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Estimating the Irish public's willingness to pay for more sustainable salmon produced by integrated multi-trophic aquaculture

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Abstract

Integrated Multi-Trophic Aquaculture (IMTA) has been put forward as a potential sustainable alternative to single fin fish species aquaculture. In IMTA, several species are combined in the production process. Integrating species has a conceivable dual advantage; the environmental impact can be lowered through nutrient cycling and from an economic perspective there is potential for increased efficiency, product diversification and a higher willingness to pay for more environmentally friendly produced salmon. This paper presents the results from a choice experiment which examines whether the Irish public is willing to pay a premium for "sustainably produced" farmed salmon from an IMTA process. Uniquely, an ecolabel was used in the design, based on familiar energy rating labels, to communicate the environmental pressure of fish farming to respondents. The experiment demonstrates that the Irish public has a willingness to pay a price premium for sustainability in salmon farming and for locally produced salmon.

Keywords:

Sustainable aquaculture; Choice experiments; Ecolabels; IMTA; Willingness to pay

1. Introduction

Despite the contribution that an expansion in aquaculture can make through significant employment and economic opportunities in rural areas and in feeding a growing global population, concerns exist over the environmental implications of such an expansion. These concerns are especially evident for the production of carnivorous fin fish species such as Atlantic salmon (Salmo salar) which utilizes feeds derived from wild caught fish [1]. Other environmental impacts consist of the intensive use of drugs and chemicals [2], the spreading of diseases and parasites [3], emissions of organic waste [4], escapees [5] and the intrusion of nets and sound into the natural environment [6]. However, substantial geographical differences should be recognised, as environmental impacts fluctuate according to appropriate production technologies and governance. Over the last decades, improved feed and feeding technologies have led to a steep decline in the FiFo ratio (Fish In – Fish Out ratio); i.e. the rate between the mass of harvested fish used for aquafeed and the mass of harvested fish from the fish farm) [7]; improved site location and sea cage technology have significantly reduced waste sediments; better management and improved equipment has seen a drop in the number of escapees and the development of oil-based vaccines has led to a decrease in the use of antibiotics and chemicals in salmon farming [8]. Environmental safeguards include regulatory, control and monitoring procedures such as in place at the European and national level [9]. In the case of salmon production in Ireland, environmental standards and monitoring requirements have developed that focus on sea lice, impacts on the benthos and nutrient concentrations in the water column and on the sea bed. Additional monitoring programmes required under various EU Directives are in place, including the monitoring of chemical residues in salmon and disease status [10,11]. Nevertheless, the development plans for large scale salmon farms in Ireland have been met with serious public opposition due to concerns about the impact on the marine environment [12] and especially in relation to the spread of sea lice.

Integrated Multi-Trophic Aquaculture (IMTA) could help resolve the apparent conflict between the growing demand for seafood and environmental concerns. IMTA has been proposed by NGO's, industry actors and scholars as one approach to decrease the environmental impact of aquaculture [13,14]. In an IMTA system several species are combined in the production process, selected by their function in the ecosystem and their economic value. Species are combined to facilitate the absorption of undesirable outputs from the production process, allowing for nutrient cycling and decreased nutrient outflow [15]. IMTA has several advantages over monoculture, as it diversifies the economic risks of fish farmers by generating income from additional marine products such as lobsters, sea cucumbers, mussels, crabs and seaweed, rather than just the primary finfish species [16]. Additionally, higher profits may be made if production costs are lower through nutrient cycling [14] or if consumers are willing to pay a price premium for aquaculture products with lower environmental impacts. Higher profit margins on products may act as a stimulus for fish farmers to shift from monoculture to IMTA production techniques.

Research has indicated that consumers value an IMTA approach to salmon farming. A small scale study in New York found a positive attitude towards IMTA in comparison to monoculture salmon. IMTA salmon was perceived as being better for the environment and animal welfare and, to a lesser degree, as being safer and healthier [17]. In addition, a positive consumers' Willingness to Pay (WTP) was identified in several studies for salmon produced in an environmentally friendly manner, similar to what would result in an IMTA scenario (in Scotland by Whitmarsh & Wattage [18], in the US West coast by Yip et al. [19] and in Canada by Barrington et al. [20]). It is also recognised that in order for IMTA to be accepted, consumers must be able to distinguish between conventionally farmed salmon and IMTA salmon [21]. Eco-labelling is an increasingly used tool to differentiate aquaculture produce and stimulate informed purchasing decisions, thus creating economic incentives for producers to adopt environmentally friendlier technologies. Wild seafood products with ecolabels have been found to be preferred by consumers [22–25], but research on preferences for aquaculture ecolabels is limited to Roheim et al. [26] and Yip et al. [19]. Aquaculture products are viewed distinctly different from wild-caught products, where wild-caught is generally preferred over farmed produce [26]. Yet within the aquaculture market, consumers prefer Closed Containment (CC) and IMTA systems over monoculture production, with strongest preferences expressed for IMTA.

A key aspect of investment in IMTA will be the extent to which consumers are willing to pay higher prices for fish and shellfish which are produced using this technique. This paper estimates the Irish publics' WTP for IMTA salmon products labelled with quantitative information on sustainability using a choice experiment (CE). The current plans to expand Irish aquaculture and invest in the sector, paired with national and EU policy goals to facilitate blue growth and protect marine ecosystems, means that uncovering evidence on the value of sustainable production is necessary. In what follows, the details of the design of the choice experiment are set out in Section 2 and the survey containing the CE is then outlined in Section 3. The Irish publics' attitudes and WTP are reported in Section 4 while Section 5 draws conclusions and sets out policy recommendations.

2. Methodology

Choice experiments (CE) are widely used to estimate public preferences and willingness to pay (WTP) for changes in environmental quality and new products with new attributes or attribute levels [27–29]. This approach is consistent with other applied literature in seafood valuation, such as Yip et al. [19], Jaffry et al. [24], Uchida et al., [25], Roheim et al. [26], Brécard et al. [23] and Johnston et al. [30]. The CE approach is rooted in consumer theory and the concept of utility maximization as described by Lancaster's consumer theory [31]. According to Lancaster, a product derives its utility from the characteristics of that good, not from the consumption of the good itself. Thus, the value of a good is represented by the sum of the value of its attributes. Based on this theory, in a choice experiment, respondents are presented with choice cards that present a set of alternatives out of which the respondents chooses his/her preferred alternative. Each alternative consists of several attributes that vary in terms of the level which they take. Respondents are asked to select their preferred alternative in each choice card, so they have to take into consideration their preference for a relative change in attribute A versus a relative change in attribute B. Choice experiments are based on the assumption that a rational decision making process underlies every choice, so the respondents' utility is maximized in every choice. The various choice sets that make up the choice cards allow the random utility model (RUM) to derive the underlying utility function for each product attribute [32,33].

The statistical analysis of the CE data, which aims to derive respondents' utility is based on random utility theory. Random utility theory recognises that there is both an observable and unobservable component to a products' utility. While the former is "observed" through survey response data, the researcher has to make assumptions about the distribution of the unobserved components of utility when modelling the probability function to predict which alternative are most preferred over the sample. More formally, the indirect utility function (*u*) of individual respondent (*i*) given the j options, consists of two independent parts; (1) the deterministic part (V), comprised of the CE attributes (*X*) under the j alternatives in the choice set; and (2) a stochastic part (*e*), which reflects the unobserved factors that influence respondents' selection of the choice card alternatives, and/or randomness in the choice process itself. The utility function is represented by

$$U_{ij} = V_{ij}(X_{ij}) + e_{ij} = \beta_{ij} \quad (1)$$

where V_{ij} is typically specified as being a linear index of X_{ij} and β_{ij} reflects the utility associated with that attribute [34]. In creating a model, the researcher aims to maximise the variation in the data captured by V_{ij}, while minimising the stochastic part, so that the modelled utility β_{ij} represents as accurately as possible the utility of the population. It is assumed that respondents always select the option that maximises their utility; or the probability that a respondent chooses alternative k over alternative j in any given choice card is considered equal to the probability that the respondents' utility from alternative k exceeds the utility from option j. This can also be expressed as

$$P[(U_{ik} > U_{ij})\ \forall\ k \neq j] = P(V_{ik} - V_{ij}) > (e_{ij} - e_{ik})] \quad (2)$$

The parameters of V are commonly estimated by the multinomial logit (MNL) and the random parameter logit (RPL) models. Under the MNL, the random term is assumed to be independent and identically distributed (IDD) [35]. The RPL model often supplements MNL as it allows for correlation between the error terms in each individual's multiple choices, allowing the parameters of the CE attributes to differ across individuals.

The aim of the choice experiment and the resulting model estimation procedure is to derive marginal values of the attribute levels from the preferences of each respondent. The CE design usually includes a monetary indicator as an attribute, allowing implicit prices to be elicited for each of the parameters (*β*). This implicit price reflects the respondents' WTP for a relative change in the attribute, given the changes in the other attributes [36]. Implicit values for a product attribute x are derived by:

$$-\frac{\beta_x}{\beta_m} \quad (3)$$

The WTP estimates reflect changes in consumer utility for variations in individual attribute levels. However, an aquaculture product will consist of a set of attributes that vary across products; i.e. production location, sustainability and price. Changes in attribute levels may therefore be considered in combination with other product attributes so that the WTP for the product can be assessed as a complete set of attributes [37,38]. The marginal WTP for the different attributes in our model (the implicit prices) and the welfare impact from a move from x° to x^1 (where x° to x^1 represent the attribute levels before and after the change respectively) are conditional on the individual taste parameters being logit. The CS measure can be derived using the standard CS log-sum formula from Hanemann [39]:

$$CS = -1/\beta_m\,[\ln[\sum \exp(\beta x^1)] - \ln[\sum \exp(\beta x^0)]]. \quad (4)$$

where β_m is the estimated price coefficient. For the RPL model the formulae needs integration over the taste distribution in the population so that:

$$CS = \int \{-1/\beta m\,[\ln[\sum \exp(\beta x n^1)] - \ln[\sum \exp(\beta x n^0)]]\} f(\beta)\, d(\beta) \qquad (5)$$

This integral is approximated by simulation from draws of the estimated distributions for the random parameters in our chosen model [40]. Using this formula, one can estimate the welfare impact of a change in the attributes of the salmon product purchased by the consumer in a supermarket, from a "conventional production" scenario to a scenario where the fish was farmed in a sustainable manner along the lines of an IMTA process.

3. Survey design

The surveys were distributed online among a population of randomly selected contracted clients of ICM Research, an independent survey firm. The sample was restricted to the age group of 18–64 to ensure representativeness of the sample due to lower internet accessibility and use rates among the elderly. The survey was divided into four sections. The first section covered knowledge and attitudes towards aquaculture and IMTA, in which respondents were questioned about their perception of benefits and threats resulting from aquaculture, as well as questions on marine environmental issues.

This was followed by an explanation of the term IMTA as presented in Annex A before moving to the choice experiment. In the survey, respondents were introduced to the term 'ecolabel' and explained that "[ecolabels]… show consumers that a product fulfils certain sustainability criteria. The idea behind using eco-labels on fish products is that people can chose to buy more sustainably produced fish and less of unsustainably-produced fish." The third part covered respondents' attitudes towards salmon products and purchasing behaviour, in which questions were asked on respondents' salmon purchasing behaviour in relation to the use of ecolabels. The final part asked respondents' demographic information, which was used to determine the effect of socioeconomic factors on the preferences elicited in the choice experiment.

The choice experiment was designed to elicit the effect of a shift in salmon farming production techniques from a monoculture system to an IMTA system on consumers' WTP for a fillet of salmon. An example of a choice card is given in Fig. 1. Respondents were presented with eight choice cards, each choice card containing three alternatives; two salmon products and an opt-out. The first two alternatives presented a fillet of salmon which differed in its attribute levels of production location, degree of sustainability and price. The third alternative did not vary across cards; it represented the opt-out (no purchase) option.

The levels of each of the three attributes; production location, sustainability level and price per kg of fresh, unfrozen and skinless salmon are outlined in Table 1. In selecting attributes and determining attribute levels, a market study was conducted to identify the main production elements important to consumers in their salmon purchase. A production location indicator on salmon products was found to be important. Additionally, studies suggest that consumers prefer locally produced food over other sourced food [24,41,42] and in some cases this preference is found to be stronger than for organic attributes [43]. Therefore, production location was included in the choice experiment as an attribute. The experiment thus distinguished between (a) salmon produced in Ireland and (b) salmon produced outside of Ireland.

The second attribute was related to the degree of sustainability of the salmon production process. Indications that consumers have a WTP both for the sustainability of seafood [18,19] and for ecolabels reflecting sustainability [25,44,45] led to the decision to include product differentiation with regard to the sustainability of the production method as choice experiment attribute. To indicate the degree of sustainability, a hypothetical ecolabel was designed that resembles the EU energy rating label [46], which is common on the Irish market and therefore familiar to Irish respondents. As shown in Fig. 1, the ecolabel consist of a range of scales ranging from D to A, D being the base category in the estimated models and each scale signifying a 10% increase in sustainability.

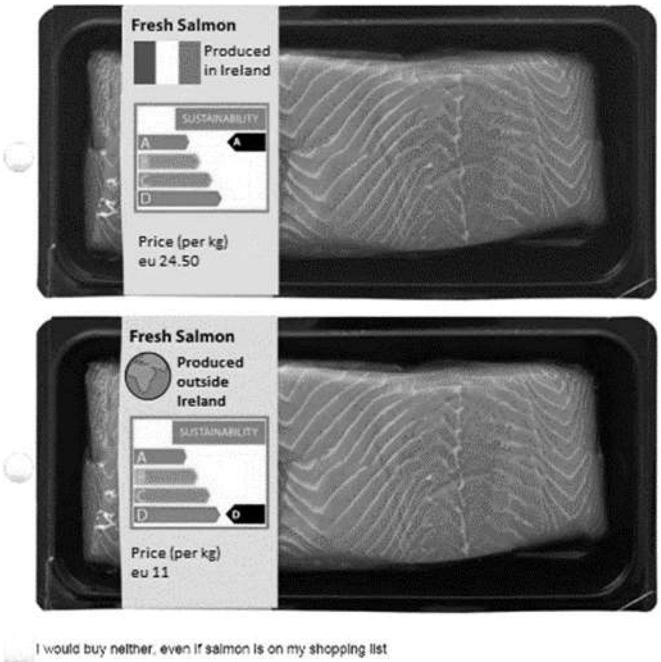

Fig. 1. Example Choice Card as Presented in the Choice Experiment.

The ecolabel rating is broadly based on the main impacts of aquaculture as described in the literature. It is however not intended to capture the full change in environmental impact due to IMTA for two reasons. Firstly, the precise effect of a shift of monoculture production towards an IMTA production process on the marine environmental impact of aquaculture production is still not fully established. Secondly, the certification of ecolabels is a highly complex issue, involving a compilation of standards covering multiple aspects of aquaculture production. To develop such standards for a choice experiment is both challenging and highly unpractical for both researchers and respondents [26]. This label is therefore simplified to values ranging from A-D. This is comparable to the effect of IMTA as described by Martinez-Espineira et al. [21]. In their choice experiment IMTA farms were assumed to reduce waste by assigned values of 10–50% (10% increments) relative to conventional aquaculture farms. The sustainability label as used in this study is thus simplified due to practicality limitations.

Table 1
Overview of CE Attributes and Attribute Levels.

Attribute	Attribute Level	Description
Production Location	Produced in Ireland Produced outside of Ireland	The salmon is produced in Irish waters The salmon is produced outside Ireland
Sustainability	Sustainability Level A Sustainability Level B Sustainability Level C Sustainability Level D	A 30% decrease in environmental pressure due to a change towards an IMTA production system. A 20% decrease in environmental pressure due to a change towards an IMTA production system A 10% decrease in environmental pressure due to a change towards an IMTA production system Monoculture production with no environmental pressure change.
Price per kg	€11 €17.50 €24.50	

The monetary attribute (price) was included to enable the estimation of the publics' marginal WTP for the attribute levels of production location and sustainability. The price levels included in the experiment were based on the price range for a kilogram of salmon on the Irish market. Low, medium and high prices were picked from the price range on the Irish market. A pilot study of the survey was conducted to evaluate the experiments' appropriateness in estimating the publics' WTP. The pilot study indicated that the attribute levels were appropriate as the respondents selected the full range of attributes and confirmed the price range to be realistic.

Respondents were briefed on the choice experiment and the attributes. Before taking the choice experiment respondents were informed that they were expected to select one of the options presented to them according to their preferences for the product attributes. The briefing included a cheap talk script in order to negate hypothetical bias [47,48]. Respondents were also given information in relation to the choice attributes. On the ecolabel and its' interpretation the briefing stated that: "…integrated aquaculture attempts to mimic the natural ecosystem and produces less pollution. Depending on how the farms are set up, the amount of pollution will be different. The sustainability labels show you how good or bad the farming method is for the environment. The labels range from A-D, with A being the best and D being the worst for the environment. The labels show how much the environmental pressure of producing the salmon in the package has decreased from what we now consider normal aquaculture (monoculture). Every label has a step of a 10% improvement in environmental sustainability." An image was included, showing the possible ratings and a subscript stating the environmental impact associated with each rating. Thus, respondents were introduced to the ecolabel and given a definition of the sustainability ratings.

The decision to include certain variables in the model while excluding others warrants further explanation. First, although several CE studies do incorporate attitudinal and other latent variables [26,30], attitudinal variables were excluded from the model.[1] Approaches for including latent variables into discrete choice models are criticized as they can lead to inconsistent and biased estimators and can be misleading [49,50]. To avoid such biased estimators the attitudinal variables were excluded from the model. Second, interactions of the alternative specific constant with demographic variables, including gender, third level education, age, being married and income level, were included in the models. A significant coefficient for these interaction terms signifies that the opt-out option is more likely to be chosen for the specified demographic group.

In the final version of the survey, sixteen profiles were blocked into 4 versions of 8 choice cards, each containing the two alternatives and the opt-out option as shown in Fig. 1. An efficient Bayesian experimental design based on the minimisation of the Db error criterion was used to vary attributes and levels [51]. D-efficiency is one of the most common approaches for measuring the efficiency of experimental designs used in the literature [52].

4. Results

A sample of 500 surveys was collected from individuals throughout Ireland. Overall, the sample is perceived to be representative of the Irish population when compared to data from the census of Ireland [53]. Table 2 presents a summary of the respondent statistics. The sample was comparable to the Irish population in terms of age (42 versus 39 in the population) and marital status (64% versus 61% are married). The sample consisted of slightly less males (44% against 49% in the

[1] The inclusion of attitudinal variables led to model non-convergence. This may be due to the fact that inconsistent and biased estimators can result when one includes ordinal qualitative variables (as is the case with our Likert scale attitudinal variables) as regressors in the model [49,50].

population). A significant difference between education levels of the sample and the Irish population should be recognised. Third level education, i.e. a bachelor's, master's, associate or doctorate degree, was completed by a larger group (45%) in the sample versus 21% in the general population, which is not uncommon in online surveys. With regard to income, respondents were presented with the national average income and asked if their income was much below, somewhat below, comparable to, somewhat higher or much higher than the national average. Accordingly, the self-reported income of the sample was skewed to the right with a stated mean below the national average. This skewed representation of income may lead to a more conservative welfare estimates and should be taken into consideration when interpreting the WTP estimates.

With regard to the Irish publics' perception of environmental problems related to food production, 92% of the respondents deemed this as problematic. When asked if they were familiar with IMTA, 9.8% said they knew what the term meant. However, when presented with a follow-up question asking them to explain the term, none of the respondents provided an answer, suggesting that the true familiarity of the sample with the term is lower. Respondents were asked about their perceptions of aquaculture practices and its economic and environmental impact. The economic benefits of aquaculture were rated at an average of 4.26, whereas the environmental impact was rated 3.89 on a Likert-scale of 1–5, where 1 signified "no impact" and 5 "significant impact". Respondents were provided with information on IMTA before proceeding to the choice experiment.

Table 2
Summary Statistics of Sample.

N = 500 Demographic variables	Mean	Standard Deviation	National mean
Male (proportion)	0.44	0.49	0.49
Age	42.2	12.16	39.0
Married/partner (proportion)	0.64	0.48	0.61
3rd level education (proportion)	0.45	0.5	0.21
Self-stated 'income below average' (proportion)	0.68	0.47	
Attitudinal variables			
Overfishing recognition (proportion) [a]	0.92	0.27	
Have you ever heard of the term integrated aquaculture? (proportion)	0.1	0.3	
Economic benefits from aquaculture (Likert scale 1–5) [b]	4.26	0.87	
Impact from aquaculture (Likert scale 1–5) [c]	3.89	0.94	
Believe IMTA has economic potential (proportion)	0.86	0.34	
Believe IMTA has environmental potential (proportion)	0.8	0.4	
Respondent uses ecolabels (proportion) [d]	0.58	0.49	

[a] Proportion of sample that scored positive on indicators for recognition of overfishing by answering "yes" on (1) "Do you think salmon is being overfished?" and (2) "Do you think overfishing is a problem?".

[b] Average Likert score (1–5) on indicators for perceived economic benefits from aquaculture; (1) job creation, (2) economic boost in coastal areas, (3) prevention of overfishing of wild stocks, (4) Reliable and affordable food source.

[c] Average Likert score (1–5) on indicators for perceived impact from aquaculture; (1) the spreading of diseases and parasites, (2) escapees, (3) overfishing, due to aquafeed, (4) scenery impact, (5) pollution from feed, wastes and treatment (eg. Antibiotics), (6) animal welfare.

[d] When you are buying seafood, do you look at ecolabels to decide which product you want to buy?

Table 3
Results of Conditional Logit and Random Parameter Logit Model.

(N = 500) Variable	Conditional Logit Coefficients	Random Parameter Logit Coefficients	Standard Deviation
Random parameters			
Sustainability C	0.27*** (0.07)	0.42 [a]*** (0.28)	0.30 [a]** (0.24)
Sustainability B	0.58*** (0.08)	0.0.88 [a]** (0.15)	0.64 [a]*** (0.12)
Sustainability A	1.34*** (0.07)	2.24 [a]*** (0.10)	2.29 [a]*** (0.09)
Irish Produced	1.10*** (0.06)	1.53*** (0.12)	1.97*** (0.12)
Nonrandom parameters			
Price	−0.17*** (0.01)	−0.24*** (0.01)	
ASC	−2.96*** (0.21)	−3.95*** (0.27)	
Interactions with Status Quo Alternative			
Male	−0.29*** (0.09)	−0.43*** (0.12)	
Third Level Education	−0.02 (0.09)	−0.04 (0.12)	
Age	0.02*** (0.004)	0.03*** (0.01)	
Married	−0.26*** (0.09)	−0.29** (0.12)	
Income below Average	−0.52*** (0.09)	−0.58*** (0.12)	
Information criteria			
Log-likelihood	−3545	−3199	
AIC	7112	6427	
BIC	7193	6538	

Notes: values in parenthesis indicate the standard errors.
***, ** indicates significance at $p < 0.01$, $p < 0.05$.
[a] Sustainability attributes were assumed to follow a log-normal distribution; coefficients and standard deviations reported are corrected by $\exp(b_p + s_p^2/2)$ and $(b_p + s_p^2/2) \times \sqrt{\exp(s_p^2) - 1}$, respectively, where b_p is the mean and s_p is the standard deviation of the natural logarithm of the price coefficient [54].

Eighty six percent of respondents acknowledged economic benefits to IMTA and eighty percent acknowledged environmental benefits when compared to current production practices. With regards to purchasing behaviour, a majority of the respondents said they used eco-labels as a part of their seafood purchasing decisions (58%) (either sometimes (36%), most of the time (14.3%) or always (7.6%)).

The analyses using conditional logit and random parameter logit regressions were performed using Stata. The results of the conditional logit and random parameter logit models are reported in Table 3. The conditional logit model indicates that any increase in sustainability is valued positively by consumers and is statistically significant (P < 0.01). The Irish publics' utility is positively related to sustainability and the coefficients show a positive and significant scale effect; relative to current monoculture practices (label D). An increase in sustainability of 10% (label C) has a positive coefficient and the magnitude of the coefficients rise with further increases in sustainability of 20% (label B) and 30% (label A) ceteris paribus. The Irish public also positively values locally produced salmon (P < 0.01), signifying a preference for Irish produced salmon over internationally-produced salmon. The negative coefficient for price indicates a negative relationship between utility and higher prices, which is in line with consumer utility theory. The variable ASC represents the opt-out option, i.e. respondents' preference for the opt-out option in the experiment. The negative coefficient indicates an average preference of the Irish public to select one of the presented options rather than opting out of the purchase.

The conditional logit model also included terms consisting of interactions of the alternative specific constant with demographic variables, including gender, third level education, age, marital status and income level. The model suggests that male respondents and respondents with higher incomes are more likely to choose to purchase salmon under the conditions presented to them in the choice experiment, whereas older respondents are more likely to opt-out. The interaction terms for the effect of the level of education and income on the choice selected were found to be insignificant.

The results of the random parameter logit model are listed alongside the conditional logit results in Table 3. As discussed, RPL models take into consideration preference heterogeneity. The preferences for the sustainability attributes were assumed to follow a log normal distribution, as respondents were expected to prefer either the status quo or an increase in sustainability. All other attributes were assumed to be distributed normally. Additionally, with the random parameter logit model, dependence across repeated choices made by the same respondent was accounted for by specifying a panel version of the model. Overall, the same preference pattern as in the conditional logit is visible. The Irish publics' preferences are positive for sustainability and increase as the products become more sustainable ceteris paribus. Positive preferences were expressed for Irish produced salmon, while price and ASC indicate negative preferences.

The estimated standard deviation parameters for the attribute variables in the model are all found to be significant. This indicates that the preferences for location and sustainability do indeed vary across the population. It is interesting to note that the random taste variation remains even after the inclusion of observed sources of preference heterogeneity (i.e., respondent's income level, age, marital status and education level). This is in line with findings elsewhere [40] and suggests that preferences vary considerably more than can be explained by the observed characteristics of respondents.

The model again included several interaction terms related to respondents likelihood of choosing the opt-out option. Respondents who were male or married were less likely to select the opt-out; i.e. they were more inclined to choose one of the presented purchasing decisions. Respondents with a higher level of education and those with high income levels were more likely to select the opt-out, as were older respondents.

In comparing the fit of the CL and RPL models, the information criteria of the log-likelihood, the Aikike Information Criteria (AIC) and Bayesian Information Criterion (BIC) were used. The log-likelihood of the RPL model (−3199) is higher than the conditional logit model (−3544). The AIC and BIC are lower for the RPL model (6427 and 6538, respectively) than for the CL model (7112 and 7193, respectively). The likelihood ratio Chi^2 statistic (692.05) also indicates that the parameters in the RPL are jointly statistically significant at the 95% level. All information criteria indicate a preference for the RPL model over the CL model.

Based on the models, implicit prices were calculated for the attributes of both models, as presented in Table 4. This table lists the marginal willingness-to-pay for the change in attribute levels independent of the changes in the levels of the other attributes. As mentioned in the methodology section, the CL model estimates were calculated by β_x/β_m, where β_x is the attribute coefficient and β_m is the price coefficient. The WTP estimates from the RPL model were simulated with 10,000 random draws on the model coefficients. The coefficients for both models were similar in size and sign.

The conditional logit WTP estimates indicate that the Irish public has a positive WTP for sustainable production approaches which increases as sustainability increases. An increase in sustainability of salmon production leads to an average marginal value of €1.59 (for 10% more sustainable production methods), €3.45 (for 20% more sustainable production methods) and €7.91 (for 30% more sustainable production methods) per kilogram. The model results indicate that the Irish public values Irish produced salmon €6.53 per kilogram more than salmon that has been farmed abroad.

The random parameter logit WTP estimates indicate that the Irish public has a WTP of €1.72 per kilogram for a 10% decrease in the environmental pressure. When the environmental pressure decreases by 20%, i.e. the salmon is 20% more sustainable, marginal WTP is €3.65 and a 30% decrease is associated with a marginal WTP of €9.26. In comparison, the Irish public has a marginal WTP of €6.33 per kilogram for salmon that is produced nationally, as opposed to salmon produced outside of Ireland. Overall the CL and RPL models show comparable results with regard to the marginal WTP for the experiment attributes. While the WTP estimates for sustainability based on the RPL model are slightly more conservative than the WTP estimations based on the CL the differences between the marginal WTP estimates of the two models are insignificant, as seen by the overlapping confidence intervals in all cases.

The valuation of individual attribute levels as presented above has limited practical significance as salmon products consist of a combination of attribute levels. Therefore expressing the utility gained from a change in one single attribute will provide only partial information on the product in question. Hence it is common to include an estimation of marginal WTP for bundles of attribute levels. The valuation of a set of attributes can be estimated by calculating the Compensating Surplus (CS) for combinations of attribute levels, in order to assess the added consumers' WTP for salmon products with certain characteristics – i.e. production location and sustainability. Table 5 gives an overview of the CS for all possible combinations of the attributes and their levels included in the choice experiment – production location (produced in Ireland or produced outside of Ireland) and sustainability (level A, B or C as expressed in an ecolabel).

Table 4
Mean and Confidence Interval of Marginal WTP per Attribute across CLM and RPL.

Variable	Conditional Logit Model			Random Parameter Logit Model		
	Mean WTP	95% CI		Mean WTP	95% CI	
Sustainability C	€ 1.59	€ 0.73	€ 2.45	€ 1.72	€ 1.36	€ 2.51
Sustainability B	€ 3.45	€ 2.49	€ 4.42	€ 3.65	€ 3.41	€ 4.69
Sustainability A	€ 7.91	€ 7.08	€ 8.74	€ 9.26	€ 6.09	€ 13.51
Location	€ 6.53	€ 5.86	€ 7.20	€ 6.33	€ 5.02	€ 7.25

Note: WTP is estimated in € per kilogram of fresh, skinless unfrozen salmon.

Table 5
Maximum Willingness to Pay for Different Types of Salmon.

Scenario	Production Location	Sustainability	CS WTP	95% Confidence Interval	
Scenario 1	Ireland	Label A	€ 15.67	€ 11.16	€ 22.55
Scenario 2	Ireland	Label B	€ 10.03	€ 7.31	€ 14.19
Scenario 3	Ireland	Label C	€ 8.09	€ 6.42	€ 10.60
Scenario 4	Outside of Ireland	Label A	€ 9.30	€ 6.11	€ 14.68
Scenario 5	Outside of Ireland	Label B	€ 3.66	€ 2.25	€ 6.31
Scenario 6	Outside of Ireland	Label C	€ 1.73	€ 1.37	€ 2.72

A total of six scenarios were created, consisting of all possible combinations of attributes as presented in the choice experiment. Scenarios one to three include the ‘produced in Ireland’ level of the location attribute and the sustainability levels A, B, C which have a CS of €15.67, €10.03 and €8.09, respectively. Scenarios four to six similarly cover the ‘produced outside of Ireland’ level of the location attribute and the sustainability labels A, B and C, which have a CS of €9.30, €3.66 and €1.73 respectively. The CS's reported are the mean estimates based on the results of the RPL model. Table 5 includes the lower and upper bound estimates of the 95% confidence interval. The results show firstly that the Irish public has a higher WTP for products with high sustainability attributes and secondly, the Irish public values salmon products with the Irish produced attribute more than the internationally produced salmon products. The estimation of the WTP of each set of attribute levels discloses that, even though the Irish public has a higher WTP for Irish produced salmon products, the value for high sustainability (label A) compensates to such a degree that internationally produced salmon with high sustainability levels is valued higher than Irish produced salmon products with low sustainability levels.

5. Discussion and conclusions

In this paper, an environmental premium associated with sustainably farmed finfish was estimated, using the Irish public as a case study. Results were obtained for preferences and willingness to pay for different sustainability labels and for locally produced salmon using both conditional logit and random parameter logit models. Both models showed a positive preference for high levels of sustainability and home production location. RPL model marginal WTP estimates of €6.33 for Irish produced salmon and €1.72, €3.65 and €9.26 for 10%, 20% and 30% more sustainably-produced salmon, respectively were estimated.

The Irish public acknowledges marine environmental impacts associated with aquaculture and regards IMTA aquaculture as a potential solution. Respondents to the survey did not consider themselves to be informed enough to make a good decision when purchasing salmon, and expressed the wish to receive more information on environmental pressures resulting from production of the goods offered. It also appears that a majority of the Irish public does not use existing ecolabels on a regular basis to select their salmon. Low ecolabel use rates were paired with low recognition rates for the main ecolabels on the seafood market. This may relate to the fact that the scarce uptake of marine ecolabels has been attributed to a variety of factors, including saturation of the market and lack of transparency of the labels’ criteria, resulting in consumer confusion and low credibility of existing eco-labelling schemes [55,56].

Indeed, potential may exist for the development of an ecolabel as presented in this paper. The European Union is currently exploring the feasibility of mandatory labelling schemes for sustainable seafood production. The hypothetical labelling scheme used in the research was based on a mandatory energy rating scheme widely in use around Europe for electronic goods and buildings. In comparison to current ecolabels, the proposed label has several advantages. A common criticism of eco-labelling concerns the pass-fail mentality [57], but a rating label provides an incentive to producers to continuously improve the production process. Also, the broad recognisability of the rating label in Europe gives the proposed label added value in comparison to existing labelling schemes. There exists a need for institutions and legislation which work at a supranational level, to improve transparency, to increase competition in eco-labelled markets and to facilitate product comparisons through standardization of labels. The EU can play a vital role in this regard. This links in with Irish seafood environmental awareness campaigns and expressed demand for information on seafood sustainability. The positive results achieved using the rating labelling approach suggest that this is a potential means of successfully communicating information on the environmental impact of food production to the public.

Sustainability labels should take into account all impacts of a product's life cycle using evaluation methods that are both reliable and verifiable [58]. Proportional changes in sustainability levels as expressed by the label used in the experiment were assumed to occur based on a shift towards multi-trophic aquaculture. However, the eco-label was not explicit in the specific type of sustainability being addressed. The environmental benefits of IMTA as opposed to monoculture are widely acknowledged [59,60] but the development of an objective measure of environmental pressure remains a challenge. Aquaculture impact assessments must consider a range of sustainability issues, including but not limited to, consumption of fossil fuels, production of waste and by-products and impacts on non-fishery components of marine ecosystems. Furthermore, the sustainability of IMTA systems is dependent on species selection and the optimization of the production process. Further research is needed to assess IMTA impacts.

This paper focused on the Irish salmon market. However, considering the globalized market in which aquaculture takes place and the indication of considerable variation between preferences for ecolabels across countries [30], additional research is needed on the added value of sustainable aquaculture across Europe. An estimation of the WTP of the European public for sustainably produced salmon could contribute to estimating the market potential of IMTA practices for the wider European aquaculture industry. Applying this method of aquaculture could therefore assist in the development of European aquaculture in general, which is currently lagging behind global growth rates for the sector.

Annex A

See Fig. A1

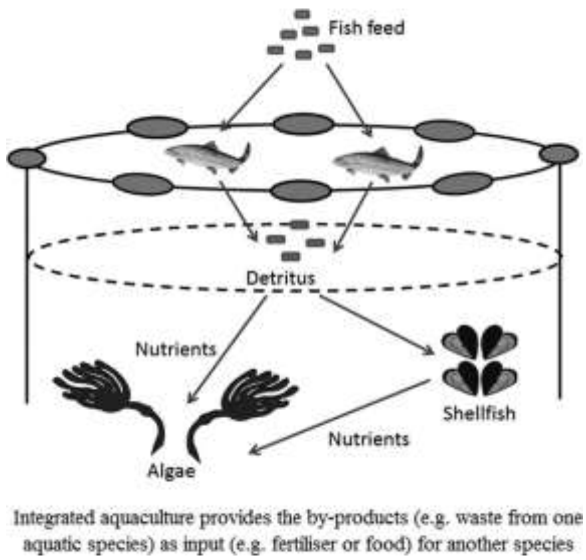

Fig. A1. Explanation of the term "Integrated Multi-Trophic Aquaculture" to the Respondents in the Survey.

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