To tell or not to tell: Preference elicitation with and without emphasis on scientific uncertainty

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Abstract

Decisions about the optimal use of coastal and marine resources must be taken under high uncertainty about environmental impacts and may conflict with public perception of the risk associated with current blue growth initiatives. In a discrete choice experiment conducted in valuation workshops in five communities in Arctic Norway, we examine public preferences for various aquaculture expansion paths. Respondents prefer a smaller expansion in terms of the number of aquaculture sites compared to the planned expansion. Emphasizing scientific uncertainty regarding the negative environmental impacts of aquaculture leads to lower resistance against the planned expansion.

Keywords: Discrete choice experiment, valuation workshop, aquaculture, environmental impact, uncertainty, Arctic

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1 Introduction

Blue growth is a long-term strategy to support the sustainability of ocean-based industries (European Commission 2017). Many European economies, including Norway, view oceans and coasts as critical economic drivers. The aquaculture industry is one of the most prominent sectors with a high potential for sustainable job creation and growth. Globally, Norway is the largest producer of farmed Atlantic salmon, and according to Government plans, the industry is expected to increase substantially in the coming decades (Ministry of Trade, Industry, and Fisheries 2015).[1] Scenarios have been presented for a five-fold increase in production, based on the 2010 level, implying about 5 million tons in 2050 (Olafsen, Winther and Skjermo 2012). Such an expansion signals aquaculture production at an unprecedented scale in coastal environments resulting in high uncertainty related to the environmental impacts. In 2015, a coastal plan approved for a region covering five municipalities in Arctic Norway suggested an increase corresponding to 22 new sites, implying a doubling capacity (Tromsø Municipality 2015). After a round of public hearings, this was reduced to 12 new sites. In some parts of Arctic Norway, there is local opposition towards fish farming in open sea pens. One reason is that it could affect the extensive use of the coast for recreational activities (Aanesen et al. 2018). On the other hand, many rural parts of Arctic Norway, including two of the municipalities encompassed by the plan, lack jobs for young people and experience declining populations. The planned aquaculture expansion may secure future employment and income for some of these rural communities. At a national level, aquaculture is considered one of the most crucial industries to replace an inevitable decline in Norway's export income from the oil and gas industry. However, for the aquaculture industry to grow, national authorities require that the sector controls the spread of the salmon parasite sea lice and take measures against the escape of farmed salmon from sea pens that impact threatened wild salmon stocks (Lie et al. 2021). Aquaculture can also affect marine ecosystems and biological diversity by discharging nutrients and organic waste material and altering food webs, potentially harming commercial species like cod, saithe, and shrimp (Svåsand et al. 2017). However, the scientific community has yet to establish a scientific consensus regarding the environmental impacts of aquaculture production. Hence, public planners need to make management and expansion decisions under considerable uncertainty.

To achieve sustainable growth in the aquaculture industry, public planners must consider environmental and economic factors and public opinion (Krøvel et al. 2019). Currently, the public opinion in Norway regarding aquaculture expansion is divided and depends on whether adverse environmental effects can be mitigated or avoided (Krøvel et al. 2019; Bjørkan and Eilertsen 2020). Public preferences for aquaculture expansion are, amongst other factors, influenced by personal values and beliefs and people's knowledge about environmental impacts. Stated preference (SP) methods, i.e., discrete choice experiments (DCEs) and contingent valuation (CV), are applied to elicit people’s monetary valuation of changes in ecosystem services (ES). Valuation of ES translates people’s motivations to mitigate adverse environmental impacts from human behavior into monetary estimates of welfare effects (Bateman and Mawby 2014). SP methods usually involve hypothetical questions about willingness to pay (WTP) to avoid a specified assumed loss of ES due to increased human use of natural resources. There are reasons to believe that inhabitants’ assessment of how preferable aquaculture expansion is depends not only on its environmental impacts, but also on how certain it is that such impacts will arise. According to Munro and Hanley (2001), more information *per se* will not necessarily result in a change in welfare estimates. However, if the additional information relates to environmental outcome uncertainty (OU), WTP estimates may be impacted. In principle, relevant uncertainty and risk dimensions should generally be part of the valuation scenario. Nonetheless, it is not apparent how uncertainty in SP surveys should be communicated, and previous studies provide little guidance on how to express uncertainty about possible attribute levels as a part of the design (Johnston et al. 2017). We implemented a split-sample DCE study where the environmental impacts of aquaculture expansion was communicated to respondents in workshops via a pre-recorded video prior to a paper-based survey. In half of the workshops, the video mentioned the possible environmental impacts of aquaculture expansion without emphasizing uncertainty regarding such impacts (baseline). The other half of the workshops showed a video wherein the uncertainty regarding environmental impacts was more explicitly emphasized (treatment). A chi-square test comparing respondents' beliefs in a set of statements regarding the environmental effects of aquaculture expansion demonstrated some post-information differences across the two sub-samples (see Table 3). Hence, the study design enables us to test the sensitivity of preferences for aquaculture expansion to different information sets regarding the certainty of the scenario outcomes.

In light of traditional utility theory about consumer behavior under uncertainty (see e.g. Varian 2014) we hypothesize that treatment respondents will have lower WTP than baseline respondents for reductions in planned aquaculture expansion. The argument is that the more uncertain the detrimental environmental effects of aquaculture expansion are, the lower is the expected increase in welfare for the public by reducing expansion, *ceteris paribus*. Assuming rational economic agents, WTP to reduce the detrimental effects will equal the expected increase in welfare.

The remainder of the paper is structured as follows: Section 2 presents previous literature on the communication of scientific uncertainty regarding environmental quality changes in SP surveys. Section 3 provides an overview of the survey, data collection, and the econometric model. Sections 4 and 5 present and discuss the results. Finally, Section 6 concludes.

2 Literature background

Among the earliest studies of the effects of information provision on estimated WTPs is a study by Hoevenagel and van der Linden (1993). These authors showed that large differences in the description of a good have significant effects on stated WTP, while small differences do not have such effects. They conclude, "*It seems certain information thresholds have to be overcome to affect WTP values*" (Hoevenagel and van der Linden 1993, page 223). Similarly, Munro and Hanley (2001) conclude, "*There are clear lessons to be learnt from the empirical evidence to date. First, the influence of the level of information on a subject's WTP for an environmental amenity is potentially significant, particularly when non-use values are being elicited.*" (p.261). Although numerous papers (see e.g. Bateman and Mawby 2004; Needham et al.; 2018, Hanley and Czajkowski 2020) have been published on the issue, the question regarding the optimal information provision in SP surveys and the potential effect of various degrees of information provided has not been resolved. Of the more recent publications, Czajkowski, Hanley and LaRiviere (2016) did not demonstrate significantly higher differences in WTP for respondents given more extensive and positively framed information in a split sample DCE. However, their results displayed a larger mean relative scale and lower scale variance for the more informed respondents.

Torres, Faccioli and Font (2017) consider a situation with dual uncertainty, (i) regarding the realization of potential detrimental impacts due to climate change, and (ii) regarding the effectiveness of specified policies to address expected losses. In this decision-making context, people can either "go slow" and point to the level of uncertainty as an argument to postpone action today or perceive uncertainty as a stimulus to act, following a precautionary principle. People applying the former strategy are expected to have a higher WTP for a policy to mitigate potential climate change impacts. Based on a CE to elicit people's preferences for adaptation policies aimed at reducing expected climate change impacts on bird species, they show that people are willing to pay for mitigating policy efforts even if there is a chance that expected detrimental impacts do not occur. Furthermore, the WTP under inherent (uncontrollable) uncertainty is either higher or equal to a corresponding scenario in which detrimental impacts are to occur with certainty (Torres, Faccioli and Font 2017).

Another DCE eliciting the effects of varying information about the OU is Wieglus et al. (2009). In a three-way split sample, they elicited recreational anglers' WTP to increase the number and size of fish caught. Respondents in the first sub-sample did not receive any information about scenario uncertainty, while respondents in sub-samples 2 and 3 received scenario outcome probabilities of 60% and 90%, respectively. The estimation showed that the mean WTP per angler for one unit increase in both attributes (number and size of fish) was USD 460, 232, and 234 in sub-samples 1, 2, and 3, respectively. Under an expected utility-maximizing hypothesis, the sub-sample 1 WTP implies an outcome probability greater than 90%. These results indicate that WTP decreases with uncertainty, although not linearly.

Regarding the communication of uncertainty in DCEs, most studies incorporate uncertainty by introducing a separate attribute indicating scenario likelihood or the probability of a specific attribute configuration. Most studies demonstrate that while the attribute that indicates scenario outcome or conveys uncertainty regarding which attribute levels will be realized is negatively assessed, welfare estimates for the remaining attributes are primarily unaffected (see, e.g., Lundhede et al. 2015; Glenk and Colombo 2011; Makriyannis, Johnston and Whelchel 2018).

3 Methods and data

Empirical case and survey formulation

The aquaculture expansion plan of the Norwegian Government (Ministry of Trade, Industry, and Fisheries 2015) requires the municipalities to dedicate coastal areas as sites for new aquaculture production. As a response, a region in Arctic Norway encompassing five municipalities with almost 100,000 inhabitants, including the largest city in Arctic Norway, Tromsø, adopted a joint coastal plan which implied a 50% increase in sites for salmon farming (Tromsø municipality 2015). The map in Figure 1 gives an overview of the region and existing aquaculture sites in 2015.

[[Insert Figure 1 here]]

To elicit how inhabitants in the region perceive the expansion in the number of aquaculture sites and whether uncertainty regarding the environmental impact of aquaculture affects their preferences, we set up an in-person survey, including a CE. The survey questionnaire was constructed based on three focus groups held in Tromsø in the spring of 2018. These included representatives from the seafood industry (aquaculture and coastal fisheries), NGOs (kayaking club and ENGOs), municipal administrations, scientists in aquaculture and fisheries, and the general public. The focus group participants were explicitly probed about the possible environmental impact of a potential aquaculture expansion. Based on input from focus group participants and in close cooperation with scientists in marine and freshwater biology and aquaculture technology, four non-cost attributes were chosen for the DCE design: (1) impact on the coastal cod, (2) impact on wild salmon, (3) impact on the seabed, and (4) above-sea impacts associated with visual intrusion and noise. Table 1 gives details on the attributes and their experimental levels.

[[Insert table 1 here]]

The selected payment vehicle was increased municipal taxes (attribute COST in Table 1). Importantly, this payment vehicle is consequential because Norwegian municipalities receive bi-annual transfers from the Government according to the number of aquaculture sites in production or ready for production within their administrative boundaries (Zawojska, Bartczak, Czajkowski 2019).

The non-cost attribute levels in Table 1 should be considered indicative as the scientific evidence is still inconclusive and somewhat disputed (e.g., Uglem et al. 2017; Taranger et al. 2015; Abolofia, Asche and Wilen 2017; Svåsand et al. 2017). For example, fishermen argue that aquaculture negatively affects coastal cod stocks (Brattland and Eythorsson 2016). However, there is no scientific evidence of adverse impact on coastal cod from aquaculture to date.[2] Regarding adverse effects on wild salmon stocks, there is some scientific agreement that larger volumes of farmed salmon in a fjord increase sea lice prevalence (Vitenskapelig råd for lakseforvaltning 2021). Juvenile salmon, Arctic char, and sea trout are vulnerable to a sea-lice infestation when migrating from the river to the sea (lethal and sub-lethal effects). If fewer juvenile salmonids reach the sea to grow up, fewer salmonids will return to the river to spawn. However, it remains to be statistically verified that there is a negative relationship between migrating wild juvenile salmon and farmed salmon biomass in Norwegian fjords (Nikitina 2019).

In order to avoid seabed sedimentation, the authorities require producers to systematically survey and sample the seabed to determine its environmental status. In addition, after each production cycle, a site must rest for a specific period, depending on the biological and oceanographic conditions of the site. The heavier the seabed sedimentation, the longer the site must rest before new production can occur. Aquaculture companies will first use sites with *good biological and oceanographic conditions*, meaning that the site has to rest a short time before production can start. New and less optimal sites will be used with expanding production, implying that the rest period will increase.

The physical area occupied by salmon farming sites corresponds to about 85 km^2, excluding the sub-sea moorings (Johnsen and Hersoug 2013), which corresponds to only about 0.5% of the available coastal area within the sea baseline. However, visually the salmon farms cover a significantly larger area. Although the Norwegian coastline is vast, recreational users in the focus groups complained about pressure on coastal areas previously undisturbed by visual and noise intrusion. Therefore, we included seascape as a final attribute to cover this impact.

The survey included nine choice cards for each respondent; see Appendix A Figure A1 for an example. According to the local expansion plan, alternative 1 represents business as usual (BAU), i.e., a situation realizing the planned increase, corresponding to 12 new sites used for aquaculture production. Alternatives 2 and 3 are generic restricted expansion options with randomized attribute levels. We purposely did not quantify the alternative expansions but instead stated in the information framing that the number of new aquaculture sites would be lower than in Alternative 1 (BAU). The reason for this approach was to avoid triggering respondents to think about an acceptable number of new aquaculture sites. Instead, we wanted the respondents to concentrate on the potential adverse effects on coastal ES, represented by non-cost attributes, and to what degree they found these acceptable.

The pictures used to represent the non-cost attributes in the choice card were chosen to give a realistic picture of the current situation in the area. For example, we chose to represent increased mortality for wild Atlantic salmon smolt with an image of a healthy young salmon without sea lice. Currently, sea lice infestation of young wild Atlantic salmon is moderate in the case area and not an immediate threat to wild salmon spawning in its rivers. The coastal cod is a species utilized both commercially and by recreational fishers. Using an image with a few small harvested (dead) fish was intended to suggest that an aquaculture expansion would not pose a threat to the cod stocks *per se*, but instead, that harvest may decrease. While it is true that there always will be some sediments from feed waste and feces below aquaculture pens, the volume of sediment varies significantly due to the strength of the currents. Relatively strong currents have made the sedimentation under aquaculture pens in the case area moderate, as illustrated by the chosen image. Lastly, the picture used to illustrate the above-sea impacts is from a representative salmon farm in the case area.

The choice card design (combination of attribute levels) was generated by Ngene (Choice Metrics 2021) for a multinomial model linear in the attributes.

The paper-based survey questionnaire included the choice tasks and 19 additional questions. The first six questions were about residence proximity to aquaculture facilities, knowledge about the coastal expansion plan, and beliefs about the effects of aquaculture production on the natural environment. Following the choice tasks, the respondents were asked about attribute importance and scenario consequentiality before the questionnaire concluded with nine questions about personal background.

A video was used to inform survey respondents about the potential environmental consequences of the planned aquaculture expansion, including uncertainty regarding their prevalence. The video lasted about 8 minutes and included pictures relevant to each non-cost attribute. Among them were also the pictures used in the choice card. The pictures were supported by audio information in a local dialect. The baseline video version mentioned OU but did not elaborate on or stress the scientific uncertainty regarding environmental impacts. In contrast, the treatment video added a few sentences for each environmental attribute emphasizing that its impact was uncertain and that the scientific community had not concluded on the issue. The two videos were otherwise identical.[3]

A pilot survey was conducted for a split sample of 40 inhabitants in Tromsø municipality in October 2018. After this, the design of the choice cards was updated in Ngene using results from the pilot as priors. The final survey was implemented in 20 valuation workshops across the five municipalities. Two consecutive workshops took place at the same location on weekday evenings, excluding Fridays; one presenting the baseline scenario and the other the uncertain (treatment) scenario, resulting in 10 "baseline" workshops and 10 "treatment" workshops. The workshops took place in a hotel, town hall, or another public venue during October and November 2018. We alternated the order of the two versions to ensure that each version was run first and last equally often. A professional polling company recruited participants through random phone dialups. The population from which workshop participants were recruited included inhabitants above 18 years, representing 72 percent of the region's total population. The polling company recruited 458 persons in the five municipalities, of which 302 persons turned up for the workshops, resulting in a *conditional* response rate of 66%.[4] The samples were stratified on gender and age to represent the region. Participants were offered a gift card amounting to approximately 30 euros.

The valuation workshop protocol was as follows: (1) participants welcome, (2) brief study introduction, (3) information video, (4) choice card demonstration, and (5) survey administration. The questionnaire was on paper and filled out without speaking to others. After completion, the participants were thanked individually and asked to leave the room.

Econometric model

According to Lancasterian consumer theory, the utility a person gets from a good can be attributed to the characteristics of the good (Lancaster 1966). Furthermore, random utility theory suggests that a person's total utility from a good can be divided into a deterministic part,

V, which the researcher can empirically identify, and a random part, e, (McFadden 1974). The utility to person *n* of choosing alternative *j* in choice situation *t* is thus given by:

$$U_{njt} = V_{njt} + e_{njt} \quad [1]$$

We use the deterministic part to estimate preference weights and WTPs and to investigate potential differences in welfare estimates across the two sub-samples.

To test for statistically significant differences between baseline and treatment coefficients, we specify [1] as follows:

$$U_{njt}^{*} = \boldsymbol{X_{njt}} \cdot \boldsymbol{b_n}\left(1 + \frac{\boldsymbol{gn}}{bn \cdot \sigma} \cdot Q\right) + \varepsilon_{njt} \quad [2]$$

where $\boldsymbol{X_{njt}}$ is a vector of attributes, including the ASC, specifying the good, b_n is a vector of individual-specific preference weight coefficients associated with the attributes, $\boldsymbol{g_n}$ is a vector of shift parameters, i.e., estimates for the difference between baseline and treatment coefficients, which are estimated along with the attribute vector $\dot{\boldsymbol{b}}_{\boldsymbol{n}}$. Q is a dummy taking the value 1 for choices made by treatment respondents and 0 for baseline respondents. The stated preferences are said to differ across the two sub-samples if the estimated shift coefficients ($\boldsymbol{g_n}$) are significantly different from 0 (Hill, Griffiths and Lim 2018). This procedure corresponds to a t-test for parameter equality. Similarly, the consistency of choices differs across the sub-samples if the estimated σ_T is significantly different from 1. The parameter σ is the scale parameter for treatment respondents relative to baseline respondents. The scale parameter is inversely correlated with the variance of the error term and can be interpreted as how consistent respondents are when making their choices (Swait and Louviere 1993; Train 2009). We are interested in whether the scale is different for treatment respondents relative to baseline respondents. As it is not possible to estimate separate scale parameters for the two sub-samples simultaneously, we normalize the scale for the baseline choices to one.[5] $\varepsilon_{njt} = \frac{e_{njt}}{\sigma}$, is an independent and identically (iid) extreme value (usually Gumbel) distributed error term with constant variance given by $\frac{\pi^2}{6}$.

As we allow the preference weight coefficients to be heterogeneous across individuals, the vector $\mathbf{b_n}$, can be written as:

$$\mathbf{b_n} = \mathbf{b} + \boldsymbol{\mu}_\mathbf{n} \cdot \mathbf{C} \quad [3]$$

where **b** is the mean preference weights on the attributes across all respondents, $\boldsymbol{\mu}_\mathbf{n}$ is person *n*'s specific deviations from the mean, and **C** represents draws from the underlying distribution. Our analysis uses normal distribution for non-cost attribute coefficients and lognormal distribution for the cost attribute coefficient.

Given the interest in establishing estimates of WTP for the non-monetary attributes, it is convenient to use the following specification of [1], which is equivalent to estimating the parameters in WTP space (Train and Weeks 2005):

$$U_{njt}^{**} = \frac{bc}{\sigma}(p_{njt} + \boldsymbol{\beta_n W}_{njt}) + \varepsilon_{njt}^{WTP} \quad [4]$$

where $\boldsymbol{W_{njt}}$ is a vector of non-cost attributes and p_{njt} represents the cost attribute. Under this specification, the vector of parameters $\boldsymbol{\beta_n} = \frac{\boldsymbol{bn}}{bc}$ is scale-free and can be directly interpreted as a vector of implicit prices for the non-cost attributes. Note that it includes estimated prices for each of the sub-samples. As the scale is irrelevant for interpreting WTP results, we assume a common scale for the two sub-samples, denoted σ.

The unconditional logit probability that individual *n* is choosing alternative *j* at choice occasion *t* is given by:

$$P_{njt} = \int \left(\frac{exp^{(Vnjt)}}{\sum_k exp^{(\boldsymbol{Vnkt})}}\right) f(b)db \quad [5]$$

Assuming that each respondent's choice is independent of that of other respondents, the probability for observing the actual sequence of choices for all respondents is given by:

$$L = \prod_{n=1}^{N} \prod_{t=1}^{T} \left(P_{njt}\right)^{ynjt} \qquad [6]$$

Here, y_{njt} is a dummy taking the value 1 if alternative j is chosen by respondent n at choice occasion t, and 0 otherwise. Taking the log of [6], we obtain the log-likelihood function, which is maximized conditional on the vector of attributes (**X**) to obtain an estimate of the vector of coefficients (β_n) (Train 2009).

Data

The usable sample for our analysis includes 293 survey participants described in Table 2. We removed nine respondents because they did not complete any choice tasks.

[[Insert Table 2 here]]

There are some differences in socio-demographic characteristics between the baseline and treatment sub-samples. Table 2 shows that the treatment sub-sample has a lower female share, which must be considered when interpreting results from the statistical models. We will come back to this in the discussion. For other socio-demographics, the two sub-samples are comparable.

The two sub-samples also differ somewhat from the aggregate population of the five municipalities (region). Respondents in the two sub-samples have a lower female share and are somewhat older and better educated than the regional population. Hence, we need to be careful when drawing conclusions regarding the preferences of the regional population.

As part of the survey, we asked the following question: *"How positive or negative do you think it is that the current coastal plan for the Tromso region allows aquaculture activities at more sites?*". Using a Likert scale, 1=very negative, 6=very positive, the mean attitude score was 3.04 in the baseline sub-sample versus 3.00 in the treatment sub-sample, a statistically indistinguishable difference (t-test statistic =0.70, p-value = 0.49).

We also tested whether the two sub-samples differed regarding beliefs about the possible consequences of aquaculture expansion. We did so through nine statements that respondents categorized on a certainty scale (1 = *very uncertain*; 5 = *very certain*).[6] Table 3 compares sub-sample mean scores and provides tests of statistical differences across the two sub-samples.

[[Insert Table 3 here]]

The chi-square test in the last column assumes equality of frequency of reported certainty levels across sub-samples, and p-values greater than 0.05 indicate that we can reject the equality assumption. There are some differences across sub-samples, specifically for the seventh statement regarding nutritional spillovers on the seabed and the last statement regarding noise spillover. In both cases, the treatment respondents feel more certain that these effects are prevalent.

4 Results

Status quo choice-propensities

The 293 respondents made 2 599 choices, distributed as 1 347 for the baseline sub-sample and 1 252 for the treatment sub-sample. Table 4 shows the distribution of stated preferences across choice card alternatives.

[[Insert Table 4 here]]

Table 4 shows that the BAU expansion plan is selected in 16.5% of the total choice occasions, while an alternative involving less than twelve new sites is selected 83.5% of the time. Treatment respondents choose the BAU alternative more frequently than baseline respondents, 19% versus 14% of all choice occasions. The difference is significant at a 1% level (t-value=4.84, 2594 d.f.).

Model results

To investigate whether baseline and treatment respondents state different preferences for the BAU and the attributes in the DCE, we jointly estimate attribute coefficients for baseline respondents and shift relative to baseline for treatment respondents. The model is estimated in preference space, and we estimate the relative scale for treatment choices along with the BAU and attribute coefficients and shift parameters. Allowing for preference heterogeneity, we run a mixed logit model (MXL), assuming that the alternative specific constant (ASC) and non-cost attribute coefficients are normally distributed and that the cost attribute coefficient is negative lognormal. Estimation is executed in R-Studio using the Apollo package (Hess and Palma 2019). The simulation maximum-likelihood procedure uses 1000 Sobol-Owen-Faure-Tezuka draws from the specified distributions. Results are reported in Table 5. Note that in the survey, higher non-cost attribute levels mean higher adverse effects on the natural environment. As (almost) all non-cost attribute estimates are negative, instead of reporting negative preference weights and WTPs for higher adverse environmental effects, we reformulate the model to express positive preferences for lower adverse effects. This reformulation implies that the ASC expresses preferences for avoiding the implementation of the BAU.

[[Insert Table 5 here]]

Estimated coefficients for all baseline attributes except wild salmon are significant. As expected, mean baseline non-cost attribute coefficients are positive, indicating preferences for lower detrimental environmental effects from aquaculture expansion. The estimated ASC is associated with the BAU scenario, and its positive sign indicates that respondents prefer avoiding the BAU and thus prefer lower aquaculture expansion.

The shift parameters are significant for the ASC and the wild salmon attribute. Hence, stated preferences differ across the baseline and treatment sub-samples for these two dimensions. The negative ASC shift parameter implies that treatment respondents are more favorable to the BAU scenario, i.e., the planned expansion, than baseline respondents, confirming the significant difference in choices reported in Table 4. Furthermore, the positive sign of the wild salmon shift parameter indicates that treatment respondents have stronger preferences for reductions in detrimental environmental consequences associated with this attribute compared to baseline respondents. Recall, however, that the preference weight of wild salmon is not significant for baseline respondents.

The estimated relative scale coefficient of 1.04 indicates a larger scale for the treatment sub-sample, implying less choice stochasticity, but it is statistically indistinguishable from 1. Hence, we cannot reject the hypothesis of scale equality across sub-samples.

Willingness-to-pay estimates

Next, we turn to a welfare analysis, discussing the respondents' estimated willingness to pay (WTP) for lower adverse environmental effects and to avoid the planned expansion given in the BAU scenario. First, such WTP estimates inform the magnitude of the preferences for the non-cost attributes. Second, we can check the robustness of the shift parameters presented above by jointly specifying and estimating separate coefficients (WTPs) for baseline and treatment respondents and comparing them. Importantly, we can directly compare WTP estimates across baseline and treatment respondents as WTP estimates are scale-free (Rose and Masiero 2010). Table 6 presents mean WTP coefficients for non-cost attributes and 95% confidence intervals.

[[Insert Table 6 here]]

The results in table 6 demonstrate a positive and significant willingness to pay for less detrimental environmental effects from aquaculture expansion for all except the seascape attribute. Still, the dominating explanatory variable for both baseline and treatment respondents is the alternative specific constant (ASC). The ASC expresses the effects of unincluded factors on the BAU alternative relative to the other alternatives, and the positive and significant amount indicates that respondents (for reasons not included in the model) are willing to pay a positive amount to avoid implementing the BAU scenario, i.e., the current expansion plan. Hence, the choice between the current plan or a more modest expansion path has substantial welfare implications. This amount is significantly smaller for treatment respondents than baseline respondents, in line with the results reported in table 5.

The effects of the OU information treatment on the attribute WTPs are ambiguous. While the estimated WTP for the cod and seabed attributes is higher among baseline respondents, treatment respondents have higher WTP for wild salmon and seascape. However, the reported confidence intervals show that the WTPs do not differ significantly. When measured in monetary units, the WTP for wild salmon is significant among baseline and treatment respondents, but the amounts are no longer significantly different. Hence, the positive and significant shift parameter for wild salmon in table 5 most likely indicated a significant and positive preference weight for wild salmon among treatment respondents.

For additional comparison, we ran a simpler model, allowing no preference heterogeneity across respondents, in WTP space (the MNL model). The results are reported in Appendix A Table A1, and they largely confirm the results in table 6, showing that WTP for cod and seabed is higher among baseline respondents, whereas WTP for wild salmon and seascape is higher among treatment respondents, but for none of the attributes the difference is significant. On the other hand, the MNL model has negative ASC WTPs. This result is contrary to that of the MXL model. The ASC, capturing effects on the utility of unincluded factors, now also includes suppressed heterogeneity. The very high standard deviations for some of the attributes, as demonstrated in the MXL model and reported in table 6, indicate that there will be respondents both with positive and negative WTP for the included attributes. As all estimated attribute WTPs are positive in the MNL model, there will be negative values that are now captured by the ASC, resulting in a negative ASC estimate. The result that the ASC WTP for baseline respondents is less negative than for treatment respondents confirms the results from previous models.

5. Discussion

We used a split-sample choice experiment to elicit the preferences of inhabitants in Arctic Norway regarding planned aquaculture expansion and to investigate the effect on stated preferences of informing people differently about how certain or uncertain detrimental effects of such expansion were on the natural environment. In general, inhabitants of the region were opposed to the planned expansion and were willing to pay positive amounts to reduce detrimental effects on a set of environmental attributes. The results are, however, ambiguous as for some attributes (cod and seabed), baseline respondents have higher WTPs, whereas for other (wild salmon and seascape) treatment respondents have higher WTPs, although none of the differences were significant. Hence, our results do not support the hypothesis that treatment respondents will have lower WTP for reducing the detrimental environmental effects of aquaculture expansion.

The results also demonstrate considerable heterogeneity within each sub-sample. For example, about 40% of the treatment respondents were not willing to pay to reduce the detrimental effects of aquaculture expansion on cod stocks, and 41% of baseline respondents were not willing to pay to reduce detrimental effects on the wild salmon. Results for the seabed and seascape were far more homogenous, and for the seabed, less than 3% of the respondents, independent of sub-sample, were not willing to pay for reduced adverse effects. Seascape was the attribute respondents cared the least about.

The fact that WTPs did not differ significantly across the sub-samples indicates that the difference in information sets was modest. According to Hoevenagel and van den Linden (1993), only substantial differences in a good's description are likely to affect its WTP estimates. Furthermore, the insignificance finding is consistent with studies that use an additional attribute to incorporate uncertainty about the scenario outcome in the DCE (e.g., Glenk and Colombo 2011; Lundhede et al. 2015). They all demonstrate that while preferences for the attribute expressing uncertainty are unambiguously negative, as expected, preferences for the remaining attributes are statistically the same as when the uncertainty attribute is omitted. These results indicate that uncertainty has a limited effect on preferences and implicit prices for most attributes in DCEs, but is concentrated on the one attribute expressing such uncertainty explicitly.

Focusing on the types of information given in DCEs, Czajkowski, Hanley and LaRiviere (2016) failed to find significant differences in WTPs for respondents given more comprehensive and positively framed information. On the other hand, the more informed respondents had higher mean relative scale and lower scale variance, implying greater choice consistency. Our results for differences in WTP estimates align with those of Czajkowski, Hanley and LaRiviere (2016). However, contrary to our a priori expectation, we did not establish scale differences across our two sub-samples.

One could speculate whether some of the results can be explained by the difference in gender distribution across the two sub-samples, with a somewhat higher proportion of men among treatment respondents. As shown in Appendix A Table A2, men are less averse to the BAU scenario and have a higher WTP for the seascape attribute. The results in Appendix A Table A2 also show no significant difference in scale across women and men, indicating they make equally consistent choices. To scrutinize the issue, we constructed two sub-samples comparable concerning age and gender using the propensity score matching (PSM) technique (Caliendo and Kopeinig 2005). Re-running the model on the PSM sample yielded results comparable to those in Table 5, reaffirming a significant difference in the BAU and for the wild salmon between baseline and treatment respondents. These results are reported in Appendix A Table A3.

It is interesting to note the coherence between differences across model results and the ex-ante statements regarding the certainty of the environmental effects. For example, Table 3 indicates that treatment respondents are surer that aquaculture activities can be heard many kilometers away. At the same time, they also have a higher preference for reducing this negative environmental effect than baseline respondents. Furthermore, Table 3 demonstrates that treatment respondents are surer that some emission from the aquaculture pens to the seabed is positive, and they also have a lower WTP for avoiding such effects on the seabed. However, these differences are not statistically significant.

Torres, Faccioli and Font (2017) demonstrate that people are willing to pay to avoid losses in ecosystem services due to climate change, also when such losses are uncertain. In fact, they are willing to pay more for preventive policy efforts when losses are uncertain compared to if the losses are certain. They argue that this result supports the precautionary principle, establishing an elevated need for action to address uncertain environmental effects of climate change. Our results are partly in contrast to those of Torres, Faccioli and Font (2017), as we show that those told that detrimental environmental effects of aquaculture expansion are very uncertain (treatment respondents) were more likely to choose the BAU, i.e., the scenario with the most extensive expansion and the lowest cost (0 payment). Furthermore, Torres, Faccioli and Font (2017) distinguish between two strategies, one described as "precautionary", which includes people who will pay more the more uncertain it is if climate change effects occur. The alternative is a "go slow" strategy, using the uncertainty as an argument to postpone or even avoid measures to mitigate negative impacts. In light of these interpretations, our results indicate that inhabitants in the Tromsø region have adopted a "go slow" rather than a precautionary strategy. One reason for the difference in results between our study and Torres, Faccioli and Font (2017) could be that people at the outset think that long-term climate change impacts are inherently more uncertain and can cause much larger impacts than aquaculture expansion, and therefore support the use of different strategies for handling these environmental problems. Still, the "go slow" strategy implies that inhabitants in the region prefer less expansion in aquaculture activities than the municipality is planning. There is agreement that potential detrimental effects on the seabed from aquaculture activities must be kept low and that impact on the seascape is of little importance. On average, the inhabitants also want to avoid the detrimental effects of aquaculture activities on wild fish stocks like Atlantic salmon and coastal cod, but there is less agreement on this, and a large share of the inhabitants are not willing to pay to reduce these externalities.

6 Concluding remarks

Marine spatial planning and decisions about growth in ocean industries are often made under scientific uncertainty about the environmental impacts (Berke and Lyles 2013; Savini 2017).

In addition to eliciting inhabitants' preferences for aquaculture expansion, we have presented a study on the effect of different degrees of information about scientific uncertainty of the scenario outcomes on stated preferences. Our study demonstrates that inhabitants are generally willing to pay for a smaller expansion in aquaculture activities, causing (uncertain) detrimental environmental impacts compared to what is planned. Hence, local and regional decision-makers may not have consent from Norwegian households for the planned growth in sea pen-based aquaculture. Our results also show that respondents receiving information emphasizing uncertainty about the negative environmental impacts of aquaculture expansion are less skeptical of the current expansion plans.

It should be noted that the underlying choice experiment was framed in terms of expanding sea-based aquaculture in open pens, a production technology that represents 99% of current Norwegian salmon farming. In contrast, moving the production onshore, which various stakeholders suggest, is one possibility for achieving blue growth. However, this technology is costly and presents its own environmental challenges (Lie et al. 2021).

The analysis presented in this paper has also demonstrated that emphasizing scientific uncertainty regarding the environmental impacts of aquaculture expansion when communicating potential policy scenarios to the public does not lead to less consistency in stated preferences. Thus, future DCEs should explore how different ways of communicating scientific uncertainty could improve the validity and reliability of welfare estimates of environmental impacts, both from aquaculture and other activities in vulnerable areas like the Arctic and other parts of the world. To ensure the respondents' understanding of the survey instrument and that they did indeed watch the video presenting the differences in the certainty of environmental effects of aquaculture expansion, we implemented the study as a series of valuation workshops. This data-collection approach is time-consuming and expensive compared to online surveys, limiting the number of respondents within a given budget, which is unfortunate in cases with strong and diverse public opinions, such as aquaculture expansion in Norway. Hence, future research should allow larger samples to produce more precise WTP estimates across sub-samples.

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Table 1 Attributes and attribute levels of the discrete choice experiment (DCE)

Attribute	BAU* level	Alternative levels
Reduction in the recruitment of coastal cod (COD)	8%	4%, 2%
Increase in sealice induced mortality for young migrating wild salmon (WILD SALMON)	10%	5%, 2%
Time for recovery from waste discharge to the seabed (SEABED)	Two years	One year, six months
Share of regional coastal area with visual or noise intrusion (SEASCAPE)	30%	20%, 10%
Increase in municipal tax per household per year in Norwegian kroner (NOK)[7] (COST)	0	500, 800, 1000, 2000, 3000, 4000

*Business As Usual. It defines the current plans for increase in aquaculture sites corresponding to 12 new sites.

Table 2 Sample characteristics and socio-demographics of the regional population

	Sample Respondents		**Regional population**
	Baseline sub-sample (n = 150)	Treatment sub-sample (n = 143)	
Female share (%)	46	37	49
Age: share below 50 years (%)	52	46	66
Education (%)			
- primary school	10	7	25
- secondary school	33	33	36
- lower university degree	19	18	24
- higher university degree	38	42	13
- unreported			2
Share in the labor force	62	60	71
Mean personal gross annual income in Norwegian kroner (NOK)[i]	497.5k	468.8k	516.0k (County average)[8]

[i] The PPP-corrected exchange rate for Norwegian kroner (NOK) is 1 NOK = 0.07 Euro.

Table 3 Mean value of response for each of nine statements on possible consequences of aquaculture expansion measured on a Likert scale from 1-5, for baseline/treatment sub-sample respondents, respectively, the p-value for chi-square test for equal distribution of answers across the sub-samples

Statement	**Mean certainty score baseline/treatment**	**Chi-square test statistic**	**Chi-square test; p-value**
A high density of aquaculture facilities implies increased sea lice infestation for wild salmon	4.38/4.23	112.96	0.000
Aquaculture facilities along the coast imply sustainable communities	3.41/3.44	33.44	0.000
The seabed under aquaculture pens gets covered by mud	4.13/3.91	81.627	0.000
If escapees breed with wild salmon, the genetics of the wild salmon will change	3.96/3.69	38.381	0.000
Feed from aquaculture facilities is nutrition for wild fish and thus strengthens wild stocks	3.40/3.40	15.006	0.010
The use of medicines against sea lice is harmful to shrimp and other crustaceans	4.09/4.10	44.502	0.000
Some release from the pens may have a positive impact on the seabed	3.54/3.60	6.182	0.289
Aquaculture facilities lead to a reduction in cod stocks	4.03/3.71	23.358	0.0003
Aquaculture facilities can be heard at many km distance	3.44/3.66	10.665	0.058

Table 4 *Distribution of stated preferences across choice card alternatives (absolute number in parenthesis), total choice occasions (total number of respondents in parenthesis)*

	Alternative 1 (BAU): Aquaculture expanded to 12 new sites	**Alternatives 2 & 3: Aquaculture expanded to less than 12 new sites**	**Total choice occasions (respondents)**
Total sample	16.5% (429)	83.5% (2170)	2599 (293)
Baseline sub-sample	14% (192)	86% (1155)	1347 (150)
Treatment sub-sample	19% (237)	81% (1015)	1252 (143)

Table 5 Estimated BAU (ASC) and attribute coefficients (mean and standard deviation) for baseline respondents, and shift (mean) relative to baseline for treatment respondents, full sample model in preference space

Attribute	Mean	St. Error of mean	St. Deviation	St. Error of St. Deviation
ASC_baseline	17.2***	2.82	12.34***	2.05
COST_baseline[i]	-0.5**	0.24	2.94***	0.21
COD_baseline	0.31***	0.04	0.23***	0.04
WILDSALMON_baseline	0.002	0.009	0.16***	0.04
SEABED_baseline	0.37***	0.13	0.25	0.17
SEASCAPE_baseline	0.03**	0.01	0.04***	0.02
ASC_shift_treatment	-1.25	0.82		
COST_shift_treatment	-0.08	0.09		
COD_shift_treatment	-0.04	0.03		
WILDSALMON_shift_treatment	0.33***	0.07		
SEABED_shift_treatment	0.05	0.12		
SEASCAPE_shift_treatment	0.015	0.014		
Rel.scale treatment[ii]	1.004	0.176		
Model diagnostics				
LL-value	-1453.66			
Adjusted R2	0.45			
BIC	3056.7			
AIC	2945.3			
N/k/parameters	2599/293/19			

* p < 0.1; ** p < 0.05; *** p < 0.01

[i] This is the mean and std.deviation of the natural log of the negative cost parameter.

[ii] Not significantly different from 1

Table 6 Mean marginal household Willingness-To-Pay (WTP) coefficients, standard errors (in brackets) and 95% confidence intervals for WTP for baseline and treatment respondents for the MXL model. Values for the non-cost attributes in Norwegian kroner (NOK).

	Baseline		**Treatment**	
	Mean WTP	95% CI	Mean WTP	95% CI
ASC	9,780***	(-12,071, -7,489)	4,364***	(-5960, -2769)
COD	381***	(215, 547)	174***	(34, 315)
WILD SALMON	204***	(26, 382)	251***	(136, 365)
SEABED	704***	(252, 1155)	665***	(291, 1038)
SEASCAPE	-19	(-47, 8)	16	(-8, 39)
	Std.dev.		Std.dev.	
ASC	17,064***	(11,634, 22493)	7,511***	(5757, 9265)
COD	598***	(420, 776)	679***	(455, 904)
WILD SALMON	749***	(564, 934)	611***	(458, 764)
SEABED	165	(-374, 705)	342***	(122, 580)
SEASCAPE	69***	(21, 118)	129**	(76, 183)
LL-value	-1625.27			
Adj.R2	0.422			
BIC	3439.25			
AIC	3298.54			
Obs./N/k	2599/293/24			

[1] The previous Government mentioned a five-fold expansion from the level in 2010 and up to 2050, and the new Government, taking seat autumn 2021 has not changed this goal.
[2] This issue is currently being investigated in a large publicly financed Norwegian research project: “Impact of salmon farming on Atlantic cod stocks – SalCod”, 2019-2023, RCN project number 294631.
[3] The scripts, translated from Norwegian, and the pictures used in the videos are provided in Appendix B.
[4] Unfortunately, due to many unanswered calls, the company did not maintain an accurate record of the total number of persons actually contacted. Hence, an *unconditional* response rate cannot be computed for our study.
[5] Note that this implies that we assume the scale to be equal for all choices made by respondents within each of the sub-samples but not across the two sub-samples.

[6] There was also a category 6=I don’t know, but entries in this category is not included in the results of table 3.
[7] The PPP-corrected exchange rate for Norwegian kroner (NOK) is 1 NOK = 0.07 euro.
[8] Mean income is not available for the sample region.