental aspects of the marine environment for which improvements are needed can be easily identified, and while the costs of the

[1] The MSFD defines GES as "the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations" (European Commission, 2008, art. 3(5)).

improvement actions can be readily estimated (e.g., Wulff *et al.*, 2014), the valuation of the benefits from undertaking these actions is challenging. This is mainly due to the fact that most of these benefits are not valued by the market. To assess the value of improvements for the potentially-benefiting population of Latvia, we employ the stated preference discrete choice experiment (DCE) method. A representative sample of 1,247 Latvian citizens is utilized. In addition to economic benefit estimates, the DCE approach allows one to identify which aspects of improvements are considered most important by respondents. To capture the multidimensionality of the coastal and marine waters improvements, survey respondents are asked to state their preferences towards avoiding reductions in marine biodiversity, having better water quality for recreation, and limiting new occurrences of invasive alien species. Explicit incorporation of this multidimensionality helps determine specific characteristics of the optimal (maximizing social welfare) program of improvements.

Additionally, this paper addresses the problem of modelling the observed preference heterogeneity. "Preference heterogeneity" describes the way in which the values which people obtain from environmental improvements (or indeed any other kind of benefit) vary across a population. We use this study to illustrate a new method of accounting for variability in preferences related to observable differences in socio-demographic characteristics of respondents. The approach we propose is more statistically efficient than the typically used approaches, because we simultaneously estimate the links between socio-demographic characteristics and latent (unobservable from the modeler's perspective) factors, and the links between these latent factors and respondents' preferences. This allows a quantification of how the benefits of improvements to GES vary across the sample of respondents, and by inference, across the population.

2. Previous studies on valuation of the Baltic Sea environment

One of the major threats to the Baltic Sea is eutrophication, and this problem is addressed in several studies. Eutrophication occurs because of excess nitrogen and phosphorus inputs to waterbodies from detergents, fertilizers, livestock wastes and sewage. The economic value of reductions in eutrophication has been measured in the Stockholm archipelago of Sweden (Söderqvist and Scharin, 2000) and in Lithuania, Poland and Sweden (Markowska and Żylicz, 1999), as well as over the entire Baltic area (Ahtiainen *et al.*, 2014). All these studies employ the contingent valuation method to evaluate various improvement scenarios related to reduced eutrophication. Discrete choice experiments have also been used to assess the value of changes to the Baltic Sea with respect to other characteristics of the marine ecosystem. Eggert and Olsson (2009) carry out a survey among residents on the west coast of Sweden to estimate the welfare benefits of improved coastal water quality which is described in terms of the coastal cod stock level, bathing water quality and a biodiversity indicator. Kosenius (2010) examines the willingness to pay (WTP) of citizens for better water quality in the Gulf of Finland, and considers improvements with regard to water clarity, the abundance of coarse fish, the status of macro algae such as bladder wrack, and the occurrence of blue green algae blooms. Kosenius and Ollikainen (2015) evaluate actions undertaken within the Baltic Sea Action Plan in the areas of the Finnish-Swedish archipelago and the Lithuanian coast, which aim at healthy aquatic vegetation, conservation of currently pristine areas, and the protection of fish stocks. Karlõševa *et al.* (2016) look at the preferences of Estonian households between developing off-shore sites into wind farms or establishing marine protected areas. Tuhkanen *et al.* (2016) investigate how Estonians evaluate reductions in pollution by oil and chemicals, better water quality for recreation, and fewer non-indigenous species.

Although stated preference methods offer a useful, and widely employed, tool for valuation of improvements to the Baltic Sea environment, revealed preference approaches, which are based on the actual recreational behavior of individuals belonging to the benefiting population, are also sometimes applied. For instance, using travel cost and visitation data for each of the nine Baltic Sea countries, Czajkowski *et al.* (2015) assess social welfare benefits related to recreational use of marine waters from water quality improvements. The results show large differences in how much each country gains from improving the environmental quality of the Baltic Sea (similarly to Ahtiainen *et al.*, 2014), with some countries enjoying much larger benefits from others. While the focus in Czajkowski *et al.* (2015) is mainly on how average benefits vary between Baltic countries, the present paper deals with how benefits vary within a given country. In the assessment of the benefits resulting from improving environmental status and reaching GES in the coastal and marine waters of Latvia, we follow a stated preference approach close to that employed by Eggert and Olsson (2009), Kosenius (2010), and Kosenius and Ollikainen (2015), since we aim at evaluating multiple environmental problems and estimating both use and non-use values from improvements in environmental quality (Hanley and Barbier, 2009). The next section details the design of this discrete choice experiment.

3. Valuation approach and design of valuation survey

The Discrete Choice Experiment approach uses respondents' choices over goods or policy options as stated in a hypothetical choice situation to estimate their preferences. The good or the policy considered in a DCE is described by its characteristics (attributes) and the levels which these characteristics can take (Lancaster, 1966). Respondents are asked to choose their most preferred combinations of attribute levels in a series of multiple choices. Among the characteristics of the good or the policy, a price or a cost attribute is typically included to enable monetary valuation of changes in the non-price attributes. DCEs are particularly useful for valuation of non-market goods, such as environmental improvements when individuals' preferences cannot be gauged on the basis of their market behavior. Furthermore, DCEs allow not only for overall valuation of a good or a policy, but also for valuation of its separate characteristics.

With the use of the DCE, we evaluate Latvians' preferences towards improving the quality of the coastal and marine waters of Latvia. Figure 1 shows the study area. We use the preference estimates to generate welfare benefit estimates for specified environmental improvements aimed at achieving GES in the Latvian Baltic Sea. Marine scientists from the Latvian Institute of Aquatic Ecology identified four descriptors with respect to which the Latvian coastal and marine waters fail to reach GES. Those comprised maintaining biological diversity, preventing further invasions of non-indigenous species, reducing eutrophication, and improving sea floor integrity (D1, D2, D5, and D6, respectively, as defined by European Commission (2008)). These descriptors were matched to attributes to be used in the DCE design. Three coastal and marine waters attributes were defined. To evaluate the improvement of marine biodiversity and sea floor integrity, an attribute depicting the size of marine areas in which the variety of native species is declining was used. The improvements related to reductions in nutrient pollution and eutrophication were evaluated through the attribute "water quality for recreation", which was described by coastal water clarity and algae washed ashore, as these two water characteristics constitute important observed negative effects of eutrophication. Preventing introductions of non-indigenous species was captured in the attribute "new harmful alien species establishing", which focuses on invasive alien species (alien species that cause negative impacts). The levels of each attribute were defined for three policy scenarios: a no-additional-actions scenario (henceforth referred to as the "status quo"), which does not involve additional costs; a planned-additional-actions scenario, which is the "business-as-usual" scenario according to the MSFD requirements;[2] and a scenario assuming the full implementation of all measures necessary for

[2] In line with the MSFD, the risk of failing to reach GES should be appraised against the "business-as-usual" scenario. The "business-as-usual" scenario accommodates the expected development of the use of marine waters

reaching GES. The levels as described in the survey are presented in Table 1. Each choice alternative also contained a monetary attribute related to a cost faced by every individual when a given policy was introduced. The monetary attribute was defined as a yearly payment per person and took values 0, 2, 5 and 10 Latvian lats (LVL).[3] The payment vehicle was coercive in the sense that the cost would be imposed on every Latvian citizen if the policy was implemented (for example, as higher taxes).

Figure 1. Map of the study area

Figure 2 presents an example of a choice task. The survey included 12 choice tasks per respondent, with three alternatives in each choice task. One of these alternatives was always a no-additional-actions, no-additional-cost option, that is, the status quo option. The experimental design was optimized for Bayesian D-efficiency of a multinomial logit model (Bliemer, Rose and Hess, 2008; Scarpa and Rose, 2008) with priors for the choice parameters obtained from a pilot study and personal interviews. The order of the choice tasks was randomized to avoid possible ordering effects.

and the implementation of the current and planned policy measures, which will influence the marine environment. When the environment assessment indicates a gap between the "business-as-usual" and GES states, additional measures must be undertaken to ensure reaching GES.

[3] 1 LVL ≈ 1.4 EUR

Table 1. The environmental attributes of the discrete choice experiment

Attributes	No additional actions	Planned additional actions	Action plan for reaching GES
Reduced number of native species	on large areas	on small areas	no such areas
reduction of the areas in which the native species naturally live, in percentages	30%	10-20%	0% (species are present in all their natural areas)
Water quality for recreation (in coastal waters in summers)	Bad	Moderate	Good
visual quality	Water is unclean every summer. It can be seen through less than 3 m in the Gulf of Riga and 4 m in the Baltic Sea (on average).	Water is unclean every 2nd-3rd summer. It can be seen through at least 3 m in the Gulf of Riga and 4 m in the Baltic Sea (on average).	Water is mainly clean (unclean in rare summers). It can be seen through at least 4 m in the Gulf of Riga and 4.5 m in the Baltic Sea (on average).
algae washed ashore	Every summer in large amounts.	Every 2nd-3rd summer in small amounts.	Only after large storms.
New harmful alien species establishing	Often	Rarely	In exceptional cases
one new species on average	in 5 years	in 15-20 years	not more often than in 50 years

Figure 2. An example of a choice task[4]

	Program A	**Program B**	**No additional actions**
Reduced number of native species	No such areas	(on) Small areas	(on) Large areas
Water quality for recreation in coastal areas	Bad	Good	Bad
New harmful alien species establishing	Rarely	In exceptional cases	Often
Your yearly payment	5 LVL	2 LVL	0 LVL
Your choice:	○	○	○

The questionnaire began by asking respondents about their use of Latvian coastal and marine waters for leisure activities. This was followed by a detailed description of the environmental problems of the Latvian part of the Baltic Sea, including questions about the respondents' prior knowledge and perceptions of these problems. Subsequently, the possible policy scenarios for improving the state of the Latvian coastal and marine environment were explained, providing respondents with information about proposed policy attributes and their levels, as detailed in Table 1. The sequence of 12 choice tasks was then presented, in which respondents were instructed to choose their most preferred alternative from the provided set, treating each choice

[4] Latvian and Russian versions of the questionnaire were used in the study. Figure 2 presents a translated choice task.

task independently of the other choice tasks. At the end of the survey, socio-demographic data was collected.

The survey was designed based on extensive pre-testing, including focus group discussions with individuals representing the Latvian population and a pilot study. The pilot survey was conducted in the form of paper and pen interviews and administered to a sample of 100 respondents representative to the Latvian population at their places of residence. The main survey was conducted in October 2013 with a random sample of 1,247 respondents, which was representative of the general population of Latvia aged 18-74 with respect to age, gender, nationality, education level, and place of residence (administrative region). The details of the socio-demographic characteristics of the study sample and of the Latvian population aged 18-74 are presented in Table 2.

Table 2. Socio-demographic characteristics of the study sample and the Latvian population aged 18-74

	Sample (%)	General population (%)
Aged 18-24	12.3	12.8[1]
Aged 25-34	18.8	20.3[1]
Aged 35-44	24.1	18.6[1]
Aged 45-54	19.1	19.2[1]
Aged 55-64	11.1	16.5[1]
Aged 65-74	14.6	12.7[1]
Male	43.9	47.4[1]
Latvian	60.5	58.2[1]
Average household size	2.88	2.43[2]
Primary school or incomplete compulsory education	1.1	1.1[2]
Complete compulsory education	9.2	14.7[2]
General secondary education	26.3	26.6[2]
Vocational secondary education	34.2	32.6[2]
Higher education	29.1	25[2]
Live in Riga and Pieriga	50.9	49.7[1]
Live in Vidzeme	10.5	10.2[1]
Live in Kurzeme	12.8	13.1[1]
Live in Zemgale	11.5	12.1[1]
Live in Latgale	14.4	14.9[1]

Sources: [1] Office of Citizenship and Migration Affairs of Latvia (data for 2013, January 1); [2] Central Statistical Bureau of Latvia (data about household size for 2013, and about education for 2012)

The main survey data was collected by a professional polling agency from 606 respondents with Computer Assisted Web Interviews (CAWI) over the internet, and from 641 respondents interviewed in-person at their place of residence using Computer Assisted Personal Interviews (CAPI). Except for the differences related to each interviewing mode, the questionnaires did not differ between CAWI and CAPI. CAWIs were conducted among respondents in the age of 18-54, while CAPIs were conducted for respondents in the age of 35-74. The combined approach was used in order to reduce the costs of data collection while maintaining sample representativeness. Internet interviews are recommended when the use of Internet in the general population exceeds 60%,[5] however, this is not the case of Latvia for the age group above 55 years old, and, thus, CAWI and CAPI were employed in tandem.[6]

4. Econometric approach

Our modeling preferences from discrete choices made by respondents is based on random utility theory (McFadden, 1974). This theory assumes that a utility function of an individual can be decomposed into a deterministic component, which includes observable characteristics of the proposed good or policy, and a stochastic (random) component, which includes factors unobservable from the modeler's perspective, but which affect the individual's choices. Alternatively, this random component can represent a random element in the choice process of the individual (due to uncertainty about what an individual prefers, for instance). The DCE approach allows one to identify the effects of changes in each attribute on individual's choices, and to estimate the monetary value of changes in each non-monetary characteristic of the good or the policy to individuals.

To explain variability in preferences across individuals on the basis of their socio-demographic characteristics, one common practice is to include these characteristics as explanatory variables in the choice model, by interacting them with the choice attributes[7] (e.g., Harris and Keane, 1998; Axhausen *et al.*, 2008; Longo, Markandya and Petrucci, 2008; Kosenius, 2010; Ziegler, 2012). The second common approach consists of a two-step procedure in which, first, a sub-set of factors which best explain the variance of socio-demographic characteristics is identified, and, subsequently, individual factor scores are used to explain respondents' choices (e.g., Salomon and Ben-Akiva, 1983; Boxall and Adamowicz, 2002; Nunes and Schokkaert, 2003; Milon and Scrogin, 2006). The former approach gives a rise to the estimation problem that many out of the socio-demographic variables included often appear as insignificant predictors in the model because of being strongly correlated with each other. Further, the many additional coefficients necessary to be estimated substantially lower the number of the degrees of freedom. The latter approach is not statistically efficient – the factors which best capture the variance in socio-demographic characteristics are not necessarily those which provide the most explanatory power in the discrete choice component of the model.

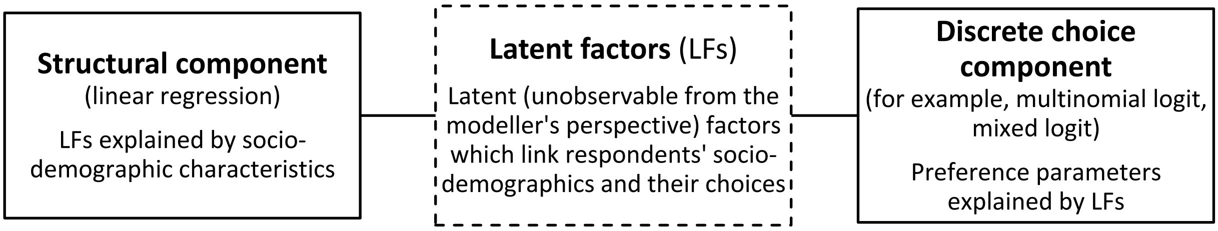
The new approach we propose here consists of a structural and a discrete choice component (see Figure 3 for illustration) which are linked via latent factors (LFs). These LFs are explained using respondents' socio-demographic characteristics, and are used to help explain respondents' choices in the discrete choice component. This allows for a convenient linking of multiple socio-demographic characteristics with respondents' preferences for environmental improvements, and the identification of the most important factors which drive these dependencies. As such, our approach fits into the broader class of "hybrid choice" models (Ben-Akiva *et al.*, 2002), which are structural models that incorporate choice and non-choice components. For recent applications of these models in environmental economics see, for example, Hess and Beharry-Borg (2012), Czajkowski, Hanley and Nyborg (2016) or Czajkowski *et al.* (forthcoming).

[5] *ICC/ESOMAR International Code on Market and Social Research* (2008).

[6] Translation of the original questionnaire is available online at the website of the GES-REG project (gesreg.msi.ttu.ee/en/results; in the annex of the *WP5 GES-REG WT5.3 Valuation Study LV Report*).

[7] The conditional multinomial models used to explain respondents' choices cannot include choice-invariant explanatory variables directly as they cancel out in calculating utility differences between alternatives. Thus, the only way to include them is via interactions with choice attributes.

Figure 3. Components of the model used to link socio-demographic variables with discrete choice experiment data



Formally, the relationship between the latent factors, $\mathbf{LF}$, and the socio-demographic variables, $\mathbf{Y}$, for respondent i can be expressed by:

$$\mathbf{LF}_i = \mathbf{Y}_i \boldsymbol{\varphi} + \boldsymbol{\eta}_i , \tag{1}$$

with $\boldsymbol{\varphi}$ being a matrix of coefficients, and $\boldsymbol{\eta}$ denoting error terms, which are assumed to be normally distributed with zero mean and a diagonal covariance matrix.

In the discrete choice model, the utility derived by individual i from choosing alternative j in choice task t can be represented by:

$$U_{ijt} = \mathbf{X}_{ijt} \boldsymbol{\beta}_i + \varepsilon_{ijt} , \tag{2}$$

where $\mathbf{X}$ expresses the attribute levels associated with an environmental outcome, and the stochastic component ε captures the unobservable from the modeler's perspective factors that influence individual's utility (choices).[8] The individual-specific parameters $\boldsymbol{\beta}_i = \mathbf{b} + \mathbf{u}_i \boldsymbol{\tau} + \mathbf{LF}_i \boldsymbol{\gamma}$ consist of the parameters representing means $(\mathbf{b})$, individual-specific deviations from these means representing unobserved preference heterogeneity $(\mathbf{u}_i \boldsymbol{\tau})$ and a component which allows individual preferences to be a function of latent factors $(\mathbf{LF}_i \boldsymbol{\gamma})$, where $\mathbf{b}$, $\boldsymbol{\tau}$ and $\boldsymbol{\gamma}$ are vectors of coefficients to be estimated.

In order to make identification possible, the scale of every LF needs to be normalized (Daly *et al.*, 2012). We do this by normalizing variances of the error terms in the structural equations to one. In addition, to facilitate interpretation, we normalize the mean of each LF to zero. This way $\mathbf{LF}_i$ can be interpreted as individual-specific, normally-distributed deviations in the factors from the sample mean.

Finally, given our interest in establishing estimates of willingness-to-pay values (WTP) for the non-monetary attributes, we introduce the following modification which is equivalent to using a money-metric utility function (aka estimating the parameters in wilingness-to-pay-space; Train and Weeks, 2005):

$$U_{ijt} = X_{ijt}^{p} \beta_i^{p} + \mathbf{X}_{ijt}^{-p} \boldsymbol{\beta}_i^{-p} + \varepsilon_{ijt} = \beta_i^{p} \left(X_{ijt}^{p} + \mathbf{X}_{ijt}^{-p} \frac{\boldsymbol{\beta}_i^{-p}}{\beta_i^{p}} \right) + \varepsilon_{ijt} = \beta_i^{p} \left(X_{ijt}^{p} + \mathbf{X}_{ijt}^{-p} \mathbf{W}_i \right) + \varepsilon_{ijt} . \tag{3}$$

[8] The stochastic component of the utility function is of unknown, possibly heteroskedastic variance. Identification of the model typically relies on normalizing this variance, such that the error term is i.i.d. type I extreme value with constant variance $\operatorname{var}(\varepsilon_{ijt}) = \pi^2/6$, which allows for convenient close-form formulas for choice probabilities. Note that due to the ordinal nature of utility, this normalization does not change the properties of the utility function (it still represents the same preferences), and the estimates of model parameters, which can now be seen as products of taste parameters and a scaling coefficient, do not have direct interpretation anyway.

In the above equation, the choice attributes $\mathbf{X}$ are disaggregated into non-monetary attributes $\mathbf{X}^{-p}$ and a single monetary attribute X^{p}, whose units are later used for calculating WTP. By dividing all parameters by β_i^p (i.e., the marginal utility of X^{p}), the coefficients of non-monetary attributes become $\boldsymbol{\beta}_i^{-p} / \beta_i^p = \mathbf{W}_i$ and, hence, they can readily be interpreted as marginal rates of substitution of X^{p} for $\mathbf{X}^{-p}$, i.e., marginal WTP.

Consequently, the conditional probability of choices made by individual i is given by:

$$P\left(\mathbf{y}_i \mid \mathbf{X}_i, \mathbf{b}, \boldsymbol{\tau}, \boldsymbol{\gamma}, \mathbf{LF}_i\right) = \prod_{t=1}^{T_i} \frac{\exp\left(\beta_i^p \left(X_{ijt}^{p} + \mathbf{X}_{ijt}^{-p}\mathbf{W}_i\right)\right)}{\sum_{k=1}^{J}\exp\left(\beta_i^p \left(X_{ikt}^{p} + \mathbf{X}_{ikt}^{-p}\mathbf{W}_i\right)\right)} . \tag{4}$$

Both components of the model are estimated simultaneously. The full information likelihood function is:

$$L_i = \int P\left(\mathbf{y}_i \mid \mathbf{X}_i, \mathbf{Y}_i, \mathbf{b}, \boldsymbol{\tau}, \boldsymbol{\gamma}, \boldsymbol{\varphi}, \mathbf{u}_i, \boldsymbol{\eta}_i\right) f\left(\mathbf{u}_i, \boldsymbol{\eta}_i \mid \mathbf{b}, \boldsymbol{\tau}\right) d\left(\mathbf{u}_i, \boldsymbol{\eta}_i\right). \tag{5}$$

As random disturbances $\mathbf{u}_i$, as well as error terms in structural equations $\boldsymbol{\eta}_i$ are not directly observed, they must be integrated out of the conditional likelihood. We estimate the model using a simulated maximum likelihood approach. The multidimensional integral is approximated using quasi Monte Carlo methods.[9]

5. Results

Results from estimation of the model described above are presented in Table 3.[10] We use six LFs, because this specification performs best in terms of the Akaike information criterion (AIC) and interpretability of the results.[11]

The first panel of Table 3 reports the results of the structural equations, in which the LFs are regressed on socio-demographic variables. Each LF mirrors the respondents' characteristics which are unobservable from the perspective of the modeler, but which are correlated with respondents' socio-demographic characteristics. The structural equations model these relationships, by linking the LFs to the observed socio-demographics. The second panel of Table 3 presents the results of the discrete choice component of the model, which captures the links between LFs and willingness to pay. This component reveals how LFs influence the respondents' preferences (expressed by choices made in the survey). In the estimation procedure of the structural equations, each continuous explanatory variable is standardized to have zero mean and a unit standard deviation. Consequently, the expected value of every LF is zero. Placing variables on similar scales is known to help with convergence properties of numerical algorithms and eases the interpretation of relative importance of the explanatory variables.

[9] The software codes for the model were developed in Matlab and are available at github.com/czaj/DCE under Creative Commons BY 4.0 license.

[10] The hybrid choice model is estimated via the simulated maximum likelihood method, using 5,000 Sobol draws. We assume a normal distribution of all non-monetary attributes and a lognormal distribution of the cost parameter.

[11] The estimation results of the models with other numbers of LFs and other specifications are available from the authors upon request.

Table 3. Estimation results of the model linking respondents' socio-demographic characteristics with their discrete choices

	Structural component (linear regression)					
	LF 1	**LF 2**	**LF 3**	**LF 4**	**LF 5**	**LF 6**
	coefficient (s.e.)	**coefficient (s.e.)**	**coefficient (s.e.)**	**coefficient (s.e.)**	**coefficient (s.e.)**	**coefficient (s.e.)**
Age	0.28** (0.13)	0.56 (0.60)	0.05 (0.16)	-0.13 (0.20)	1.10*** (0.41)	0.50** (0.22)
Male	0.10 (0.07)	0.50* (0.28)	0.01 (0.08)	0.29*** (0.10)	0.18 (0.21)	0.36*** (0.11)
Latvian	-0.25* (0.14)	-1.29** (0.54)	0.23 (0.15)	-0.41** (0.18)	0.64* (0.37)	-0.79*** (0.21)
Household size	0.47*** (0.13)	1.18** (0.51)	-0.41*** (0.15)	0.13 (0.17)	0.17 (0.36)	0.24 (0.19)
Number of children	-0.14 (0.12)	-0.10 (0.33)	0.20** (0.10)	0.19* (0.12)	0.41 (0.30)	-0.09 (0.14)
Education: *primary*[12]	1.04 (0.68)	6.13** (2.71)	-1.51* (0.79)	1.03 (0.77)	0.07 (1.54)	1.11 (0.79)
Education: *complete compulsory*	-0.30*** (0.10)	-0.59 (0.38)	0.08 (0.11)	-0.21* (0.13)	-0.16 (0.27)	-0.23 (0.15)
Education: *general secondary*	-0.26* (0.14)	-1.28** (0.56)	0.22 (0.16)	-0.51*** (0.19)	-0.56 (0.41)	-0.65*** (0.22)
Education: *vocational secondary*	-0.32*** (0.12)	-1.17** (0.47)	0.25* (0.14)	-0.37** (0.15)	0.16 (0.37)	-0.47*** (0.18)
Occupation: *part-time*[13]	0.06 (0.06)	-0.28 (0.23)	0.06 (0.07)	-0.22*** (0.08)	-0.09 (0.16)	-0.04 (0.09)
Occupation: *retired*	-0.01 (0.11)	0.41 (0.44)	-0.07 (0.12)	0.02 (0.15)	-1.02*** (0.31)	0.00 (0.17)
Occupation: *student*	0.20* (0.12)	0.79 (0.49)	-0.03 (0.14)	0.46*** (0.17)	0.83** (0.34)	0.42** (0.19)
Occupation: *at home*	-0.01 (0.07)	0.23 (0.29)	-0.06 (0.07)	0.05 (0.11)	-0.35* (0.18)	0.10 (0.11)
Occupation: *self-employed*	-0.07 (0.07)	-0.03 (0.24)	-0.03 (0.09)	-0.05 (0.08)	0.15 (0.18)	0.00 (0.12)
Occupation: *unemployed*	0.34*** (0.13)	1.31*** (0.50)	-0.32** (0.14)	0.37** (0.17)	-0.23 (0.37)	0.57*** (0.20)
Region: *Pieriga*[14]	0.28** (0.12)	0.80* (0.44)	-0.28** (0.13)	0.41*** (0.14)	-0.24 (0.29)	0.76*** (0.16)
Region: *Vidzeme*	0.24* (0.13)	1.26** (0.52)	-0.18 (0.15)	0.48*** (0.17)	0.10 (0.35)	0.76*** (0.21)
Region: *Kurzeme*	-0.20 (0.14)	-0.62 (0.44)	-0.13 (0.12)	-0.08 (0.17)	-0.91** (0.40)	0.48** (0.19)
Region: *Zemgale*	0.09 (0.11)	0.51 (0.37)	-0.11 (0.11)	0.23* (0.12)	-0.48** (0.21)	0.53*** (0.15)

[12] The reference education level is "higher".
[13] The reference employment status is "full-time".
[14] The reference region is "Rīga".

Region: *Latgale*	0.10 (0.09)	0.47 (0.38)	-0.19* (0.11)	0.04 (0.12)	-0.23 (0.23)	0.56*** (0.14)
Net personal monthly income	0.22* (0.12)	0.73* (0.43)	-0.30** (0.12)	0.20 (0.14)	-0.37 (0.32)	0.24 (0.16)
Income missing	0.18* (0.10)	0.52 (0.36)	-0.32*** (0.10)	0.11 (0.12)	-0.33 (0.29)	0.26* (0.14)

	Discrete choice component							
	means (main effects)	**standard deviations**	**interaction with LF 1**	**interaction with LF 2**	**interaction with LF 3**	**interaction with LF 4**	**interaction with LF 5**	**interaction with LF 6**
	coefficient **(s.e.)**	**coefficient** **(s.e.)**	**coefficient** **(s.e.)**	**coefficient** **(s.e.)**	**coefficient** **(s.e.)**	**coefficient** **(s.e.)**	**coefficient** **(s.e.)**	**coefficient** **(s.e.)**
Status quo	8.21*** (0.48)	55.30*** (1.95)	0.04 (0.23)	39.85** (15.57)	28.27*** (10.08)	-24.43*** (8.15)	-0.63** (0.26)	16.65*** (5.31)
Reduced number of native species:[15]								
On small areas	0.38** (0.17)	0.42*** (0.07)	-0.30 (0.20)	2.14*** (0.76)	-0.08 (0.22)	0.69** (0.33)	0.10 (0.16)	-1.60*** (0.54)
No such areas	0.20 (0.21)	0.25*** (0.08)	0.75** (0.30)	2.53*** (0.94)	0.03 (0.27)	2.50*** (0.87)	-0.08 (0.23)	-3.66*** (1.19)
Water quality for recreation:[16]								
Moderate	4.25*** (0.21)	0.02 (0.06)	3.69*** (1.15)	-7.41** (3.43)	-3.65*** (1.31)	8.24*** (2.74)	-1.57*** (0.27)	-4.52*** (1.48)
Good	4.79*** (0.28)	0.07 (0.08)	4.75*** (1.47)	-11.80** (5.00)	-2.30*** (0.89)	13.13*** (4.35)	-1.59*** (0.38)	-5.35*** (1.71)
New harmful alien species establishing:[17]								
Rarely	1.64*** (0.17)	0.09 (0.09)	1.08*** (0.36)	-2.07* (1.20)	-2.69*** (0.96)	1.90*** (0.67)	0.50*** (0.15)	-1.37*** (0.51)
In exceptional cases	0.89*** (0.19)	0.38*** (0.07)	1.74*** (0.54)	-1.38 (0.86)	-1.76*** (0.66)	1.63*** (0.63)	0.36** (0.16)	-1.99*** (0.67)
Cost (scale)	-0.11 (0.09)	0.12 (0.10)	0.60** (0.24)	2.63* (1.42)	2.85*** (1.01)	-1.68*** (0.55)	-0.16 (0.15)	0.62** (0.28)

[15] The reference level is "on large areas", as defined in the survey.
[16] The reference level is "bad", as defined in the survey.
[17] The reference level is "often", as defined in the survey.

Model diagnostics	
Log-likelihood (constant only)	-15,296.83
Log-likelihood	-6,518.40
McFadden's pseudo R^2	0.5739
Ben-Akiva Lerman's pseudo R^2	0.7196
AIC/*n*	0.8283
n (observations)	16,212
k (parameters)	196

Notes: *** and ** indicate significance at the level of 1% and 5%, respectively. Standard errors (s.e.) are given in brackets.

The results of the structural equations inform how each LF (each of the unobserved drivers of respondents' choices) is related to the observed socio-demographics. Therefore, the coefficients can be interpreted similarly to factor loadings in explanatory factor analysis. We summarize the statistically significant relationships between the LFs and the socio-demographic variables in Table 4. The respondents whose choices are driven by unobserved factors included in LF 1 are more likely to be students and unemployed than full-time employed, and are more likely to live in the regions Pieriga and Vidzeme than in Riga; they are less likely to be Latvian and to have completed compulsory, general secondary and vocational secondary education rather than higher education. The perceptions included in LF 1 also correlate positively with age, household size, and income. The choice drivers captured by LF 2 are more likely to be of the respondents who are male, live in large households, have only primary education, are unemployed, live in the region of Pieriga and Vidzeme, and have high income. At the same time, the choices' drivers captured by LF 2 are less likely to be of the respondents who are Latvian and have general secondary and vocational secondary education. The perceptions reflected by LF 3 correlate positively with the number of children and with vocational secondary education, and correlate negatively with income, household size, having primary education, being unemployed, and living in the regions of Pieriga and Latgale. The respondents whose choices are driven by unobserved factors included in LF 4 are more likely to be male, students, unemployed, have many children, and live in the regions of Pieriga, Vidzeme and Zemgale, and are less likely to be Latvian, part-time employed and have complete compulsory, general secondary and vocational secondary education. The perceptions represented by LF 5 correlate positively with age, being Latvian, and being a student, while they correlate negatively with being retired, working at home, and living in Kurzeme and Zemgale. Finally, the respondents whose choices are driven by unobserved factors included in LF 6 are more likely to be older, male, students, and unemployed, and less likely to be Latvian, have general secondary and vocational secondary education and live in Riga.

In short, we can probabilistically associate each LF with the following characteristics:

LF 1 – older, wealthier, Russian, from larger households, students, unemployed, from Pieriga and Vidzeme;

LF 2 – wealthier, male, Russian, from larger households, with primary education, unemployed, from Pieriga and Vidzeme;

LF 3 – poorer, from smaller households, having children, with vocational secondary education;

LF 4 – male, Russian, having children, students, unemployed, from Pieriga, Vidzeme, Zemgale;

LF 5 – older, Latvian, students;

LF 6 – older, male, Russian, students, unemployed, not from Riga.

Table 4. Relationships between LFs and socio-demographic characteristics

	LF 1	LF 2	LF 3	LF 4	LF 5	LF 6
Age	+				+	+
Male		+		+		+
Latvian	–	–		–	+	–
Household size	+	+	–			
Number of children			+	+		
Education: *primary*[18]		+	–			
Education: *complete compulsory*	–			–		
Education: *general secondary*	–	–		–		–
Education: *vocational secondary*	–	–	+	–		–
Occupation: *part-time*[19]				–		
Occupation: *retired*					–	
Occupation: *student*	+			+	+	+
Occupation: *at home*					–	
Occupation: *self-employed*						
Occupation: *unemployed*	+	+	–	+		+
Region: *Pieriga*[20]	+	+	–	+		+
Region: *Vidzeme*	+	+		+		+
Region: *Kurzeme*					–	+
Region: *Zemgale*				+	–	+
Region: *Latgale*			–			+
Net personal monthly income	+	+	–			
Income missing	+		–			+

The above analysis allows us to identify the main latent factors which differentiate respondents with respect to their socio-demographics. Note that so far we have not made any arbitrary assumptions – we include all the available socio-demographic variables in the regression and allow the data to speak for itself, that is, the factors are identified in such a way that they explain

[18] The reference education level is “higher”.
[19] The reference employment status is “full-time”.
[20] The reference region is “Rīga”.

the most variation in these socio-demographic variables. We believe this to be a more robust approach than arbitrary selection of socio-demographic variables to be used as explanatory variables for variations in preferences.

The second panel of Table 3 presents the results of the discrete choice component, that is, the mixed logit model which contains the interactions of the attribute levels with the LFs. Thereby, the discrete choice component explains the respondents' stated choices as a function of the attributes with the preference parameters being influenced by the unobserved factors (which, in turn, are correlated with specific socio-demographics). The discrete choice component of the model is estimated in WTP-space, meaning that the coefficients of the non-monetary attributes represent marginal WTP values. The significant standard deviations again imply that respondents differ substantially in their preferences towards some of the attributes, which justifies the use of the mixed logit specification.

The main effects reported in the second panel of Table 3 need to be interpreted with caution, as the impacts of each attribute on choices (and thus on willingness to pay) is explained not only by the main effect, but also by the interactions with the six LFs. The interaction effects reveal the preference heterogeneity explained by differences in socio-demographic characteristics. Thus, the main effects in the discrete choice component of the hybrid model represent preferences of an average respondent, excluding the indirect impact on preferences of the socio-demographic characteristics for which we control in the structural equations. When this impact of socio-demographic characteristics is excluded, we observe that on average, respondents value to the highest degree better marine water quality for recreation, but they are also willing to pay for the two other improvements, namely for limiting reductions in populations of native species and for depleting new occurrences of invasive alien species. At the same time, on average, respondents reveal preference towards the current state of environmental protection of the Baltic Sea (the status quo) for reasons unconnected with the modelled environmental improvements.

The analysis of the interactions of dummies for each attribute level with LFs included in the discrete choice component of the hybrid model provides an insight into how the preferences of respondents are affected by unobserved factors related to particular socio-demographics. As shown in the second panel of Table 3, many of the interactions of the attribute levels and the LFs appear significant, which indicates that at least a part of the variability in the respondents' WTP for the environmental improvements can be attributed to their socio-demographic differences. The perceptions represented by LF 1 intensify preference towards each of the improvements considered, as implied by the positive coefficients of those interactions. Similarly, the perceptions captured in LF 4 increase the respondents' WTP for the improvements. For the latter group of the respondents, the increase in WTP is much more substantial in the case of every attribute level than for the former group. Further, the respondents characterized by high scores of LF 4 reveal strong aversion towards the status quo. These respondents are definitively the strongest supporters of the proposed improvements in the Baltic Sea environment among the groups of respondents distinguished by the six LFs.

The interactions with LF 2 and LF 5 suggest that the respondents with the perceptions represented by these LFs are willing to pay less for some of the improvements and more for other improvements than an average respondent. The respondents who are characterized by high scores of LF 2 reveal negative WTP for better water quality for recreation, in contrast to the positive WTP of an average respondent. They also have significantly stronger preference towards the status quo. At the same time, these respondents are much more interested in seeing limited reductions of populations of native species than an average respondent. The respondents sharing the perceptions included in LF 5 are also willing to pay statistically significantly less for better water quality for recreation than an average respondent, although their WTP for this improvement is still positive. Conversely, these respondents are inclined to pay more for reductions in new occurrences of invasive alien species. They also reveal weaker preference towards the status quo.

The groups of the respondents with the perceptions captured by the remaining LFs (namely LF 3 and LF 6) are more skeptical about the proposed improvements, as it is shown by the negative coefficients by the interactions with these LFs and by the substantially stronger preference towards the status quo of these respondents in comparison with the preference of an average respondent.

To illustrate how the hybrid model can be applied to examine differences in WTPs related to differences in socio-demographic characteristics, we now consider several illustrative types of Latvian individual and compare their predicted marginal WTPs for the proposed environmental improvements. We look at the following individuals: a young female student living alone in Riga, a head of a family with many children, a middle-age businessman with a higher degree, a single mother working at home, and a male pensioner. The full set of the socio-demographic characteristics for each individual is specified in Table 5.

Table 5. Socio-demographic characteristics of the individuals used for WTP simulation

	Student	Family head	Businessman	Single mother	Pensioner
Age	20	45	35	30	70
Male	No	Yes	Yes	No	Yes
Latvian	Yes	Yes	No	No	Yes
Household size	1	6	2	2	1
Number of children	0	4	0	1	0
Education	General secondary	Vocational secondary	Higher	Complete compulsory	Complete compulsory
Occupation	Student	Full-time	Self-employed	Home	Retired
Region	Riga	Vidzeme	Riga	Pieriga	Kurzeme
Net personal monthly income	50 LVL (20'th percentile)	410 LVL (70'th percentile)	710 LVL (90'th percentile)	Missing	260 LVL (50'th percentile)

For every individual, we simulate marginal WTP for the attribute levels on the basis of the hybrid model. We report the results of the simulation in Table 6 which, for each individual considered, presents marginal WTP values (with 95% confidence intervals) for every attribute level. The student appears to be the one most in favor of the proposed improvements, being at the same time against the existing state of environmental protection of the Baltic Sea (the status quo), while the pensioner seems to be at the opposite edge, having negative marginal WTPs for each attribute level and disclosing strong preference towards the status quo. Both the family head and the businessman are willing to pay for the proposed improvements, but they also reveal strong preference towards the status quo. The single mother is interested only in having better water quality for recreation, while her WTPs for all other improvements do not differ significantly from zero. When marginal WTPs for the attributes are compared across the individuals, we find that the means of WTP for avoiding reductions of native species range from LVL 0.73 to LVL 2.43, and the values do not differ significantly as indicated by the overlapping confidence intervals (we do not distinguish between the levels of the attribute because the means do not differ significantly). Better water quality for recreation is the improvement which everyone, except for the pensioner, wants to see implemented. We observe some differences across the positive WTPs for this improvement between the individuals. For example, the single mother is willing to pay statistically significantly more than the family head for having water quality for recreation improved to a moderate state; the student is willing to pay statistically significantly more than the businessman for having water quality for recreation improved to a good state. The student, the family head, and the businessman are the only who would pay for limiting new occurrences of invasive alien species. Regardless of the attribute level, the mean WTPs range from LVL 1.15 to LVL 3.23, and they do not differ significantly from each other as shown by the confidence intervals.

Table 6. Simulated mean WTPs for attributes with 95% confidence intervals for five individual's types

	Student	Family head	Businessman	Single mother	Pensioner
Status quo	-17.18***	11.10***	5.91***	-0.01	12.37***
	(-19.32; -15.03)	(9.55; 12.65)	(5.03; 6.80)	(-1.79; 1.76)	(10.05; 14.70)
Reduced number of native species: *On small areas*	1.20**	1.49***	0.73**	-0.06	-1.53**
	(0.07; 2.32)	(0.48; 2.50)	(0.15; 1.30)	(-1.14; 1.02)	(-2.81; -0.26)
Reduced number of native species: *No such areas*	2.40**	2.43***	0.86*	-0.62	-4.64***
	(0.57; 4.23)	(0.84; 4.00)	(-0.10; 1.82)	(-2.38; 1.13)	(-6.70; -2.58)
Water quality for recreation: *Moderate*	6.94***	4.27***	5.60***	8.10***	-2.26**
	(5.05; 8.84)	(2.75; 5.80)	(4.72; 6.47)	(6.35; 9.85)	(-4.28; -0.25)
Water quality for recreation: *Good*	11.17***	7.77***	6.66***	9.16***	-4.44***
	(9.42; 12.94)	(6.01; 9.53)	(5.45; 7.86)	(7.05; 11.28)	(-6.52; -2.36)
New harmful alien species establishing: *Rarely*	2.13***	3.23***	2.12***	1.40*	-1.76**
	(0.76; 3.51)	(1.79; 4.68)	(1.19; 3.06)	(-0.05; 2.84)	(-3.47; -0.05)
New harmful alien species establishing: *In exceptional cases*	1.96***	2.34***	1.15***	-0.14	-2.78***
	(0.53; 3.40)	(0.85; 3.84)	(0.30; 2.00)	(-1.56; 1.27)	(-4.54; -1.01)
Cost (scale)	-0.83*	-0.08	-0.52*	-1.37***	0.26
	(-1.79; 0.14)	(-1.03; 0.86)	(-1.09; 0.05)	(-2.30; -0.45)	(-0.93; 1.44)

Notes: ***, ** and * indicate WTP significantly different from 0 at the level of 1%, 5% and 10%, respectively. 95% confidence intervals for the means are given in brackets.

Overall, this analysis provides a deep insight and a far better understanding of the respondents' preference heterogeneity than other methods used to date, and allows us to associate respondents socio-demographic characteristics with specific changes in their mean WTP. Such an insight offers a valuable contribution to any policy analysis which would now be able to identify who would gain and who would lose the most, and whether a policy is likely to be supported by different sections of the population.

6. Conclusions

In this paper, we evaluate the economic benefits to citizens of Latvia resulting from an improving environmental status of coastal and marine waters of the Baltic Sea. By employing the stated preference discrete choice experiment method, we are able to gain insight into which characteristics of the Baltic Sea environment are the most important to the general public, and how much would they be willing to pay for such improvements. We find that while an average respondent to our survey is willing to pay for financing environmental improvements, a substantial share of respondents reveals aversion to any new policy and rather chooses the status quo scenario. Looking at the specific attributes, people are willing to pay the most for improving recreational water quality (about LVL 4-5 per year per person), followed by avoiding reductions in marine biodiversity and limiting new occurrences of invasive alien species (about LVL 0.5 per year). We do not observe statistically significant scope effects for these improvements, so that willingness to pay for environmental improvements does not vary according to the size of these improvements in most cases (within the ranges contained in the experimental design). Overall, this suggests that Latvians, on average, place rather low values on improvements in the environmental quality of the Baltic Sea, especially when compared to similar studies for other Baltic Sea nations as described in Section 2. This finding is in line with earlier results observed by Ahtiainen *et al.* (2014) and Czajkowski *et al.* (2015) using different methods.

We find substantial preference heterogeneity among the Latvian respondents, and we are able to attribute much of this heterogeneity to observable socio-demographic differences between them. We identify six unobservable latent factors correlated with respondents' socio-demographics which turn out to significantly matter for the respondents' WTP for environmental improvements in coastal and marine waters of the Latvian part of the Baltic Sea. By incorporating these latent factors in the estimation procedure, we account for systematic (observed) differences in the respondents' preferences associated with the differences in their socio-demographics, and enables us to show which kinds of people place the highest values on water quality improvements.

Finally, the approach outlined here provides an insight into the distribution of benefits from environmental policy across members of society which is complementary to recent work which maps the spatial distribution of such benefits (eg Czajkowski et al, 2016). Taken together, such approaches allow the analyst to show how benefits from a policy vary across socio-demographic characteristics of a national population and across space. Those who benefit more from an environmental policy change are more likely to support it politically. Understanding the multiple dimensions of how benefits vary across people is important in predicting the political acceptability of environmental policies and how benefits (and costs) are distributed on grounds of fairness.

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